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INTEGRATION OF SHRIMP AQUACULTURE WITH MOLLUSCAN CULTURE

K.K. Appukuttan and V. Kripa

Central Marine Fisheries Research Insitute, P.O. Box 1603,
Kochi-682 014, Kerala.

In the recent years concern for finding remedies for the negative impacts of aquaculture practices has surfaced. It has been proved that for long term growth of aquaculture industry both ecologically sound practices and sustainable resource management are a pre requisite. Shrimp pond water replete with suspended solids and algae have been found to increase growth rates of bivalves and the filtering capacity of these organisms have improved the water quality. A brief account of integrated farming-a concept, which can be considered as a natural remedy for the sustainable aquaculture, is discussed. Suspended culture of oysters and mussels along with shrimp or in drainage ponds will be beneficial to both bivalves and shrimps.

INTRODUCTION

Global production of farmed shellfish and fish has more than doubled during the past 15 years, a period of heightened ecological and economic integration. Environmental concerns have surfaced in the recent years and it has been proved that for long term growth of aquaculture industry both ecologically sound practices and sustainable resource management are a pre requisite. Formulating policies and regulations for ecological conservation and protection is possible. But in developing countries these are neither economically and socially feasible, nor politically enforceable. Despite significant improvements in the industry, there remains a considerable distance between ecologically sound technologies on the shelf and those actually implemented in the field. A suitable alternative which is simple and economically beneficial has to be developed to dilute the negative impacts of certain aquaculture practices. A brief account of integrated farming - a concept which can be considered as a natural remedy for the sustainable aquaculture is discussed.

STATEMENT OF PROBLEM

Among the aquaculture practices, semi intensive and intensive farming of shrimp and finfish have done considerable damage to the environment. The excessive use of supplementary feeds and the metabolic wastes from high-density farms have made the effluent pond water quality detrimental. Very

high levels of suspended solids, organic carbon and frequent algal blooms are all indicative of the ecological imbalance - signs of negative impacts. Suspended solids are essential for growth of shrimps and absence of suspended solids may also adversely affect shrimp . It has been reported that within 1-2 h after feeding, shrimp guts were 30 to 70% full of detritus and sediments, which are the primary components of suspended solids. In Hawaiin commercial shrimp ponds contain about 140 - 220 mg/liter of suspended solids (Wang, 1990). Suspended heavy solids when allowed to accumulate at the bottom of the shrimp pond, form an anoxic layer and therefore it is important to remove them from the water column or keep them in suspension until they can be removed. If kept in suspension, the smaller and lighter suspended solids can be removed from the water column by mechanical filters, biological filters (such as bivalves) or other filters, while the heavier particles have to be removed with the use of sedimentation devices.

Tookwinas and Songsangida (1995) observed that water drainage from intensive marine shrimp farms in eastern part of Thailand was 67,000 tons hr^{-1} during a culture period of 5 months. The BOD_5^{20} loading was 67,400 $tons^{-1}$ $crop^{-1}$. The traditional method of maintaining water quality is by flushing the pond water, which requires a high water exchange rate which may lead to severe discharge and economic problems. A mean water exchange of 60% of the pond volume which works to 4200 liters/min/ha suggesting that the cost of cleaning up shrimp pond effluent can break an otherwise successful operation.

Intensive fish culture systems also have produced detrimental impacts. The feed required to produce 1 tonne of fish contains 110 to 130 kg N, of this 20-25% is retained in the fish, and remainder is either not ingested or converted to waste products. Similarly high concentration of Chlorophyll *a* has been reported within 500 m of the salmon farms. To utilise excess algae and suspended solids, farming bivalves and seaweeds has been suggested. Bivalves low in the food chain are filter feeders and seaweeds are autotrophic utilising the dissloved nutrients.

BIVALVES AS BIOLOGICAL FILTERS

Bivalves subsist mainly on particles filtered from the surrounding water which they pump through the lamellae of their gills. Filtration rate can be termed as the volume of water from which all particles are removed in a given period of time. Filtering rate is equivalent to pumping rate if all the suspended particles are removed from the water passing through the filtering mechanism. The filtration rate of a bivalve depend on a) size of the species b) environmental conditions like temperature, salinity, pH etc c) water movement and d) particle size and their concentration/ density. Some of the particles are utilized while others are rejected as pseudofaeces. Studies have also shown that bivalves remove more cells from flowing water than from stagnant water.

