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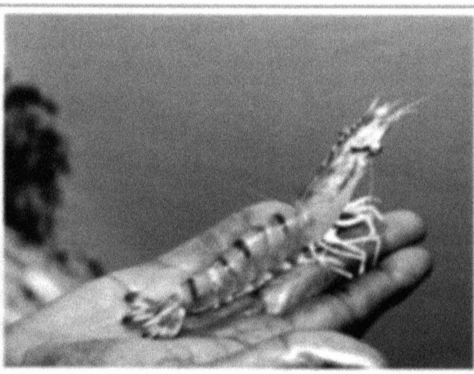

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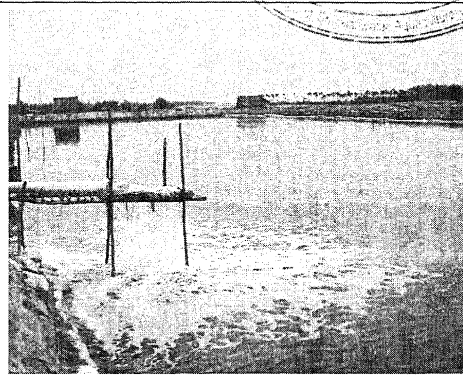

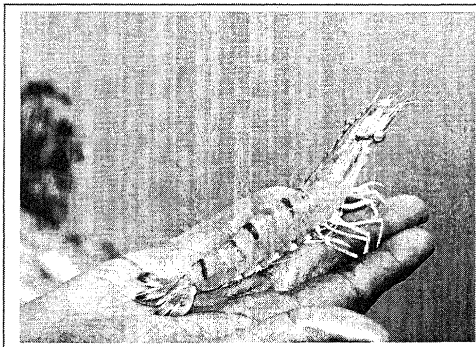

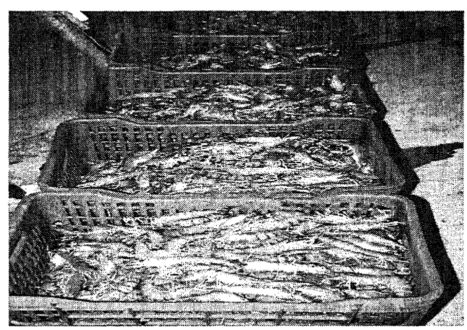

भाकृ अनुप
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Training Manual on Better Management Practices in Shrimp Farming

SHRIMP FARMING STATUS, ISSUES AND STRATEGIES FOR SUSTAINABLE DEVELOPMENT

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1. INTRODUCTION

In India, shrimp culture as a traditional activity is followed since ages. For a developing country like ours, shrimp farming is a high potential sector with enormous scope for increasing the foreign exchange and employment generation. Early nineties witnessed a phenomenal growth of the sector which was entirely dependent on the culture of a single species, the tiger shrimp, *Penaeus monodon*. During this period, the shrimp culture was a low-risk, high-profit venture. In late 90s, there were serious problems of viral diseases and environmental safety issues, which arose mainly because of the lack of planning and regulation. Presently culture of *P. monodon* in the country has become a high-risk, low-profit venture. There is an urgent need to ensure sustainability of shrimp farming in the country with technical appropriateness, economic viability, food-safety, environmental soundness, social acceptability, equity, and conservation of resources. This presentation aims to bring out the various issues that affect the sustainability of shrimp farming and the possible remedial actions that need to be taken at farm level and at National level.

2. GLOBAL STATUS OF SHRIMP FARMING

Shrimp culture continues to dominate the crustacean aquaculture at global level. It has grown from 0.8 million tonnes in 1991 to 3.3 million tonnes in 2007 with the corresponding value of 5.1 billion US$ to 13.4 billion US$ during the period (Fig. 1). Though more than 35 countries have reported shrimp aquaculture production, the top ten countries contributed about 92% of the total production. In 2007, out of the total production of 3.3 million metric tonnes of shrimps, 40% was contributed by China, 15% by Thailand, 12% by Vietnam and 10% by Indonesia. India stand at the 7th position in shrimp aquaculture production with a contributed of about 3% (Fig. 2) (FAO Fishstat, 2009)

Fig.1. Global Shrimp Aquaculture Production and Value

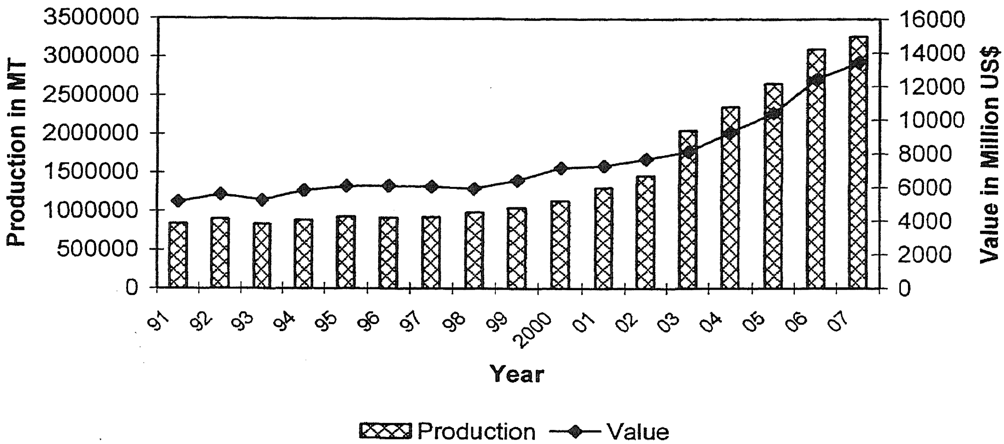
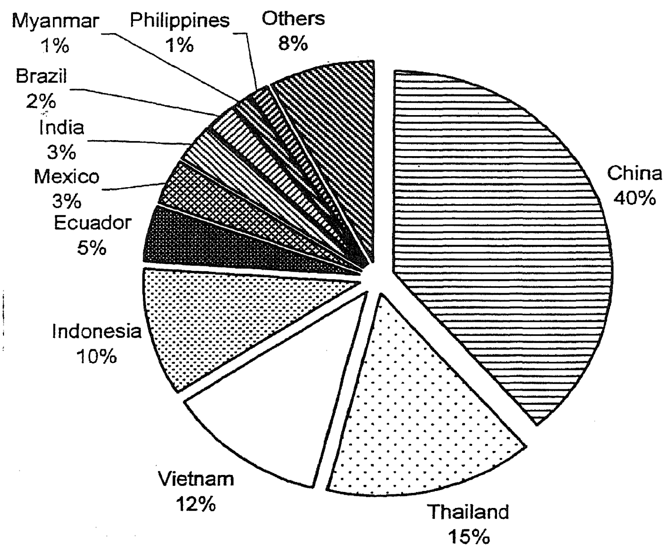


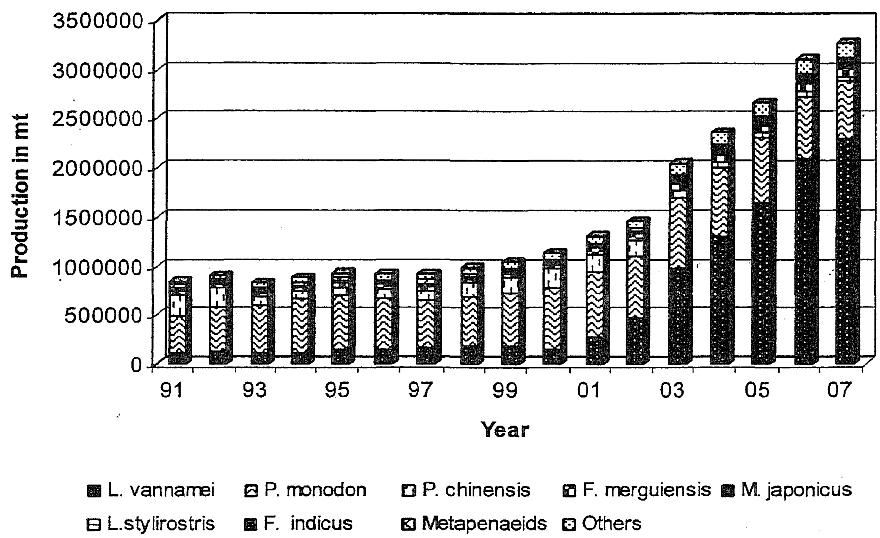
Fig.2. Percentage contribution of different countries in Aquaculture shrimp production (2007)

Total Production – 3.3 million metric tonnes



More than 20 species of shrimps are being commercially cultured in various countries but the major contribution of production is from 6 species of shrimps – *Penaeus monodon, Litopenaeus vannamei, Fenneropenaeus merguiensis, F. indicus, P. chinensis and Marsupenaeus japonicus*. Higher rate of growth in shrimp aquaculture production observed since 2002 is mainly because of the introduction of culture of *L. vannamei* in China and other Southeast Asian countries in place of *P. monodon.* Till 2002, *P. monodon* was the major contributor (50-60%) in shrimp culture production with *L. vannamei* contributing about 15-20%. In 2007, the contribution from *L. vannamei* has touched about 70% while the contribution of *P. monodon* is reduced to 18% (FAO Fishstat, 2009) (Fig. 3).

Fig. 3. Global Aquaculture shrimp production



3. STATUS OF SHRIMP FARMING IN INDIA

3.1. Development of shrimp farming

India has vast potential for the development of brackishwater aquaculture in coastal saline affected lands. The importance of shrimp farming to country's economy was realized in the early seventies and the first Experimental Brackiswater Fish Farm was started in Kakdwip, West Bengal by Central Inland Fisheries Research Institute under

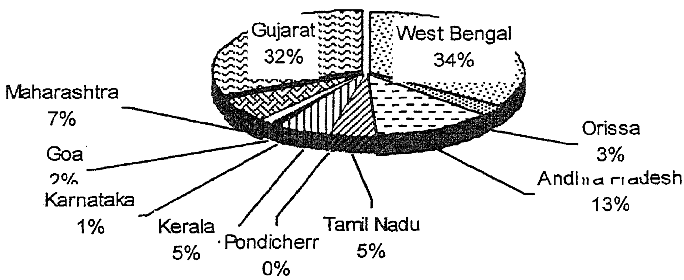
Indian Council of Agricultural Research in 1973 and an All India Co-ordinated Research Project on Brackishwater Fish Farming was started in 1975 by ICAR with centres in West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Goa. Concurrently shrimp seed production studies were initiated in Narakkal, Kochi by Central Marine Fisheries Research Institute (ICAR). Large scale development of shrimp farming took place only after 1988-89, with the establishment of commercial shrimp hatcheries by Marine Products Export Development Authority. Further, semi-intensive culture technology was demonstrated in a pilot-scale project by MPEDA. A number of development schemes were initiated by Ministry of Agriculture and Ministry of Commerce, Govt. of India for the development of shrimp farming which has paved the way for the establishment of a number of shrimp hatcheries and farms in the coastal states during the early 90s.

The growth rate of the sector was phenomenal till 1995. Since 1995, the sector is plagued by viral diseases, especially White Spot Syndrome Virus (WSSV). Further, the environmentalists had filed a Public Interest Litigation against the shrimp farming claiming it to be environmentally damaging. In 1996, the Apex Court ordered the closure of all extensive and semi-intensive shrimp farms located within the CRZ excepting the traditional farms and establishment of Aquaculture Authority to regulate all shrimp farming activities in the Country. In 1997, Ministry of Agriculture established the Aquaculture Authority under the Environment Protection Act, 1986. In 2005, Coastal Aquaculture Authority Act was enacted and the CAA was established, which had the mandate to regulate the culture of all aquatic organisms in the coastal area.

3.2 Coastal resources and Potential area for brackishwater aquaculture

India, by virtue of its extensive geographical stretch and varied terrain and climate supports a wide diversity of inland and coastal wetland habitats. The eastern coast is low-lying with lagoons, marshes, beaches and deltas while the western coast is dominated by rocky shores. The islands of Lakshadeep are composed of atolls while the Andaman and Nicobar Islands are volcanic in origin, arising from a submerged mountain chain. The coastal areas are productive and rich in natural resources. India has 14 major river systems, which has led to the formation of wide network of creeks and estuaries in the coastal areas of the country thus facilitating the coastal aquaculture. The Ministry of Environment and Forests, Government of India estimated that India has total estuarine area of 3.9 million ha and backwaters of 3.5 million ha. Among these coastal salt affected lands 1.2 million has been identified to be potentially suitable for shrimp farming. West Bengal and Gujarat are the two States which have the majority of the potential area because of the high tidal amplitude. The state-wise details of the potential area for brackishwater aquaculture is presented in Fig. 4.

Fig. 4 State-wise Potential area available for brackishwater aquaculture
Total area - 1.2 million ha



3.3 Systems of farming:

3.3.1 Traditional farming

In India, brackishwater aquaculture is traditionally practiced in West Bengal, Kerala, Goa and Karnataka. In West Bengal, the *bheri* fishery, locally known as "*bhasabhadha*" fishery, is in practice for centuries in the district of 24 Parganas. In this system of culture, tidal water is impounded in inter-tidal mudflats by raising bunds. Tidal water with all the assorted fish and shrimp seed is allowed to enter through the sluice gates during the spring tides. Harvesting of marketable sized fish and shrimp is done regularly during the spring tides through traps placed near the sluice gate. No manuring and feeding is done. Water is exchanged during every spring tide. In some *bheries,* paddy cultivation is carried out during monsoon months while in perennial *bheries,* aquaculture is carried out throughout the year. The average production from this type of system is about 500 – 750 kg/ha with shrimps contributing 20 – 25% of the total production. Presently about 44,000 ha is under this traditional system of culture.

In Kerala, two types of shrimp culture are practiced traditionally in low-lying backwaters. In perennial fields shrimp culture is carried out throughout the year using the trap and culture method. In seasonal fields, rice cultivation is carried out during monsoon months using the variety known locally as "*Pokkali*" and after the harvest of paddy, shrimp culture is practiced by trapping tidewater. In these types of culture also auto-stocking of seed from wild takes place. A total of about 11,300 ha is under traditional system of culture.

In Karnataka shrimp culture is traditionally carried out in Kharlands after a crop of *'Kagga'*, a salt resistant variety of paddy. An area of about 2500 – 3000 ha is under this type of culture. The production levels from this type of culture is low at 50 – 150 kg/ha.

In Goa around 500 ha of "*Khazan*" lands are under traditional farming. Shrimp farming in these areas are practiced during December to April after paddy harvest.

3.3.2 Modern scientific farming

Modern or scientific methods of shrimp farming include advanced animal husbandry methods such as removal of pests and predators, development of natural food by using manures and fertilizers, stocking of healthy seed, feeding with nutritionally balanced feed, monitoring and maintenance of water quality and health management. In these methods various degrees of control are maintained and accordingly various types have been classified.

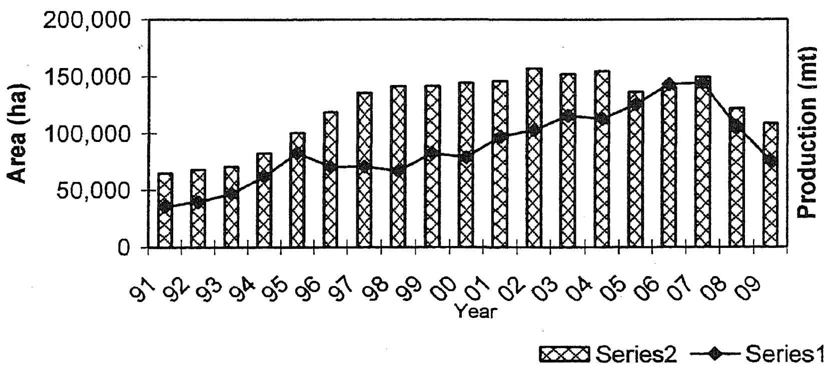
Improved traditional	In the tide-fed traditional system of culture, selective stocking and feeding with local feed is done to increase the production and productivity. Stocking density kept between 40,000 and 60,000/ha.
Extensive/ Improved extensive/ modified extensive	No difference between improved traditional and extensive. systems of culture except that the farms are of recent origin. Stocking density also remains at the same level. Either tide-fed or pump-fed. Feeding with high protein diets.

Semi-intensive	Stocking density increased up to 1 – 3 lakhs/ha; Water quality management increased with the addition of pond aeration. Feeding with high protein diets with strict feed management. Improved health management. Presently, such high stocking densities are not permitted by Coastal Aquaculture Authority.
Intensive/ Super-intensive	Cultured under fully controlled conditions with high stocking densities. Presently not being practiced in India.

3.4 Area under culture and production:

Out of the total potential area available hardly 16% has been developed into shrimp farming which includes 4% of traditional farming in West Bengal, Kerala, Goa and Karnataka. The area under shrimp culture has been more or less stagnant during 1997 to 2007 at around 140,000 to 150,000 ha. In 2008-2009, the culture area has drastically reduced to about 100,000 ha which is equivalent to the pre-1995 level. Similarly the shrimp aquaculture production showed a phenomenal increase between 1990 to 1995 and thereafter there was stagnation during 1996 to 2000. From 2000 onwards there was a gradual increase in production which reached a maximum of 1,40,000 mt in 2006-07. But in 2007-08 and 2008-09, the production levels reduced drastically and reached the pre-1995 level of 75,000 mt. The details are presented in Fig. 5.

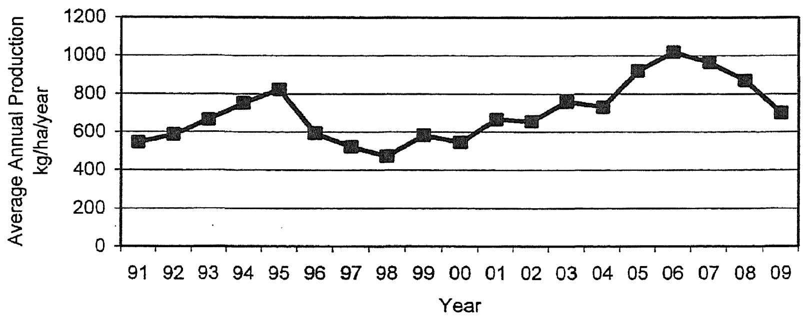
Fig. 5. Area under shrimp farming and production



3.5 Productivity

The average annual productivity of *Penaeus monodon* ranged between 472 to 1018 kg/ha/annum during the period 1990 to 2009, which is very compared to the productivity levels observed in Thailand and other southeast Asian countries. This is mainly because of the 40,000 ha of traditional systems of farming where the productivity levels are very low. The maximum productivity level of 1018 kg/ha/year was achieved in 2005-06, which had fallen down to 700 kg/ha/yr during 2008-09. The details of the productivity levels are presented in Fig. 6.

Fig. 6 Average Annual Productivity of P. monodon in India during 1991-2009



Among the States, Kerala, West Bengal, Orissa, Karnataka and Goa registered lowest productivity levels of about 500-600 kg/ha/yr and Gujarat registered maximum productivity level of 2 t/ha/yr.

3.6 Contribution to Marine Products Exports

Indian Marine Products exports touched all-time high of Rs.8299 crores in 2006. Shrimps is one of the major constituent of the Marine Products Exports contributing nearly 55% by Value (Rs. 4500 crores). Shrimp exports comprises of both capture and culture production. During 2000-2007, cultured shrimp contributed above 80% of the total value of shrimp exports (Rs.3300 to 3870 crores). But in 2008-09, the total contribution from cultured shrimps has fallen to the pre-1997 level of Rs. 1900 crores. The contribution of cultured shrimps to total shrimp exports by volume and by value is presented in Fig. 7.a & b

Fig. 7 a. Contribution of Aquaculture in shrimp exports by quantity

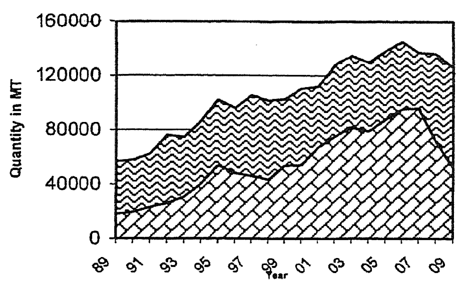
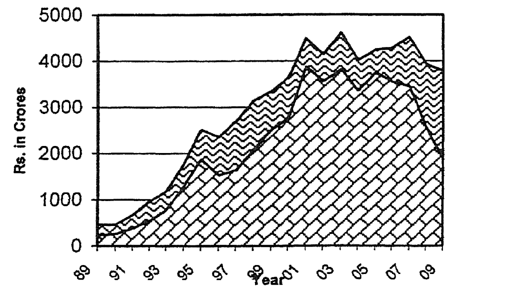


Fig. 7 b. Contribution of Aquaculture in shrimp exports by value



4. Major issues in coastal aquaculture

- The sector has grown based on a single commodity (shrimp) and with total export orientation and so far has neglected the large potential for diversification and domestic market. Because of the dependance on single species the sector is under high economic risk. The viral disease out break in 1995 and emerging new diseases have resulted in loss in production and productivity.

- About 30% of the total area developed is under traditional farming systems in West Bengal and Kerala wherein the annual productivity levels are very low at 250 to 500 kg/ha.

- Unplanned, unregulated and un-scientific development of shrimp farms in the private sector has led to environmental and social issues in certain areas. Most of the potential coastal areas do not have infrastructure facilities such as roads, electricity, communication and even drinking water is scarce. Areas where such infrastructure facilities are available are highly overcrowded.

- There is a huge reduction in the profit levels for the farmers due to increase in cost of inputs, reduction in global price for the produce, appreciation of rupee, and anti-dumping duty levied in US under WTO regime.

- Strict Sanitary and Phyto Sanitary issues under WTO has resulted in strict food-safety standards in importing countries which lead to rejection of export consignment.
- Increasing global environmental concerns regarding use of fishmeal in the aquatic animal feed and mangrove deforestation.

- State fisheries departments are expected to carry out the extension activities as well as the implementation of the decisions of the Coastal Aquaculture Authority and most of the states the fisheries departments do not have the necessary manpower and funding.

- More than 90% of the land area under brackishwater aquaculture is with the small farmers owning less than 2 ha of land. Such small farms share the same water source for the intake and outfall. There is a total lack of bio-security in such system of farming.

- Overall policy guidelines to promote aquaculture development on socially and environmentally sustainable level are lacking.

5. Strategies for the sustainable development

5.1 Increasing the area under aquaculture and increasing the average productivity

- Develop technological interventions for improving production from traditional shrimp farming systems.

- Reassessment of potential sites for coastal aquaculture as per the provisions of CAA Act, 2005, through remote sensing and GIS.

- Develop planning tools which incorporate aquaculture zonation, site selection based on species cultured and carrying capacity of the ecosystem.

- Land lease policies of states should be standardized

- States like Gujarat, Maharashtra should be helped with aquaculture planning to bring new areas under aquaculture.

- Domestication of *Penaeus monodon* and development of SPF and SPR broodstocks.

- Adoption of Better Management Practices to prevent disease transmission

- CAA should develop quality standards for seed and guidelines for seed certification.

- Develop bio-security protocols that can be adopted in hatcheries and farms.

- Diversification into other shrimp species, fish and crabs should be given importance and pilot scale schemes should be developed for the adoption of already available technologies like sea bass and mud crab culture.

- Develop quarantine mechanisms and protocols for introduction of exotic species and assist the DAHD & F to establish quarantine facilities.

- Facilitate the establishment of a net work of laboratories for monitoring and surveillance of diseases under DAHD & F.

- Development of grow-out technologies for culture of shrimps and fishes in inland saline areas.

- Policy framework for considering aquaculture at par with agriculture in the matters of credit, insurance and inputs like electricity.

- Promotion of value chain for each of the diversified species with development of market strategies for domestic and export market.

6.2 Prevention of environmental and social impacts

- Develop bio-remediation products from agro waste and microbe mining that can be used safely in ponds to bring down levels of organic carbon, nitrogen and phosphorus levels.

- Based on the field and modeling work on the carrying capacity of creeks, develop brackishwater culture guidelines that can be applied in different geographic areas.

- Environmental impact due to aquaculture development is prevented through sound planning by application of GIS and addressing choice of sites , zonation and carrying capacity of ecosystem

- Improve the existing effluent treatment plants to be adopted by farms of above 5 ha and development of common ETP for farm clusters.

- Development and promotion of organic aquaculture and zero water exchange systems of farming.

- Introduction of certification schemes for food-safety, environment-safety and social acceptability

- Development of eco-friendly feeds which will reduce the nutrient loading in source water.

- Technology development for reducing the costs of feed through replacement of fish meal with alternate plant protein sources.

- Regulation of drugs and chemicals of unproven efficiency being marketed to avoid wasteful expenditure by farmers.

OPTIMIZING SITE SELECTION FOR THE DEVELOPMENT OF SUSTAINABLE AQUACULTURE

M.Jayanthi and P.Ravichandran

1. Introduction

Aquaculture has developed quickly over the last three decades to turn into important economic activity world wide. It has been attracting heavy investment due to the availability of sound technologies and limitless potential for export especially shrimp. Globally, Landings from worldwide aquaculture has increased 10-15 % per year in the last two decades and this growth was due to the combined effects of scientific farming, availability of infrastructure facilities, changing consumer preferences and export market potential to developed countries. There are several forecasts on demand for aquatic foods and it is expected that it will be 183 million tonnes by 2030. As the capture fishery production is stagnating at around 90 million tonnes, aquaculture is seen as the only alternative to bridge the widening gap in demand and supply.

Globally, pressure on coastal and marine resources have increased in the past years due to development and deteriorating water quality. Development of aquaculture has raised many environmental issues such as conversion of mangroves, conversion of agricultural lands and water bodies, salinization of drinking water resources and agricultural lands adjacent to aquaculture farm Its impressive growth has also often accompanied by significant failures and environmental issues. World public attention has been drawn to the crisis in world fisheries, highlighted by collapses and conflicts over resources in the developed world including sector competition, trade restrictions, over capitalization and concerns over environmental impacts.

To overcome these problems while maximizing aquaculture production, needs comprehensive development planning based on the evaluation of water, land and human resources and interpretation of environmental and socio-economic constraints. Therefore, there is a need for an approach, which can be used to rapidly identify areas of a country, a state or smaller units, suitable for various aquaculture activities as an aid to development planning.

The success or failure of shrimp farming depends on the environmental conditions of the location of the farms. The social and environmental impacts like soil and drinking water salinisation and nutrient loading which are attributed to shrimp farming, mainly arise due to improper location of the shrimp farms. A vast majority of problems affecting the shrimp culturists as well as the environment could be avoided by proper site selection. The following criteria are recommended for consideration during site selection.

2. Shrimp farm site selection

2.1 Social and Environmental considerations

Location of shrimp farms in relation to other land uses and human habitation assumes greater importance in view of the various social and environmental conflicts reported due to shrimp farming. The following aspects should be kept in mind while deciding on a site for shrimp farming.

- Mangrove forests play a very important role in coastal ecosystem. They are a source of livelihood for the coastal population and it protects the coastal settlements. They also act as habitat and nursery for a variety of marine organisms. Hence, destruction of mangroves for any purpose will have far reaching social and environmental impacts. Further mangrove areas are generally acidic in nature and are not suitable for shrimp farming. In view of these facts, shrimp farms should not be located in mangrove forest area.
- Similarly, shrimp farms should not be located near ecologically sensitive areas like marine parks and sanctuaries to avoid any disturbance to the otherwise, fragile ecosystem.
- Establishment of shrimp farms by converting productive agricultural lands and saltpan will have social consequences since these are essential commodities for human beings and involve the livelihood of many farmers. Use of unproductive agricultural lands located in the tail end of the river systems could be used for setting up of the shrimp farms, but only after getting it reclassified by the concerned Government authorities/ agencies.

- The nearness of shrimp farms to various other land uses may have some negative impacts due to the seepage of water, which will increase the salinisation of land and water resources. To avoid such salinisation impacts, buffer zones should be provided in such areas depending on the soil conditions. Sandy and/or porous soils should be avoided. The extent of buffer zones required is given below.

Land use	Location of shrimp farm
Agriculture/ Horticulture	50 – 100 m
Human settlement	100 – 300 m
Freshwater/ Drinking water source	100 – 200 m
Major towns/ heritage areas	1 – 2 km

- Locating shrimp farms close to one another prevents access to the traditional users of the water front. Hence it is advisable to leave enough space between the farms for free access to the water front. Smaller farms of 2-5 ha should leave a minimum of 20 m between the farms. Larger farms of above 5 ha should design their farm in clusters of atleast 5 ha. each with free access provided between clusters.
- Shrimp farms should not be located on natural flood drains. Construction of shrimp farms adjoining each other without any space between them will lead to flooding in human habitations.
- Water spread area of a farm should not exceed 60 per cent of the total area of the land. The rest of the 40 per cent could be used approximately for other purposes.
- Wherever the intake and outfall are in the same creek, over crowding of the farms should be avoided. The total area of shrimp farms that could be supported by a creek depends on the water flow, tidal amplitude, water retention time, and level of intensification of culture systems. This is defined as the 'carrying capacity' of the particular creek and can be estimated taking all these parameters into account. New farms can be permitted only after an assessment of the carrying capacity of the creek.
- Integrated Coastal Zone Management Plans have been prepared by all the maritime states in the country and the states are expected to develop master

plans for the development of aquaculture farms taking all the environmental and social issues into account.

