Environmentally Sustainable Shrimp Aquaculture Systems

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Abstract: Future development of the aquaculture industry is limited by resources, such as water, land, fishmeal, and by other factors, such as environmental pollution. The problems caused by aquaculture wastes to the receiving water have drawn great attention worldwide in recent years. Intensive shrimp farming has been developed steadily over the last decade in response to increasing world market demand. The production system evolved from extensive toward intensive with increasing inputs of high quality feed and water supply. Thus, waste loads from culture ponds as uneaten feed and metabolic wastes was increased. In traditional intensive shrimp culture, the deteriorated pond water is frequently exchanged with new external water supply to maintain desirable water quality for shrimp growth. The nutrient laden effluent discharged from shrimp farms can cause eutrophication of coastal waters and its impact has been a major environmental concern. Many technology and method has been developed to protect the water resources and environment from being polluted and wasted. In these systems shrimp is cultured next to other organisms, which are converting otherwise discharged nutrients into valuable products. Long-term growth of the shrimp aquaculture industry requires both ecologically sound practices and sustainable resource management.

Sustainable Aquaculture Systems

Sustainability may be expressed in terms of three interrelated aspects (Fig. 1): production technology, social and economic aspects, and environmental aspects (AIT 1994). An aquaculture farming system needs to be sufficiently productive to make it an attractive option to alternative or competing uses of resources i.e., land and water, capital and labour, and farm by-products. Social and economic aspects of aquaculture have received relatively little attention compared to production aspects and are major constraints to development through aquaculture (Edwards 1994). Environmental aspects are only now beginning to receive the attention they require to prevent humans from exceeding the global carrying capacity for our species. An Environmental Revolution has been called for, as momentous as the Agricultural and Industrial Revolutions that had such an impact on the evolution of human society (Harrison 1993).

Production technology may be subdivided into three main aspects: cultured species, culture facility and husbandry. The choice of species influences the type of facility and together these determine the type of husbandry needed for the various stages of production (hatchery, nursery, grow-out). Husbandry may involve various methods of stock management (monoculture or polyculture; single or multiple, stocking and harvesting strategies), use of different feeds (natural, supplementary or complete feed), management of substrate and water quality, and disease prevention and therapy.

Social and economic factors influencing sustainable aquaculture may be considered at the macro-level (international, national and regional aspects) and the micro-level (community and farm household). Macro-level issues include world trade, national development goals, government policy, and social characteristics such as cultural attitudes and input supply and marketing. Micro-level issues are mainly alternative uses of resources.

The environment is defined as being external to the aquaculture system and includes the natural resources used for aquaculture development such as land, water, nutrients and biological diversity; the internal environment of the culture system is considered as part of the husbandry of production technology. The external environment is defined broadly to include the two-way interaction between itself and the aquaculture system. The natural environment (climate, geomorphology, hydrology and soils) and its human transformation (agroecology, urbanization, industrialization), exert major influences on aquaculture, which may be either positive or negative. As an example of positive interaction between aquaculture and the environment, a pond dug on a small-scale farm functions as a nutrient trap and provides water for irrigation of rice seedlings and vegetables in addition to providing fish. Fish ponds may also be used to treat human sewage, manure from feedlot livestock as well as effluents from intensive aquaculture. Negative interactions between aquaculture and the environment are the adverse effects of pollution on aquaculture and adverse effects of aquaculture on the environment such as eutrophication, misuse of chemicals, and reduction of biodiversity and mangrove destruction.

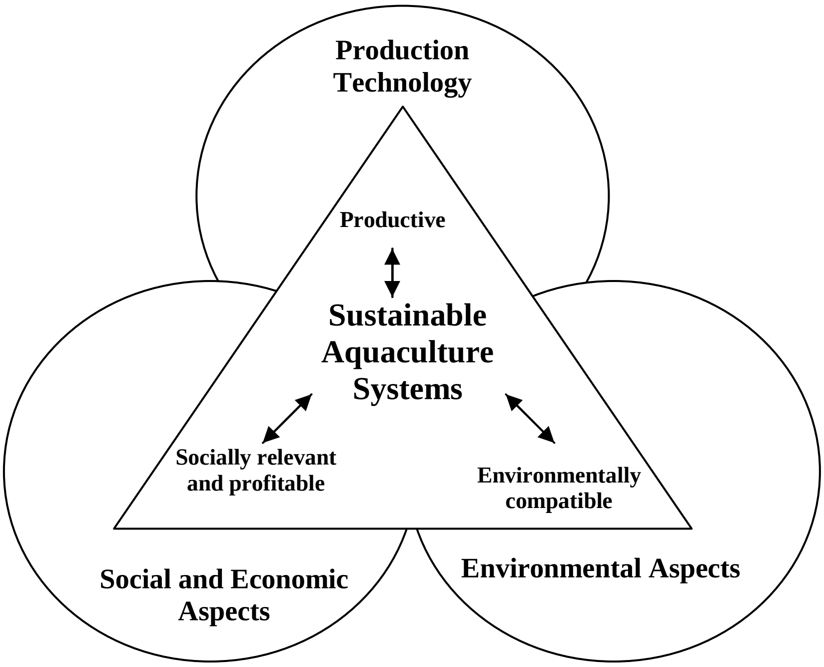

Figure 1: Sustainability of Aquaculture Systems (AIT 1994).