Phytoplankton has been identified as the main component of bivalve feed. Apart from phytoplankton, suspended solids are also observed to play a positive role in bivalve growth. Several studies have indicated that considerable weight gain is observed in oysters when a small quantity of suspended solids is added to the oyster diet. Wyban *et al* (1988) has found that diatoms, which are excellent food, dominated the algal blooms in shrimp ponds. Considering these, it is suggested that the solution to shrimp pond water effluent control may well be in the utilization of the effluent instead of the current practice of discharging it into the open waters

INTEGRATED FARMING

Bivalves like mussels, oysters and clams are considered a delicacy in the temperate countries and the possibilties of utilising the nutrient rich water from the shrimp pond for farming oysters has been worked out since the 70s (see Table 1). Huges - Games (1977) observed higher growth rate and survival of *Crassostrea gigas* grown with fishes and prawns. Low fouling and good shape of the farmed oysters indicating their suitability for half shell trade were some of the advantages. Shrimp pond water replete with suspended solids and algae have been found to produce excellent half-shell oysters in Hawaii also (Lam and Wang,1989). *Crassostrea virginica,* which were fed with commercial shrimp pond water, grew from 0.1 g to 54.2 g (average weights) in 198 days with 96% survival. Thirty-nine per cent weighed more than 55g and the meat-to-shell ratio and condition factor average values for these oysters were 16.3 and 14.9% respectively. In China, Lin *et al* (1992) observed that mussels can be farmed with shrimp *(Penaeus monodon)* and the presence of mussels in the farms have played a significant role in the sustainable production of shrimp. Quantifying the benefits, Hu *et al* (1995) has stated that integrated farming of *Penaeus japonicus* with *Ostrea rivularis* was able to increase the shrimp yield by 30%, survival rate of oysters by 17% and meat percentage by 20.3%. However Hopkins *et al* (1993) observed that growth and survival of shrimp was not affected by bivalves..

Table 1. Details regarding the integrated farming experiments.

Candidate Groups	Observations	References
Crassostrea gigas with fishes and prawns	Higher growth and survival of oysters but very little gonad development, oyster shape was good for half shell trade Oysters free from Fouling.	Hughes - Games, 1977
Oyster with shrimp, *Penaeus vannamei*	Growth and survival of both species high, Oysters free from Dermo, *Perkinsus marinus*	Manzi et al, 1988
Crassostrea virginica in commercial shrimp pond water	Capable of producing excellent half-shell oysters in Hawai. High growth rate (0.1 g to 54.2 g in 198 days) survival 96%, meat to shell ratio 16.3 and condition factor 14.9%.	Lam and Wang (1989)
Ulva lactuca grown in fish pond effluent in Israel	$10m^3$ of Ulva can remove 90% of the ammonia produced by approximately 75 kg of fish.	Cohen and Neori 1991, Neori et al 1996
Seaweed in shrimp farm effluent water	In 24 hrs ammonia-nitrogen was absorbed by seaweed at 100% efficiency and BOD_5^{20} reduced by 39%.	Daroonchoo 1991 Chiyakam and Tunvilai 1992
Abalone (*Haliotis rufescens*), mussels (*Mytilus californianus*) and spot prawns (*Pandalus platyceros*)	Growth of abalones and prawns were significantly higher in Polyculture systems.	Hunt, 1991
Crassostrea gigas with chinook salmon, *Oncorhynchus tshawytcha*	Growth and condition indices of oysters near the fish farms three times higher, growth increments were dependent on POM and Chlorophy ll a.	Jones and Iwama, 1991