- Remote Sensing and Geographical Information Systems are being used to delineate the suitable sites based on the above said criteria.

2.2. Soil quality

Soil is the most important component in a culture system. The quality of soil should be ascertained for pH, permeability, bearing capacity and heavy metal content. Soil with low pH of below 5 and acid-sulfate soils should be avoided. Similarly soils with high concentrations of heavy metals also should be avoided. The soil characteristics suitable for a shrimp culture farm are

pH	-	7-8
Organic carbon	-	1.5 - 2.5%
Calcium carbonate	-	>5%
Available nitrogen	-	50-75 mg/100 g soil
Available phosphorus	-	4 - 6 mg/100 g soil and
Electrical conductivity	-	> 4 mmhos/cm

Generally clayey loam soils are preferred. Sandy soils are seepage prone and will lead to problems of salinisation of adjoining land and water resources. Further, maintenance of a farm in sandy area needs high capital and operational costs. Hence, sandy areas should be avoided. A best site is the one, which involves lesser capital investment for constructing fully drainable ponds.

2.3. Water Quality

Availability of good quality water in required quantities is one of the most important prerequisite for sustainable aquaculture. While locating the farm site, careful study should be made on the source of water, quantity of water available during the different seasons and the quality of water. The optimal levels of various water quality parameters required for the best growth and survival of cultured shrimps are presented below.

Water quality parameters	Optimal level
1. Temperature (°C)	28 - 33
2. Transparency (cm)	25 - 45
3. pH	7.5 - 8.5
4. Dissolved oxygen (ppm)	5 - 7
5. Salinity (ppt)	15 - 25
6. Total alkalinity (ppm)	200
7. Dissolved P. (ppm)	0.1 - 0.2
8. Nitrate - N (ppm)	< 0.03
9. Nitrite - N (ppm)	< 0.01
10. Ammonia - N (ppm)	< 0.01
11. Cadmium (ppm)	< 0.01
12. Chromium (ppm)	< 0.1
13. Copper (ppm)	< 0.025
14. Lead (ppm)	< 0.1
15. Mercury (ppm)	< 0.0001
16. Zinc (ppm)	< 0.1

2.4. Site elevation

Since drying of the pond bottom and proper water exchange form integral part of the technology of shrimp farming, ponds that are drainable by gravity are essential for a successful venture. Hence, the elevation of the site from the lowest low water level of the supplying creek should be given due consideration while selecting the site. A minimum elevation of 0.45 to 0.6 m is essential to ensure proper drainage.

2.5 Hydro-meteorological parameters

The hydro-meteorological data of the proposed area is very important to develop the design of the farm. The most important data required are rainfall, tidal fluctuation, wind direction and velocity, flood levels, frequency and time of occurrence of natural calamities such as storm, cyclone, hail storm etc., Construction of farms in cyclone prone areas should be avoided.

2.6 Infrastructure facilities

The infrastructure facilities like roads, electricity, proximity to hatcheries, ice plants, processing plants should be considered while choosing the site for a shrimp farm since these play very important roles in the economics of culture operations.

3. Tools for site selection and management

The conventional methods such as manual surveying, collection of secondary data from the farmers field or revenue records used for site selection are labour intensive, time consuming, non-repetitive, inaccessible to remote areas, low in accuracy and not synoptic. It does not provide information on the associated land features of aquaculture farms. Hence, there is a need for a mechanism to get real time data with its associated features for the larger area assessment so that coastal resources can be utilized effectively and would help in arriving production potential.

3.1 Remote sensing and Geographic Information System (GIS)

The meaning of remote sensing for a common man , is sensing any object or phenomenon from a distance without coming to physical contact. Scientifically it is understood that it is a process of acquisition of information about an object or phenomenon on the earth's surface by means of an optoelectronic device called sensors without any physical contact between the object and the sensing device. This is done by sensing and recording reflected or emitted energy and processing analyzing and applying that information.

Remote sensing techniques has emerged as an appropriate tools in providing spatial information because of its systematic approach in data acquisition through satellites, easy affordability, high level of precision and possibility of time series data. GIS is an integrated assembly of computer hardware, software, geographical data and personnel designed to efficiently acquire, store, manipulate, retrieve, analyse, display and report all forms of geographically referenced information geared towards a particular set of purposes (Burrogh, 1986).

GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and strategies (ESRI, 1998). Several methods such as classification, simple overlay, and connectivity analysis can be used either singly or in combination, by GIS practitioners to integrate spatial information into useful format for analysis and decision making. There has been history of methodology developed using GIS for the planning and management of aquaculture (Nath et al., 2000).

Remote sensing integrated with GIS can play a major role in sustainable aquaculture development by providing information on land use/land cover, water quality, productivity, tidal influence and coastal infrastructure. By using remote sensing technique and GIS, the advantage is not only in time and cost effectiveness but also in achieving a more comprehensive and integrated pattern of aquaculture development criteria, which is difficult through conventional techniques.

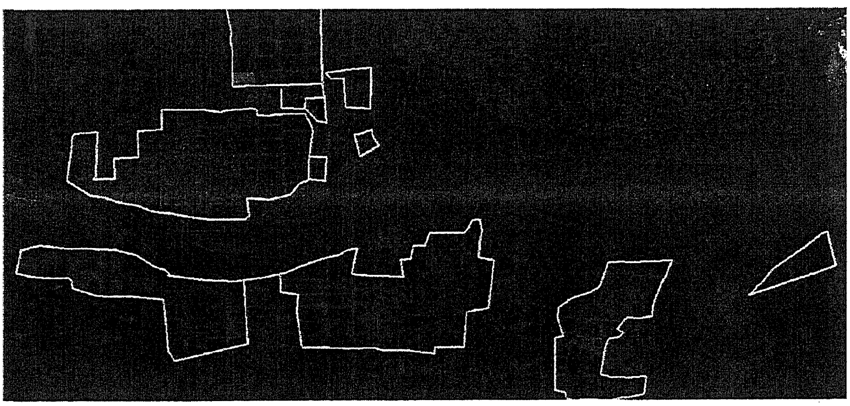


Figure 1. Delineation of aquaculture farms and unused farms from IKONOS data

Sustainable aquaculture development leads towards increased well being of coastal communities from the wise use of coastal resources without any land use conflicts or environmental degradation. This ensures local food security coupled with increased agricultural production, conservation of mangroves, enhanced fisheries catch etc.

Recent advances in remote sensing and geographic information has led the way for the development of hyperspectral sensors. Hyperspectral remote sensing, also known as imaging spectroscopy, is a currently being investigated by researchers and scientists with regard to the detection and identification of minerals, terrestrial vegetation, and man-made materials and backgrounds. There are many applications which can take advantage of hyperspectral remote sensing are geology, ecology, and coastal water. The chlorophyll, phytoplankton, dissolved organic materials, suspended sediments can be monitored using remote sensing techniques.

Aquaculture planning and monitoring is inherently spatial, satellite data can be used for the analysis of both qualitative and quantitative data types, identify associations between land types, and therefore, build a living database with exploratory data analysis, interpretative and assess the impact on coastal resources such as mangroves and water bodies. The requirements can be mapped as various layers and the overlay analysis will deliver the suitable sites with optimum conditions for the development.

3.2 Monitoring Coastal Waters

Satellite remote sensing is an excellent tool for monitoring coastal waters. The great gain of the digital data is the possibility of multi-spectral and temporal evaluation and accuracy compared to prolonged field sampling. The concentrations of optically active water constituents namely chlorophyll, coloured dissolved organic matter (CDOM) and total suspended solids (TSS) can be estimated from satellite images by the interpretation of the received radiance at the sensor at different wavelengths (Gordon and Morel, 1983). The observation of the biological productivity by satellite data serves as a practicable application for coastal water quality monitoring. The quantification of optically visible water constituents in marine and inland waters can be done with atmospherically corrected multi spectral remote sensing data. The intrusion of sea water in coastal areas and associated changes on the ground water salinity and vulnerability of the groundwater salinity in coastal areas .can be mapped using remote sensing techniques by mapping the surface manifestation of salinity.

Remote sensing has been widely used in water resource applications and in particular hyper spectral remote sensing is emerging as the more in depth means of investigating spatial , spectral and temporal variations in order to derive more accurate estimates of information required for water resource applications.

Conclusion

The advanced spatial technologies have opened up new vistas to utilize our natural wealth in a sustainable manner. With given trend, spatial tools will provide a range of functions embedded in various components that can be tailored for the sustainable utilization of coastal resources. It can support adaptive, real time planning and management approach through regular updating with time series information based on the well defined user interfaces. Absence of the national framework that coordinates all the spatial database creators and users in a single platform is the major issue to be addressed to prevent the unknown repetition and provide the sustained support for the sustainable management of coastal resources and aquaculture.

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DESIGN AND BIOSECURITY REQUIREMENTS IN SHRIMP FARM

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Introduction

Biosecurity in aquaculture is the protection of shellfish from infectious agents (viruses, bacteria, fungi or parasites). It is a set of practices that will reduce the probability of a pathogen introduction and its subsequent spread from one place to another. Disease epizootics have negatively affected production and expansion of the shrimp culture industry. This, along with environmental concerns regarding limited water resources and contamination of receiving streams, has caused the industry to investigate more sustainable and biosecure management practices. Most diseases threats have so far resulted from unregulated movement of live aquatic animals and associated introductions and/or transfers of pathogens. It has been realized that the best approach to managing aquatic animal heath is to improve biosecurity at all levels. Biosecurity provides a strategic framework and integrated approach to assess and manage the risk that threaten food safety, animal life and health, plant life and health, and associated environmental perils. Factors such as food security, protection of the natural environment, biodiversity conservation, societal demands for healthy products, and the general socio-economic development and work-being of a nation have driven the improvement of biosecurity practices.

The vast majority of shrimp culture in the world is conducted in outdoor earthen ponds that are typically located in coastal zones and exposed to a variety of pathogens. The worldwide experience of the shrimp farming industry is that pathogens, especially viruses, are a serious threat to the productivity and even survival of the industry. While axenic, closed systems may be feasible for enclosed hatchery and breeding facilities, practical means to protect existing production assets need to be considered. There exists then an engineering challenge to devise systems that provide effective defenses from diseases affecting shrimp farms while retaining their essential physical, ecological, and husbandry characteristics.

DESIGN CONDITION EXISTING IN SHRIMP FARMING

The pond design and construction in conjunction with the cluster of shrimp farming at a particular place needs to be suitable and site specific. General guidelines and protocols to be followed in designing has been given below

Culture system

There are three types of shrimp culture being practiced in India.

- Traditional/Extensive Cultures
- Semi-Intensive Culture
- Intensive Culture

Three types of intensive culture systems are operated, depending on the quality of the water supply.

Open System.

This system requires a high supply of good quality water because it needs a water, exchange of more than 20% of the total pond volume at one time, in order to reduce pond wastes and the density of the plankton. Fry can be stocked up to 60 fry/m^2 and will grow to 25-35 grams within 120 days. The open system has recently become less favorable to farmers since the environmental conditions, especially the quality of water, tends to deteriorate with time.

Re-circulation System .

In order to avoid deterioration of the environmental conditions, farms have been advocated to adopt the re-circulation system to minimize contact with poor quality water from outside the farm. However, the farm must devote 40-50 % of the area for the construction of water storage/ reservoir sedimentation pond, and treatment pond and drainage canals. To operate the system, cleaned seawater is initially pumped into the pond and kept within the system. During the culture period, the effluent from culture pond is drained into the sedimentation pond , treated with chemicals and pumped into the reservoir for re-supply to culture ponds. The stocking density for this system generally varies between 30-50 fry/m^2 and the culture period is between 110-130 days.

Minimal Water Exchange System .

The majority of the shrimp farms in are of small scale. These small farms cannot support space for construction of the water treatment pond and reservoir as in the case of the re-circulation system. To reduce contact with the water from outside the farm, the minimal water exchange system or closed pond system is practiced. The system involves filling up the pond with cleaned seawater, treating it with chemicals to eradicate predators and competitors. Since the system does not require water exchange, but maintains the water level in the pond by replacing the water loss due to evaporation and seepage with seawater or freshwater, it can be operated anywhere, even in the inland area where seawater is not easily accessible. The disadvantages of this system are that it requires low stocking density and high efficient water and waste management. However, it is suitable for production of small size shrimp because the culture period is limited.

SHRIMP FARM DESIGN AND CONSTRUCTION

A shrimp farm should be designed according to the characteristics of the selected site and the culture system. There is no unique design, but optimum and functional farm layout plan and design should be based on the physical and economic conditions prevailing in the locality. The ponds and buildings should be laid out for efficient and economic operation and the best utilization of the land. Construction of ponds and drainage systems should be planned and supervised by both an aquaculturist and an engineer, particularly if a large system is to be constructed.

An ideal shrimp farm is a complex establishment consisting of:

(a) various size ponds for nursery and grow-out,
(b) water control structures including embankments, supply and drainage canals and sluice gates, and
(c) support facilities such as roads, bridges, living quarters, workshops and warehouses, etc.

Careful layout of the described facilities and appropriate structural design in relation to the physical features of the area ensure smooth and effective operational management. The improved structural design is largely required due to the behavior of the Penaeid shrimps. P monodon is a benthic animal and it has a habit of gathering along tank walls. Any design to increase the wall surface eg. adding substrates or an elevated earthen platform extending along the edges of a pond, can promote high stocking densities.

Topography and type of pond

The topography of the land will in part determine the type and shape of some or all of the ponds. There are three basic structural types of ponds.

- Excavated pond
- Levee ponds
- Ravine ponds

The most common type is the excavated pond in which earth is removed and used for building the banks. This type of pond can be constructed on flat or undulating land. The construction has been done by hiring a tractor and forming the bund at cheaper cost. Levee ponds are constructed on very flat land and are similar in structure to rice bays except that the banks must be high enough to contain the necessary depth of water. Gully or ravine ponds are restricted to hilly country and are constructed by damming valleys or gullies.

Water Supply System

A shrimp pond is filled with water mostly by pumping. The pumps should be installed at locations where they can obtain water from the middle of the water column with least sedimentation and pollution. The pumps and inlet canal should be large enough to allow the ponds or the reservoir to be filled within 4-6 hours. A screen should be installed at the inlet canal prior to the pumps to prevent clogging at the inlets. Influent water system is very important with the biosecurity perspective.

Reservoir pond

A reservoir is important for the control of pond environment and storage of water supply when the water quality is inconsistent or the supply is intermittent. It is recommended that the area of a reservoir within a farm should be about 30% of the total farm area in order to hold a sufficient volume of the water supply. Some farms may use part of the reservoir for sedimentation purpose where biological filter feeding organisms are stocked. The reservoir must have an outlet that can allow total drainage. For effective biosecurity the reservoir is must in farms and this has been adopted by farmers in most of the areas. It has become a common practices among the farmers in shrimp farming areas . The chlorination is done in the pond

Pond design

Earthen ponds comprise the major capital investment in aquaculture facilities throughout the world. More than 90 per cent of the total global production is from ponds A well-designed pond will facilitate the management of water exchange, harvesting of the product, waste collection and elimination, and feeding. It would allow circulation of the water such that wastes will be accumulated at the center of the pond.

Size and shape of culture ponds

Ponds should be square or rectangular to make the most efficient use of available land. It is more economical to construct square ponds; however, rectangular ponds are easier to manage. The longest axis of a pond should be parallel to the prevailing wind direction. This facilitates water movement generated by wind action thereby increasing dissolved oxygen in the water and minimizing water temperature fluctuations in summer or warmer months..The breadth of a pond depends largely on the purpose and the operational system employed. Some farmers improve the water movement in the square and rectangular ponds by making the corners of the pond rounded through addition of soil. The following are the various sizes recommended:

Table 1 : Pond size for different culture system

Type of pond	Type of culture system	Size of the pond
Nursery pond		500 to 1,000 m^2
Grow-out pond	- intensive	0.25 to 1.0 ha
	- semi-intensive	0.5 to 2.0 ha
	- extensive	1.0 to 10 ha

Smaller ponds are easier to manage but the construction and operation can be costly. Ponds of 0.5-1.0 ha. are commonly used in intensive culture and 1-2 ha. for semi-intensive culture.

There is a large variation in the size of earthen ponds used in aquaculture throughout the world and authorities disagree on the optimum size of ponds. A number of factors will determine the preferred size of ponds on each farm: the function, techniques and stocking densities, cost of land, topography, capital and equipment available for construction and the planned production capacity.Construct ponds no larger than about 2ha to enable the efficient management necessary under intensive conditions.

Dikes

Dikes do not only serve as boundaries to indicate pond size and shape but also function to hold water within the pond as well as protecting other farm facilities from flood. Diking materials must preferably be tested for load bearing capabilities and compactibility. In some cases where the quality of the soil is inferior for diking, other materials, viz: concrete or clay must be used as core materials to be placed at the pond bottom. Earthen dikes, with or without lining, are found to be the most economical.

Design and construction of embankment must be based on sound engineering principles and economic feasibility.

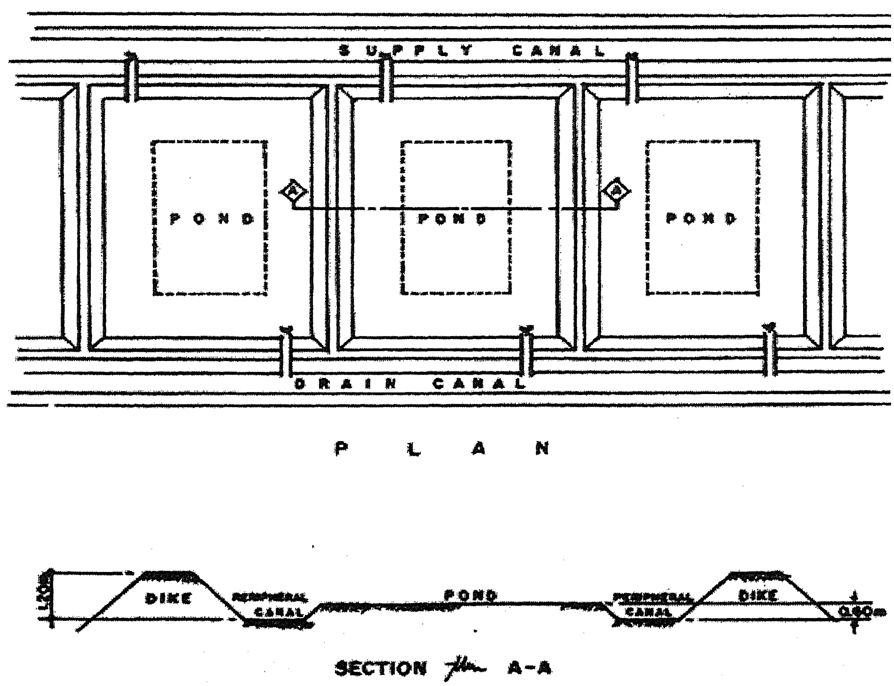

Fig 1 : Earthen pond layout with peripheral canal (Plan and section)

Height of dike

Coastal soil used as diking material usually shrinks initially. As such, the height of perimeter dike should have a free board of 0.6–0.7 meter above the desired water depth. Free board allowance is determined from the occurence and frequency of flood levels over a period from 5–15 years at the farm site.To compute for the height of dike, the following formula could be used:

$$H = \frac{(Hw - G) + FB}{1 - \% \text{ of shrinkage}}$$

H = height of designed dike
Hw = highest high water level from past record
G = ground level over mean sea level
FB = height of free board
% = percent shrinkage

To give a concrete example, let us assume that a proposed shrimp farm has a ground elevation of 1.0 meter above mean sea level and normal high tide of 2 meters. Previous records indicate that the highest tide occuring every 10 years is 2.8 meters. The rate of soil shrinkage after the embankment have been consolidated is 20% and the estimated free board allowed is 0.60 meter. Height of dike is then calculated from the formula:

$$H = \frac{(2.8 - 1) + 0.6}{1 - 20\%}$$

H = 3 meters

Dyke Slope

The slope of perimeter dike is maintained at an average ratio of 2:1 to 3:1. Very often, external slopes are made at a ratio of 2.5:1 to 3:1. Dikes with steep slopes are always subjected to erosion and require higher maintenance cost (Fig. 9). Slope of a dike also highly depends on soil quality. For good clay soil, the recommended slopes are:

1:2 when dike height is above 4.26 m and exposed to wave action;
1:1 when dike is less than 4.26 and the tidal range is greater than 2 meters;
2:1 when the tidal range is 1.0 m or less and the dike height is less than 1.0 meter.

The crown of the dike between ponds should be 1–5 meters. It would be advantageous if fast growing grass species are planted on the dikes to control soil erosion.

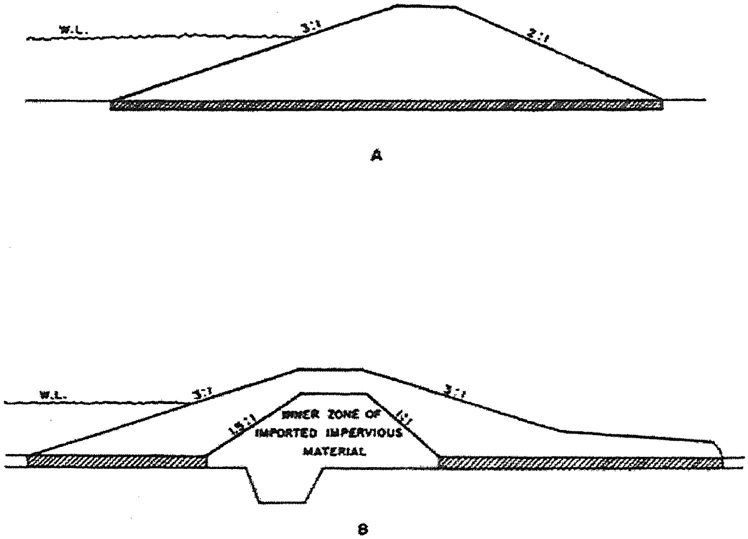

Fig 2 Dike (A) constructed with entirely impervious material and

(B) with trench or core

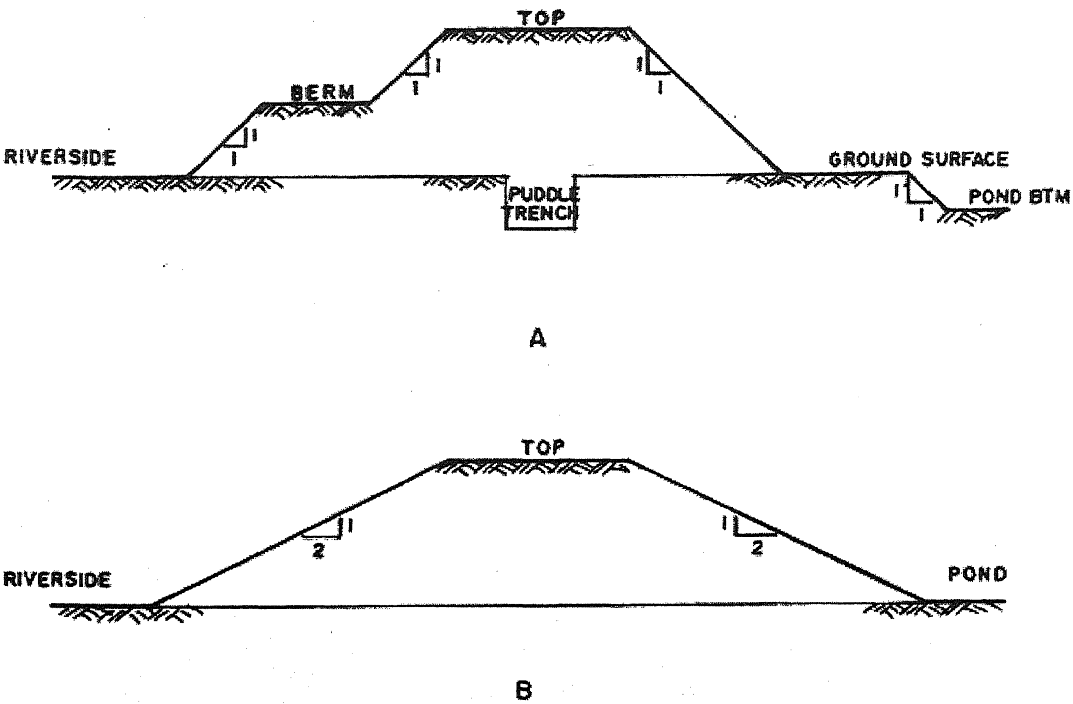

Fig 3 : Design of peripheral Dyke

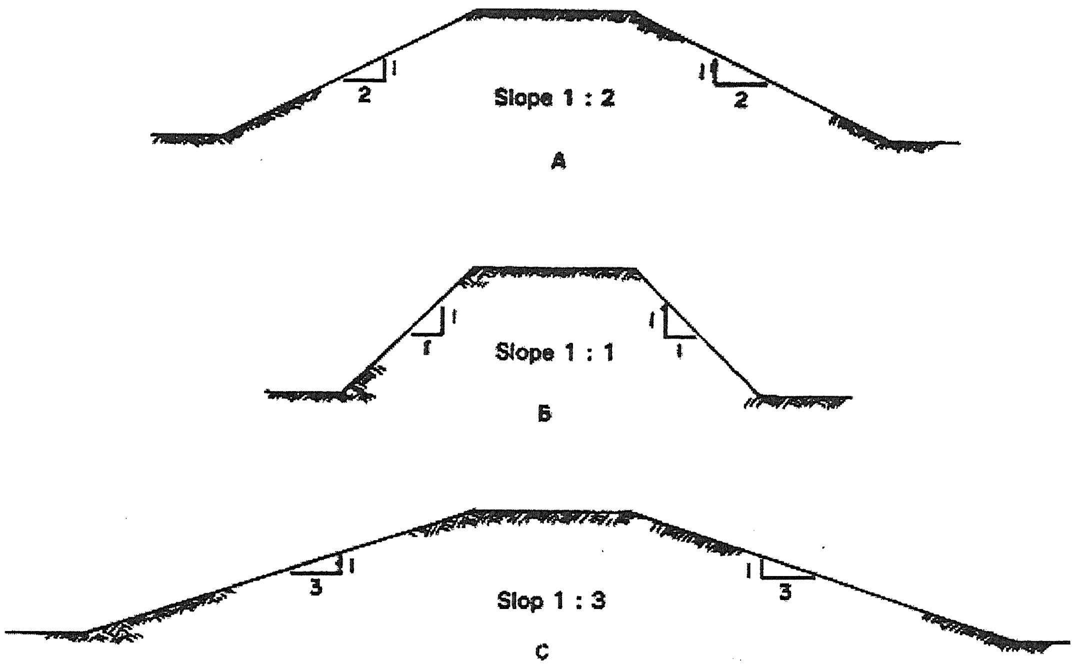

Fig 4. Dyke slope

Dikes should be designed to impound higher than 1 m. depth of water and must be high enough to prevent flooding during the rainy seasons and the highest high tide. The slope of the dike depends on the nature of the soil. A slope of not less than 1:1.5 is normally used in the sandy soil area to avoid erosion and 1:1 is used for clay soils. One must be aware that shallow slopes will encourage the growth of benthic algae which will impair the quality of the water in the pond. Some dikes in a farm may be wider than the others to provide space for the access road, storage, electricity and aerators.

Pond bottom slope

Pond bottom should be as even as possible; free from projecting rocks and tree stumps. The bottom must have a gradual slope from the inlet gate towards the drainage gate. The suggested ratio of the slope is 1:500.

Pond Lining

Lining materials are used in pond where the soil contains a high percentage of sand, and organic matter and is acidic in nature. Lining can reduce erosion, water seepage, waste accumulation in the soil and the leaching of ammonia, hydrogen sulfide, acidic compounds, iron and other potentially stressful compounds into the ponds. The lining also allows easy removal of wastes from the feeding areas, reducing the time and costs to clean the ponds between cycles. Several lining materials are currently available, including the compact laterite, compact clay, bitumen impregnated polypropylene textiles (geotextiles), polyvinylchloride (PVC), polyethylene (PE) and high density polyethylene (HDPE). Farmers may line the pond totally or partially, depending on economic/financial consideration. Another factor will be the rate of waste accumulation in an area on the pond bottom. The economic life of liners varies according to the maintenance and the duration of exposure to sunlight.

Among the liners, laterite soil is less expensive and commonly used in shrimp farms. However, laterite soil liner may allow the penetration of wastes and requires effective cleaning up. pond liners with PVC plastic sheeting and geotextiles can reduce the cost for aeration and cleaning up due to the easy movement of wastes and uneaten food on the smooth surface. The disadvantages of PVC plastic and geotextile-lined ponds are difficulties in maintaining plankton bloom within the first month of culture, problem of tears and the floating of the liner if the water and gas accumulate underneath them.

Experimental studies were conducted in CIBA experimental farms on various cost effective seepage control structures.