An Overwiev on the World Shrimp Aquaculture

Shrimp is one of the most popular types of seafood in the world. Approximately 5 million metric tons of shrimp are produced annually. Shrimp farms are being created throughout the world to help meet the demand for shrimp. In 1975, the shrimp aquaculture industry contributed to 2.5% of total shrimp production. Shrimp aquaculture, which increased nine fold during the 1990s and is one of the fastest growing forms of aquaculture, now accounts for one-third of the shrimp produced globally. Most shrimp aquaculture occurs in China, followed by Thailand, Vietnam, Indonesia, Ecuador, Mexico, India, Brazil, Bangladesh, Myanmar, Philippines and Malasia (Fig. 2).

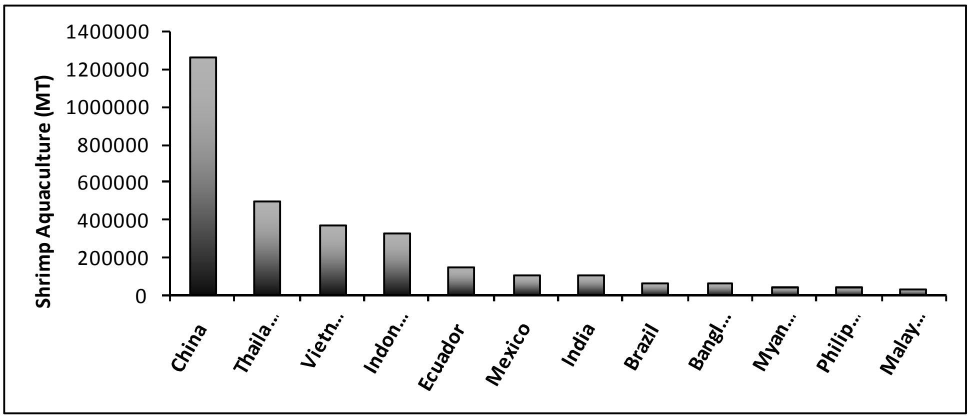

Figure 2: World Shrimp Aquaculture by Countries (FAO 2007)

The white shrimp, Penaeus vannamei, accounts for more than half of the total shrimp aquaculture output. Other important commercial species are P. monodon, P. merguiensis, P. japonicus, P. chinensis and P. indicus. In recent years, the export of Penaues vannamei to Asia has created a boom production, especially in China. The majority of farmed shrimp is imported to the United States, European Union and Japan. The growth has generated substantial income for developing and developed countries particularly Asia, the Americas and Africa but also has raised concerns about how shrimp farming affects the environment and society (FAO 2007).

Shrimp Farms and the Environment

Future development of the aquaculture industry is limited by resources, such as water, land, fishmeal, and by other factors, such as environmental pollution (Schneider et al. 2005). Shrimp farming has the capacity to dramatically transform coastal areas. Extensive farms have an enormous requirement for land and the development of intensive culture practices increases nutrient impacts on the local coastal environment. Alongside environmental changes such as eutrophication, salination and land use changes, are attendant social transformations. Articles in popular science journals have focused public attention on the potential negative environmental impact of aquaculture, in particular intensive production of salmon and shrimp (Bunting 2006). The high demand for shrimp in overseas markets changed traditional farming practices along the coastal areas for peasant farmers. Thai rice farmers converted their coastal fields and often the mangrove forests that bordered them, to shrimp ponds. The production system evolved from extensive toward intensive with increasing inputs of high quality feed and water supply. Consequently, waste loads from culture ponds as uneaten feed and metabolic wastes was increased. Generally more intensive culture systems produce higher loads of nutrients such as N (Nitrate) and P (Phosphate) in their discharge (Alonso-Rodriguez & Paez-Osuna 2003). Formulated diets fed to shrimp consist of high amount of protein 35-50%, nitrogen 5.9-7% and phosphorus 1.5-2.1%. However, much of the feed is not assimilated into shrimp tissue but is discharged as dissolved and particulate waste. Based on food conversion ratio (FCR) of 2.0 with stocking density 30-50 shrimp/m^2, shrimp feed of 2 tons, generates 1 ton of shrimp and waste of 900 kg organic matter, 87 kg nitrogen and 28 kg phosphorus. These compounds, together with excrement from the shrimp, increase organic matter, resulting in a high biochemical oxygen demand that can stimulate oxygen deplation (Jeganaeson & Annachhatre 2001, Tacon & Forster 2003). The two significant components of the pond environment are the pond water and sediments which interact continuously to influence the culture environment. Pond management activities are a third external factor which influence the culture environment. Management activities include feeding, use of aerators, water exchange and liming (Fig. 3) (Funge-Smith & Briggs 1998).