Candidate Groups	Observations	References
Sparus aurata (gilthead seabream) with *Crassostrea gigas*	Reduction in phytoplankton level possible to reduce the input of fresh water by 50%.	Shpigel and Blayloch (1991)
Artemia and green mussel	In 24 hrs could reduce ammonia-nitrogen, chlorophyll a, total suspended solids and BOD in effluents with an efficiency of 67,87,13 and 77% respectively.	Chiyakam and Tunvilai 1992, Tunvilai and Tookwinas (1991)
Peneaus monodon and mussel	Good production of mussel and shrimp, mussel culture component played a significant role in sustainable shrimp production.	Lin et al 1992
Prawns and clams	Net profit increased by 69.53% compared with monoculture.	Yue and Sizhong, 1992
Penaeus vannamei, Clams, *Mercenaria mercinaria* and oyster *Crassostrea madrasensis*	Growth and survival of shrimp not affected by the bivalves. Low survival of clams and oysters placed on bottom, high, 95% survival of oysters placed in trays.	Hopkins et al 1993
Crassostrea virginica grown in effluent water from shrimp pond in Hawaii	High growth rate of oysters - hydrographic parameters not studied.	Jacob et al 1993
Crassostrea gigas grown in fish farm effluent	Better growth rate, condition indices in oysters grown in the effluent water Reasons attributed are : Higher algal diversity, additional nutritious food consisting of benthic diatoms and stable algal concentrations.	Shpigel et al 1993

Candidate Groups	Observations	References
Green mussel in Shrimp effluent drainage canals	1 kg of mussel for an effluent load of 4 tons per day reducing the concentration of organic matter by approximately 50%.	CP Aquaculture News (1994)
Penaeus japonicus and *Ostrea rivularis*	Shrimp yield increased by 30%, survival rate of oysters raised by 17%, meat percentage increased by 20.3%, High economic benefit.	Hu et al 1995
Perna viridis grown in effluent water from shrimp ponds	One kilogram of mussel significantly decreased the concentration of Ammonia - Nitrogen, nitrite-nitrogen, dissolved oxygen phosphate and total suspended solids per ton of effluent.	Tookwinas and Thiraksapan (1997)
Saccostrea cucullata and *Penaeus japonicus*	Reduced the effluent total suspended solids to 49%, Bacterial numbers to 58%, Total nitrogen to 80%, Total phosphorous to 67%, Chlorophyll a to 8%.	Jones and Preston, 1999
Crassostrea madrasenis in shrimp farm effluent	Higher level of reduction of suspended solids and chlorophyll concentration possible with larger oysters.	Wanninayake et al, 2000

Integration of bivalves especially mussels and oysters as candidate species with fish farming has also been studied extensively. Wallace (1980) observed two-fold increase in growth rate of mussels cultured with salmon. The main reasons attributed to this were a) direct enrichment of water by soluble wastes such as ammonia and urea as by products of metabolism as a source of nitrogen for phytoplankton bloom and b) direct nutritional contribution to mussels by particulate organic waste made up of consumed fish meal and faeces. Jones and Iwama (1991) and Shipgel *et al* (1993) observed better growth rate and higher condition indices for *Crassostrea gigas* grown in fish farm effluent. They attributed the reasons for better growth performance to the higher algal diversity consisting of benthic diatoms. Contrary to these observations, Taylor *et al* (1992) found that growth of mussels near the salmon farms was not increased by the effluents from the farms. Seston and chlorophyll concentrations were not higher in the water from the fish farms. No effect of fish feed or faeces were observed.

Most of the studies have not critically evaluated the effect of integrated farming on improving the water quality effluent in the pond water. However, in the reçent years the role of bivalves in improving the water quality of pond water was studied. Shpigel and Blayloch (1991) observed that it was possible to reduce the input of fresh water by 50% (through reduction in phytoplankton concentration) in seabream farms when *Crassostrea gigas* were stocked with the fish. CP Aquaculture News (1994) have reported that green mussel farmed in effluent drainage canals can reduce the concentration of organic matter by approximately 50%. Tookwinas and Thiraksapan (1997) have observed that one kilogram of *Perna viridis* can significantly reduce the concentration of ammonia-nitrogen, nitrite-nitrogen, phosphate and total suspended solids per tonne of shrimp pond water. Jones and Preston (1999) observed that when *Saccostrea cucullata* is grown with *Penaeus japonicus,* the effluent total suspended solids was reduced by 49%, bacterial numbers by 58%, total nitrogen by 80%, total phosphorous to 67% and Chlorophyll *a* to 8%. Wanninayake *et al* (2000) have reported that high level of reduction of suspended solids and chlorophyll concentration was possible by culture of large sized *Crassostrea madra-sensis* in the shrimp pond water.