Pond depth

The rearing pond must have a minimum depth of 1.0 meter. Most traditional brackishwater ponds for shrimp farming are relatively shallow. To satisfy depth requirement, a ditch is constructed along the dike or a central canal between two opposite sides of the pond. The average depth is 1.0 – 1.2 meters and depth of the platform is 30–60 cm. Such pond design with peripheral ditches and central platform affords several benefits:

a. The ditch provide better living conditions during hot weather.
b. The shallow, centrally located platform serves as growing area for the natural food organisms.

The ditch also serves as harvesting canal

Supply and drainage

Design of canal

Not all shrimp farms are located close to the coast or estuaries. For those that are located far away from the water sources, it is necessary to construct supply and drainage canals.

Conceptually, a shrimp pond must possess separate canals for drainage and supply and for avoiding probable contamination of the water supply. Both supply and drainage canals would likewise serve as water level control in the pond and as temporary holding areas for shrimps. It is important that the siting of the canal systems takes advantage of the natural waterways within the proposed site.

Dimensions of supply and drainage canals are calculated by using the following equation:

$$Q = AV$$

Where:

Q	=	volume of water discharge
A	=	cross-sectional area of the canal
V	=	velocity of water flow

V value can be calculated by the following formula:

$$V = R^{2/3} \times S^{1/2} \times 1/n$$

where:

R	=	depth of water flow
S	=	canal bed gradient
n	=	coefficient of roughness (0.02)

Each pond should have a separate inlet and outlet. Both should be screened; the inlet to prevent the entry of trash fish and other undesirable aquatic fauna, and the outlet to prevent the loss of stocked fish. The diameter of supply and drainage pipes should be at least 15 cm. Lay all pipes underground and do not plant trees close to drainage or supply lines. Construct ponds so that they can be drained individually, completely and rapidly. This will enable the removal of all fish during harvesting and facilitate efficient management, particularly when water quality and disease problems occur. Complete drainage can be achieved by a raceway or well in the deeper section of the pond. The bottom of the pond should be level and slope gradually towards this area. The outlet structure should enable the adjustment of water level and also allow for the overflow of excess water. It is important that water can be drained from the bottom as well as the surface, so that the 'dead' water (low or deficient in oxygen) can be removed.

Each pond should have a deep (at least 2 metres) and a shallow (1-metre) section; however, the preferred depth varies with the species and the locality. A deep section has the following advantages:

- the deeper water is a buffer against extreme temperatures in summer and winter
- facilitates harvesting
- increases production (at least up to depths of about 3 metres)
- reduces evaporation during summer
- reduces or eliminates the growth of macrophytes

Gates for Inlet and Outlet

Each shrimp pond should have at least one gate for filling and draining water. However, a typical pond of 0.5-1 ha. usually consists of two gates having similar structure for the inlet and outlet gates. The size of the gate is dependent on the size of the pond, but must allow the pond to be filled or drained within 4-6 hours. Gates of 0.5-1.0 m. wide are usually constructed, since gates wider than 1 m. will cause difficulty in screening and will allow strong currents which will cause erosion of the soil. The position of the outlet should be at the lowest point of the pond with a gradual slope of 1:200 from the inlet to allow total drainage of the pond during harvesting.

The conventional gates constructed at the side of the pond should have a double screen, with fine a mesh for the initial period of culture and a coarser one for a later period. Some farmers may place both meshes in a single frame and cut out the finer mesh when the size of the shrimps are larger than the opening of the coarser mesh.

Design of the Gates (sluice type)

When designing a sluice gate, it is essential to consider tidal fluctuations and gravity in order to ensure effective control of the inflow and outflow of water within a given period of time.

The water gates are classified according to function as main (primary) gate or secondary gate. Main gates are strategically situated at the perimeter and are usually constructed of reinforced concrete. These are the main structure controlling the quantity of water for distribution to the shrimp farm.

Irrespective of the material to be used to construct the water gates (eg., wood, reinforced concrete, ferrocement), the following requirements should be met

a. a gate should have adequate capacity for the required amount of water to be taken in or drained out;
b. a gate should be constructed in a position that water can be totally discharged;
c. a gate should have sufficient grooves for placement of filter screens, slabs and harvest nets;
d. a gate should be firmly placed at the pond bottom and properly linked with the dikes to prevent seepage and possible collapse.

A standard gate design consists of tide stern wing, side walls and bed structure. The side walls are often designed in accordance with the slope of the earthen dike. Grooves for slabs are usually set at the inner side of the gate

The size of the gate is based on the total water requirement of a pond. Water intake volume is calculated using the equation:

$Q = CA\ [2g(H - h)]^{1/2}$

where:

- Q = rate of flow (m/sec)
- C = cross section of the flux (calculated by multiplying the width of gate opening and its depth)
- A = coefficient of discharge (0.61)
- g = gravitational constant (9.8 m/sec^2)

Central Drain

This has been employed in some farms and consists of perforated pipes laid horizontally at the center of the pond and connected to a pipe leading to the outlet. A screen of small mesh size is used to cover the drain for the first 50 days of culture and is removed to allow for easy removal of water when the shrimps are larger than the diameter of the pipe. This method has the advantages in that it can remove the waste and clean the pond bottom any time throughout the culture period.

Several techniques to accomplish carrier exclusion will lead to record production . First they minimize water exchange in what they refer to as the closed or zero-exchange system in which the pond is filled upon stocking and then maintained without replacement for the entire culture cycle of 120_ 130 days. Some farmers cautiously compensate for evaporation and infiltration losses toward the last half of the cycle, but all of them strive to minimize exposure to carriers by very discriminating exchange of water. Note that this 'closed' approach is highly dependent on mechanical to maintain satisfactory water quality for the duration of the crop cycle.

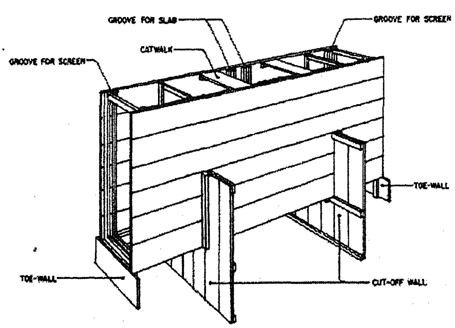

Fig 5 . Wooden sluice gate

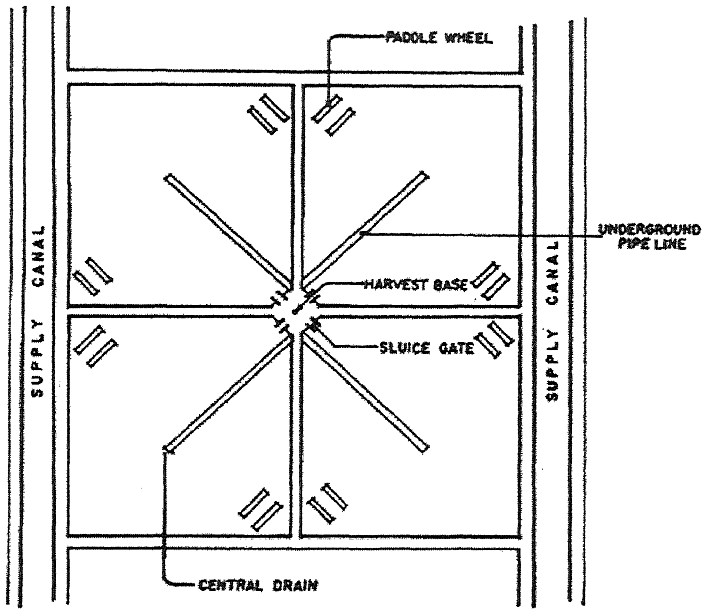

Fig 6 Typical intensive pond with central drain

AERATION

The dominant culture form in Indian condition is described as intensive with typical production yields of roughly 3_ 10 mt/harvest cycle. Intensive culture is characterized by mechanical aeration and by relatively small ponds (e.g., 0.5_ 2 ha). Yields and feeding rates are relatively high and proportional to the applied aeration power. Generally any mechanical aeration capacity defines the lower limit of intensive culture. Aeration capacity may be as large as 40 kW/ha although typical installations range from 5 to 20 kW/ha. At high levels of productivity and minimum water exchange and the heterotrophic pond ecology clearly becomes the dominant feature in pond management. Shrimp feed on, in addition to their prepared ration, matrices of flocculated organic material consisting of bacteria, cellular remnants, protists and invertebrate grazers. Bacteria nitrify and denitrify the nitrogenous waste, becoming an in situ biological filter. Although zero-exchange is not actually attainable, such systems approach theoretically minimal water exchange. Although dependent on mechanical aeration to provide the respiratory needs of the shrimp and the heterotrophic ecology, mechanical energy consumption in intensive ponds generally conforms to approximate estimate of roughly 1 kW of aeration capacity/500 kg of shrimp harvested.

Principal design criteria

(1) The presumptive farm configuration is a geometrically compact array of mechanically aerated intensive ponds with robust physical barriers on its perimeter to exclude terrestrial viral carriers.

(2) Minimizing water supply requirements is a requisite of the most efficient water supply treatment for viral carriers; therefore a semi-closed recirculating distribution is indicated.
(3) A recirculating system with remedial retention ponds conserves water and fertilizer, reduces exposure to viral pathogens, and allocates water among ponds in different stages of production in proportion to their biological demands.
(4) Filtration is a requisite treatment prior to ozonation. Treatment of the raw water supply with an effective dose of ozone preceded by mesh filtration enhances deactivation of viral particles; even those embedded in smaller tissue fragments that pass micro-filtration.
(5) Effective mesh (100_ 300 mm) filtration devices at the intake port of every pond provide a final barrier to viral carriers at the pond threshold. Additional filtration sites in the water system include filtration of raw water replenishment and recirculation flows.
(6) While the emphasis of ozone treatment is primarily focused on the raw water supply, using ozone at lower doses to 'polish' a recirculating stream is an alternative mode of application.
(7) All of these criteria are assumed to be implemented in a context in which other reasonable biosecurity protocols for preventing viral contamination from seedstock, implements, and feed are observed.

Drainage Canal and Sedimentation pond

The drainage canal of a shrimp pond should be at least 50 cm. lower than the lowest point of the pond to allow drainage by gravity. The effluent will be drained into a sedimentation pond to settle the particulate wastes before water is pumped into the reservoir or released out of the farm. It is recommended that the sedimentation pond should be approximately 5-10% of the culture area and should be deep enough to prevent mixing and re-suspension of the wastes. Baffles or soft walls made of fine mesh net or plastic sheeting supported by stakes driven into the pond bottom, may be constructed in the sedimentation pond to decrease the velocity of water and increase the retention time which will enhance the settlement of the wastes. The wastes in the sedimentation pond should be removed periodically and discharged into the waste dumping area.

Waste Dumping Area

A shrimp farm should provide 5-10% of the area for dumping of the wastes. Wastes from the pond must be collected carefully and dumped into this area without discharging to nearby areas, which will contaminate the natural resources.

Buildings

Accommodation, storage, shop and guard houses may be built in the farm as required. It is advised that accommodation for workers should be set up at various points around the farm for security purposes and to allow the ponds to be adequately monitored.

Biosecurity Program for Aquaculture Facilities

The principles of a good Biosecurity program apply to all systems whether they be land based, flow through, recirculation sea cage systems.

External barriers –
preventing the spread of disease organisms onto and off a farm by focussing on;

- Pathogen-free water source at all times for land based farms
- Total ban on movements of shrimp fish from other farms or at least a total ban on movements of shrimp
- Restrictions on movements of fish between farm sites of the same company
- Restriction on visits to the shrimp farm.
- Restriction on access to a farm site i.e. fence around the site, locked doors etc.
- Strict sanitary measures for any people entering the shrimp farm
  - protective clothing (washed regularly in hot water and disinfected)
  - foot dips and hand hygiene
  - cleaning and disinfection program
  - pest management control

Internal barriers - preventing the spread of disease organisms within a farm by;

- Separation of each unit within a facility and isolation of these units from each other.
- Define sanitary units or areas on each farm site
- Define sanitary measures (i.e. cleaning & disinfection, pest control program) inside each unit or area.
- Define sanitary measures on movements between different units or areas i.e total ban of movements from area X to area Z
- Restrict movements of tools and fish
- Strict sanitary measures for any people entering the fish farm
  - protective clothing (washed regularly in hot water or disinfected)
  - foot dips and hand hygiene
  - cleaning and disinfection program
  - pest management control

Implementing strict biosecurity measures at the farm level can be very expensive and may not be feasible in open farming systems. Identifying and weighing the relative risks associated with different pathogen carriers and routes of entry through epidemiological studies would help to target resources towards the major risks, for biosecurity measures to be cost effective at the farm level. Biosecurity measures will be adopted at the farm level only if they are shown to effectively prevent the occurrence of the disease and at a cost the farmer can afford

Some commonly followed biosecurity requirement in shrimp farm includes

(1) screening for viruses and *Vibrio harveyi* prior to stocking of postlarvae and juveniles in nursery and grow-out farms (100%);
(2) lowering of stocking density (70%);
(3) use of water reservoir with fish or green water culture system, mostly using tilapia (65%);
(4) use of commercial probiotics (68%); and
(5) employment of biosecurity measures (35%).

The biosecurity measures include the use of tire bath for incoming vehicles , foot bath for footwear, and hand washing and disinfection at the farm entrance for farm personnel and visitors. The tire and foot baths contain a strong solution of chlorine or formalin while hand disinfectant commonly used is 70% ethyl alcohol. Bird scaring device and crab fence using polyethylene liners along the side of the dikes are installed to prevent entry of animals that are possible carriers of viruses. Entry of non-farm personnel is also limited. Individual ponds have designated tools and materials for exclusive use. Farm personnel are also advised to have specific work clothes.

Implementation of Biosecurity in shrimp farms

A practical example of biosecurity program is demonstrated by a shrimp disease control project in southern India implemented in 2000 by the Marine Products Export Development Authority (MPEDA) of India, Ministry of Commerce and Industry, with technical assistance from the Network of Aquaculture Centers in Asia-Pacific (NACA) (Padiyar et al. 2003). The outcomes of this study led to the development of better management practices (BMPs) to reduce the identified risks, followed by wide consultation with farmers and other agencies to gather consensus on the study finding and their practical application to improve performance of shrimp farming systems.

The BMPs include three main management strategies focusing on:

(a) pond bottom preparation and water management prior to stocking,

(b) seed selection and stocking, and

(c) Post-stocking management.

Conclusion

Biosecurity for aquaculture production systems could be implemented successfully if appropriate site specific farm design was conceived and constructed with the coordination of an engineer and biologist.. By following internationally agreed upon policies and guidelines and a variety of management strategies successful aquaculture could happen . The key elements of biosecurity can be summarized as reliable sources of stock, adequate diagnostic and detection methods for excludable diseases, disinfection and pathogen eradication methods, best management practices, and practical and acceptable legislation. Biosecurity awarness at the farm level is not simply about having footbaths at the entrance to a facility. Biosecurity awarness is the creation of a state to mind in farm staff such that there is constant vigilance at the farm level, on fish health issues that may impact the profitability and sustainability of the enterprise. It is not created ovenight, but requires effort and resources. Finally though, the cost benefit associated with that effort will be positive and significant.

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Pre- Stocking Management – Pond Preparation

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Typical problems during grow out such as over blooming of benthic macro algae, depletion of oxygen during early hours and characterized by swollen opercula resulting to mass mortality or developing WSD outbreak are common in shrimp aquaculture world wide. In most culture operations if shrimp survive until the 3rd month frequently develop black gill disease (fouling) followed by low level mortality. Also other forms of frequent problems encountered are 'Pinky disease WSD or uneven growth of shrimps. So a serious concern was felt amongst culturists led to the concept of adherence of Best Management Practices (BMP).

The main theme of the BMP were to

- To reduce the risk of white spot disease in semi- intensive shrimp ponds
- To improve farmers' shrimp production
- To alleviate poverty among coastal communities

So the BMP program was centered around biosecurity against WSSV for shrimp ponds by stocking PCR test negative PLs and keep the virus out of the pond by setting a fencing around the pond to prevent introduction of virus carrier such a crabs, birds and animals. However, the perquisite for successful implementation of BMPs in shrimp culture depended not only on quality of seed but on the mode of site selection which includes the type of soil, water source and quality. On selection of the culture site, the next factor in BMP of prime importance is the pond preparation followed by the culture management thereafter.

Thus the 5 basic BMPs in shrimp culture are:

- Site selection
- Proper pond soil preparation
- Water treatment (elimination of WSSV carriers)
- Providing good quality seed (including two step PCR test negative for WSDV as per OIE standard procedure)
- Proper water quality management (providing paddle wheels as oxygen stabilizer)

- Better feed management

Pond Preparation

Generally due to unprepared ponds that are not well dried, the organic matter from previous crops accumulated in pond bottom cause crop losses. Even if the bottom is partially dried, the rich blackish organic muddy soils are removed and just put inside of the dike which again is the cause of poor pond preparation. Thus, for shrimp culture to be successful much depends on good bottom soil condition and its pre- preparation before shrimp stocking.

However, there is a diversity of soil which plays a vital role in shrimp culture systems. Among different soils, some soils may have undesirable properties like potential acid sulphate acidity, high organic matter content or excessive porosity. On the other hand, even if the site is good, the problems may still crop up due to the large quantity of inputs used during culture like feed and fertilizers, which lead to excessive phytoplankton production, low dissolved oxygen, high ammonia, poor bottom soil condition and other problems. Most of these problems can be avoided by adopting proper best management practices during pond preparation and culture period.

1. POND PREPARATION

The main objectives of pond preparation are to provide the shrimp with a clean pond base and appropriate stable water quality. Pond preparation has to be done for both virgin or newly constructed and in already existing ponds.

1.1 Newly constructed ponds

In newly dug out ponds, the characteristics of the soil has to be analysed first before adopting the various measures to prepare the pond. Soil samples are taken from different locations of the pond and are thoroughly mixed together and a representative portion is analysed for its characteristics. Soil deficiencies should be identified and treated in new ponds before stocking. If a soil of a new pond is acidic, it should be limed before initiation of aquaculture. Based on the soil parameters, the management strategies are adopted in terms of liming, manuring and fertilization. .

1.2 Post Harvest Pond preparation

Before initiating a second crop, the pond has to be prepared by drying, removing the earlier organic matter etc. before restarting the culture. However, after every cropping, the soil conditions change tremendously and are never of the same characteristic as the virgin ponds or before the first crop initiation. The various pond preparation strategies include :

i) Cleaning

During production cycle, considerable quantity of waste accumulates in the ponds depending upon the culture practices. This waste must be removed to ensure sustained production in the pond. Removal of waste by draining and drying of the pond bottom after the end of the production cycle, are some of the steps to be followed for keeping pond environment clean. Two systems are commonly used to clean the pond after a production cycle. One is to allow the pond to dry out and then remove the waste or the other is to wash away the waste before it dries off.

ii) Dry method

In this method after the final drain harvest, the pond bottom is allowed to dry and crack, primarily to oxidize the organic components left after the previous culture. The pond bottom should be dried for at least 7-10 days or the soil should crack to a depth of 25 - 50 mm. After drying, the waste can either be removed manually or with machines at least 5cm of the top soil. Drying and cracking of pond bottom enhances aeration and favours microbial decomposition of soil organic matter. Soil respiration measured in a pond bottom increases drastically during first 3 days after drying. The optimum moisture content for dried soil should be 20%, but varies in different soils from different ponds. Another advantage of pond drying is it enhances the mineralization of organic phosphorous which is dependent to the availability in the water column and pond soil. It is an effective method for elimination and control of undesirable species in the pond. This method has some advantages as the solid waste present in the soil can be dispensed easily away from the ponds. One of the main BMP components in pond preparation is the disposal of solid waste away from the pond site instead on the pond bunds which is cost driven and needs site for dumping.

iii) Wet method

Alternatively in ponds where complete drying is not possible organic, biodegradable, piscicides such as Mahua oil cake (100-150 ppm) and tea seed cake (15-20 ppm) can be used for eliminating unwanted organisms. In this method, after the final drain harvest, the accumulated black material on the pond bottom is flushed in the form of thin slurry using a pump. It is quick and more efficient process than the dry method, reducing the period between production cycles. The advantage of this method is that waste is removed in suspension. This method needs a settling pond where waste is removed from the water and treated repeatedly to avoid polluting the local environment.

iv) Pond maintenance

During pond preparation the weak dikes are strengthened with soil and the inner slope of the dike is consolidated with outside soil other than from the pond bottom. Tunnels and holes caused by burrowing organisms are plugged. Reconditioning of the bottom trench, levelling of pond bottom using tractors and repairs of sluice structures and sluice screens are also done.

v) Liming

The reason for liming aquaculture ponds is to neutralize soil acidity and increase total alkalinity and total hardness concentrations in water. This enhances pond productivity of food organisms for higher aquatic animal production. Based on either the total alkalinity or soil pH, agricultural limestone dose is estimated. If both are available and values are not in agreement, use the variable that gives the greatest agricultural limestone dose. Brackishwater ponds with total alkalinity below 60 mg l^{-1} and any pond with soil pH below 7 usually will benefit from liming.

The amount of usage of lime materials to raise the pH to 7 varies in different lime materials. Agricultural limestone should be spread uniformly over bottoms of empty ponds up to the top of the dike and left for 10 - 15 days, or alternatively, it may be spread uniformly over water surfaces. A large proportion of the lime should be spread on the feeding areas and any part of the pond that has remained wet. Agricultural limestone will not react with dry soil, so when applying over the bottoms of empty ponds, it should be applied while soils are still visibly moist. Tilling after liming can improve the reaction of agricultural limestone with soil. Generally, for low pH 4.0 to 4.5 of about 11.5 to17.0 tons/ha is required of quick lime or agricultural lime or dolomite with lowest for quick lime. Similarly for different soil pH, the quantities have been assessed and applied accordingly.

vi) Tilling

Tilling bottom soils can enhance drying to increase aeration and accelerate organic matter decomposition and oxidation for reduction of compounds. Soil amendments such as agricultural limestone or burnt lime can be mixed into soil by tilling. Accumulations of organic matter of other substances in the surface layer of soil also can be mixed with deeper soils to reduce concentrations of the substances in the surface layer. Pond bottoms are not be tilled when they are too wet as the tillage machinery may not function to its capacity. Ruts caused by machinery will fill with soft sediment and be likely sites for anaerobic conditions. Ruts also interfere with draining and increase the difficulty of drying pond bottoms. Depth of tillage usually should be 5 to 10 cm, so mould board plows, often called turning plows, can be used to turn soil over. Tilling can be counterproductive in ponds where heavy mechanical aeration is used. Tilling will loosen the soil particles and aerator-induced water currents will cause severe erosion of the pond bottom. Thus, if bottoms of heavily aerated ponds are tilled, they should be compacted with a heavy roller before refilling.

vii) Fertilization

Decomposition in organic soils is slow because pH usually is low and the amount of carbon to nitrogen (C:N ratio) is high. Nevertheless, because of high organic matter content, such soil often becomes anaerobic during shrimp culture. Application of agricultural limestone and inorganic nitrogen fertilizers increases the pH and supply of nitrogen for faster soil organic matter degradation during fallow periods between crops. Urea can be spread over pond bottoms at 200 to 400 kg ha^{-1} at the beginning of the fallow period to accelerate decomposition of organic soil. Agricultural limestone should not be applied until a few days after urea is applied to prevent a high pH. Sodium nitrate can be applied @ 20 to 40 g m^{-2} to wet soil to encourage organic matter decomposition in wet areas. However, nitrate fertilizers are more expensive and are not recommended where soils can be adequately dried.

The rate of application of inorganic fertilizers ranges from 25 - 100 kg/ha as a basal dose during pond preparation with minimum water depth of 10 - 15 cm. When the shrimp culture progresses, depending upon the phytoplankton density as exemplified by turbidity of the pond water, required quantity of the fertilizers may be applied in split doses at short intervals for sustained plankton production. The main nutrient limiting phytoplankton production in brackishwater ponds is phosphorus. Hence both phosphorus and nitrogen should be applied in the ratio of 1:1. Excessive application of urea and ammonium fertilizers may cause ammonia toxicity to shrimps and also may lead to algal blooms reducing of dissolved oxygen.

Shrimps being bottom dwellers, benthic organisms constitute their main food items. Hence fertilization of soil instead of water is more effective. Productivity of benthic organisms may be low in ponds with concentrations of organic carbon below 0.5 to 1.0%. Organic fertilizer can be applied to such soils to enhance organic matter concentration. Chicken and other animal manures have been applied at 1,000 to 2,000 kg ha^{-1} to pond bottoms during the fallow period. In brackishwater conditions decomposition of cattle dung is slow and hence application of chicken manure, if available, is advisable. The rate of chicken manure is one-third of cattle dung. However, application of a higher quality organic matter such as plant meals—e.g., rice bran, soybean meal, and crushed corn—or low-protein-content animal feed at 500 to 1,000 kg ha^{-1} are more efficient. When organic fertilization of pond bottoms is practiced, ponds should be filled with 10 to

20 cm of water and allowed to develop a dense plankton bloom. In shrimp farming, both organic manures and inorganic fertilizers are supplementary to each other and one cannot be exchanged for the other. It is always better to apply both organic and inorganic fertilizers together as a basal dose during pond preparation for optimum result.

viii) Nutrient exchange between soil and water

The two most important nutrients in pond aquaculture are nitrogen and phosphorus because these two nutrients often are present in short supply and limit phytoplankton growth. These two nutrients are added to ponds in fertilizers, manures, and feeds. Fertilizer nitrogen usually is in the form of urea or ammonium, and urea quickly hydrolyzes to ammonium in pond water. Ammonium may be absorbed by phytoplankton, converted to organic nitrogen, and eventually transformed into nitrogen of shrimp protein via the food web. Ammonium may be oxidized to nitrate by nitrifying bacteria, and nitrate may be used by phytoplankton or denitrified by anaerobic microorganisms in the sediment. Nitrogen gas formed by denitrification diffuses from sediment to pond water to the atmosphere. Ammonium is in equilibrium with ammonia, and ammonia also can diffuse from pond waters to the atmosphere. A small amount of ammonium may be adsorbed on cation exchange sites in pond bottom soils. Organic nitrogen in plankton and in aquatic animal feces may settle to the bottom to become soil organic nitrogen. Nitrogen in soil organic matter may be mineralized to ammonia and recycled to the pond water, but the rate is slow.

Phosphorus usually is present in fertilizer as calcium or ammonium phosphate. Phytoplankton can rapidly remove phosphate from water, and phosphorus in phytoplankton may enter the food web culminating in shrimp. Pond soil strongly adsorbs phosphorus, and the capacity of pond soil to adsorb phosphorus increases as a function of increasing clay content. Most of soil phosphorus was tightly bound, and only a small amount was water soluble. Pond soils are not a major source of phosphorus to water because soil-adsorbed phosphorus is highly insoluble. Phosphorus released by decomposition of organic matter in pond bottoms is rapidly adsorbed by soil and little of it enters the water. Soils that are near neutral in pH have less capacity to adsorb phosphorus and a greater tendency to release phosphorus than do acidic or alkaline soils Nevertheless, even neutral soils remove phosphorus from the water and are a sink rather than a source of phosphorus. Once dissolved in the water, nitrogen and phosphorus originating from manures and feed also will enter the same pathways as nitrogen and phosphorus applied in chemical fertilizers.

ix) Application of microbial products for improvement of soil quality

A number of products are promoted to enhance beneficial chemical and biological processes and to improve soil quality. These products include cultures of living bacteria, enzyme preparations, composted or fermented residues, plant extracts, and other concoctions. There is no evidence from research that any of these products will improve soil quality. Nevertheless, they are not harmful to the culture species, surrounding environment, workers, or quality of aquaculture products.

x) Raising of water level

The pond is filled with brackish or seawater by pumping or by opening the sluice with proper screens to prevent entry of unwanted organisms into the pond. The water level is maintained to 30 - 40 cm and allowed to remain for 10 - 15 days. By this time, the colour of water may turn dark green with algal bloom and a layer of benthic algae along with associated food organisms will form at the bottom. Subsequently small doses of organic and inorganic fertilizers are applied based on the secchi disc observations (transparency with 25-30 cm -optimal) of algal production. The water level is then raised to 100-125 cm. Now the pond is ready for stocking post larvae of shrimps.

xi) Monitoring of soil parameters during pond preparation

Monitoring of soil quality condition can be valuable in shrimp culture pond management. Major concerns in pond bottom soil management are low soil pH, high soil organic matter, loss of the oxidized layer, and accumulation of soft sediment. In older ponds with impaired soil quality, problems should be corrected and prevented from recurring. These materials have combined effect on the environment of the pond bottom. To understand the condition of the pond bottom, the following parameters are monitored :

a) Soil pH

This is one of the most important soil quality parameters since it affects the pond condition. Generally, soil pH ranging between 6.5 and 7.5 is the best suited where availability of nitrogen, phosphorus, potassium, calcium and magnesium is maximum. The micronutrient whose requirements are very small is also available in this pH range. The low pH of bottom sediment indicates unhygienic condition.

b) Organic matter - .Redox-potential

The changes observed during culture period in the soil bottom in terms of increasing organic load forms a indicator of the soil quality conditions. Anaerobic condition developes in pond, when input of organic matter exceeds and the supply of oxygen needed for decomposition of organic matter depletes. This reducing condition can be measured as the redox potential (E_h). Redox potential indicates whether the water or soil is in reduced condition or oxidized (E_h with '+' ve value) condition. Reduced or anaerobic sediments may occur at the pond bottom in heavily stocked pond with heavy organic load and poor water circulation. Under anaerobic condition in the pond bottom, reduced substances such as H_2S, NH_3, CH_4 etc. are formed which are toxic to benthic organisms. In shrimp ponds, development of highly reducing conditions at the inter phase layer of water and pond mud is highly undesirable. Water circulation by water exchange, wind or aeration helps to move water across mud surface and prevents the development of reduced condition. Draining at the centre of pond, as is being practiced by some farmers, is an ideal remedy for the prevention of formation of highly reducing condition especially during the last phase of culture period. Bottoms should be smoothened and sloped to facilitate draining of organic waste and toxic substances. The redox potential (E_h) of mud when exceed -200 mV, the pond condition is critical. So, during pond preparation, drying of the pond is essential as it changes anerobic condition to aerobic condition of bottom soil.