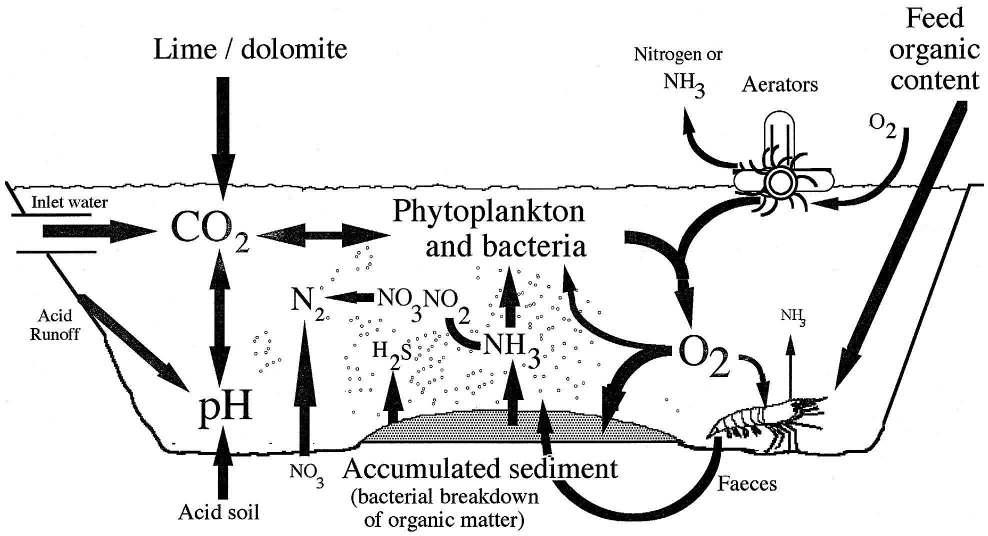

Figure 3: Water Quality interactions and Management Activities in intensive Shrimp Ponds.

The solids budget shows that erosion of pond soil was the major source of both solids (88–93%) and organic matter (40–60%) in the pond. The feed applied to the pond was a significant source of organic matter (31–50%) but contributed little solids (4–7%) to the system. Applied feed accounted for 78% of the input of N to the ponds. Erosion of the pond soils, whilst a major contributor of solids, accounted for only 16% of N added to the system. Other minor contributions were influent water (4%) and fertilizer, rainfall and postlarvae (2%). The sinks for nitrogen were the sediments (24%), harvested shrimp (18%), and discharged water (27%). The principal source of phosphorus in this system was the applied feed (51%). The 26% shortfall in inputs was assumed to be the eroded pond bottom (Funge-Smith & Briggs 1998). Hence shrimp farming become a curse in coastal areas due to their heavy discharge of used water with high organic and inorganic load and it has been regulated strictly under legislations (Tacon & Forster 2003).

Environmentally Sustainable Shrimp Aquaculture Systems

Typically the pattern of production from a shrimp farm is that of an initial 'honeymoon period,' characterized by success and good production followed by gradual decrease in yields over successive crops. Depending upon a wide range of factors, decreased yields are manifested as reduced growth, higher FCR, and disease outbreaks that require emergency harvesting. Serious production losses have occurred in shrimp producing countries around the world, principally due to poor rearing environments and pathogenic disease. In response to this, shrimp farmers are changing their culture methods. Long-term environmental sustainability and community acceptance of the shrimp farming industry requires on-going development of effcient cost-effective effluent treatment options. It is important to acknowledge that shrimp aquaculture systems can fulfil all the general sustainability criteria outlined in Tab. 1.