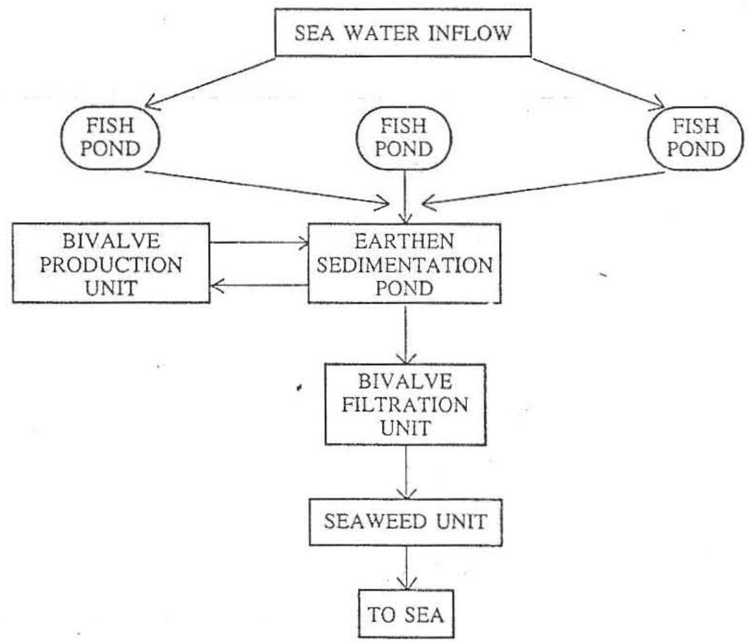
MODEL SYSTEMS

Reduction of particulate organic matter by sedimentation and microseiving (Gowen *et al* 1989; Bergheim et

al 1991) have been found to be relatively expensive requiring regular maintenance. The biological treatment of sewage by algae and bivalves have proved to be efficient and expensive but the questionable quality of the cultured organisms as food have lead to the discontinuation of this method in many areas. Such objections do not arise for biofilter organisms cultured in fish/ shrimp pond effluents as long as the fish/ shrimp consume commercial feed and the water source is clean.

The concept of developing an environmentally clean aquaculture practice based on an integrated fish - mollusk- seaweed system has been tried at the National Center for Mariculture in Israel (Shpigel *et al*, 1993). In the model (Fig.1) the water from the fish ponds drains through an earthen sedimentation pond, a bivalve filtration unit and a seaweed filtration /production unit and is finally discharged back into the sea. An additional loop recirculates water from the sedimentation pond through a bivalve production unit. The performance of each of the component in terms of total nitrogen budget is: fish yield, 26% of N introduced in the feed; bivalve yield

Fig. 1. Schematic diagram of the integrated system proposed by Shpigel et al (1993)



, 14.5%; seaweed yield, 22.4%; settled feces, 32.8% suspended and dissolved discharge back into the sea, 4.25%. Folke and Kautsky (1992) have also proposed a model for integrated coastal aquaculture linking species from different trophic level such as salmon, mussels and seaweeds. Building on this model, Newkrik (1992) has suggested that environmental impact can be further reduced by including a benthic species such as detritus consuming bivalves, bait worms etc.

FEASIBILITY OF INTEGRATED SHRIMP AQUACULTURE WITH BIVALVE FARMING IN INDIA.