Thus adoption of best management practices during pond preparation paves way for higher production, lesser incidence of disease outbreaks and crop losses provided further BMP procedures are strictly followed during stocking and culture phase also. One of the BMPs principle that governs a successful crop in an area is strict, uniformed and disciplined adoption of all principles by one and all in the shrimp culturists within the culture activity zone.

BETTER MANAGEMENT PRACTICES IN SHRIMP SEED PRODUCTION

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Shrimp aquaculture from a traditional activity, has transformed in to a commercial enterprise over the years by the interventions of research and developmental agencies. The sector which was in its nascent stage has grown by leaps and bounds to attain its present level. By and large, shrimp farming is synonymous to the culture of tiger shrimp *Penaeus monodon* in our country. From its modest level of activity as practiced during the 1070s, this sector expanded rapidly by the entry of corporate sector during the late 1980s and early part of 1990s. With the rapid growth witnessed in aquaculture, problems in the form of viral diseases also cropped up and the sector saw its nadir in mid 1990s. The uncontrolled and unplanned expansion of area for culture and the least importance given to the health and environmental issues resulted in the recurrence of the viral disease outbreaks especially that of White Spot Virus Syndrome (WSSV). Very often WSSV is transmitted through shrimp seed. This could be prevented by producing healthy seed under biosecured hatchery conditions and this could be achieved by following Best Management Practices (BMPs) in the hatchery.

Best management practices in shrimp seed production can be defined as the practices or measures or methods adopted to secure a disease free environment in all production phases in the hatchery for improved seed quality. BMP is the ability to prevent losses to disease through effective elimination of pathogens and their carriers. The shrimp aquaculture industry has been experiencing severe setbacks due to the devastating viral diseases. These diseases are believed to be transferred between regions through the importation of hatchery broodstock, postlarvae and shrimp products. Once new pathogens are imported to an area, infection of wild stock appears to be inevitable, eliminating future possibilities of using uncontaminated wild stock to culture.

BMP encompasses policy, regulatory and programme frameworks in response to managing risks associated with diseases. The basic elements of a BMP programme in a shrimp hatchery include the physical, chemical and biological methods necessary to protect the hatchery from all diseases of high risk. Responsible hatchery operation must also consider the potential risk of disease introduction into the natural environment and its effects on neighbouring aquaculture operations and the natural fauna.

The BMP issues in shrimp hatcheries may be either **internal** concerning the introduction and transfer of pathogens within the facility or **external** concerning the introduction and transfer of pathogens from outside sources to the facility or vice versa. In case of disease outbreak within the aquaculture facilities the options available are either **treatment-** by application of methods that reduce the effects of the diseases,

containment- by restriction of the disease from spreading to other tanks/facilities, or **elimination-** of the diseases from the vicinity. Implementation of BMP programme for a shrimp hatchery should include the following elements:

- Specific pathogen free (SPF) or high health (HH) shrimp stocks should be used.
- All the incoming stocks should be quarantined in the designated area.
- All incoming stock should be analyzed for diseases.
- All incoming water sources should be treated to eliminate pathogens.
- Equipment and materials should be sterilized and maintained clean.
- Personal hygiene measures like shower bath including washing of hands and feet and clothing.
- Knowledge of the potential pathogenic diseases and the sources of risk and methods and techniques for their control and /or eradication
- Specific pathogen resistant (SPR) stocks to be used.
- Maintenance of optimum environmental conditions.
- Immune enhancers and probiotics to be used in place of antibiotics.

INFRASTRUCTURE REQUIREMENTS

Shrimp hatcheries should be designed (or modified, in the case of existing hatcheries) to ensure good biosecurity, efficiency, cost-effectiveness and the implementation of the hatchery standard operating procedures (NACA, 2005). A well-designed shrimp hatchery will consist of separate facilities for quarantine, acclimatization, maturation, spawning and hatching, larval and nursery rearing, indoor and outdoor algal culture, and for the hatching of *Artemia*. Additionally, there will be supporting infrastructure for handling water (facilities for abstraction, storage, filtration, aeration, heating and distribution), and feed (laboratories for analysis and preparation and storage facilities), as well as maintenance areas, packing areas for nauplii and PL, offices, storerooms and staff living quarters. The physical separation or isolation of the different production facilities is a feature of good hatchery design and should be incorporated into the construction of new hatcheries. In existing hatcheries with no physical separation, effective isolation may also be achieved through the construction of barriers and implementation of process and product flow controls. The hatchery facility should have a wall or fence around the periphery of the property, with enough height to stop the entrance of animals and unauthorized persons. This will help to reduce the risk of pathogen introduction by this route, as well as increase overall security.

WATER QUALITY AND TREATMENT

Water for the hatchery should be filtered and treated to prevent entry of vectors and any pathogens that may be present in the source water. This may be achieved by initial filtering through sub-sand well points, sand filters (gravity or pressure), or mesh bag filters into the first reservoir or settling tank. Following primary disinfection by chlorination, and after settlement, the water should be filtered again with a finer filter and then disinfected using ultraviolet light (UV) and/or ozone. The use of activated carbon filters, the addition of ethylene diamine tetra acetic acid (EDTA) and temperature and salinity regulation may also be features of the water supply system.

Each functional unit of the hatchery should have independent water treatment facility and it should be isolated from other water supply systems for other areas. Separate recirculation systems may be used for part or the entire hatchery to reduce water usage and further enhance biosecurity, especially in high-risk areas. The discharge water from the hatchery, particularly that is known or suspected to be contaminated (for example, water originating from the quarantine areas) should be held temporarily and treated with hypochlorite solution (>20 ppm active chlorine for not less than 60 minutes) or another effective disinfectant prior to discharge. This is particularly crucial where the water is to be discharged to the same location as the abstraction point.

BROODSTOCK SELECTION AND QUARANTINE

Some viral diseases are believed to be transmitted vertically from parent to offspring and this may be eliminated by the use of SPF domesticated shrimp. If SPF shrimp are not available, broodstock should be tested for infection by an appropriate diagnostic test and any infected individuals should be destroyed. Shrimps testing negative for the disease or pathogen should still be considered a risk and placed in a quarantine facility until their health status is fully known.

Hatcheries normally prefer wild broodstocks since they produce more healthy nauplii. In recent years, however, the high risk of introducing viral pathogens with wild broodstock has changed this preference. Domesticated stocks either genetically improved or suspected to be resistant or tolerant to specific pathogens may be used as broodstock. SPF stocks are generally maintained in highly biosecure facilities and their offspring (designated "high health" rather than SPF) are supplied to the industry. SPR shrimp are those that are not susceptible to infection by one or several specific pathogens, and Specific Pathogen Tolerant (SPT) shrimp are those that are intentionally bred to develop resistance to the disease caused by one or several specific pathogens.

The quarantine facilities are essentially a closed holding area where shrimps are kept in individual tanks until the results of screening for viruses (and for bacteria, where applicable) are known. The broodstock quarantine unit should be physically isolated from the rest of the hatchery facilities. If this is not possible, the hatchery design should be altered so that there is no possibility of contamination from the quarantine or holding area into the other production areas. Particular care should be taken with waste disposal and effluent treatment. Staff working in this area should not be permitted to enter other production sections and should follow sanitary protocols at all times. The quarantine unit should have the following characteristics:

- ✓ Adequate isolation from all of the rearing and production areas to avoid any possible cross contamination.
- ✓ Should be in an enclosed and covered building with no direct access to the outside.

- ✓ There should be means provided for disinfection of feet (footbaths containing hypochlorite solution at >50 ppm active ingredient) and hands (bottles containing iodine-PVP (20 ppm and/or 70% alcohol) to be used upon entering and exiting the unit.
- ✓ Entrance to the quarantine area should be restricted to the personnel assigned to work exclusively in this area.
- ✓ Quarantine unit staff should enter through a dressing room, where they remove their street clothes and take a shower before going to another dressing room to put on working clothes and boots. At the end of the working shift, the sequence should be reversed.
- ✓ An adequate number of plastic buckets should be available in the quarantine room to facilitate effective daily routine movement of shrimp in and out of the facility.
- ✓ The quarantine facility should have an independent supply of water and air with separate treatment and disinfection systems and a system for the treatment of effluents to prevent the potential escape of pathogens into the environment.
- ✓ The seawater to be used in the facility must enter a storage tank where it will be treated with hypochlorite solution (20 ppm active ingredient for not less than 30 minutes) before inactivating with sodium thiosulfate (1 ppm for every ppm of residual chlorine) and strong aeration.
- ✓ All wastewater must be collected into another tank for chlorination (20 ppm for not less than 60 minutes) and dechlorination before release to the environment.
- ✓ All mortalities or infected animals must be incinerated or disposed of in another approved manner.
- ✓ Used plastic containers and hoses must be washed and disinfected with hypochlorite solution (20 ppm) before reuse.
- ✓ All the implements used in the quarantine unit must be clearly marked and should remain in the quarantine area. Facilities for disinfection of all equipment at the end of each day should be available.

BROODSTOCK HEALTH SCREENING

When broodstock are large in numbers, the tests may be carried out on pools of 10 individuals from different broodstock groups. Although PCR testing should be conducted on broodstock upon arrival during their quarantine, it is worthwhile to conduct additional PCR testing (at least for WSSV) after spawning. This is because there is evidence that broodstock that tested PCR-negative for WSSV during quarantine may test positive if analyzed following exposure to a stress such as spawning. Infected animals should be disposed of by incineration or some other method (e.g. autoclaving and deep burial) that will prevent the potential spread of virus. Animals should be kept under observation in the quarantine facility until all tests are completed prior to transferring them to the acclimatization area. The equipment used for the transfer should be kept separate from that used in the quarantine room and disinfected before and after transport. All equipment used in the quarantine area should remain in the quarantine area and be disinfected at the end of each day in tanks specially designated for that purpose.

BROODSTOCK NUTRITION

Fresh feeds such as squid, polychaetes, *Artemia*, mussels, oysters, clams etc., must be screened for contamination before use and it is always better to use fresh feeds. The feeds may be sterilized or pasteurized to inactivate any virus as long as this does not affect the acceptability or nutritional quality of the feed. Different types of frozen feeds should be stored in separate freezers to avoid cross contamination.

SPAWNING AND HATCHING

Spawning should be done in a separate room from the maturation area in order to keep the spawning area clean and to be able to carry out daily washing and disinfection of tanks without disturbing the broodstock. Water-purification steps should be taken including UV light treatment and passage through activated carbon and cartridge filtration to <1 µm. The eggs should be collected and washed with adequately treated seawater (filtered and sterilized) and then disinfected using iodine-PVP (50–100 ppm/10–60 sec) before rinsing again with abundant clean seawater.

Hatching facility should also be a separate one. The nauplii should be collected and washed with adequately treated seawater (filtered and sterilized) and then disinfected using iodine-PVP (50–100 ppm/10–60 sec) before rinsing again with abundant clean seawater. While transporting nauplii the transport vehicle should first be disinfected before entering the hatchery facilities. After unpacking the nauplii, the packing material must be incinerated. The spawning and hatching tanks are to be washed daily with calcium (or sodium) hypochlorite solution (30 ppm active ingredient), and rinsed with abundant treated water before being refilled. This disinfection will help to reduce the risk of disease transmission.

LARVAL REARING AND MAINTENANCE

Entrance to the larval rearing areas should be restricted only to the personnel who work in these areas. Sanitary mats or footbaths containing a disinfectant solution must be placed at the entrance of each room of the hatchery. The disinfectant solution must be replaced as necessary. At each entrance to the larval rearing room, containers with iodine-PVP (20 ppm) and/or 70% alcohol should be available and all personnel must wash their hands in the disinfection solution on entry to, and exit from, the rooms.

Each room should have a complete complement of materials such as filters, meshes, buckets etc. for routine operation. A tank (500–600 litres) containing disinfectant (hypochlorite solution, 20 ppm active ingredient) should be provided to disinfect hoses, buckets, etc. Common-use equipment can be placed in this disinfecting tank at the end of every day and rinsed before re-use the following day. The disinfectant in this tank should be replaced daily or as required. Additionally, beakers, nets etc. used for each tank should be maintained in a bucket filled with sodium hypochlorite solution (20 ppm active ingredient) and dedicated to that one tank to prevent cross-contamination between tanks within the same unit. Samples of larvae and postlarvae for routine checking should be taken in disposable plastic containers that are disposed of once used. After the daily check is complete, the larvae or postlarvae should be discarded into a plastic container with sodium hypochlorite (20 ppm active ingredient) or another suitable disinfectant. Larvae and postlarvae used in the daily checks must never be returned to the larval rearing rooms or larval tanks.

LARVAL NUTRITION AND FEED MANAGEMENT

All sources of live, fresh or frozen food should be considered from the point of view of pathogen risk. Staff from these areas should not be able to enter other production areas.

Algae

Appropriate sanitary and microbiological procedures should be used to ensure the quality of the culture. Contamination with protozoans that feed on algae, other species of algae, and bacteria (in particular harmful *Vibrio* spp.) should be avoided. Alternatively, pure starter cultures can be purchased from reputable algal culture laboratories and be on-grown in the hatchery's massive tanks using sanitary procedures. The procedure of buying one lot of pure algal culture and continuously sub-culturing it throughout each larval culture cycle is not recommended, as it can easily lead to contamination of the algae and eventually, of the larvae themselves. Following disinfection of the algal culture tanks with calcium (sodium) hypochlorite solution (10 ppm active ingredient), they should be rinsed with clean, treated water and washed with a 10% muriatic acid before being left to dry.

Artemia

Certification may be requested for freedom from TSV, WSSV and YHV viruses by PCR analysis for all *Artemia* cysts purchased. After harvest, the tanks used to hatch *Artemia* must be washed with detergent and water, and then disinfected using a sponge dipped in sodium hypochlorite solution (20 ppm active ingredient), rinsed with abundant treated (filtered and sterilized) water and washed again with a 10% solution of muriatic acid. Frozen *Artemia* nauplii or adults should be stored in a separate, exclusive freezer.

STOCKING PERIOD

Each separate unit of larval rearing tanks within a hatchery or, preferably, the whole hatchery should be stocked with nauplii in as short a time period as possible, usually limited to three to four days. Prolonging this stocking period often results in increased incidence of disease for the later-stocked larvae, presumably through bacterial contamination from the older to the younger tanks. This phenomenon is often associated with the so-called "zoea-2 syndrome", where late zoea 1 and early zoea 2 stage larvae refuse to eat and suffer high mortality with associated bacterial problems. This problem may be controlled through restricting the time of stocking to less than four days, using probiotics and maintaining good cleanliness in all areas of the hatchery at all times.

SHIPPING AND TRANSFER OF POSTLARVAE

All shipping containers and equipments (nets, air stones, air lines etc.) should be disinfected before and after use. If plastic bags are used, they should be incinerated after use, they should not be re-used for shipping postlarvae or broodstock shrimp. The vehicles that deliver the postlarvae are a potential source of contamination, as they may visit several farms and hatcheries in the course of making deliveries. If possible, postlarval packing should take place at a point isolated from the production facilities, and the transport trucks (at least the wheels and tires) should be disinfected before entry to the hatchery.

FACILITY MAINTENANCE

After each cycle, sanitary dry out (for larval rearing)for at least every three to four months (for maturation facilities), with a minimum dry period following cleaning of seven days should be practiced. This will help prevent the transmission of disease agents from one cycle to the next. Concrete tanks painted with marine epoxy or plastic-lined tanks are easier to clean and maintain than bare cement tanks. Tanks used for broodstock spawning, egg hatching, and holding of nauplii and postlarvae should be thoroughly cleaned after each use. The procedures used for cleaning and disinfection are basically the same for all tanks and equipment. They include scrubbing with clean water and detergent to loosen all dirt and debris, disinfecting with hypochlorite solution (20–30 ppm active ingredient) and/or a 10% solution of muriatic acid (pH 2–3), rinsing with abundant clean water to remove all traces of chlorine and/or acid, and then drying. The walls of tanks may also be wiped down with muriatic acid; outdoor tanks and small tanks can be sterilized by sun drying. All equipment and other material used in the room (filters, hoses, beakers, water and air lines etc.) can be placed in one of the tanks containing hypochlorite solution after first cleaning with a 10% muriatic acid solution. All hatchery buildings (floors and walls) should be periodically disinfected. Before stocking tanks for a new cycle, they should once again be washed with detergent, rinsed with clean water, wiped down with 10% muriatic acid and once more rinsed with treated water before filling. Disinfection procedures may require adjustment according to the special needs of the facility. Appropriate safety measures must be taken when handling the chemicals used for disinfection.

CONCLUSION

BMP protocols are intended to maintain the "security" of a facility with respect to certain diseases causing organisms that may not already be present in a particular system. It should not be viewed rigidly as a single line of defense that, once breached by the disease factor, is worthless. Rather it should have several layers of protection and planning to accommodate the possibility of disease penetration. Implementation of a biosecurity measures by shrimp hatcheries will ensure in restriction of the disease from spreading to other facilities or elimination of the diseases from the vicinity of the aquaculture facility.

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Shrimp seed quality: Criteria for assessment of post larval quality

C. P. Balasubramanian

Shrimp aquaculture has undergone revolutionary development over the past few decades and it is one of the world's fastest growing agri-industry. Although this growth in production is impressive, there have been several problems and impediments that have yet to be resolved. In recent years, problems have continued to mount as outbreaks of disease and crop losses. Furthermore, variability in post larval (PL) quality has made culture technology unreliable and limited the commercial feasibility of shrimp culture (Castle et al 1993). Even with good husbandry practices, stocking the pond with poor quality fry results low yields at harvest. These low yields are often related to poor survival rate or slow growth resulting in unprofitably high fed conversion ratio. As a consequence to unpredictable production in grow out; farmers and researchers are more concerned today about the quality of PL entering the rearing system.

The importance of PL quality evaluation has been acknowledged since the early phase of the development of shrimp culture industry (Bauman and Jamandre, 1990). Factors affecting the PL quality are determined by the intrinsic properties of the PL itself and environment in which PL is subsequently reared. Post laraval quality is extremely variable; some of the factors affecting PL quality are known, but many (probably most) are unknown. The components of PL quality may be endocrine status of oocytes in the ovary, or sperm, diet of the broodstock or genetics of the broodstocks. Indeed, several criteria for larval quality assessment have been proposed, and some of them are widely used by aqua culturists. However, most of these criteria are based on anecdotal evidences rather than the empirical data. The experimental studies to establish the link between the predictive criteria used to assess the larval quality in hatcheries and the actual performance in grow - out system is extremely limited (Racotta et al 2004). The objectives of this article were to summarize the various procedures currently used to evaluate the larval quality in shrimp hatcheries and grow out system. Based on the available information a practical set of criteria have also been proposed.

Criteria for offspring quality

Generally the term larval quality refers to the physiological conditions, performance during culture and resistance to stress test. Although there is no accepted method of determining PL quality, many different criteria have been suggested for the evaluation of the PL quality (Samocha et al 1998). Larval qualities are generally assessed following several criteria and methodological tools that can be broadly categorized into: 1) morphology 2) behavior, 3) survival to stress test, 4) time needed to complete larval metamorphoses, 5) Survival during larval development 6) PL size 7) Screening of PL for major Pathogens (Bray and Lawrence 1992; Racotta et al 2004)

Morphology

In this category large sets of variables have been used such as size, weight, occurrence of deformities, colour, muscle/gut ratio, gill and digestive system morphology etc. (Racotta et al 2003). The most simple and widely used criterion is the visual observation of fry. Active fry with dark colour is considered to be best for stocking. The PL with clean carapace should be selected and it indicates the animal is growing fast and moulting frequently. Slow growth is indicated by the presence of pathogens and necrosis.

Muscle gut ratio: It was reported that the wild fry has a tail muscle generally exceeds their hind gut diameter by a ratio of at least 4:1. Based on this, muscle gut ratio is used widely to assess the PL quality in many hatcheries. The measurement is taken half way between the telson and last abdominal segment. The muscle should completely fill the shell form the gut down to the ventral side. Poor quality fry will often have muscle gut ratio less than 4:1. This method is proved to be very successful. However, it should be noted that this procedure is limited to stages before PL_{20}, as in older fry (>22 days) it is hard to measure due to the prominent pigmentation.

Post larval size: Increased growth and reduced variability in size during post larval stage is proved to be related to further growth to juvenile stage (Castle et al 1993). Uniformity of length of hatchery reared PL is widely used as an early indicator of PL quality. Studying the production characteristics of *Litopenaeus vannamei* Clifford (1999) proposed a scale (Fig 1). Length uniformity was evaluated using the coefficient of variation (C. V.), which is calculated as the standard deviation divided by the mean. If the C. V is lesser than 10% the population is considered to be excellent for stocking, and if C. V. is greater than 15% the population may have been infected.

Gill area: Gill area is proposed to be a predictive criteria for the good quality and survival (Racotta et al 2004), although their potential application in commercial rearing system has yet to be established. They confirmed that large gill area of PL is positively correlated with high survival rate.

Behaviour

Larval behaviour has often been regarded as a predictive criterion for good larval quality. The positive phototrophic behaviour of nauplii is widely used to harvest nauplii, and it is also thought to be an indirect indicator of larval quality (Bray and Castle 1991). However, later it was proved that this trait would last only up to the protozoeal stage and after this stage there would not be any significant difference between larvae had higher phototropism and remnant larvae (Ibarra et al 1998). Swimming activity is also used widely as an indicator for larval quality (Clifford 1992). Poor or erratic swimming activity obviously suggests a lower physiological activity.

Survival to stress test

Stress tests have been proposed as a meaningful tool for assessing fish and shrimp larval quality in aquaculture industry and environmental research management (Wedemyer and McLeay 1981, Clifford 1992, Fegan 1992). Defining stress is a difficult task. Selye (1973) defined stress is a response of organism to any demand placed on it such that it causes an extension of physical state beyond the normal resting state. Philosophy behind the stress test is that high resistance of PL to stress may be a security for their growth/survival performance in a grow out ponds. It is based on the principle of exposing an organism to a short but extreme external condition in which physiological state of the animal determines its chances of survival (Fegan 1992). In other words, batches of shrimps in poor health will be less able to tolerate such stresses than the batches of healthy shrimps, and the tolerance can be determined by a stress test before any impact on the growth can be noted. Salinity stress test and formalin stress tests are the most widely used stress tests used in the shrimp seed production industry. Another test proposed with potential application is ammonium stress test.

Salinity stress test: Osmotic stress has been used as a tool to evaluate the quality or hardness of post larvae produced in shrimp hatcheries (Samocha et al 1998). It is one of the most widely used criteria for assessing the larval quality. High survival from this test is supposed to be associated with high performance in grow-out systems. This stress test can be applied to PL_1 and PL_{20}. The test for PL_1 would be used to select a best of batches of PL_1 for further larval rearing in the hatchery where as PL_{20} would be used to evaluate grow-out performance. The methodology used for salinity stress test varies from hatcheries to hatcheries. The most common procedures are summarized below.

1. The post larvae are abruptly transferred to dilute media (in the case of PL_1 it can be 15-18 ppt and for PL_{20} it should be below 3ppt) for 30 minutes then back to the original sea water for another 30 minutes. At the end of the test survival is measured by counting dead organism.
2. The larvae are held at reduced salinity for a period of 4 hours and then mortalities are recorded.

Clifford (1994) suggested a scale for assessing larval quality based on salinity stress test (Fig 2). According to this scale survival rate above 70% is acceptable. Even though this test is widely used in Penaeid hatcheries world wide, there are still controversies regarding the efficacy of this challenge test. The shrimp species like *L. vannamei* and *P. monodon* are euryhaline, and, there fore less susceptible to low salinity stress. More over, the survival to salinity stress test is an individual measure of diverse complex process such as nutritional status, mobilization of nutrients under a sudden stress, the degree of development of PL, osmoregulatory capacity of gills etc (Racotta et al 2003). Therefore, the likelihood for obtaining positive correlation between the low salinity tolerance and better grow–out performance is almost unlikely. Recent experimental studies show that the salinity stress test is useful for predicting of survival during stocking and, however, it is not a reliable predictive indicator of performance (survival and growth) during grow-out.

Formalin stress test: Acute formalin stress test has also been widely used in Penaeid hatcheries. Samocha et al (1998) proposed formalin stress test methodology for *L. vannamei*. The methodology proposed by them is summarized below.

Place a pre determined number of PL in seawater containing formalin, and count the number of live PL after 2h. If the number of live PL is above the expected number (proposed by them) then the PL used are hardier and can be accepted for further stocking (Table 1). For example, 100 animals are kept in 200 ppm formalin for 1h, and if survival is >90% 20 points can be given. If survival is between 80 and 89% 10 points should be given.

Ammonia stress test: A challenge test using ammonia has also been proposed as a predictive criterion to evaluate the larval quality (Racotta et al 2004), although this test is not being used in commercial Penaeid hatcheries. The feasibility of using this test in commercial hatcheries has yet to be evaluated. The methodology proposed by Racotta et al (2004) is summarized below.

The test is used at protozoeal stage. A total of 30 protozoea are exposed to ammonia for 24 h and survival of protozoea is assessed after 24 h. They observed a positive correlation between survival to ammonia stress test and survival of nauplii to PL_1 (Fig 2).

Screening of post larvae for major pathogens

Owing to the frequent viral epizootics (white spot syndrome virus) and associated crop losses many shrimp aquaculturists are keen to evaluate the presence of pathogen before stocking. Therefore, larval screening for pathogens has become a pivotal part of the larval quality evaluation. Testing for virus using molecular diagnostics such as Polymerase Chain Reaction (PCR) has become increasingly common.

Principle of the PCR: Basically PCR is a method of amplifying DNA of the target organisms (in this case white spot syndrome virus). For this purpose a small, complementary fragment of the virus DNA (= primer) is used as a template to amplify the target DNA. The primer along with sample tissue is placed in the PCR vial with reagents and enzyme *taq* polymerase. Repeated cycles of heating and cooling causes the DNA to separate and anneal, resulting the doubling the quantity of targeted DNA in the process. Thus, the concentration of DNA increases enough to be detected by electrophoresis. If band correspond to the primer are found in the gel, the virus is present.

Apart from the anecdotal evidences, very few empirical studies have been conducted to evaluate the association of WSSV negative seed and the successful grow out performance. Peng et al (2001) surveyed the production characteristics of 27 *P. monodon* culture ponds. The ponds were grouped into 3 groups based on the WSSV infection level at the initial PL level; group 1 consists of ponds with >50% animals are infected, group 2 with 1-49% animals are infected and group 3 with WSSV negative PL They reported highest proportion of successful harvest in those ponds where the post larvae were WSSV free, whereas none of the ponds stocked with population having > 50% WSSV positive PL was cultured through the harvest (Fig 2). In another study conducted in Thailand Withychumnarnkul, 1999, reported almost similar results. In his study, he used a farm comprised of 188 earthen ponds following semi-closed intensive culture system. The ponds were classified into 5 groups. One group is stocked with WSSV PCR positive PL and all other group were stocked with WSSV PCR negative PL While only 5% ponds only survived in the ponds stocked with PCR positive seeds, ~70% ponds survived in the ponds stocked with PCR negative seeds. In conclusion, initial detection of WSSV rates can be used to predict the fate of cultured shrimp population.