LAND USE
Local . Do not convert mangrove ecosystems or agricultural land into shrimp ponds
. Reduce the negative indirect impact on mangroves caused by access roads and water canals
. Initiate mangrove restoration programs where aquaculture has caused significant damage to this ecosystem
. Minimise land use by good management
. Place pond in areas with low population density to minimise land and water use conflicts
. Use feasibility studies prior to development to minimise risk of arising resource use conflicts
. Avoid overcrowding of ponds that exceeds the environmental carrying capacity
Global . Locate ponds in consumer countries
SEED AND INTRODUCTION OF ALIEN SPECIES AND DISEASE
Local . No use of gentically modified organisms (GMO)
. Use hatchery produced seed
. Close cycle in shrimp hatcheries by domesticating shrimps
. Farm only native species
Global . No transport of seed and broodstock between countries
WATER USE
Local . Reduce water exchange rates and thus water input requirement
. Site-specific methodlogical considerations:
. Develop shrimp farming in fully marine waters to reduce the dependence on fresh water sources
. Develop shrimp farming in low salinity waters to minimise the risk of salinisation of adjacent soil and water
FEED
Local . Use culture system that utilise natural or stimulated production in the ponds or incoming waters
. Minimise the food conversion ratio (FCR) through proper management
Global . Develop and use formulated feeds not based on fishmeal and fish oil, or reduce content of these
. Use fish meal based on trimmings of fish processed for human consumption
NUTRIENT LOADING
Local . Use only certified organic fertilisers
. Reduce water exchange rates and thus the amount of effluent discharge
. Reduce nutrient concentrations in effluents by investing in settling and biological treatment ponds, including integrated farming with e.g. seaweeds and filter feeders
. Improve feeds and management to reduce the food conversion ratio (FCR)
. Remove salt from sludge and use as fertiliser
CHEMICAL AND ANTIBIOTIC USE
Local . Reduce the need for chemicals and antibiotics by improved pond and water management that limit the risk of exceeding the local carrying capacity of the environment
Global . Minimise or refrain from chemical use
. Refrain from antibiotic use
. Use probiotics

Table 1: Defining the Local/Regional and Global Criteria for Improved Environmental Sustainability in Shrimp

Aquaculture (Rönnbäck 2002).

Integrated Shrimp Aquaculture

Recently, integrated closed recirculation systems have been developed because of growing concern of water pollution and avoidance of disease infection through water intake. In the system, high organic particles and nutrients in the water from intensive shrimp pond flow to the treatment ponds and then recycle back to the shrimp pond. The integrated culture of plants and herbivores side-by-side with fish and shrimp is a practical technology (Naylor et al. 2000). The system uses algae, fish, mussels, and other aquaculture species to reduce the waste in the effluent. Algae can reduce turbidity and phosphate in the effluent and the algae itself is a good feed for shrimp as well as fishes. Mussels are also reported to reduce the turbidity but can increase ammonia concentration. Fish as discussed is a good way to get rid of algae and other plankton. Several studies have been reported on integrated culture of shrimp with bivalves and macroalgae. For example, oyster removes suspended particulates and phytoplankton, while macroalgae absorbs dissolved nutrients (Wang 1990, Jones et al. 2001, 2002). However, high biofouling and the negative affect of high concentration of particles on growth of oyster were observed (Tanyaros 2001). Thus, sedimentation pond may be an important component in shrimp–bivalve and shrimp–macroalgae integrated culturing to reduce the level of suspended solid before oyster and macroalgae ponds (Jones et al. 2001, 2002). Fish has also been proposed for removing particulate organic matter in shrimp effluent (Tookwinas 2003). For example, grey mullet (Mugil cephalus L.) is effectiven in removing macroalgae from the effluent treatment system. Omnivorous tilapia can be effective for utilizing waste from intensive aquaculture. Closed polyculture systems of Chinese shrimp with constricted tagelus (Sinonovacula constricta Lamarck) and hybrid tilapia (Oreochromis mossambicus x O. niloticus), in which tilapia was confined in a net cage, showed that the retention of input nitrogen (feed+fertilizers) into tilapia biomass ranged from 2.58 to 2.90% and the retention of phosphorus into tilapia biomass ranged from 6.07 to 11.04% (Tian et al. 2001). Systems that integrate shrimp and red seaweed have been studied, the largest being in Hawaii (Nelson et al. 2001, Gracilaria), and small-scale efforts have been reported by Phang et al. (1996) (Gracilaria) from Malaysia, Kinne et al. (2001) (various algae) from the USA and Chang and Wang (1985), Yin (1987), Wei (1990) and Liu et al. (1997) from China, all of them with Gracilaria. Ali et al. (1994) reported on a laboratory-scale integrated culture of shrimp and green seaweed (Ulva) in Japan.

Integrated Shrimp Aquaculture System (ISAS) Desing and Lay Out

Lay out Plan

The lay-out plan of the ISAS is depicted in Fig. 4 (Ramanujam 2001). As per norms, 10 per cent of the cultivable area should be assigned for the ISAS. For example, for a farm of 5.0 hectare water spread area, 0.77 hectare land area or approximately 0.50 hectare water spread area (actual operational area) will be required for construction of the ISAS. For farms more than 5.0 hectares, the area under ISAS will also proportionately increase (e.g. for a 6.0 ha. farm area, 0.6 hectare under ISAS; for a10 hectare farm area 1.0 hectare under ISAS and so on). The size of the settlement pond, bio-pond and aeration pond has also been suggested taking into consideration the optimum production level of 2.0 tonnes/ hectare/ culture and specific water management practices. Water exchange schedule to be followed for operating the system. The schedule is based on the availability of a reservoir of suitable size for storage and treatment of water for initial filling of the ponds, topping up of water level during the first two months of rearing and limited water exchange during the third and fourth months of rearing (Ramanujam 2001).