India has a diverse range of cultivable bivalve species among the Indian backwater oyster like *Crassostrea madrasensis* and the green mussel *Perna viridis* and is commercially farmed. Though these are euryhaline the lower limit of salinity tolerance varies widely. Integration of shrimp culture with green mussel was done in a shrimp farm along the Gujarat coast with technical guidance from Central Marine Fisheries Research Institute, Cochin. The farm had a waterspread area of 9.36 ha with 9 ponds of 0.5 ha and 5 ponds of 0.25 ha independently fed through a feeder canal and drained into a drain canal. The drain water was collected in a waste settling pond of 0.5ha before disposal. The pond was provided with paddle wheel aerators. About 306 kg of mussel was obtained from 48m^2 area (32.6% meat percentage). With a stocking density of 60,000 per ha it was possible to obtain 330 kg Penaeus *monodon* in 150 days (Subramanyan and Gopalakrishnan 2000). Similar results were obtained in Goan shrimp farms also.

Growth and survival of bivalves are location specific and information on their tolerance ranges and filtration rates is essential before stocking them with shrimp. Rajesh *et al* 2000 have found that the filtration rates of these commercially important species varies with the salinity of the environment, the concentration of the algal species and the size of the species. Oysters were found to be having higher filtration rates than mussels and clams (Table 2). Experiments conducted at the demonstration farm of CMFRI at Ashtamudi Lake, Kerala have shown that the brown mussel, *Perna indica* is not suitable for farming in the estuaries. Though the salinity range falls within the tolerance limit, their growth and survival was very low. Location testing studies have shown that the oyster *Crassostrea madrasensis* can survive in low salinities even below 10 ppt. while for the mussels it is on the higher side, between 15 and 18ppt. Based on these, it is possible to work out a model for different coastal regions of India.

Table 2. Species-wise threshold and critical cell densities and the peak FR and IR

Species	Threshold cell density cells.ml^{-1}	Critical cell density cells.ml^{-1}	Salinity at which maximum FR & IR	Peak FR l.h^{-1}.animal^{-1} ± 2 SE	Peak IR cells (x 10^6) h^{-1}.animal^{-1} ± 2 SE
Perna viridis	100,000	75,000	32 ppt	18.2 ± 0.47	280.8 ± 5.94
Crassostrea madrasensis	100,000	75,000	20 ppt	24.1 ± 0.45	282.7 ± 1.76
Paphia malabarica	75,000	50,000	32 ppt	5.61 ± 0.28	116.0 ± 0.95

Feasibility of integration of shrimp and finfish in a bivalve farm was experimentally tried in Ashtamudi Lake, Kerala with the main objective of increasing the profit obtained from the bivalve farm. In the estuarine systems the usual grow out system is the wooden rack. In this farm where mussels and oysters are the main crops, shrimp seed, *Penaeus monodon and Etroplus suratensis* were stocked in separate closed cages in the space between the vertical poles. High growth rates and survival were observed for both the species. Though only very few studies have been conducted in this line, the preliminary results have indicated the scope for developing an integrated approach in the aquaculture practices of India.

CONCLUSION

Though bivalves can be considered as natural clearing agents of blooms, they filter other substances like calcium from the system. Since calcium carbonate is the major component of clam and oyster shells, it would undoudtely be depleted from the water faster than other salt. Galtsoff (1964) found that *Crassostrea virginica* (size unspecified) held in flowing seawater deposited a median of 1.4 mg of shell material /cm^2 of shell surface per day during peak growing season. When grown in a system they will release their own metabolic wastes. Hammen *et al* (1966) observed that the nitrogenous excreta of *Crassostrea virginica* as (micromoles per g of oyster wet weight including shell per hour as): ammonia, 0.0052 ; urea, 0.001; amino acids, 0.004; and unidentified N,0.0013. Similarly excessive pseudofaeces production coupled with low water movement can damage the benthic habitat structure and ecological web. Before taking up integrated farming it is essential that the information is gathered.

1. The rate of consumption of food, oxygen and dissolved chemicals by the animals
2. The rate of production of wastes by the animals

3. The tolerance of the animals to various water quality conditions and particularly those resulting from accumulation of their own wastes.

Among the bivalves, oysters and mussels will be better than clams. Studies have shown that placing bivalves on bottom will affect their survival (Hopkins *et al*,1993) .Most clams are infaunal and their growth and survival depends on the nature of the substratum and habit. Moreover, shrimps are mostly benthic and their feeding habits also do not recommend the use of clams in shrimp ponds. Suspended culture of oysters and mussels will be beneficial to both bivalves and shrimps.

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