Recommended criteria for evaluation of Penaeus monodon post larvae in commercial hatcheries

Decision to stock or not to stock a batch of post larvae is ultimately an assessment of risk. It is extremely difficult to suggest a fixed guideline or standards. We suggest the following guideline that should be finalized after a series of discussion with hatchery managers, farmers and scientists. The following tentative guideline is proposed

FRY Analytical Procedures	
MBV	By malacite green straining. Absence of occulusion bodies is negative
WSSV	By nested PCR method. Minimum 100 post larvae to be taken for the PCR analysis
Stress test with Formalin	100 animals are subjeted to 200 ppm formalein for one hour. Survival above 90% = 20 points Survival 80-89% = 10 points
Stress test with salinity	It can be done by increasing or decreasing the salinity by 10 ppt for one hour Survival above 90% = 20 points Survival 80-89% = 10 points
Muscle Gut Ratio(M G R)	Compare the thickness (Ventrodorsal distance) of the mid portion of the sixth abdominal segment with the width of the gut at the same position. 4:1 Ratio. Above 75% carries 10 points
Body length (BL)	Distance between the tip of the Rostrum to the tip of the Telson.
Gut	Empty / Half / Full
Swollen hind Gut (S H G)	The hind gut portion swollen due to bacterial infection.
Chromotophore	I / II / III
PL Age	It is determined based on the Rostral spine 4 to 5 5 to 6 6 to 7 7 to 8
Size variation	Uniform size 90 - 100 animals 10 points Uniform size 80 - 89 animals 8 points Uniform size 70 - 79 animals 6 points

FRY HELATH ANALYSIS

SUMMERY REPORT

Date:

SAMPLE PARTICULARS

Sl.No.	Client Name	Sample code	Received on	Lab code
1				
2				
3				
4				

TEST REPORT

Lab	MBV	White spot	Salinity	PL age	Stress test	Summary score

MBV : By malachite green staining

WSSV : By nested PCR

Stress test : 200 ppm formaline for one hr. (passing score 80%)

Summary report passing score 80%

Analysed by	Verified by

Note: This report relates to the samples given and is meant for guidance and not for litigation.

FRY HELATH ANALYSIS

Code:

Age :

Salinity

Date

mple	Rostral spine (RS)	Chromatophore	Gut	No SHG (10%)	Body length (10%)	MGR (20%)	No Foul.org (10%)	No endoparasite.	No Nec (10%)
tal									

HARACTER OF QUALITY SEED		Stress test survival 20%	=
MBV: & white spot	**Negative**	No size variation 10%	=
Stress test survival	**above 80%**		----------------------------
Muscle gut ratio **(MGR)**	**4:1 above 75%**	Total Score	----------------------------
Body length **(B.L)**	**above 11.0 mm**		
Gut	**Full/ half**		
Size variation	**Less than 10%**		
Swollen hind gut **(SHG)**	**No / minimum**		
Fouling organisms **(Foul-org)**	" "		
Endoparasites **(ENDO.PA)**	" "		
Necrosis **(NEC)**	" "		
Chromotophore	**2nd /3rd**		

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lote: This report relates to the samples given and is meant for guidance and not for litigation.

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Table1. Recommended exposure concentration and expected survival for formalin stress test of PL_7 of *Litopenaeus vannamei*

PL age	Recommended exposure (ppm)	Expected survival (%)
1	300	40
2	300	40
3	300	50
4	300	50
5	400	40
6	500	50
7	600	50

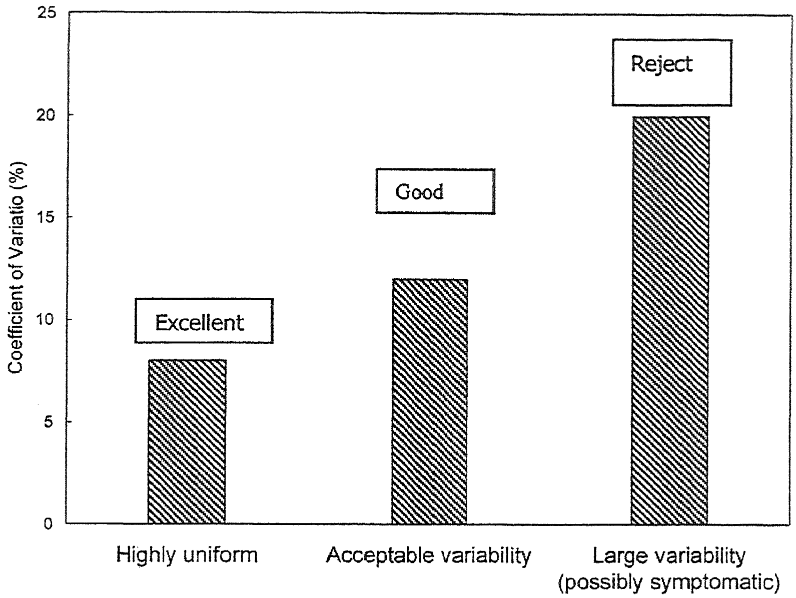

Fig 2 Larval quality based on the uniformity of size of PL (modified from Clifford 1994)

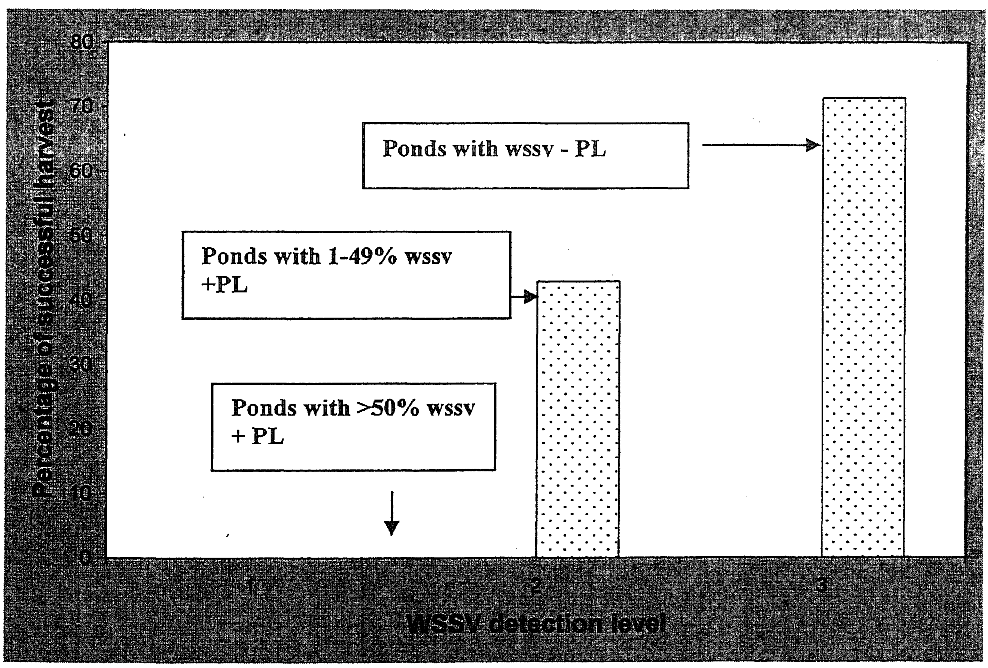

Fig 2 WSSV infection and harvest out come for cultured Penaeus monodon (Figure is redrawn by using the data from Peng et al (2001)

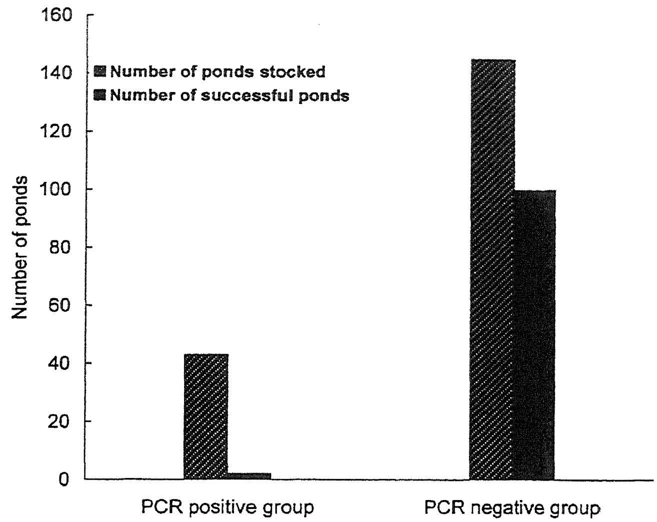

Fig 3. Screening of PL for WSSV and harvest results for culture *Penaeus monodon* in Thailand (Figure is redrawn from Withyachumnarnkul, 1999)

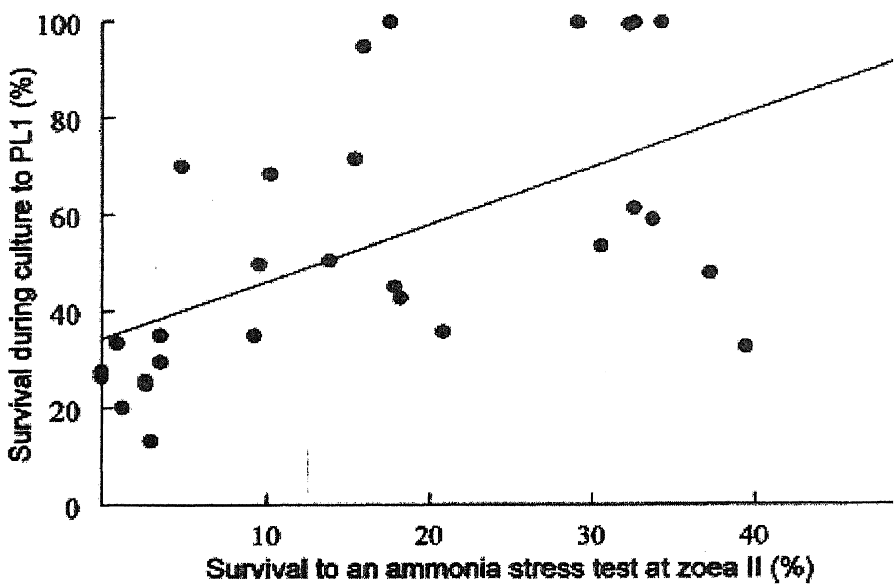

Fig 4 Relationship between ammonia stress test and survival upto PL 1 in Litopenaeus vannamei (after Racotta et al 2004)

Shrimp seed packing, transportation, acclimatization and stocking

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Introduction

Selection of disease free quality shrimp seed is the foremost requirement for the success of shrimp farming operation. It has a direct relationship with the survival and growth of the cultured shrimps. The seed should be properly packed, transported to the farm site without much stress and conditioned to the pond conditions before stocking to avoid physiological shock of changed water quality conditions.

Packing and transportation

Packing

Two types of containers are used in packing shrimp seed. They are (i)transparent cylindrical shaped polythene bags with fused bottom and an air tight mouth on the top (fig. 1) and (ii) a simple transparent polyethylene bag with fused bottom and an open mouth , which can be tied with a jute thread (Fig 2). Each container can conveniently hold 6 liter of sea water and 4 liter of oxygen with a total capacity of 10 litre. These two types of polythene bags are to be packed .in carton boxes. To control the temperature during the transport, thermocole sheets are provided as an inner lining of the carton box all around the polythene bag. These bags should be kept in vertical position in the carton box to avoid the leaking of water during the transport.

Seed packing polythene bags

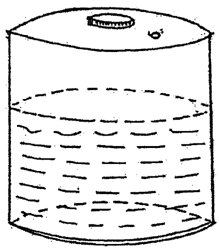

Fig. 1

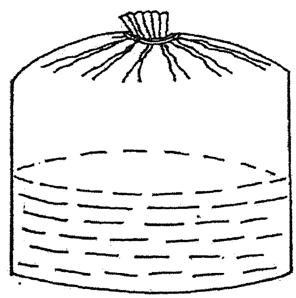

Fig. 2

Transport

Criteria to be followed for successful transportation

- Healthy and uniform sized animals should be chosen.
- Seeds should be subjected to quality tests for their hardiness, health and proper behaviour.
- On the day of transportation, the PL should be carefully harvested, held in tanks containing clean, disinfected, filtered and aerated seawater. Seeds should be acclimatized in the hatchery itself to the required salinity of grow out ponds.
- Polythene bags with fused bottom only should be used. Otherwise, those bags with bottom tying would result in the entanglement of seeds and their subsequent mortality.
- The polythene bags should be used in double to prevent bag breakage and should be filled to 1/3 level. Generally, 6 liters of fresh and filtered sea water and 4 liters of oxygen should be provided for each bag.
- Care should be taken to ensure the bags are tied or closed properly to avoid the oxygen leaking,
- Adequate precautions should be taken to control the temperature of water medium. Controlling the temperature will depend upon the duration of the transportation.
- Typically, no temperature reduction is required if the hatchery is within one hour of the farm. Temperature should be reduced to 26-28°C for transportation times of 1-3 hours, 25-26°C for 3-12 hours or 23-25oC for over 12 hours.
- The temperature should be decreased gradually (by adding bagged ice) until the desired transport temperature is reached.
- Decreasing the temperature from 28-30°C to 23°C should take at least 30-40 minutes to help reduce stress. Transportation temperature reduction is required to lower the metabolic rate of the PL so that they will use less oxygen, excrete less waste and remain calm during transportation.
- Packing in carton boxes lined with thermocole sheets would help to reduce the temperature considerably.

- The fastest mean of transport such as air may be engaged for long distance travel to ensure great survival.
- The seed should be transported with minimal stress. Transportation should be done in the evening or night in insulated vehicles to avoid excessive temperature during transport.
- Packing of seed under oxygen in polythene bags is an accepted practice. It can also be transported in large closed tanks with continuous oxygen supply.
- Optimal density for longer duration and higher density of short duration of transport may be followed. Visual counting should be accurate to avoid over stocking in the transport bags.
- Optimal packing density for the transport of PL20 is 500-1000 no./lit. However the seeds are packed in different densities depending on their size and age. For PL-15, optimal packing density is 1000-2000 no./lit.
- Seeds should be acclimatized in the hatchery itself to the required salinity of grow out ponds.
- No artificial / conventional wet feed should be given during the transport period. If these feed are given, the left over feed will pollute the water in the container, resulting in a mortality of the shrimps.
- To enhance the overall survival of seeds, appropriate live feeds such as *Artemia* nauplii are added in the water used during the transport. Live *Artemia* nauplii should be disinfected, washed (with fresh water) and added @ 15-20 no./PL as feed for each 4 hours of transport to prevent cannibalism during transportation

Acclimatization

Acclimation, in simple terms means adaptation to new environment. Adaptation must be gradual in order to avoid stress to the animal.

Factors involved in acclimatization

Among numerous factors which affect adaptation, changes in salinity and temperature seems to be the most important.

Salinity as a factor

The effect of salinity is best explained by correlating with osmolality (a property of water dependent on the amount of dissolved particles). Osmolality increases salinity.

Control of water content and the amount of dissolved particles in the body fluid is essential to survival. In the absence of any osmoregulatory mechanism, an organism exposed to medium with lower amount of dissolved particles (lower osmolality) than its body fluids would swell, and shrink when exposed to medium with higher osmolality. Both these conditions would impair normal functions. Shrimp like *Penaeus monodon* has been found to be an efficient osmoregulator. Changes in salinity would not be much of a problem if the shrimp is given time to acclimatize. It adapts to changes in salinity by actively (against concentration gradients and with expenditure of energy) taking in ions (osmotically active particles) in dilute media (lower salinity) and exceeding out these particles in concentrated media (higher salinity). Through these mechanisms, osmolality of the haemolymph is little affected by environmental salinity in shrimp. However, abrupt and larges in salinity of the medium would cause confirmation, i.e. haemolymph concentrations would tend to equalize with that of environment. The cells which are bathed with the extra cellular fluid would also equalize with haemolymph resulting in swelling and shrinking. Thus, changes in salinity must be gradual to allow time for the regulatory mechanisms of the shrimp to work efficiently.

Temperature as a factor

Extreme temperature usually leads to mortalities.

Very low temperature (a) can inhibit the catalytic action of enzymes, (b) dehydrate the cells by freezing of the extra cellular fluids (haemolymph), (c) distort structure and function, (d) depress metabolic rate or functions to the extend that essential maintenance functions cannot be carried out satisfactorily and (e) cause death.

On the other hand, extremely high temperature can cause (a)an increase in oxygen demand leading to insufficient supply of oxygen, (b) desiccation, (c) changes in the concentration of lipids, leading to increase permeability of membranes and (d) break down of proteins and enzymes all of which lead to death.

Adaptation to changes in temperature requires time and is achieved by the shrimp-seed through changes in enzymes affinity, form or concentration. Such changes allow metabolic pathway to proceed at a normal rate. Therefore, for shrimp seeds, the change should occur gradually during acclimation to cope with changes in temperature.

Shrimp seed acclimatization

Acclimatization can be done either in the hatchery before packing or at the pond site before stocking the seed.

Acclimatization in the hatchery

In hatcheries, sea water having a salinity of 30 to 35 ppt is used for broodstock maintenance, breeding, spawning, larval and post larval rearing. Since the salinity of grow out ponds in the estuarine system ranging from 10 to 30 ppt, seeds are acclimatized to required lower salinities in the hatchery itself by adding freshwater in a phased manner before packing. Hence, it is advisable to inform the hatchery operators regarding salinity, prevailing in the grow-out culture pond so that the acclimation can start at the hatchery itself. The rate of acclimation may be at 1 ppt per 15 minutes. Salinity acclimation should be done only after the PL10 stage with well developed gills.

Acclimatization at the pond-site before stocking

After transport and upon arrival at the pond area, seeds should be allowed to rest and acclimated to the pond water before stocking in ponds. Good results have been obtained by acclimatizing the seeds for about 6 hours. Feeding is not necessary during acclimation as seeds usually do not eat under disturbed conditions. The seed should be acclimated to the pond water pH, salinity and temperature before stocking to avoid stress and shock. Acclimation to temperature is easily achieved by floating the seed bags for about 30 minutes in the pond before opening it. Acclimation to pH is done by mixing equal volume of pond water into the seed bags and keeping for 30 minutes before release. Weak and dead seed should be removed before stocking. This is achieved by keeping the seed in FRP tanks and treating them with 100 ppm formalin for 30 minutes under strong aeration. After the treatment the strong and active seed should be segregated and stocked in the ponds. Stocking should be done during early morning when the temperature is the lowest.

On-farm nursery rearing before stocking the seed in grow out ponds

In view of the existing disease conditions, it is advised to initially introduce the transported seed in nurseries, rear them for a very short period and subsequently transfer them from nurseries to grow-out ponds in order to reduce the stress and thus minimize the chance of disease occurrence. For this type of operation, nursery ponds of area 500 to 1000 m2 are required in which PL 15, transported from hatcheries, can be stocked @ 50-75 no/m^2 and reared for 15 – 20 days, by which time the seeds reach 1 to 1.5 g size. By this operation, they can be easily transferred from nursery ponds to grow-out ponds with minimal stress.

On-farm nursery rearing may be carried out in 'Hapa' or net enclosures in the grow-out pond itself for 10-15 days to evaluate the capacity of the PL to adjust to the pond conditions.

Stocking in grow-out culture ponds

Stocking density

The rate at which the shrimp seed is to be stocked in the pond depends on many factors. Overstocking may lead to high mortality and poor growth and at the same time under stocking might lead to uneconomical culture with less profit. The optimal stocking density is generally dependent on the type of management system followed, number of culture days possible and the expected size at harvest. High density culture requires intensive water quality management and any failure of the machinery during the course of culture will lead to problems associated with heavy mortality of shrimps. Further, high density cultures will lead to serious deterioration in pond soil conditions. Presently, due to the prevalence of viral diseases and environmental issues, low- density cultures are only permitted in the country. A maximum density of 6 no/m^2 within the CRZ and a maximum of 10 no/ m^2 outside the CRZ, is permitted by the Aquaculture Authority.

Water and Soil Requirements and Management in Shrimp Farming

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A pond with good soil and water quality will produce healthier shrimp than a pond with poor soil-water quality. Hence, it is essential to understand the pond soil and water characteristics and their optimum requirements, and their management to increase the productivity of the ponds in general and thereby augmenting shrimp aquaculture production. Poor environmental conditions in pond bring in a state of stress that is unfavourable for the cultured animals but favourable for the disease causing agents. Out break of disease in shrimp culture system is related to the environment factors such as deterioration of water and soil quality. Soil and water quality can be maintained within the optimal range by giving importance starting from site selection and suitable pond preparation methods.

1. Soil requirements

A detailed sub-soil survey is essential to ascertain the suitability of the site for pond construction. The sub-surface soils should be tested for compaction and seepage properties, as well as surveying contours. Soil samples from different depths at random points within the site should be analysed for texture, pH, organic matter content, sulphur concentration and possibly other variables. Pond soils may have negative effects on aquaculture production if one or more of their properties are outside the optimum range for aquaculture. The optimum ranges of important soil properties to shrimp farming are given in Table 2. Successful shrimp culture depends on good bottom soil condition. Some soils may have undesirable properties like potential acid sulphate acidity, high organic matter content or excessive porosity. Understanding of the soil parameters helps to decide the management strategies to be followed in terms of liming, manuring, fertilization, water management etc.

Table 1. Soil requirements for brackishwater aquaculture

Parameter	Optimum Range
pH	6.5-7.5
Organic carbon (%)	1.5-2.0
Available nitrogen (mg/100g)	50-70
Available phosphorus (mg/100g)	4-6
Calcium carbonate (%)	>5.0
Electricl conductivity (dS/m)	>4
Exchangeable acidity (%)	20-35
Depth to sulfidic or sulfuric layer (cm)	50-100
Clay content (%)	18-35

Textural class	Sandy clay, sandy clay loam and clay loam

2. Soil management

Even if the site is good with optimum soil characteristics, problems may still crop up by the large quantity of inputs like feed and fertilizers, which lead to excessive phytoplankton production, low dissolved oxygen, high ammonia, poor bottom soil condition and other problems. Most of these problems can be avoided by proper management practices during pond preparation and culture period.

2.1. Pond preparation

The main objectives of pond preparation are to provide the shrimp with a clean pond base and appropriate stable water quality. Pond preparation is generally dealt in two categories viz., newly constructed ponds and existing culture ponds. In newly dug out ponds, the characteristics of the soil has to be understood first before adopting the various measures to prepare the pond. Soil samples taken from different locations of the pond are thoroughly mixed together and a representative portion has to be taken for analysis. Soil deficiencies should be identified and treated in new ponds instead of waiting until poor bottom soil quality develops later. For example, if soil in a new pond is acidic, it should be limed before initiation of aquaculture. The pond preparation after harvest before initiating a second crop is entirely different from that of a newly dug-out pond and comprises of removal of waste accumulated during the previous crop by draining and drying of the pond bottom. The pond bottom should be dried for at least 7-10 days or until it can support a man's weight without subsiding and the soil should crack to a depth of 25 - 50 mm. In cases, where complete drying is not possible, organic, biodegradable, piscicides such as Mahua oil cake (100-150 ppm) and tea seed cake (15-20 ppm) can be used.

2.2 Pond maintenance

The pond dike is strengthened with soil wherever it has become weak and the inner slope of the dike is consolidated with soil. Tunnels and holes caused by burrowing organisms are to be closed. Reconditioning of the bottom trench levelling of pond bottom, repairs of sluice structures and sluice screens are also to be attended.

2.3 Liming

The reason for liming aquaculture ponds is to neutralize soil acidity and increase total alkalinity and total hardness concentrations in water. This can enhance conditions for productivity of food organisms and increase aquatic animal production. Either total alkalinity or soil pH may be used to estimate the liming dose. If both are available but values are not in agreement, use the variable that gives the greatest liming dose. Brackishwater ponds with total alkalinity below 60 mg l^{-1} and any pond with soil pH below 7 usually will benefit from liming. The amount of different lime materials required to raise the pH to 7 is given in Table 2.

Table 2. Amount of lime (tons/ha) to raise the soil pH to 7.0.

Soil pH	Quantity of lime material (tons/ha)		
	Dolomite	Agricultural lime	Quick lime
6 to 6.5	5.7 to 2.8	5.5 to 2.8	4.6 to 2.3
5.5 to 6.0	8.5 to 5.7	8.3 to 5.5	6.9 to 4.6
5.0 to 5.5	11.3 to 8.5	11.1 to 8.3	9.2 to 6.9
4.5 to 5.0	14.2 to 11.3	13.9 to 11.1	11.5 to 9.2
4.0 to 4.5	17.0 to 14.2	16.6 to 13.9	13.8 to 11.5

Agricultural limestone will not react with dry soil, so when applying over the bottoms of empty ponds, it should be applied while soils are still visibly moist but dry enough to walk on. Generally lime is applied after slight turning over of bottom soil. In soils with chronically low pH it may be beneficial to apply half the total dosage before slight tilling in order to neutralize underlying soil layers.

2.4 Tilling

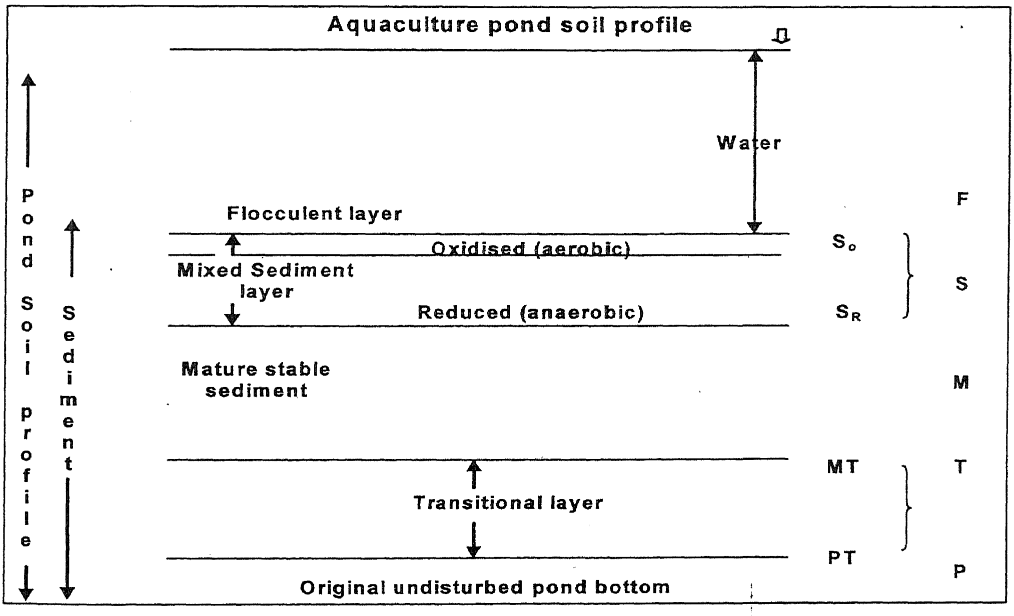
Tilling bottom soils can enhance drying to increase aeration and accelerate organic matter decomposition and oxidation of reduced compounds. Soil amendments such as agricultural limestone or burnt lime can be mixed into soil by tilling. Accumulations of organic matter of other substances in the surface layer of soil also can be mixed with deeper soils to reduce concentrations of the substances in the surface layer. Pond bottoms should not be tilled when they are too wet to support tillage machinery. Ruts caused by machinery will fill with soft sediment and be likely sites for anaerobic conditions. Depth of tillage usually should be 5 to 10 cm, so mould board plows, often called turning plows, can be used to turn soil over. Tilling can be counterproductive in ponds where heavy mechanical aeration is used. Tilling will loosen the soil particles and aerator-induced water currents will cause severe erosion of the pond bottom. Thus, if bottoms of heavily aerated ponds are tilled, they should be compacted with a heavy roller before refilling.

2.5 Fertilisation

Decomposition in organic soils is slow because of the amount of carbon relative to nitrogen (C:N ratio) is high. Nevertheless, because of high organic matter content, such soil often becomes anaerobic during shrimp culture. Application of inorganic nitrogen fertilizers to supply nitrogen will increase soil organic matter degradation during fallow periods between crops. Urea can be spread over pond bottoms at 200 to 400 kg ha^{-1} at the beginning of the fallow period to accelerate decomposition of organic soil. Agricultural limestone should not be applied until a few days after urea is applied to prevent a high pH. Sodium nitrate can be applied @ 20 to 40 g m^{-2} to wet soil to encourage organic matter decomposition in wet areas. However, nitrate fertilizers are more expensive and are not recommended where soils can be adequately dried. The rate of application of inorganic fertilizers ranges from 25 to100 kg/ha as a basal dose during pond preparation with minimum water depth of 10 to 15 cm. When the shrimp culture progresses, depending upon the phytoplankton density as exemplified by turbidity of the pond water, required quantity of the fertilizers may be applied in split doses at short intervals for sustained plankton production. Excessive application of urea and ammonium fertilizers may cause ammonia toxicity to shrimps and also may lead to algal blooms reducing of dissolved oxygen.

2.6. Management of pond bottom during culture

During culture, inputs like high-energy protein feed, fertilizers etc are added. The feed not eaten by the shrimps, the carbonaceous matter, suspended solids, faecal matter and dead plankton etc. settles at the pond bottom. These materials have combined effect on the environment of the pond bottom. All aquaculture pond bottoms become covered with sediment, and this sediment can be considered as aquaculture pond soil. In describing various physical, chemical and biological processes occurring in the pond bottom, it is convenient to refer to bottom deposit as sediment. A core taken through the sediment and extending into the original bottom soil is called a profile. Layers in the profile are known as horizons (Fig.1). For practical purposes, the F and S horizons are most important in aquaculture because they exchange substances with overlaying water to influence water quality.