Settlement Pond/ Sedimentation Pond

A settlement/sedimentation pond is basically used to remove suspended solids from the waste water flow. Shrimp farm suspended solid wastes under normal operating conditions (during culture as opposed to harvest) are primarily composed of living plankton cells, feed material and other organic material, which do not easily settle down. Sedimentation tank can trap only 5 to 10 percent of such suspended solids. A retention time of one hour is sufficient to trap the material, which can settle down. Thus settlement pond is less effective in trapping the solid contents of the waste water discharge during the course of culture. However, settlement tanks are effective in trapping suspended solids during the harvest, when solid loads are far higher and particulate matter is denser. Studies have shown that 90% of the solids in the harvest discharge settle in sedimentation ponds. Thus the sedimentation ponds prevent the release of most polluting organic matter that is discharged at the time of harvest (last 5 to 10 cm water) to the environment.

Bio-Ponds or Biological Treatment Ponds

Biological treatment aims at using plants and animals to reduce nutrient load and particulate matter in the shrimp farm discharge. Farm discharge after the treatment in settlement and bio-ponds can be readily used for recirculation to ponds for farming operation. Various options available for biological treatment of farm discharge are as follows:

- Sea weeds/ water weeds to reduce nutrient (N and P) level,
- Molluscs to reduce suspended particulate matter and
- Fish to transform the phytoplankton into organic matter

Biological treatment can only be used to treat operational farm waste water i.e. during culture period as the waste water during harvest time is biologically unsuitable in its direct form, unless diluted. However, the harvest waste water if allowed to remain in the settlement pond for requisite duration can be treated in the bio-pond. Various species of weeds and animals available for biological treatment (bio-remediation), their usefulness and the constraints in using them are given in Tab. 2.

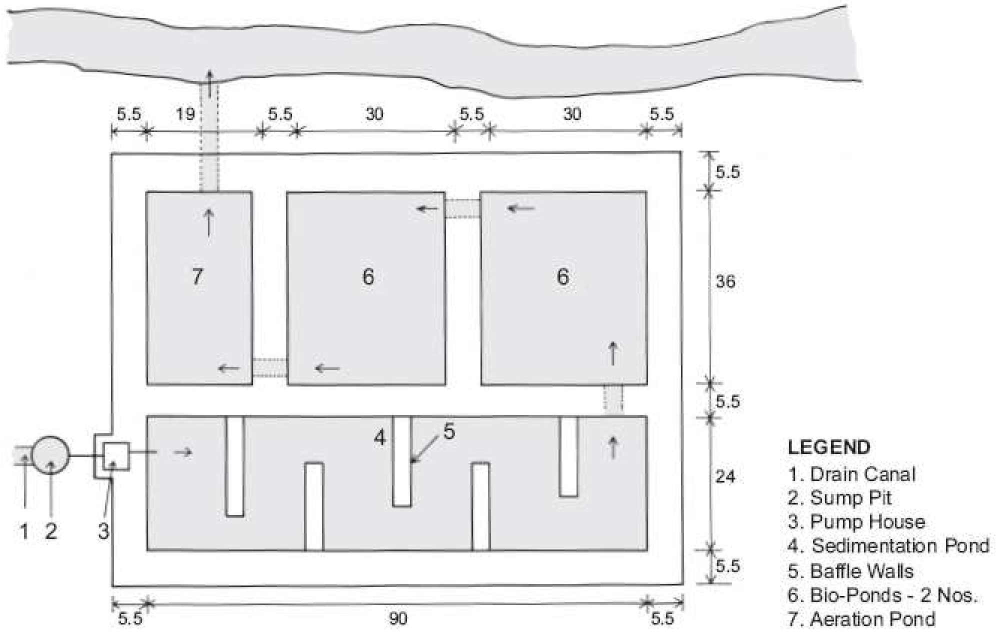

Figure 4: Layout Plan of Integrated Shrimp Aquaculture System (5.0 Hectare Shrimp Farm).

Group	Species	Usefulness	Constraints
Sea Weeds	Ulva latuca	Reduces nutrient load	Survival and grow ≥ 25 ppt
	Enteromorpha	-do-	-do-
	Gracilaria	-do-	26-32 ppt
	Photomedgetone	-do-	15-20 ppt
Mollusc	Crassistrea spp.	Removes particulate matter and control of algal growth	Grow 15-25 ppt
	Geloria sp.	-do-	15-35 ppt
	Perna viridis	-do-	20-25 ppt
	Perna indica	-do-	20-35 ppt
	Villoria	-do-	2-15 ppt
	Paphia sp.	-do-	2-15 ppt
	Anadora granosa	-do-	> 20 ppt
	Meritrix	-do-	> 20 ppt
Fish	Mugil cephalus	Reduces phytoplankton and control of algal biomass	20-35 ppt
	Liza spp.	-do-	20-35 ppt
	Chanos chanos	-do-	2-35 ppt

Table 2: Plant and Animal Species Useful for Bio-Remediation (Ramanujam 2001).

Aeration Pond

Aeration helps to increase the dissolved oxygen levels of water before it is pumped for recirculation. Besides, it also helps to oxidise any left over ammonia and organic matter in the water that comes out of the bio-pond. An integrated shrimp aquaculture system in shrimp culture is one strategy that minimizes waste from culture systems and the risk of disease and provides an additional income source as well.

Closed and Semi-Closed Systems

Common problems in the open water exchange system include phytoplankton crashes, deteriorated pond bottoms and bacterial diseases. A phytoplankton crash causes a significant increase in ammonia in the water, a decrease in dissolved oxygen and a rise in organic material. One of the vital activities in shrimp culture to maintain the proper conditions for shrimp is water exchange. Farmers have to drain water from grow-out pond and acquire make-up water for replenishment. For these reasons, shrimp farms need high amount of saline water throughout the culture period. Impact of discharges from shrimp farms can be reduced by treating the nutrient rich effluent as well as by cleaning the sediments. Systems employing water reuse and recirculation should be adopted to minimize the amount of water exchange for preventing epidemic and to overcome scarcity of make-up water at the low tide. The general scheme of closed is similar to some conventional wastewater treatment facilities, which include sedimentation ponds, biological treatment and aeration. The treated water is stored in a reservoir pond before being returned to shrimp grow-out ponds. The technology for closed farming systems is still in the experimental phase, and currently the relative contribution to global shrimp aquaculture output is marginal from these systems. In the case of inland shrimp farming in Thailand, the likelihood of no effluents being discharged into the open environment has been questioned (Flaherty et al. 2000). There is no water exchange in the first two months after stocking in these systems, although filling of the pond is necessary towards the end of the second month. Depending upon season and rainfall, evaporative loss can cause salinity to rise to an unacceptably high level. To counteract this, freshwater is pumped where available although this has very serious environmental and social impacts if aquifer water is used. Low water exchange systems such as these are complete sinks for nutrients and thus there is no outlet for wastes during production except for discharge at harvest (Tab. 3).

Nutrient	Total Effluent Loadings As a Result of Water Exchange ($kg\ crop^{-1}$)				
	Open system lined pond	Open system clay soil	Open system mangrove soil	Semi-Closed system	Closed system
Total ammonia-nitrogen	50.5	50.6	95.7	53.9	6.7
Nitrite-nitrogen	8.8	1.6	3.8	7.2	0.8
Nitrate-nitrogen	9.7	3.8	5.7	7.6	0.6
Total phosphorus	34.4	19.0	25.9	13.1	1.2
Dissolved reactivephosphorus	1.13	1.49	0.38	0.82	0.12
Chlorophyll a	5630.1	7126.2	7092.6	4261.2	312.3
Chemical oxygen demand	456.4	n.d.	432.8	244.1	21.1
Total suspended solids	4352.4	5053.5	4250.6	3555.6	336.3
Organic suspended solids	2236.7	2719.0	1836.6	1889.1	155.5

Table 3: Nutrient Loadings As a Result of Water Exchange Activities (Funge-Smith 1996).

Polyculture of Shrimp with Tilapia

Euryhalinous tilapia is characterised by good growth in seawater ponds through acclimation, easy reproduction and availability of fingerlings, resistance to disease, and marketable size reached within one growing season. Stocking performance and production in polyculture of Chinese shrimp (Penaeus chinensis) with red Taiwanese tilapia hybrids (Oreochromis mossambicus X O. niloticus) were studied by Wang et al. (1998). In two factorial design (3x4), shrimp juveniles (body length 2.85±0.16 cm) and tilapia hybrids weighing from 79.0 g to 193.8 g reared in net cages were stocked into 24 enclosures at a rate of 4.5, 6.0 and 7.5 shrimp/m^2 and 0, 0.16, 0.24 and 0.32 fish/m^2, respectively and reared by feeding commercial feed and by administration of chicken manure and chemical fertiliser. To evaluate cultural pattern on tilapia, the shrimp juveniles and the tilapia juveniles were stocked into two enclosures at a rate of 6.0 shrimp/m^2 and 0.24 fish/m^2 (outside the cages), respectively. Overall survival rate of shrimp was 78.6% and did not differ among treatments. Mean final sizes of shrimp decreased with increase in its stocking density. As stocking density of the shrimp increased from 4.5 shrimp/m^2 to 6.0 shrimp/m^2, mean shrimp yield increased from 325.4±15.3 kg/ha to 522.2±54.9 kg/ha. There was a pronounced influence of tilapia density on growth, survival and yields of shrimp at 6.0 shrimp/m^2. At 0.32 tilapia/m^2, survival rate (96.67%), final body length (10.40 cm) and yield (585.5 kg/ha) of shrimp were high. The optimum stocking density of shrimp and tilapia was 60,000 shrimp/ha and some 400 kg tilapia/ha, respectively.