F - Water with high concentrations of mineral and organic solids, aerobic
S - Sediment with high water content and low dry bulk density, abundant organic matter
S_O - Thin aerobic surface (Oxidised)
S_R - Anaerobic below (Reduced)
M - Sediment with medium water content and intermediate dry bulk density, abundant organic matter, anaerobic
T - Transition between M (MT) and P (PT) horizons with characteristics intermediate between M and P horizons, anaerobic
P – Low water content and high bulk density, usually compacted, low organic matter, not stirred, anaerobic

Fig.1 Pond soil profile showing different horizons

2.6.1 Oxidized Layer

The oxidized layer at the sediment surface is highly beneficial and should be maintained throughout the shrimp culture. Metabolic products of aerobic decomposition are carbon dioxide, water, ammonia, and other nutrients. In anaerobic sediment, some microorganisms decompose organic matter by fermentation reactions that produce alcohols, ketones, aldehydes, and other organic compounds as metabolites. Other anaerobic microorganisms are able to use oxygen from nitrate, nitrite, iron and manganese oxides, sulfate, and carbon dioxide to decompose organic matter, but they release nitrogen gas, ammonia, ferrous iron, manganous manganese, hydrogen sulphide, and methane as metabolites. Some of these metabolites, and especially hydrogen sulfide, nitrite, and certain organic compounds, can enter the water and be potentially toxic to shrimp. Methane and nitrogen gas pass through the layer and diffuse from the pond water to the atmosphere. These two gases do not cause toxicity to aquatic organisms under normal circumstances.

The oxidized layer at the sediment surface prevents diffusion of most toxic metabolites into pond water because they are oxidized to non-toxic forms by chemical and biological activity while passing through the aerobic surface layer. Nitrite will be oxidized to nitrate, ferrous iron converted to ferric iron, and hydrogen sulfide will be transformed to sulfate. Thus, it is extremely important to maintain the oxidized layer at the sediment surface in shrimp culture ponds. Loss of the oxidized layer can result when soils accumulate large amounts of organic matter and dissolved oxygen is used up within the flocculent layer (F horizon) before it can penetrate the soil surface. Even in ponds without high concentrations of organic matter in sediment, high rates of organic matter deposition resulting from large nutrient inputs and heavy plankton blooms can lead to oxygen depletion in the F horizon. Ponds should be managed to prevent large accumulations of fresh organic matter in the F horizon at the soil surface, or in the upper few millimeters of soil. Toxic metabolites entering well-oxygenated pond water will be quickly oxidized. However, if the rate of release of toxic metabolites into water exceeds the rate that metabolites that are oxidized, equilibrium levels of metabolites in the water may be high enough to have detrimental effects on culture animals. Water circulation by water exchange, wind or aeration helps to move water across mud surface and prevent the development of reduced condition. Bottom should be smoothened and sloped to facilitate draining of organic waste and toxic substances. Central drainage canal in the pond may also help in the removal of organic waste periodically.

2.6.2 Nutrient exchange between soil and water

The two most important nutrients in pond aquaculture are nitrogen and phosphorus because these two nutrients often are present in short supply and limit phytoplankton growth. These two nutrients are added to ponds in fertilizers, manures, and feeds. Fertilizer nitrogen usually is in the form of urea or ammonium, and urea quickly hydrolyzes to ammonium in pond water. Ammonium may be absorbed by phytoplankton, converted to organic nitrogen, and eventually transformed into nitrogen of shrimp protein via the food web. Ammonium may be oxidized to nitrate by nitrifying bacteria, and nitrate may be used by phytoplankton or denitrified by anaerobic microorganisms in the sediment. Nitrogen gas formed by denitrification diffuses from sediment to pond water to the atmosphere. Ammonium is in equilibrium with ammonia, and ammonia also can diffuse from pond waters to the atmosphere. A small amount of ammonium may be adsorbed on cation exchange sites in pond bottom soils. Organic nitrogen in plankton and in aquatic animal feces may settle to the bottom to become soil organic nitrogen. Nitrogen in soil organic matter may be mineralized to ammonia and recycled to the pond water, but the rate is slow.

Phosphorus usually is present in fertilizer as calcium or ammonium phosphate. Phytoplankton can rapidly remove phosphate from water, and phosphorus in phytoplankton may enter the food web culminating in shrimp. Pond soil strongly adsorbs phosphorus, and the capacity of pond soil to adsorb phosphorus increases as a function of increasing clay content. Most of soil phosphorus was tightly bound, and only a small amount was water soluble. Pond soils are not a major source of phosphorus to water because soil-adsorbed phosphorus is highly insoluble. Phosphorus released by decomposition of organic matter in pond bottoms is rapidly adsorbed by soil and little of it enters the water. Soils that are near neutral in pH have less capacity to adsorb phosphorus and a greater tendency to release phosphorus than do acidic or alkaline soils.

2.6.3 Monitoring of soil parameters during culture period

In order to understand the condition of the pond bottom, soil pH, organic matter and redox-potential (for oxidized/reduced pond bottom condition) have to be monitored regularly. The major concerns in pond bottom soil management are low soil pH, high soil organic matter and loss of the oxidized layer. The low pH of bottom sediment indicates unhygienic condition and needs regular check up. The change in the bottom in terms of increasing organic load should be recorded regularly for the management of the pond bottom. Oxygen is required for the decomposition of organic waste settling at the pond bottom during culture operations. The quantity of organic load increases with the progress of the culture. When inputs of organic waste exceed the supply of oxygen, anaerobic condition develops. Reduced or anaerobic sediments may occur at the pond bottom of heavily stocked pond with heavy organic load and poor water circulation. The redox potential (Eh) of mud should not exceed -200 mV. Negative (-) redox value shows reducing condition, whereas positive (+) value shows aerobic condition of the pond bottom mud.

3. Water requirements

Water quality and quantity determines the success or failure of an aquaculture operation. The estimation of the quantity of water required in a farm and the ways and means to meet the needs are the essential factors to be considered in the choice of a site. Day-to-day management of ponds requires only an estimation of the topping-up rate of the water supply, to combat evaporation and seepage losses. However, it should be noted that a large supply of water should be on-hand to flush ponds if needed, or refill them after draining. An annual water budget should be calculated for a potential farm site so that the supply is adequate for existing and future needs. The optimum ranges of water parameters required for shrimp aquaculture are given in Table 3.

Table 3. Water requirements for brackishwater aquaculture

Parameter	Optimum range
Temperature (°C)	28-32
pH	7.5 – 8.5
Salinity (ppt)	15-25
Transparency (cm)	30-40
Total suspended solids (TSS) (ppm)	<100
Dissolved oxygen (DO) (ppm)	4.0 - 7.0
Total ammonia-N (ppm)	<3.7
Free Ammonia (ppm)	<0.1
Nitrite-N (ppm)	<0.25
Nitrate-N (ppm)	0.2-0.5
Dissolved-P (ppm)	0.10-0.20
Chemical oxygen demand (COD) (ppm)	<70
Biochemical oxygen demand (BOD_5) (ppm)	<10
Hydrogen sulphide (H_2S) (ppm)	0.002

4. Water management

Maintenance of good water quality is essential for both survival and optimum growth of shrimps. Water treatment is an important step during pond preparation for the maintenance of good water quality at later stage.

4.1 Water treatment

- Water from the source is filtered through filters to prevent the entry of parasites and crustaceans that are carriers of diseases.
- Inorganic turbidity (suspended solids) should be removed by providing sedimentation/ reservoir pond before water to be taken into production ponds.
- Chlorination as a means to sterilise the water is practiced by many shrimp farmers. To achieve this enough chlorine should be applied so as to overcome the chlorine demand of organic matter and other substances in the water. Permissible level of chlorine residuals in treated water for use in shrimp grow-out ponds should be less than 0.001 ppm.

4.2 Water quality criteria for stocking shrimp PL

Test indicators to ensure that the pond is ready for stocking are:

(a) Secchi disc reading of around 40 cm or less
(b) A stable pH
(c) Algal bloom which is brown with a yellowish hue in colour
(d) Water temperature above 25^0C

4.3 Water quality maintenance

Good water quality is characterised by adequate oxygen and limited levels of metabolites. The parameters that should be monitored routinely are temperature, pH, salinity, dissolved oxygen and transparency. Periodical water exchange as and when required will help in maintaining the water quality in optimal range.

A. pH

As a medium for shrimp culture, brackishwater contains a high concentration of nutrient salts and is perfectly buffered medium against abrupt changes in pH. It can fluctuate between 7.5-9.5 with the accumulation of residual feed, dead algae and excreta over a 24-hour period with lowest pH occurring near dawn and the highest pH occurring in the afternoon. Low variation in pH values will indicate stable phytoplankton blooms. The pH should be in optimum level of 7.5 to 8.5. It should not vary more than 0.5 in a day.

B. Temperature

In brackishwater shallow ponds, where regular exchange between the tidal water and the pond water is not maintained during the hot dry months, the temperature of pond water may shoot up beyond the tolerance limit causing mortality of reared shrimps. The high rate of evaporation may also occur with the result of increase in salinity beyond the tolerance level. Similarly, during the winter season, the low temperature will have a chilling effect reducing metabolic and growth rates of cultured shrimps. On account of unequal distribution of temperature with higher temperature near the surface layer and decreasing temperature with depth, thermal stratification can occur in deeper ponds. This can result in reduced heat budget for the pond and formation of methane, hydrogen sulphide and ammonia can occur causing degradation of water quality. The planting of trees on pond dikes to give shade will reduce stratification but at the same time reduce the beneficial effects of wind mixing and restricts solar energy for photosynthesis. Operation of aerators during warm and calm afternoons helps to break thermal stratification by mixing warm surface water with cool sub surface water.

C. Salinity

Shrimp larvae are produced in waters with salinities of 28-35 ppt but advanced post larval stages often are stocked in ponds where salinity is much lower. At the time of stocking they should be acclimated gradually to the salinity of pond water so as to reduce stress and mortality. The acclimatization rate should not exceed 1 or 2 ppt per hour. Due to high evaporation rate in summer, salt concentration in ponds gradually increases. Salinity may increase to beyond 40 ppt, which can affect the growth of shrimps. Water should be exchanged frequently either by pumps or through tidal exchange. The groundwater with low salinity (2-5 ppt) can be utilised for reducing the salinity. Seawater (35 ppt) mixed with groundwater can be used for preparing water with required salinity for use or exchange. Sudden fluctuations in the salinity associated with the heavy rains result in heavy mortality. Maintenance of salinity of 18 to 35 ppt with variations not exceeding 5 ppt will help in reducing stress on the shrimp.

D. Turbidity

Turbidity due to both plankton density and suspended silt and clay particles can be measured in terms of transparency using Secchi disc. High value of transparency (>60 cm) is indicative of poor plankton density and therefore water should be fertilized with right kind of fertilisers. Low value indicates high density of plankton and hence fertilization rate and frequency should be reduced. The optimum range of transparency is

25-35 cm. Transparency less than 20 cm indicates that the water is unsuitable for shrimp culture and should be changed immediately to flush out excess bloom. It is wrong notion that intake of plankton rich water is good for initial tilling. Clear water is best suited. Sometimes, ponds, which develop clear water condition, are repeatedly fertilized with high doses of inorganic fertilizers with the hope to produce bloom. Once the benthic algae develop, it is useless to fertilise the ponds.

E. Dissolved oxygen (DO)

DO is the most important and critical water quality parameter because of its direct effect on the feed consumption and metabolism of shrimp as well as indirect influence on the water quality. Prolonged exposure to low oxygen content causes low feed consumption which leads to slow growth and the culture organisms become inactive and they are susceptible to disease. As photosynthesis occurs most rapidly in the surface layer of water, DO concentration decline with depth, in deeper ponds, DO may fall to 0 ppm at depth of 1.5 to 2 m. Hence it is advantageous to have fairly shallow ponds (75 cm to 150 cm deep) for shrimp, because they dwell mainly on the bottom and low DO at the pond bottom would be harmful. Over feeding should be avoided in order to maintain the DO level. Uneaten feed gets decomposed, releasing nutrients into the water. Consequently, phytoplankton abundance increases as a function of increasing feeding rate. DO concentrations decline more rapidly with depth as phytoplankton abundance increases in response to higher feeding rates. Besides, the phytoplankton die-off is greater in ponds with high feeding rate and abundant phytoplankton.

DO concentration of less than 1.5 ppm can be lethal to shrimps depending on exposure time and other conditions. Super saturation of DO is also potentially harmful. The first indication of possible oxygen stress may be reflected in the behavior of shrimps *e.g.*, crowding near the inflow, gasping for oxygen at the water surface by jumping out of water etc. DO can be affected by many factors particularly water temperature, respiration of plants and animals and the level of organic matter. In tropical waters the DO level is normally low because of higher temperature. The concentration of toxic substance such as unionized/reduced form (NH_3), sulphur (H_2S) and carbon metabolites (methane) increases when low DO level exists. However, in the presence of optimum level of oxygen the toxic substances are converted into their oxidized and less harmful forms.

The use of aerators results in mixing of water at surface and bottom and breakdowns DO stratification and also can eliminate black mud formed at interface of pond water and bottom mud. Water exchange is the best solution to prevent low DO problem in the pond where aeration is not practiced. Avoid exchange of water for first one month of stocking and later can be done when necessary. It prevents the metabolites (ammonia, nitrite and hydrogen sulphide) load in the pond water. Daily water exchange usually does not improve water quality in brackishwater ponds, because routine water exchange can discharge carbon, nitrogen and phosphorous substances from ponds before they can be assimilated. Thus water exchange rates should be reduced in brackishwater ponds and this should only be used when necessary.

F. Metabolites load

i) Ammonia

Ammonia reaches pond water as a by-product of metabolism by animals by decomposition of organic matter by bacteria. In water, ammonia nitrogen occurs in two forms, un-ionized ammonia (NH_3) and ammonium ion (NH_4^+), in a pH and temperature dependent equilibrium. As pH rises, un-ionized ammonia increases relative to ammonium ion. Water temperature also causes an increase in the proportion of un-ionized ammonia, but the effect of temperature is less than that of pH. The toxicity of ammonia nitrogen is attributed primarily to the un-ionized form and should be less than 0.1 ppm.

ii) Nitrite

Nitrite (NO_2^-) is an intermediate product in the bacterial oxidation of ammonia to nitrate (NO_3^-), a process called nitrification. The toxicity of nitrite is known to be affected by water pH, and the presence of chloride and calcium ions. Nitrite toxicity increases with increasing pH. It decreases with increasing calcium and chloride concentrations. Hence nitrite is more toxic in freshwater than in seawater. The optimum value is less than 0.25 ppm.

iii) Hydrogen sulphide

Under anaerobic condition, certain heterotrophic bacteria can use sulphate and other oxidized sulphur compounds as terminal electron acceptors in metabolism and excrete sulphide. The pH regulates the distribution of total sulphide among its forms (H_2S, HS^- and S_2^-). Un-ionized hydrogen sulphide is toxic to aquatic organisms and the ionic forms however, have no appreciable toxicity. Any detectable concentration of hydrogen sulphide is considered undesirable. Concentration of 0.01 to 0.05 mg/l of H_2S may be lethal to aquatic organisms.

The toxic effect of metabolites can be minimised in several ways.

- Maintaining sufficient level of DO facilitates oxidation of ammonia to harmless nitrate by nitrifying bacteria.
- Providing suitable slope to the pond bottom facility collection and removal of organic wastes.
- Periodic partial removal of cyanobacterial and algal blooms by flushing or scooping out the scum facilitates optimum density and prevents sudden die-off of the bloom.
- Application of 'bioaugmentation' materials to remove H_2S, NH_3 and methane and to speed up organic decomposition.

4.4 Discharge water management

The wastewater from the shrimp ponds may be allowed into a settlement pond before letting it into the environment so that the harmful minerals and suspended solids may settle at the bottom. Periodically the sludge can be removed. Aquaculture discharge water is rich in nutrients such as nitrogen and phosphorus and can be utilized by integration with other aquaculture production systems. Culture of finfish, molluscs and seaweeds in the wastewater from shrimp ponds can remove nutrients and particulate organic matter from the effluent. Another alternate method for removal of nutrients and suspended solids from aquaculture wastewater is retention of existing swamps / mangroves buffer zone close to the ponds or by replanting the same for deliberate purpose of waste treatment.

5. Application of chemicals, pond conditioners and probiotics to improve soil and water quality

External fouling is usually associated with deterioration in the pond bottom or the water quality. The shrimps under tremendous stress are prone to diseases and causes heavy mortality. The first priority, therefore, should be to ensure a clean environment for the shrimp. Chemical treatment should be resorted only if the environment has been improved but the shrimp have not moulted. A number of products both indigenous and imported are available in the market with high claims of efficiency to improve soil and water quality. These products include cultures of living bacteria, enzyme preparations, composted or fermented residues, plant extracts, and other concoctions. But the efficiency of most of them has not been scientifically proved. The farmers have to take the advice of experts before using them.

Feed Quality and Feed Management for Sustainable Shrimp Aquaculture

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1. Feed Quality

The quality of feed is of paramount important for commercial shrimp aquaculture. The feed must be palatable, nutritionally adequate and it must be free from pre-formed toxins. The digestibility of feed is important not only for better assimilation efficiency of the feed and also to reduce the environmental ill effects of feed. In general dry sinking pellets are used in shrimp aquaculture. These pellets must be water stable. The stability of feed in the pond water conditions is more critical. Soft water soaked pellets are more difficult to manipulate. If the pellets disintegrate before or during feeding nutrient loss is extremely high. A good quality feed should be water stable for a minimum of 1-2 hours and before this period the total quantity should normally be consumed. Water stability of feed also affects the performance of the feed. It will not only disintegrate fast but also causes water pollution leading to economic loss. Feed should not be too hard also as it not be properly assimilated the animal. Feed with poor water stability leads marked deterioration in water and soil quality. This will in turn leads poor FCR and higher cost of production.. In extreme cases it will predispose the animal to infection and consequent mortality. The feed bag should not contain dust and or powder.

The nutritional quality of feed varies with the type of farming being practiced. In recent studies the protein quantity has been reduced in shrimp feed where zero water exchange is being practiced. These lower proteins feeds helps in the reduction of production costs, and make the feeds more environmental friendly, considering that aquaculture effluents would have less nitrogenous compounds, diminishing the risks of eutrophication in adjacent coastal areas, as well as the reduction of dependence on fish meal component (Martinez-Cordova et al. 2003). The nutritional quality of the feed influences the assimilation efficiency of the feed. The high fibre level in the diet reduces gut passage time, blocks the diffusion of digestive enzymes and may chelate the metal ions required as enzyme cofactors.

2. Feed management

Management of feed is one of the most important aspects of successful shrimp production since feed is the main input in the shrimp aquaculture system. The objective is to produce shrimp in a sustainable manner with the largest margin of profit. Feed management means control and use of feed for aquaculture operation in such a manner that the utilization of feed is optimum with minimum wastage, negligible impact on environment, achieving best feed conversion ratio (FCR), better soil and water quality, maximum growth of fish and shrimp and production. Such feed management practice if adopted, aquaculture production will be not only economical and profitable but also sustainable and eco-friendly. A best feed can produce poor results if the feed management is poor. On the other hand a moderate feed can produce best results under good feed management. Feed management has got direct bearing on the soil and water quality Vis- a –Vis successful aquaculture.

In poorly managed shrimp farms waste derived from uneaten food, faeces and metabolism of nutrients are the major contributors to pollution. These wastes are good nutrient media for the multiplication of microbes which can induce stress and predispose the shrimp to diseases resulting in reduced growth and production. Excess waste nutrients will result in planktonic bloom, alter the dissolved oxygen profile in shrimp farms due to high BOD and COD. Thus it is utmost important to produce less pollutive high quality feed and hence the feed management strategies are considered as central elements for profitable eco friendly aquaculture.

Even though there are some investigations on the quantities of requirements of feed in relation to size and stage of the growing shrimp still research on these aspects is needed for making the feeding tables more accurate. Generally the method of calculating the daily ration is based on the body weight of shrimp. Suppose if W grams is the average weight of the stocked animal and if there are A number of animals in the pond then the total biomass in the pond is W x A grams which is equal to W x A/1000 kg. If feed is to be given at 10% of body weight then the quantity feed required per day is

$$\frac{W \times A}{1000} \times \frac{10}{100} \text{ kg}$$

To estimate the biomass accurately in a pond is not possible. Generally periodically (once a week or 10 days) using a suitable net, sampling of the shrimp and the average weight of the animal is calculated. Total biomass is calculated by multiplying the average weight by the number of animals surviving at that time. This is mainly done by counting the numbers of animals caught per each netting and estimating the total number of animals taking into account the area covered by each netting and the total area of the pond. Some times the number of animals surviving in the pond is approximately estimated by giving a margin of 10% mortality in the first month and 3-5% per month subsequently on the total number of animals initially stocked.

The quantity of feed required in a day for feeding shrimp is estimated based on biomass in the culture pond. To start with feed is offered at 15 – 20% of body weight. As the shrimps grow, it is gradually reduced and brought down to 2-3% towards the end of the culture period. The entire quantity of feed required for a day in a pond should not be put at one time. The shrimps should be offered feed at every 3 - 4 hours in small doses. Shrimps are active feeders during night, hence large doses may be offered in the evening and during night. Observations and experiences show that frequent feeding of small portions of the ration seems to help in better utilization of the feed and there by lead to efficient FCR. There must also be a mechanism in each case to monitor the feed consumption and offering of the next scheduled dose should be regulated according to the consumption from the previous feed offered. Regular observations and experience help in mastering the management of feeding in a culture farm.

Keeping the feed in bamboo or velon screen trays kept inside the pond at different locations is a good practice. These are known as feed-check trays. Periodically these check trays can be lifted up to check the feed consumption. A part of the feed may also be broadcasted for proper distribution. Instructions of the feed supplier with regard to feeding may be followed. Excess feeding leads to uneaten feed at the pond bottom. This will cause pollution of pond water and stimulates algal blooms, which may cause stress to shrimp. Under these conditions mass mortality of shrimp may occur. Feeding a little less does not do any harm, but feeding a little excess may be harmful and can cause heavy loss. Feed management needs experience and skill to obtain best results. Water quality in culture pond is also linked to feed management. If the water quality (such as dissolved oxygen, ammonia, nitrite, nitrate, hydrogen sulphide) in the pond is poor, even the best feed may give poor performance.

3. Farming Systems and Feeding Methods

The farming systems currently practiced can be broadly divided into three basic categories based on the stocking density, quantum of external inputs mainly feed and fertilizer and production levels. They are extensive, semi-intensive, and intensive farming systems. In the extensive system there is no fertilization or supplementary feeding. In the semi intensive system fertilization accompanied by supplementary/ complete feeding is practiced whereas in the intensive system is by fertilization and complete feeding. Thus the production of farmed aquatic animals is dependent upon the provision and supply of nutrient inputs either in the form of food organisms and / or compound aqua feeds, or indirectly in the form of fertilizer. It follows that the rate of supply and assimilation of nutrient inputs on-farm will play a major role in dictating the nutrient / waste output (Cho and Bureau, 2001).

Careful monitoring of populations of prey organisms is a vital component of feed management in supplementary feeds used semi- intensive culture. Hence calculation of formulated feed ration size should be based on the availability of prey food organisms. Adequate production and management of natural food can contribute to enhancing the economic feasibility of shrimp culture, as it represents great nutritional importance for the cultivated organisms (Martinez-Cordova *et al.* 1998a). Such contribution varied between 25 and 85% of the shrimp diet depending on the culture system (Nunes 2000). The natural food can be stimulated by adding organic and/or inorganic fertilizers, increasing the availability of nutrients in the aquatic environment to stimulate primary productivity (Landau 1991; Correia 1998; Hansen *et al.* 2003). The presence of live food in culture environments reduces the demand for artificial food, which limits degradation of water quality (Martinez-Cordova *et al.* 1998b). The maintenance of adequate water quality standards is known to improve the shrimp growth, reduce the necessity of water exchange and minimize the impacts of wastewater in coastal environments (Boyd 2000;

Trott and Alongi 2000; Boyd and Tucker 1998; Briggs and Funge-Smith 1994; Wang 1990).

In general the higher the intensity and scale of production the greater the nutrient inputs required and consequent risk of potential negative environmental impacts emerging from the aquaculture and the schematic representation is given in Fig. 1 (Tacon and Forster 2003).

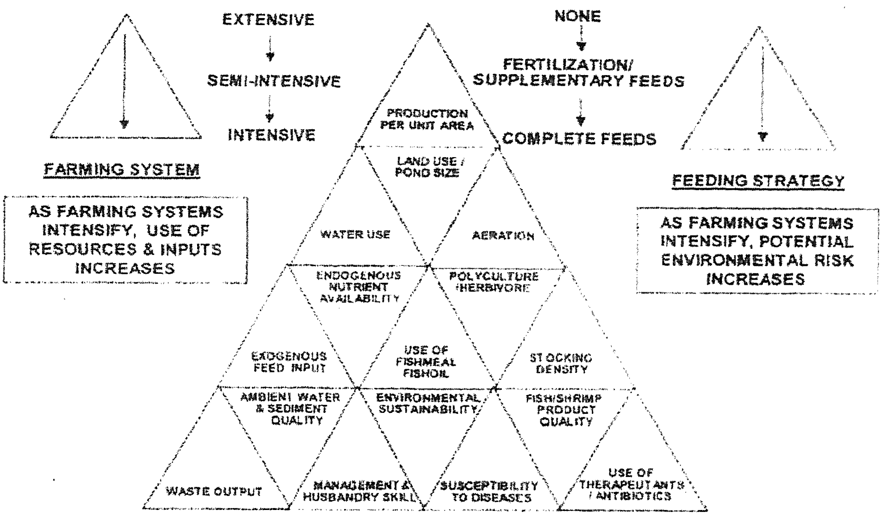

Fig-1: Main differences between extensive, semi intensive and intensive farming systems in terms of resources use and potential environmental risk.

4. Interaction effect of impact of environmental factors such as temperature, and dissolved oxygen on feeding behavior, feed regulation in relation to consumption.

The interrelationships between water quality and feeding in aquaculture are very complex. The environmental factors like water temperature dissolved oxygen; pH and weather conditions influence feeding activity, metabolism and growth and hence are of fundamental importance in feed management in shrimp culture. Feeding shrimp in culture systems in turn leads to the release of potentially harmful organic and inorganic matter into the water. Ammonia, the primary end product of protein metabolism in shrimp excreted by shrimp, may exert direct toxic effects on shrimp, while phosphorus, nitrogen and organic solids may affect shrimp indirectly through long-term degradation of environment. Apart from normal metabolic wastes excreted into system other harmful compounds may be released as a consequence of poor feeding practices or poor feed quality.

Nitrogenous wastes, primarily dissolved ammonia, and faecal indigestible nutrients, are produced more or less continuously in actively feeding shrimp. Ammonia, in its unionized form, is highly toxic to shrimp, while feces released into water rapidly breakup, contributing to both suspended and settleable solids loading of the culture system. In pond ecosystems these wastes enter the nitrogen, carbon and phosphorus cycles within the system. Under optimal culture conditions, these nutrients are reduced through microbial activity and they become available as nutrients for algae, and well-managed pond systems such nutrient cycling makes a valuable contribution to the primary productivity of the pond.

The effects on water quality of feeding shrimp in culture systems have received considerable attention in recent years. Initially issues were examined largely in terms of effluent chemistry and environmental issues, but more recently a greater emphasis has been placed on tackling the problems at the source by examining nutritional strategies (Cho *et al.*, 1994) and keeping the pond environment in a sustainable manner.

4.1 Temperature

Shrimp are termed *obligate pokilotherms*, which means that they possess little or no ability to internally regulate their body temperatures independently of their environment. But tiger shrimp has a preferred water temperature range of 28-33^0 C at which feeding, metabolism and growth are optimal. The optimal temperature range is defined as the range over which feeding occurs and where there are no signs of abnormal behaviour linked to thermal stress (Elliot, 1981). As water temperature increases within the shrimps' optimal range, there is a corresponding increase in metabolic rate. A result of increasing metabolic rate is a more increased transit rate of feed in gut of shrimp, in turn resulting in increased appetite and feed intake. Assuming that nutrients are available in excess to shrimp, and that of dissolved oxygen levels are not limiting, nutrient intake reaches an optimal level and growth rates increase to a maximum. If the shrimp are subjected to thermal stress due to bad weather conditions there will be less feed consumption which is very vital factor to be kept in mind for good feed management. The effect of temperature is to be kept in mind while adjusting the feeding frequencies. When water temperature drops below the optimum range, shrimp will burry into the pond bottom muds. Subsequent feed consumption rate typically declines as a result of decreased metabolism. In order to provide feed during times of highest shrimp activity, most feeding schedules have to be shifted to earlier in the evening or later in the morning.

4.2 Dissolved Oxygen

The availability of dissolved oxygen (DO) is a critical limiting factor in intensive shrimp culture. This is essential to all metabolic functions, including the digestion and assimilation of feed and growth. In general terms, in aquaculture, a fundamental aspect of good husbandry is maintenance of optimal or near optimal dissolved oxygen levels. When oxygen falls below optimum levels feeding and growth will be impaired and shrimp will be stressed. Microorganisms active in the decomposition of organic material in the benthos at the bottom of shrimp ponds, may also exert a significant demand on DO. This is termed the biochemical oxygen demand (BOD), and is a standard measure taken to determine the effects of organic loadings in aquatic systems.