Muangkeow et.al. (2007) was studied using outdoor tank system with 6 treatment conditions: T1, single shrimp tank system; T2, closed recirculation system without tilapia; T3 to T6, integrated closed recirculation system with the tilapia–shrimp stocking density ratio of 0.01, 0.025, 0.05 and 0.075, respectively. The shrimp were stocked at a density of 40 individual m^2 for all treatments. Shrimp were fed with commercial pellets, while tilapia was not fed with the feed pellet. The culture period was 8 weeks for shrimp and 7 weeks for tilapia. The shrimp growth rate and net income of the system of T2 was significantly higher than T5 and T6 ($P<0.05$) but was no different from T1, T3 and T4. The tilapia growth rate in T3 was significantly higher than the others ($P<0.05$). The nitrogen conversion rate into total (shrimp+tilapia) biomass of T2 to T5 was significantly higher than T1 ($P<0.05$). T6 showed a lower N conversion rate than the lower tilapia–shrimp ratio. The phosphorus conversion rate into total biomass was significantly higher in T3 to T6 than T1 and T2 ($P<0.05$). These results indicate that tilapia stocking significantly improved P conversion rate but the N conversion and shrimp growth rates decreased with high tilapia stocking. Considering all parameters, the integrated system with a low tilapia–shrimp ratio (the ratio of 0.01 and 0.025) were effective to improve the nutrient conversion rate to culture animals without lowering shrimp growth.

Rice-Shrimp Farming in the Seawater Intrusion Zone of the Mekong Delta-Vietnam

An estimated 19% (786,329 ha) of the total area in the Mekong Delta of Vietnam is affected by saline water with predominant freshwater in the rainy season and brackish water in the dry season. As saline water intrusion in the dry season is a major constraint to rice farming, many farmers develop alternating rice-shrimp farming system producing shrimp in the dry season and rice in the wet season in the same plot. In this farming practice saline water is used to flood the rice fields in the dry season to raise shrimp (Penaeus monodon). At the beginning of the wet season, farmers flush salinity out of their fields using rain and fresh river water to plant rice. The integrated farming systems increase farmers' income and improve the living standards of the local community (Vuong & Lin 2001).

Marine Microalgal Culture in Discharge Water from Shrimp Culture Pond

Marine microalgal species such as Skeletonema costatum and Chaetoceros coarctatus were cultured in Discharge Water (DW) from shrimp culture pond to recover the organic and inorganic nutrients released as waste (Vankatesan et al. 2006). Total nitrogen (N), nitrate-N and total phosphorus in the DW were observed significantly higher and their mean values were 95.261, 32.6 and 11.312 mg L^{-1}, respectively. Algal species were cultured in processed DW under 12 h light/12 h dark condition with light intensity 6000-7000 Lux and compared with cultures made in standard Conway medium which served as a control. Cell density was obtained higher over the control by 30.1 and 20.0 % in S. costatum and C. coarctatus respectively. The study inferred that, as it is a low cost technology for microalgal production as well as mean for waste water treatment, marine microalgal culture in DW from shrimp farm will be integrated a approach towards sustainable utilization of aquatic resource.

Constructed Wetlands As Recirculation Filters in Large-Scale Shrimp Aquaculture

Effluent waters from shrimp aquaculture, which can contain elevated levels of phosphorus, ammonia, nitrate, and organics, must be managed properly if shrimp aquaculture is to achieve sustainability. Constructed wetlands are ecologically beneficial, low cost treatment alternatives proven capable of reducing suspended solids, biochemical oxygen demand (BOD), nitrogen, phosphorus and heavy metals from wastewater of many sources. Tilley et al. (2002) studied to determine how well a constructed wetland performed as a filter in a full-scale shrimp aquaculture operation. A 7.7 ha (19 ac) mesohaline (3–8 ppt) constructed wetland treating 13,600 m^3 per day of effluent from 8.1 ha of intensively farmed shrimp ponds at the Loma Alta Shrimp Aquaculture Facility (LASAF) (Fig. 5), located along the coast of the Gulf of Mexico in semi-arid South Texas, was found to reduce concentrations of total phosphorus (TP), total suspended solids (TSS) and inorganic suspended solids (ISS) by 31, 65 and 76%, respectively, during recirculation, and maintained consistently low levels of mean BOD (<9 mg l−1), total ammonia (<1.8 mg N l−1) and nitrate (<0.42 mg N l−1). Constructed wetlands can perform satisfactorily as recirculation filters in large-scale shrimp aquaculture operations, reducing the impact of effluent on local water bodies, conserving large quantities of water and providing valuable ecological habitat.