In intensive shrimp ponds much of the BOD can be traced to the aerobic decomposition of excess feeds and other organic materials in the sediment. Studies have shown that sediments in intensive shrimp ponds consume up to three times as much oxygen as organisms in the water column and the biomass of shrimp combined (Fast et al., 1988). The knowledge of DO levels and potential fluctuations at the farm site are essential in optimizing feeding regimens. Since oxygen requirements are high, and oxygen has a low solubility in water, occasions may arise where oxygen levels fall close to, or below, the minimum level. Intensive shrimp ponds change from autotrophy, with net positive DO values, to heterotrophy as feed quantities increase during the production cycle.

Under low DO conditions in pond ecosystem, shrimp initially show signs of stress. This will generally first be reflected by shrimp showing a reduced feed consumption and abnormal patterns of swimming and distribution. Shrimp respond to conditions of low DO by moving into shallow water or by swimming close to the surface. Shrimp farmers frequently check the margins of shrimp ponds at night. The presence of shrimp congregating in the shallow margins is taken as an indicator of low DO levels in the pond. Low DO levels are a common cause of mortality and reduced growth in intensive shrimp ponds. DO tolerance values for penaeid shrimp range from 1.2-2.2 mg/l (Primavera, 1993).

An increase in metabolic rate and increase in oxygen consumption following the feed intake is termed as specific dynamic action (SDA) and it is related to the anabolic activities of digestion, absorption and assimilation of nutrients. In extreme cases at high temperatures, when DO levels of water are reduced and fasting metabolic demand is high, feeding to satiation can result in such high oxygen demand, necessary to satisfy SDA, that there can be mortalities (Roberts and Bullock, 1989). Under normal conditions due to SDA, the oxygen demand will be double the resting metabolism.

An appreciation of SDA is of particular importance to shrimp farmers when DO levels fluctuate with the diurnal cycles of plant photosynthetic activity. Feeding shrimp must be scheduled to avoid maximum oxygen demand, resulting in part from SDA, coinciding with low ambient oxygen levels. This may necessitate feeding shrimp earlier, or omitting one meal to avoid maximum oxygen demand occurring around dawn, when DO levels are lowest. Routine monitoring of DO levels in pond is an essential component of feed management. Actual or predicted fluctuations in DO levels generally necessitate some adjustments of feeding rates, or in extreme cases cessation of feeding in order to alleviate stressful and potentially harmful conditions.

5. Conclusion

To date, the major approaches taken by government authorities within the major aquaculture-producing countries for minimizing or reducing the potential negative feed related environmental impacts of farm effluents have included

1. Limiting or fixing the total quantity of feed the farm is able to use over a fixed time period. Examples: Denmark (European Commission, EC, 1995), Norway (Anon., 2001b);

2. Fixing maximum permissible specific nutrient levels within the compound feeds to be used to rear the species in question. Examples: Denmark (European Commission, EC, 1995), Thailand (Boonyaratpalin and Chittiwan, 1999; Corpron and Boonyaratpalin, 1999);

3. Banning the use of specific potentially high-risk feed items such as fresh/trash fish and invertebrates, and/or only permitting the use of artificial feed. Examples: Australia (shrimp farmers; Donovan, 1997);

4. Prescribing minimum feed performance criteria, such as specific levels of allowable dust/fines, feed packing material, feed efficiency or nutrient digestibility. Examples: Australia (shrimp farmers; Donovan, 1997), Denmark (European Commission, EC, 1995);

5. Requiring the use of specific Codes of Conduct, including appropriate Best/Good Management Practices for farm operations, including feed manufacture and use, and environmental management. Examples: Australia (Environmental Code of Practice for Australian Prawn Farmers: Donovan, 1997), Belize (shrimp farming; Dixon, 1997), Canada (British Columbia: Anon., 2001a), EU (Irish Salmon Growers Association, 1991; British Trout Association, 1995), Thailand (Tookwinas et al., 2000), shrimp farming (Boyd, 1999; Boyd et al., 2001), feed management (Davis, 2001), feed manufacture (FAO, 2001), general (Food and Agriculture Organization of the United Nations, FAO, 1997; Boyd et al., 2001; Tacon and Barg, 2001);

Clearly, within those countries where aquaculture is viewed as an important provider of food and/or source of income or employment, it is important that government policies be flexible (so as to address the diversity of species, farming systems, and possible rearing environments within the country in question), practical and enabling (so that they facilitate the continued growth of the sector), and protective of the environment (in that they both preserve the aquatic environment for all other users, while protecting the aquaculture sector from other water users and potential environmental polluters). There is a need to compare this with terrestrial agricultural food production systems, policies aimed at regulating off farm effluents and outputs would be more beneficial for the continued diversity and health of the sector rather than regulating on-farm feed inputs and feeding practices. The good quality feed and the best feed management helps in making the shrimp farming more profitable and environmental friendly.

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Health Management in shrimp farming systems

CP Balasubramanian and D.Rajababu

When the ability of the traditional food production systems (agriculture and animal husbandry) has shown stagnation in the new millennium, India needs to find alternative food production systems to feed the ever growing population. In this endeavour, `aqua farming' is often thought to be an alternative or at least an additional food productions system to land based agricultural system It is estimated that about 5 million tonnes of aquatic animal products can be produced annually through land based aquaculture in India, and the potential of sea farming could be many fold.

The growth and economic viability of the aqua farming primarily depend on the successful prevention or control of disease outbreaks. Unlike the land based farming, the disease problems in aqua farming are complicated due to the three-dimensional nature of culture system where the dynamic interaction of biotic fauna comprising the host and opportunistic pathogens and abiotic factors exists. The coexistence of host, and pathogen in an aqufarming environment makes it all the more difficult to control/ treat the disease. Disease prevention in aquaculture is not merely a case of dealing with the pathogen and its elimination, but it has to be dealt with a broader perspective, which is now popularly termed as AQUACULTURE HEALTH MANAGEMENT.

Disease problems were not a major deterrent when the aquaculture activities were of extensive in nature, as in the case of traditional shrimp culture operations of Kerala, Goa and West Bengal. Intensive systems lead to higher stocking densities and increasing stress. When animals become stressed, disease outbreaks often occur. Creation of Intensive rearing systems aiming for more and more production and profits, without proper planning and management, invited problems of infection and disease.

Unlike the land-based animal rearing systems, where the diseased animals can be identified and treated individually, the scope for disease control in aquaculture through detection and treatment is only of limited value, mainly due to the coexistence of the pathogen in the aquatic rearing system. The fish/shellfish is constantly bathed in potential pathogens, viz., parasites, bacteria, fungi and viruses. Separating the infected or diseased animals from the population and subjecting them for a treatment regime is impractical, if at all possible, it is not an economically viable measure. Disease treatment, therefore, becomes a difficult proposition in aquaculture, and disease prevention is a natural choice. The management practices that are designed to prevent the occurrence of disease in a fish grow out system is termed as the AQUACULTURE HEALTH MANAGEMENT. It is a holistic approach where disease monitoring or pathogen watch, fish quarantine, SPF (specific pathogen fee) selection, animal nutrition, environmental health and HACCP (hazard analysis and critical control point) principles are integrated.

Aquaculture Health Management:

Aquaculture health management primarily constitutes two aspects, the **farm health management** and the **fish health management**. Successful integration of these two factors only can deliver a disease free environment.

Farm health management constitutes

- the maintenance of good soil quality
- the maintenance of good water quality
- the maintenance of good farm productivity
- good feed management and
- the maintenance of proper farm quarantine to prevent horizontal transmission of disease causing pathogens

Fish health management constitutes

- Proper animal quarantine
- Screening of Broodstock and larvae/fingerlings
- Crop health monitoring and pathogen watch

Effective implementation of all the three aspects of fish health management depends entirely on the early and accurate **diagnosis** of the disease causing agents. The failure of accurate diagnosis of pathogens can lead to faulty treatment resulting in multiple problems like indiscriminate use of chemicals and drugs, drug resistance, large-scale mortality causing crop failure and economic loss. The occurrence of disease can be prevented by detection and avoidance of the pathogen. Timely and early use of proper diagnostics can be used as an effective tool of health care management.

Disease Diagnostics in Aquaculture

The different types of diagnostic methods used in aquaculture are

History:

History of disease at facility or in region, farm design, source of seed stock, type of feed used, environmental condition.

Required resource: Systematic record keeping.

Nature of diagnosis: Primary, inconclusive.

Behaviour:

Movement pattern, feeding pattern, mortality.

Required resource: Experienced farm technicians.

Nature of diagnosis: Primary, inconclusive.

Gross, clinical signs:

Physical clues like lesions, haemorrhage, colour changes, fouling

Required resource: Experienced farm technicians

Nature of diagnosis: Primary, inconclusive.

Direct microscopy:

Bright-field, phase contrast or dark field microscopic observation on wet mounts, stained or unstained tissue of abnormal or diseased animals.

Required resource: Experienced farm/laboratory technicians.

Nature of diagnosis: Primary, inconclusive.

Histology and histopatholgy:

Routine histological and histochemical examination of tissue sections.

Required resource: Laboratory facilities and experienced laboratory technicians. Nature of diagnosis: Secondary. Method provides specific information but poor in sensitivity and speed.

Electron microscopy:

Ultra structural examination of infected tissue sections, negatively stained virus preparations or surface scanning of samples.

Required resource: Expensive laboratories and expertise.

Nature of diagnosis: Conclusive, method is time consuming and laborious.

Culture and biochemical identification:

Standard culture methods of bacteria and fungi using selected artificial media preparations followed by biochemical tests.

Required resource: Good laboratories and expertise.

Nature of diagnosis: Conclusive. But the method is slow, and time consuming

Bioassay:

Laboratory challenge of the candidate species with selected pathogen.

Required resource: Wet laboratory and expertise.

Nature of diagnosis: conclusive, slow and time consuming.

Serological Methods:

Use of specific antibodies as diagnostic reagents in immunoblot, agglutination, diffusion, hybridisation etc.

Required resource: Good laboratories and expertise

Nature of diagnosis: Conclusive, different levels of sensitivity.

Tissue culture:

In vitro culture of pathogens in tissue culture systems, or in primary cell cultures.

Required resource: Sophisticated laboratories with expertise.

Nature of diagnosis: Conclusive.

PCR, gene probes and DNA chips:

Amplification and detection of unique sections of pathogen' s genome.

Required resource: Sophisticated laboratories and expertise.

Nature of diagnosis: Specific, most sensitive, and conclusive.

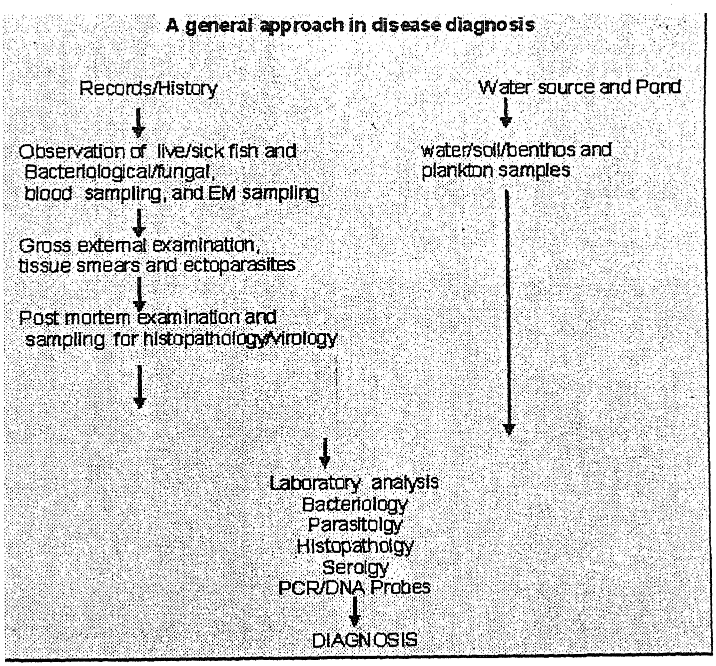
Diagnostic Procedure:

Disease is an abnormal condition characterized by a gradual degeneration of fish's/shellfish's ability to maintain normal physiological state because various factors adversely affecting its well-being.

The incidence of disease occurs in,

- Aquaculture facilities where fishes and shell fishes are commercially reared
- Ornamental fish rearing systems
- Game fishes in captivity
- Wild fishes

Once the infection or disease is suspected, the next step is to draw a diagnostic procedure, to fix the root cause of the problem. The diagnostic procedure may include a single diagnostic test or a combination of tests. In the case of routine pathogen watch or health monitoring, a set of selected diagnostic tests are performed to cover the potential pathogens. The approach generally followed is location specific and problem specific, where the first consideration is the availability of the diagnostic facility and expertise. There is no hard and fast method which can be applied for all cases.



Once the right diagnostic picture along with the water and soil parameters are available, the health management measures with respect to causative factor, can be initiated. However, the diagnosis often get complicated in the cases of mixed infections, with the involvement of primary, secondary and even tertiary pathogens.

The Genesis of Disease in aquaculture:

In an aquaculture pond the health status of the animal can become weak due to different stress factors such as

- chemical stressors
- biological stressors
- physical stressors
- procedural stressors

In such situation the opportunistic pathogens such as parasites, bacteria, fungi, and virus surrounding the animal invades the animal body, resulting an infection. All infection need not result in disease manifestation. Only when the pathogen build up disrupts the threshold of animal resistance, the animal succumbs to disease condition. The situation is a complex one where different factors such as the environment, the animal and the pathogen interacts continuously, making the health management a difficult proposition.

This can be further complicated with the involvement of more than one pathogen resulting in a mixed infection. A mixed infection can lead to faulty diagnosis. This spells the need of an integrated management approach to tackle the disease problems with respect to the animal, environment and pathogen using diagnostic a functional tool.

The integrated approach using diagnostics with farm management, can avoid the introduction of the virus via vertical and horizontal route, there by preventing the viral disease problem. The success of this approach mostly depends on the right choice and use of diagnostics along with other farm management measures, to keep both the animal and its environment in a healthy condition.

Individual health management models with a broader management approaches to control farm level environmental deterioration and preventive measures against pathogen introduction, depending on the availability of sensitive and specific diagnostics can be adopted for specific diseases caused by the pathogens such as bacteria, parasites, fungi, considering the economic aspects.

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Chemical usage in coastal aquaculture with special reference to shrimp farming in Tamil Nadu

D.Deboral Vimala and C.Gopal

Introduction

The fast pace of development in the shrimp farming sector has brought to focus on the use of a wide range of drugs, chemicals, antibiotics, antibacterial agents, therapeutants, pesticides, feed additives, anesthetics, immuno-stimulants, disinfectants and hormones by the fin and shellfish farmers. The use of such drugs and chemicals is indiscriminate and is mostly due to the lack of awareness amongst the farmers and also by the strong marketing strategy employed by the drugs and chemicals manufacturing companies. These products are sold to gullible farmers to enhance the productivity of the water bodies, increase the disease-resistance in the fin/ shellfish, promote growth and also protect against diseases such as a White Spot Syndrome in penaeid shrimps, etc

Chemicals and drugs presently in use are mostly derived from agriculture/ veterinary and have neither been tested nor evaluated specifically from the perspective of their effects on the aquatic environment. The use of many chemicals and drugs in aquaculture, if carried out properly, can be regarded as wholly beneficial either for avoiding adverse environmental effects or increased risks to the health of farm workers. However, the indiscriminate use of chemicals and drugs, especially the banned categories may have a negative impact on the environment and also incur penalties to the shrimp farming sector.

Several studies have been conducted since 90's worldwide about the use of chemical and biological products: the Philippines (Primavera *et al.*, 1993), Thailand (Graslund *et al.*, 2003) and North West Mexico (Fritch *et al.*, 2006). In India, excepting for a general review of chemicals use in shrimp farming (Pathak *et al.*, 1996), no detailed study on the use of Chemicals and Biological (CB) products has been carried out. The Food and Agriculture Organization of the United Nations (FAO, 1995) presented a Code of Conduct for Responsible Fisheries. This code asks countries to regulate the use of chemical inputs in aquaculture that are hazardous to human health and the environment, and also stresses the responsibilities of producers. The aim of this article is to bring out the market profile, products used in shrimp farming, usage pattern and steps involved in usage of chemicals.

Material and methods

An investigation was carried out in Tamil Nadu (TN) in two districts Thiruvallur and Kancheepuram. Market survey of CB products available in the study area, the claim made by the manufacturer regarding its use, and the level of information provided with the product was surveyed. The total population of the shrimp farmers in the study area was 143 in Thiruvallur and 53 in Kancheepuram district. Of which, 77 respondents from Thiruvallur district and 26 from Kancheepuram of Tamil Nadu were surveyed during August-September 2007.

Chemicals and biological products documented in the study were sorted into the following major groups: a) disinfectants, b) soil and water probiotics, c) feed additives, d) immunostimulants, e) shrimp probiotics and f) an uncertain/unidentifiable group of compounds. Some products were identified with respect to chemical formula of active ingredient whereas some were identified merely as a certain type of product (e.g. vitamins were grouped into one type; immunostimulants as another).

CB products market profile

A total of 110 CB products were available in the market. More than 26 different companies were documented as manufacturers of these products, of which, 26.92 % were overseas manufacturers. The addresses of the distributors in India have been indicated clearly in the overseas products. Attractive brand names have been used on the label in almost all the products. However, 67.27% of the product had indicated the quality and quantity of the active ingredient in the product. Information leaflets indicating the content, method for use and dosage recommended were available only in 3.63 % of the products. One of the very important observations is the absence antibiotic products in the market. This clearly is an improvement over the earlier reports available in India. The banning of antibiotics and drugs by Ministry of Agriculture and the Coastal Aquaculture Authority, followed by the awareness camps conducted by MPEDA had actually reduced the usage of antibiotics in shrimp farms. It is necessary that suppliers of CB products for use in shrimp farming provide farmers with essential basic information, so that the farmers have an opportunity to make relevant choices on which products to use and how to use them safely and efficiently.

Chemical and Biological products used in shrimp farming

Total number of CB products used by farmers of both districts was 54. Among them about 47.05% of CB products were used by both the districts were the same and farmers in Thiruvallur district used additional/new products (52.95%). The CB products used by them were categorized into disinfectants, soil and water probiotics, feed probiotics, feed additives and immunostimulants. The details of these groups are elaborated in the forthcoming section.

Table 1. Use pattern of CB products in shrimp culture

CB products	Kanchipuram n=26	Thiruvallur n=77	Total N=103
Disinfectants	5 (18.51)	5(9.8)	10 (9.70)
Soil &Water Probiotics	15 (55.56)	32(62.75)	47 (45.63)
Feed Probiotics	2 (07.40)	8(15.69)	10 (9.70)
Feed additives	3(11.11)	6(11.76)	9 (8.73)
Immunostimulants	2(7.40)	-	2 (1.94)
Total	27(100.00)	51 (100.00)	103(100.00)

(Figures in parentheses are percentage to column totals)

Disinfectants

All the farmers interviewed used some kind of disinfectant (9.73%) in the pond management. Amongst the CB products, agricultural lime or shell lime is applied by the most of the farmers at the rate of 100 kg -1000 kg/ha as a basal dose with 150 kg of Dolomite and 25 kg of Zeolite to adjust the pH. Overall liming is practiced more widely and intensively and so also the use of Zeolite. To improve the plankton growth, some farmers applied Dolomite as substitute to lime at the rate of 750 kg/ha as basal dose and if necessary top-dressed with 50kg/ha once in 10-15 days to neutralize pH fluctuations. Most of the farmers used zeolite to decrease turbidity, whereas only a few used them to remove ammonia.

In the present study in the both the districts, the source of water and the pond effluents discharge point were the same – Lake Pulicat in Thiruvallur district and Buckingham Canal in Kancheepuram district. Thus, the likelihood of disease outbreak is high whenever water quality deteriorates. Hence, the management of water quality is of primary concern, particularly in ponds with higher stocking rates ranging from 20 - 30 no $/m^2$. Since most of the farmers in the area are small land holders, without any reservoir treatment ponds, the usage of bleaching powder is quite low as compared to other areas with treatment reservoir ponds. Bleaching powder - a safe guard product is widely applied during pond preparation by few farmers, as treatment of intake water and other biosecurity measures such as decontamination of implements. The application rate varied based on the nature and intensity of the problem and generally applied between 100 to 1000 kg/ha/crop.

Probiotics

Many shrimp farmers in the study area have complained about poor water quality in coastal areas, saying that it causes stress and increased susceptibility to disease in shrimp. About half of the farmers (45.63%) gave importance for soil and water probiotics and feed probiotics (9.70%). Regular use of probiotics in fish feed in U.K. and other European countries are a common practice which has been reported to have several health benefits. (Rehana, 2003). When the presence of White Spot Syndrome Virus (WSSV) was detected, a common procedure for preparing pond soils before stocking has been evolved by the farmers. The black soil accumulated in the pond bottom was removed by all the farmers and soil probiotics was applied as a basal application. Nearly 45.63% of farmers applied soil and water probiotics as two in one. Similarly, in shrimp culture commercially available feed probiotics were mixed with feed and applied 2-5 times during the culture period and used by farmers (9.70%). To enhance the attractability of feeds, farmers generally use fish oil in addition to some of the probiotics which are feed-intake enhancers. Use of some of the probiotics has been reported to have added functions like prevention of swollen gills, red gills, tail rot and broken appendages, control of bacterial, viral, fungal and protozoan pathogens.

Feed Additives

Some farmers (8.73%) added different products to the feed in order to increase the nutrient content. Six types of Vitamin C were used in the study area. Fish oil was used as feed attractant and as a 'start-feeding' ingredient (GESAMP, 1997). Farmers used it as a nutritional management strategy. Specific compounds that are present in prey species, or in their release products, can be used to attract cultured shrimps to artificial feed. Vitamin

C is often added to shrimp feed by respondent farmers. The addition of vitamin C to shrimp feed has also been reported to be common in the Philippines (Primavera *et al.* 1993).

Immunostimulants

Two farmers in the survey area used an immunostimulant product. The product was mixed with the feed of shrimp with the purpose of providing disease-resistance and to boost the immune system of shrimp during the time of disease outbreak. The contents of two different brands used in the study were quite clear and are herbal based. Immunostimulants mainly work by increasing the bactericidal activities of the phagocytic cells. Treatment has been shown to have an immunostimulating effect or an effect against infection by *Vibrio* and YHV, in *P. monodon* (Rukyani *et al.*, 1999; Sunarto *et al.*, 1999; Sakai, 1999). Immunostimulants are used prophylactic ally. However, the response is likely to be of short duration (Sakai, 1999).

Table 2. Usage pattern of chemical and biological products

No. of Chemicals Used	**Used by no. of farmers**	**Percentage to total**
1-5	3	2.91
6-10	43	41.75
11-15	55	53.40
> 15	2	1.94
Total	103	100.00

Shrimp aquaculture production in many parts of the world is affected by diseases, particularly caused by luminous *Vibrio* and many other viruses including White Spot Syndrome Virus. Occurrences of disease and production problems vary according to different phases of shrimp culture. Effective strategy to control the occurrence and the spread of disease is the most important extension need felt by farmers all over the world.

Majority of farmers (53.40 %) used a range of 11-15 CB products for culturing one crop in 1 hectare, followed by 41.74% used a range of 6-10 CB products. Only 2.91% used within 5 products and 1.94% used up to 17 products. About 30.09% farmers have applied based on the satisfactory results of the previous application. All the farmers believed in probiotics which they believed an instant solution to their problems (Moriarty, 1998 and 1999). Hence for successful shrimp culture, the farmers ensures of the quality feed, clean pond bottom, good water management and disease free environment. In the process, farmers use independently a variety of products rather than using a particular product for a common cause. According to the nature and intensity of the problem and the advice of the technician (100.00%) or the consultant concerned with the farm, the products are applied. The usage of CB products also depends up on trial and error method (76.69%), or on the own previous experience of the farmer (42.71%), or based on the experiences and advice of his fellow farmers (11.65%), or as directed by the technician (100.00%).

Steps involved in Use of Chemicals

1Awareness Programmes

Awareness programme is vital for achieving the objectives of regulating the use of drugs, chemicals ,etc in shrimp farming. A comprehensive programme is necessary to educate the shrimp farmers on region-wise and those associated with the manufacture, supply and marketing of such chemicals , etc. The responsible Institutes could also chalk out programmes and prepare necessary awareness material in consultation with the Aquaculture Authority, MPEDA and CIBA (ICAR) .This programme would be implemented with the active cooperation of the Department of Fisheries in the coastal States/ Union Territories.

2. Labelling of chemicals used in aquaculture.

The Central/State government could have a key role to play in ensuring chemicals, utilized by aqua farmers are properly labeled, and that other important information on such inputs. Regional language should be given importance. Products without label should be banned.

3.Regulating the use of chemicals in aquaculture.

In order to promote and regulate the safe and effective use of chemicals in aquaculture, competent government authorities should work together to clarify and specify relevant mandates and responsibilities of various line agencies in charge of public health and food quality, aquaculture, animal health services, environment, etc., and develop enforceable and practical aquaculture-specific provisions and guidelines on the responsible use of chemicals.

Collaboration between aqua- farmers, researchers and chemical manufacturing industries should be promoted, to allow for testing and licensing of chemicals for use in aquaculture, as well as for formulation of sound and effective regulatory instruments on the production, distribution and use of chemicals which are known to be hazardous to human health and environment .

4. Training, extension and capacity building at farm level.

Research Institutes and State Agricultural Universities should upgrade their curriculum to include training in responsible use of chemicals and shrimp/fish health management. The Department of Fisheries website should be developed as a means of gathering and dissemination of information on Responsible shrimp farming. National Institutes should also be linked to regional information sources.(Nash, 1992; Rehana, 1995; Rajbansh, 1995; Kumar 1996 & Potipitak, 1996).

In genral, aqua farmers in many states of India are poorly equipped in terms of technical and financial resources and educational infrastructure. Appropriate and up-to-date technologies in aquatic farming are required to promote usage of chemicals. Full benefit from such technologies would require training, education and skill development programmes for local aquafarmers . States should try to establish ways to assist farmers and local communities with extension, training, and other local capacity building activities with regard to trade/company name, composition, usage, dose of application, method of application and rate particulars. In addition to that, the traders should furnish clearly the following :

When to apply?, Where to apply, What to apply?, Which time to apply?, Why to apply?
& How to apply ?

5. Encouraging practices and attitudes of aquafarmers

It is the accountability of Department of Fisheries to support individual aqua--farmers in general in encouraging responsible aquaculture practices. DoF 's of respective States should promote the establishment aquafarmer clubs/farmers associations, and support the collaboration between the private aquaculture sector and government authorities, research institutions and other food producer organizations, at local and national levels. In doing so, government authorities should generate awareness on the need for responsible attitudes in the aquaculture sector, given the fact that, increasingly, aquafarmers and those associated with aquaculture are being made accountable for their actions. (CCRF Article 9.4)

It is concluded that current status of CB products in aquaculture is really hazy and lack of knowledge on modes of actions is very evident. More information on relationship between bacteria and other microbiota and economic efficiency of the product are required to be analyzed. According to these parameters , shrimp farmers could reduce the use of CB products because of the risks to the environment, human health and production. Many probiotics being sold in market have not been scientifically proven to have a positive effect on production. It is necessary to educate the farmers and those associated with the manufacture, supply and marketing of such chemicals to create awareness of regulating the use of chemicals and biological products in shrimp farming in a rational manner for better aquatic animal health and increased aquaculture production

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HARVEST AND POST-HARVEST HANDLING OF CULTURED SHRIMPS

M.Jayanthi, C.P.Balasubramanium and P.Ravichandran

INTRODUCTION

Harvest and post-harvest handling are the final phases of a culture operation. The economy of the culture operation depends on the quantity harvested and that of marketing on the quality achieved. In the traditional shrimp culture practices in India, harvest is carried out by nets, bamboo-screen traps and complete draining of pond water and subsequent hand picking. For burrowing species like Kuruma shrimp (*Marsupenaeus japonicus*), a mechanically driven drag net is operated for harvest in Japan. The present paper deals with the nets and other methods used for harvest of shrimps from traditional and the present-day culture operation in India and the criteria to be adopted for harvest and post-harvest handling.

TRADITIOANAL SHRIMP FARMING

NETS

Conical bag net **(Fig.1):**

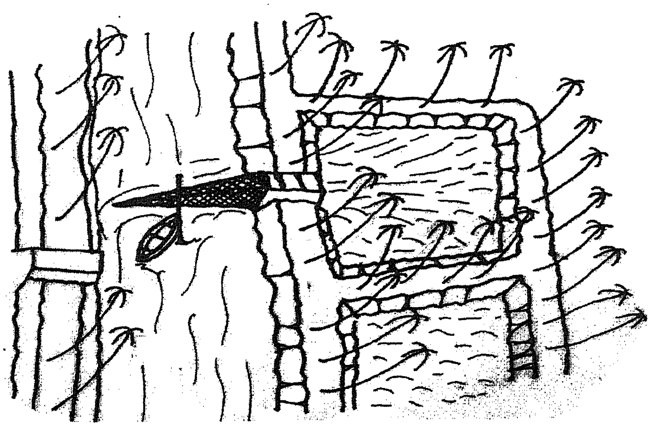


Fig. 1. Harvest by a conical shaped net from a seasonal shrimp-cum-paddy field

It measures 5 to 9 m in length with a mesh size of 5 to 13 mm and is fixed to the mouth of the sluice gate by means of a rectangular bamboo frame. The net is operated during the low tide when the water is let out through the sluice gate at night. A light is installed near the mouth of the sluice to attract more shrimps. The shrimps trapped in the cod ned of the net are removed periodically into a stationed canaoe in the outer canal. Fishing by the net is carried out for 7 to 8 nights in a fortnight, i.e. 3 or 4 nights on either side of the full moon and new moon. This type of gear is extensively used in the traditional paddy-cum-shrimp cultivation of Kerala as well as in the *bheries* of West Bengal.