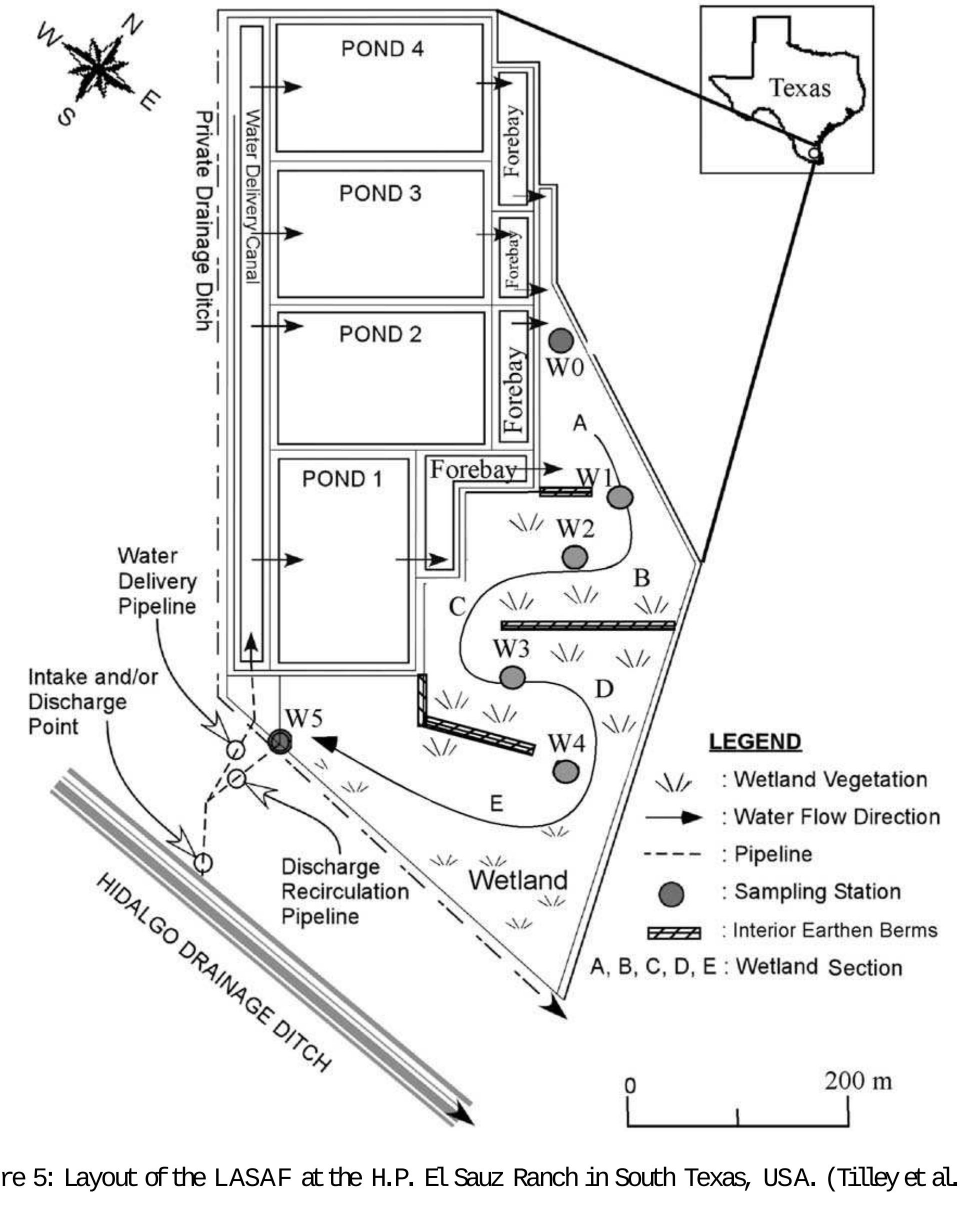

Figure 5: Layout of the LASAF at the H.P. El Sauz Ranch in South Texas, USA. (Tilley et al. 2002)

Conclusion

The rapid development of shrimp aquaculture in the coastal areas of the country has raised some environmental concerns, especially with regard to the impact of shrimp waste water on the ecology of the open waters systems. The Mediterranean coast supports many human activities, such as tourism, maritime traffic, industry, fisheries, aquaculture or conservation, all of them competing for coastal zone resources. In this context, the aquaculture industry has grown rapidly during recent years. The negative impact of shrimp aquaculture derives mainly from particulate and dissolved nutrients. The Mediterranean is an oligotrophic sea, with low nutrient levels; it is an especially sensitive area due to its low energy and has a limiting nutrient level that is the reason why a minimum increment of nutrients gives rise to important increases in the primary production.

Different methods have been tried to minimize the effects of nutrient loading. The integration of effluent treatment system as a part of the shrimp farm will therefore assist the farmers to improve waste water quality and provide long-term strategies for sustainable shrimp farming in the country.

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