Cast net **(Fig. 2):**

Fig. 2. Cast net in operation

If the water depth is one metre, it should be reduced to 0.5 metre and then cast can be operated to catch the cultured shrimp. Two cast netters can be employed for the harvest from a 0.4 ha pond.

Fig. 3. Bag net in operation

When the water level in the culture pond is knee-deep, drag net can be operated. The drag net is more suitable to tiger shrimp (*Penaeus monodon*) than the Indian white shrimp (*Fenneropenaeus indicus*) because the tiger shrimps tend to cling to the net, while the white shrimps will tart back from the net and escape.

TRAP

Bamboo trap (Fig. 4):

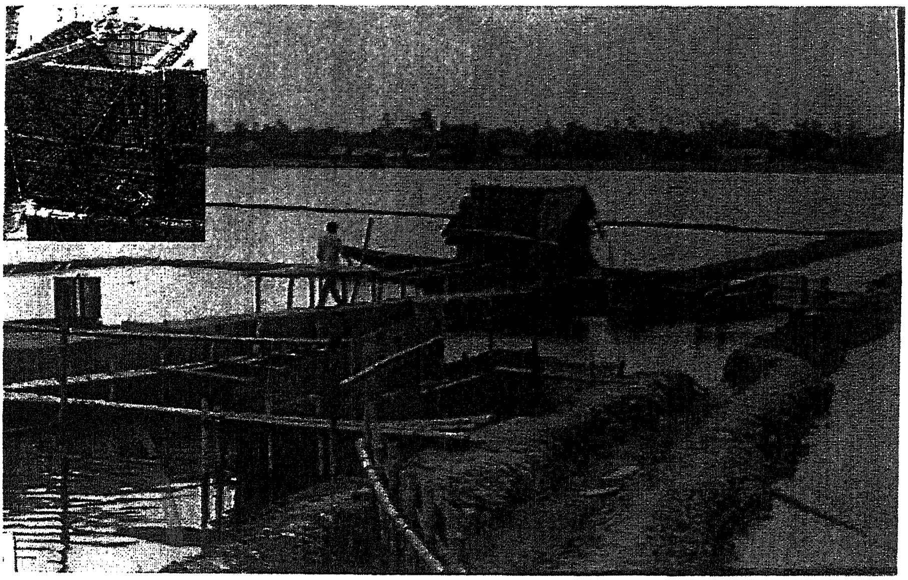


Fig. 4. *Bheries* in West Bengal where bamboo traps are used for catching shrimps inside the field

In the *bheries* of West Bengal, traps made of bamboo are laid in the bottom of the pond near the sluice gate to catch the cultured shrimp, mostly during the low tide .

HAND-PCIKING

In the final harvest of shrimp farming in paddy fields, the water is drained through the sluice during the low tide and further draining is effected by pumping. When the water level is almost nil, the cultured shrimps are hand-picked easily.

PRESENT-DAY SHRIMP FARMING

In tide-fed ponds, the maximum water is drained through sluice and the harvest is done by conical net fixed to the sluice. While the water is drained through sluice, the maximum number of shrimps which move along the water current are caught by conical net. Later, bag net/cast net are used and finally, after pumping out the remaining water, shrimps are collected by hand-picking. In pump-fed ponds, the water is partially pumped out and the shrimps are harvested by bag net/cast net and after complete draining, the remaining shrimps are collected by hand-picking. In those ponds where the complete draining is not possible, the cast net is carried out for 3 to 4 days for harvest of shrimps.

BETTER MANAGEMENT PRACTICES FOR HARVESTING AND POST HARVESTING

To retain the freshness and quality and without muddy smell in the cultured shrimps, the following criteria are suggested.

Harvest

1. Week before harvesting make sure pond bottom is clean with out any dirty area. Before the harvest, removal of algae and keeping the bottom of pond free from dirty materials are to be done.
2. Frequent exchange of water is to be done to remove algal water, in case of heavy bloom is present.
3. Avoid harvest during molting period (full moon or new moon). 2 days before harvest check if there are any newly molted shrimp, if newly molted shrimp are >10%, delay the harvest by day or two. Do not exchange water or reduce water level 3 to 4 days before harvest
4. Three to four days before harvest apply Agri. lime (100-200 kg/ha) to the pond and pond bottom where it is more black specially in corners and trenches
5. Do not feed the shrimps 6 hours prior to the harvest, in order to keep the stomach empty, thus improving the shell life.
6. During the harvesting maximum suspended particles are likely to be released into the open waters. Hence great care should be taken to prevent such a release
7. Draining of water and harvest should be completed within 6-8 hours, mostly between 6 P.M. and 6 A.M.
8. Harvesting can be done by completely draining the pond either by gravity or through pumping and hand picking or trapping.
9. Use more pumps if necessary to complete the harvesting in time
10. Harvest and packing of shrimps should not be done during hot days.
11. Usage of bag net in knee-deep water will catch more shrimps than cast net.

12. Wherever, the complete draining is not possible, lead screens may be fixed in deeper areas of the pond, which will guide the shrimps towards the bag net from where shrimps can be collected.
13. The water drained out for harvesting should be pumped into the waste stabilization ponds and kept for a few days for settlement before releasing into the open water.
14. Icing should be done immediately and liberally after harvest.
15. Generally, the processors/buyers collect the harvest from farm site and transport in refrigerated vans. When such a facility is not available and the produce has to be transported over a long distance, the shrimps should be beheaded and stored in ice to prevent spoilage.
16. There is need for organising marketing facilities for small farmers through farmers' co-operative associations to avoid monopoly of a few processors.

Post-harvest handling

1. Shrimps harvested by bag net and hand-picking should be separately kept. Those hand-picked shrimps should be thoroughly washed and packed separately.
2. Clean water should be used for washing shrimps and ice made up of potable water should be used for packing.
3. The washed shrimps should be immersed in slurry of ice for not less than 15 minutes, which enhances freshness of shrimps and increasing their weight by 5 %.
4. Do not use any chemicals while washing the shrimps or chill killing without knowledge of processors.
5. Adequate use of ice will ensure the chilling of shrimps.
6. Harvested shrimps can be packed in plastic tubs with crushed ice at 1:1 ratio (i.e. 1 kg of shrimps versus 1 kg of ice) for better preservation.
7. Before stacking the packed plastic tubs one above the other, the cleanliness of the bottom of each tub should be attended to.
8. The packed tubs should reach the processing plants quickly without any delay, which will ensure better quality

Better management practices increases the efficiency of production though better use of resources to increase production within limits imposed by the carrying capacity of the ecosystem, lower risks (to the producer, to the consumer and to the ecosystem); and minimize environmental impacts.

INTROUDUCTION OF HACCP PRINCIPLES IN SHRIMP FARMING FOR PREVENTION OF DISEASES AND FOOD-SAFETY

P. Ravichandran

Introduction

Shrimp farming development in India, during the last 10 years, suffered a serious set back due to two major issues – a) viral disease outbreaks and b) Environmental concerns raised against it. All exported food commodities are subjected to stringent quality standards imposed by the importing countries. These requirements place more attention on 'prevention' of potential food-safety problems before they occur rather than the traditional approach of inspecting or trying to find problems after they have occurred. Hazard Analysis and Critical Control Point (HACCP) is a regulatory requirement in sea-food processing industry imposed by the United States and European Economic Community (EEC). The HACCP approach does not replace the traditional regulatory approach. It is in addition to the traditional approach and depends on a solid foundation of sanitation, and Standard Operating Procedures. As a preventative maintenance program it has been used by various technical operations and food processing facilities for well over 30 years.

HACCP is an approach that brings decision-makers, management agencies, researchers, and industry representatives together to establish a plan to ensure compliance of standards on food safety set by the importing countries. HACCP is a preventive system of hazard control rather than a reactive one. It is a Risk Management tool. It simply involves a pre-planning procedure to fully outline an operation, noting potential hazards that could occur and identifying control points to prevent, minimize or correct hazards.

During recent times, HACCP principles are being applied in various fields with various objectives. Aquaculture is one of the areas where these principles could be adopted successfully in all the links in the supply chain to ensure food-safety, environmental safety and disease prevention.

2. HACCP Principles

National Advisory Committee on Microbiological Criteria for Foods (NACMCF) devised the HACCP system for the food processing in 1992 and it contained the following seven steps.

1. Conduct a hazard analysis
2. Identify critical control points (CCP)
3. Establish critical limits (CL) for each CCP.
4. Establish monitoring requirements for each CCP and CL.
5. Establish corrective actions to be taken when monitoring indicates a deviation from the CL.
6. Establish effective recordkeeping procedures.
7. Establish a HACCP verification procedure.

3. Application of HACCP principles in Aquaculture for food-safety

3.1 Hazard Analysis

The first step in the HACCP concept is the analysis of the system of production in connection with the chosen objective. For food-safety we have to list out the potential human health hazards in cultured shrimps. The major issues of concern in the importing countries are the presence of human pathogenic bacteria, residues of antibiotics, residues of chemical and therapeutics, residues of heavy metals and pesticides.

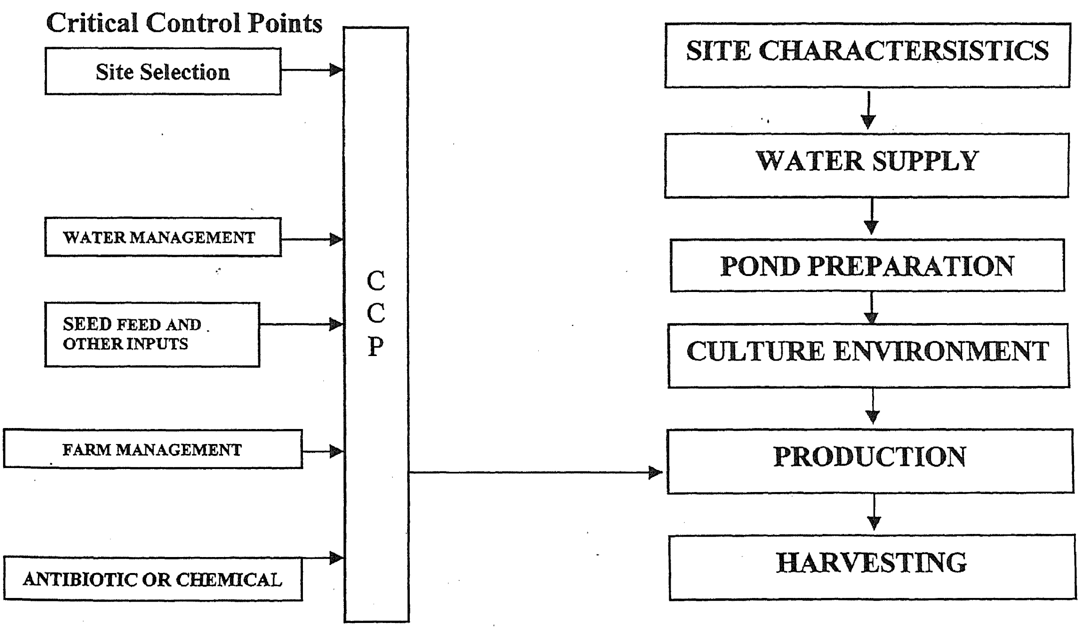
Hazards in shrimp farming

Biological hazards	Pathogenic bacteria	Salmonella, Shigella, *E.coli, Vibrio cholerae, V.parahaemolyticus, V.vulnificus, Listeria monocytogenes,* etc
Chemical hazards	Drug residues	Hormones, growth regulators, antibiotics such as chloramphenical, nitrofuran and its metabolites and permitted antibiotics which residue is not over Maximum Residue Level (MRL).
	Pesticide residues	Herbicides, fungicides, insecticides, etc
	Heavy metal residues	

Microbial quality of the cultured environment affects the microbial quality of the cultured shrimps. *Salmonella* and *Vibrio cholerae* are known to be part of the natural microflora of brackish water cultured shrimp, and pose a major concern for processors and exporters. This necessitates the maintenance of hygienic conditions in shrimp farms.

Antibiotic residues became of concern in 1992, when Japan's health authority rejected some shipments of shrimp products from Thailand and other Southeast Asian countries that were contaminated with oxytetracycline and oxoloinic acid. In 2002, Nitrofuran and chloramphenicol came under the spotlight of the European market. The US Food and Drug Authority expressed concerns over residues in shrimp and testing of the imported shrimp for the residues of antibiotics, heavy metals and pesticides have become mandatory.

The points at which these hazards could occur should be identified as Critical Control Points. The best way to do this is to draw the flow-diagram of the production process and to indicate the possible source of the contaminants.



3.2 Critical Control Points

Hazard analysis of the shrimp farming process has indicated the following critical control points and the probable hazards.

Critical Control Points	Hazards
1. Site selection	Chemical contamination
2. Water Source	Chemical contamination
3. Seed	Antibiotic residue from hatchery
4. Medicated Feed	Antibiotics, Hormones etc.,
5. Drugs and Chemotherapeutics	Chemical contamination
6. Pesticides and Herbicides	Chemical contamination
7. Harvesting	Bacterial contamination
8. Post-Harvest handling	Bacterial contamination and decomposition
9. Transportation	Bacterial contamination and decomposition

3.2 Critical Limits

In many instances, the critical limits or permissible levels for certain processing conditions, various chemical residues and microbial concerns have been established by previous regulations but other hazards may require special consideration. Without previous approvals, established use or designated action levels, the farmers should consider zero critical limits for certain pesticides and drugs. For example there is a zero tolerance for chloramphenicol in aquacultured shrimp. With the tendency for introduction of new pesticides and antibiotics through water and feed, shrimp processors should monitor on the side of caution. Critical limits must be set as the guidelines for critical control point compliance. Effectiveness and acceptance of a HACCP plan rest with current and appropriate critical limits. Govt. of India and Aquaculture Authority have banned the use of twenty drugs and chemicals in aquaculture which should be strictly complied with.

3.3 Monitoring requirements

The HACCP plan should list the actual procedures to be used in monitoring the critical control points to assure the residue levels of the contaminants in shrimp stay within the stated critical limits. Routine pesticide and drug analysis is not practical for the small shrimp farmers. Cluster based management systems have to be evolved where continuous monitoring could be maintained through random sampling. In countries like Thailand, where a certification system is existing, regular inspection teams visit the farms and take samples for analysis.

3.4 Corrective actions

Deviations in Critical Limits should attract immediate corrective actions. Inputs found to contain any hazardous contaminants should be immediately stopped and the probable impacts of its usage on the quality of the cultured shrimp should be assessed. Strict quality control of all the inputs is an essential component of the HACCP for food-safety. Certification system for the inputs should be put in place by the regulatory authorities so that the control of the CLs can be effectively done.

3.5 Record Keeping and Verification

Record keeping and verification are the two important aspect of the HACCP implementation. All activities carried out in the farm should be carefully recorded which will facilitate to identify the problems at a later stage. Further the records will help to introduce the traceability in shrimp farming, which is likely to become mandatory.

Periodic verification of the HACCP plan should be built in the proposal. This verification may include the product testing and external auditing. HACCP certification after inspection will ensure premium price for the produce.

4. Application of HACCP principles in Aquaculture for shrimp disease prevention

The above mentioned HACCP methods can also be implemented for shrimp disease prevention. Here the hazard analysis will indicate that the major hazard is the introduction of bacterial and viral pathogens into the culture facility. This can occur through vertical and horizontal transmission. The hazards for disease prevention is the presence of detectable listed viral pathogens. Hazard analysis has indicated that the pathogens could enter the system through seed, live feed, water, vector, personnel and implements. The hazard analysis is presented in the following table.

Hazard Analysis for disease prevention

Potential Hazard	Sign	Justification	Preventive measures	CCP
Pond water	Yes	Water may contain viral pathogens	Disinfection of water	Yes
Shrimp seed	Yes	Shrimps may contain viral pathogens	Only tested, quality virus free seed to be stocked	Yes
Live feed, Fresh frozen feeds, prepared feeds, Artemia cysts, Wet feed and fertilizers	Yes	Water or water borne particles with live feed may contain viral pathogens	Periodic testing of Live feed. No wet feed to be used.	Yes
Animal vectors	Yes	Vectors may transfer viral pathogens	Prevention of entry of viral pathogens. Controlled by BMPs	No
Human	Yes	Human vectors may transfer viral pathogens	Controlled by BMPs	No
Facilities and Equipment	Yes	Equipments and implements may be contaminated with viral pathogens	Controlled by BMPs	No

Introduction of HACCP principles for disease prevention is otherwise can be termed as 'Bio-security' for avoiding horizontal transmission of viral pathogens through adoption of Better Management Practices.

6. Conclusion

Shrimp farming being a 100% export oriented sector is being influenced by the global market, prices and WTO issues. Food-safety, Environmental safety and Sanitation and phytosanitation issues assume greater importance. It is expected that issues like Traceability and eco-labeling will become mandatory in a few years. Hence introduction of HACCP in shrimp farming will become an essential requirement especially for food-safety and environmental-safety.

ADOPTION OF BETTER MANAGEMENT PRACTICES (BMPs) OF SHRIMP FARMING

M. Kumaran, K. Ponnusamy and P. Ravichandran

Introduction

Indian shrimp farming has witnessed three distinct phases. The 'rising phase-I' since late eighties to 1994 wherein intensive shrimp farming was practiced by corporate companies and neo-entrepreneurs with imported technology, inputs and consultancy. Shrimp farming was done in virgin ponds, the productivity was high, price was premium and it was highly profitable in just four months. The 'falling phase-II' (1995-2001) witnessed the pervasion of virulent viral diseases, particularly the 'White Spot Syndrome Virus' (WSSV) which devastated the shrimp aquaculture totally, mainly due to greediness for high production, 'self pollution' due to poor farm management, negligence of environment and lack of cooperation among the shrimp producers. Nevertheless, as a blessing in disguise this disaster made the shrimp farming a self mature and more responsible farming regime despite colossal losses and legal interventions. The 'sustainable phase-III' (Since 2002) facilitated with interventions from research and development institutions in the form of evolution and transfer of Better Management Practices(BMPs) of Shrimp farming mainly to prevent the entry of pathogens in to the production systems. Nevertheless, though vertical entry of pathogens were prevented to some extent the horizontal transmission of viral pathogens from the affected ponds to adjoining areas has brought a havoc in most of the farming places. To circumvent horizontal transmission of pathogens a set of farm bio-security BMPs were also suggested. However, outbreak of diseases continued to happen even today which is one of the major cause for the reduction of farming area (1.4 lakh ha to 1.08 lakh ha) and production (from 1.4 lakh tonnes to 76,000 tonnes) today. There are two possible reasons for the continued threat of WSSV in shrimp farming systems. They are

1. Selected adoption of BMPs by the farmers
2. Non-adoption of BMPs by all the farmers in the shrimp farm cluster.

Adoption studies in fish/shrimp production technology indicated that techno-socio-economically robust and obligatory technologies were willingly adopted (Gupta and Rab, 1994; Kumaran *et al.*, 2003; Immanuel and Alex1998). The extent of knowledge possessed by farmers and successful demonstrations had directly aided in adoption of aquaculture technologies (Ahmed *et al.*, 1995; Gupta *et al.*,1998) and inadequate information and farm management skills prevented the adoption of farm management practices (Pretty, 1995). Researches have proved that effective and coordinated extension of best management practices could enhance the sustainability of aquaculture (Christopher et.al.2003; Bolorunduro et al. 2004) and socio-economic factors were found to have maximum influence on the adoption of shrimp culture technologies (Betru, 1997 and Carlson and Dillmon 1998; Meeran, 2000; Swathilekshmi and Chanrakandan, 2005; Swathilekshmi et al. 2005). In this context a study was conducted with around one thousand farmers in Andhra Pradesh and Tamil Nadu states to assess the extent of adoption of BMPs so that suitable refinements or modifications could be suggested to ensure the full compliance of BMPs by the farming community.

Adoption of Better Management Practices (BMPs) of Shrimp Farming

In the present investigation concentrated on adoption gaps in 36 selected BMPs of shrimp farming which are grouped in to six major heads *viz*., Site selection and Pond construction (10), Pond preparation (5), Seed Selection and Stocking (7), Feeds and Feed Management (5), Pond Management (6), Harvesting and Marketing (3). The number of practices studied under each major head is indicated in the parentheses.

site selection and pond construction

Site selection is an important process in aquaculture as this can decide the success or failure of the shrimp farm. Infrastructure availability, non-conversion of other land uses, spacing between farms, suitable soil and water quality are the important practices to be adopted while choosing a site for a shrimp farm. Further, all the shrimp farms should have been registered with the Coastal Aquaculture Authority (CAA). Mangroves, agricultural lands, saltpans etc should not be converted for shrimp farming. Shrimp farms should be located 100 m away from human settlement and drinking water sources. At least 20m distance should be there between shrimp farms. Keeping 10% of the total farm area for reservoir purpose, low stocking density and avoiding the use of bore well water and banned antibiotics in shrimp farming are the other guidelines to be followed. The water trained out for harvesting should be pumped in to the waste stabilization ponds and kept for few days for settlement before releasing into open water.

It may be noticed from the Table 1 that majority of the AP farmers did not adopt the guidelines on conversion of other land uses, overcrowding of farm more than the carrying capacity of the source water body, soil and water quality to the tune of 81%, 87%, 86 and 72 % respectively. In TN, about 41%, 82%, 27% and 27% of respondents respectively did not follow the above guidelines. It may be due to conversion of other land uses like productive agriculture lands, overcrowding of farms in excess of the carrying capacity of the source water body, soil quality other than clayey loam and water quality parameters at the farm sites surveyed.

Table- 1. Adoption of site selection and pond construction in AP and TN

Sl. No.	Site selection and pond construction GMPs	Adoption Gap(%)	
		AP (n=606)	TN(n=402)
1.	Conversion of Land	80.53	40.80
2.	Over crowding of Farm	86.80	81.59
3.	Soil Quality	85.97	29.60
4.	Water Quality	71.78	27.11
5.	Distance between farms	100.00	100.00
6.	Waste water Treatment System	100.00	100.00
7.	Reservoir	48.35	51.99
8.	Use of Antibiotics	0.00	27.11
9.	Use of Bore well	77.06	56.72
10.	CAA Registration	85.64	46.52

About 81%, 100%, 100%, 48%, 77% and 87% of AP respondents had not adopted proper site selection, distance between farms, waste water management through Effluent Treatment System (ETS), reservoir facility, stocking density, non-use of bore well water and registration. In case of TN, the percentage of respondents who did not adopt the above guidelines were 100%, 100%, 100%, 51%, 56% and 47% respectively. Conversion of agricultural lands, overcrowding of farms in excess of the carrying capacity of the creek, lack of pond for reservoir and Waste Water Treatment System (WWTS) and use of bore well water during water scarcity were the probable reasons. Small farmers having one or two ponds can not have reservoir or WWTS. Hence, the common reservoir and WWTS for group of farms could be solution.

Pond preparation

Pond preparation is an essential part of culture practices during which the metabolite load and contaminants (Chemical and biological) in the soil from the previous cycle is removed through tilling, ploughing and drying. During pond preparation, the pests and predators are removed and pH and nutrient levels in the water and soil are brought to optimal concentrations through application of lime, organic manures and inorganic fertilizers. From the Table-2 it is observed that the adoption gap in pond preparation practices in both the states was found to be less because these practices are critical and absolutely essential.

Table-2. Adoption of pond Preparation in AP and TN

Sl. No.	pond Preparation GMPs	Adoption Gap (%)	
		AP (n=606)	TN(n=402)
1	Ploughing the pond	0.00	0.75
2	Liming of pond	0.00	15.67
3	Screening the inlet	3.96	4.98
4	Disinfection of water	10.89	19.90
5	Fertilization of water	0.00	20.40

Seed selection and stocking

Seed quality has a direct relationship with the survival and growth of the cultured shrimps. Post Larvae (PL) 20 should be the appropriate shrimp seed size for stocking. Healthy and pathogen free seed from registered shrimp hatcheries should alone be used for stocking. The health status of the shrimp seed should be checked through standard testing procedures including PCR. The seed should be acclimatized before stocking to the prevailing temperature, salinity and pH in the pond conditions by gradual mixing. Stocking densities should be low as per the regulations of the CAA. It may be seen from the Table-3 that the 31% and 96% of AP respondents had not adopted the recommended seed size and stocking rate. In TN also about 74% of the respondents stocked more than the recommended level. High stocking densities might be due to the reduced sale price, single crop in a year system, fear of crop failure and greediness of farmers.

Table- 3. Adoption of seed selection and stocking in AP and TN

Sl. No.	Seed selection and Stocking GMPs	Adoption Gap (%)	
		AP (n=606)	TN(n=402)
1	Hatchery Seed	0.00	1.00
2	Size of PL	31.02	6.47
3	Quality testing of Seed	0.00	1.99
4	Type of Packing and Transport	62.38	1.24
5	Time of Stocking	0.00	5.97
6	Acclimatization of Seed	0.00	35.82
7	Stocking Density Followed	95.87	74.13

<u>Feed Quality and Feed Management</u>

Feed accounts for more than 50% of the production cost. Feed quality and conversion ratio have considerable influence on shrimp waste levels. Only nutritionally balanced pelletted feed with optimal water stability should be used. Freshly obtained feed should be used to the extent possible. Feeding rate should be determined from standard feed charts and adjusted as per the shrimp pond biomass. Feed check trays should be used to regulate feeding rates. Both overfeeding and underfeeding should be avoided. Since shrimp require four hours to digest the consumed feed, feeding frequency should be 4-6 times in a day. Since shrimps are nocturnal, more than 60% of the feed should be fed during the night. From the Table-4 it is clear that the farmers of both AP and TN had adopted the BMPs of feed quality and management.

Table- 4. Adoption of Feed Quality and Feed Management in AP and TN

Sl. No.	Feed Quality and Feed Management GMPs	Level of Adoption (%)	
		AP (n=606)	TN(n=402)
1	Feed Quality	0.00	0.00
2	Feeding Rate	0.66	0.00
3	Regular sampling and feed management	0.00	0.25
4	Feed Frequency	2.64	1.49
5	Check Tray	31.68	0.25

Water quality and health management

The health of the shrimps should be monitored continuously and those with any one or more of the following conditions are diagnosed to have some diseases: inactive and sluggish, empty gut, bluish/blackish colouration, body blisters, flared up gills, broken appendages, black/white spots, colorued gills and opaque muscles. Any disease should be diagnosed immediately with the help of the trained pathologists. Disease problems mainly attributed to pond environmental conditions. Hence, proper pond management in the form of water exchange and water quality parameters, pond fertilization, proper aeration to maintain the BOD, non-use of banned antibiotics and chemicals. Disease is the single most threat to shrimp culture. However, 68% of TN respondents (Table-5) had not followed the recommended health management BMPs which might have caused them heavily. Even a single mistake could make havoc to the entire cluster which derives water from the same creek.

Table 5. Adoption of water quality and health management in AP and TN

Sl. No.	Water quality and health management GMPs	Level of Adoption (%)	
		AP (n=606)	TN(n=402)
1	Regular Water Exchange	0.00	10.45
2	Proper Aeration	1.82	8.96
3	Water pH management	1.49	51.24
4	Pond Fertilization	3.14	22.89
5	Banned antibiotics/chemicals	25.08	24.88
6	Disease preventive BMPs	31.85	67.91

Harvest and marketing

Harvesting can be done by completely draining the pond either by gravity or through pumping and hand picking or trapping. Icing should be done immediately after the harvest. The harvesting should be planned in such a way that it coincide with maximum market price available and during festive season like Christmas. It may be seen from the Table – 6 that the farmers of both AP and TN adopted the harvesting BMPs. However, about 43% and 85% of AP and TN farmers respectively could not synchronize their harvest with maximum market price. This might be due to location specific reasons.

Table- 6. Adoption of harvest and marketing in AP and TN

Sl. No.	Harvest and marketing GMPs	Level of Adoption (%)	
		AP (n=606)	TN(n=402)
1	Time of Harvest	0.00	3.48
2	Proper Icing and Ice Killing	0.17	1.74
3	Market Price Orientation	46.37	84.58

As a whole the study has shown that about 70% of the BMPs were adopted by the farmers and 30% of the BMPs were not adopted (Table-7). BMPs which are critical for producing the quality shrimp were mostly adopted. But, BMPs which addresses environmental, social and food safety issues like proper site selection, conversion of other land uses, overcrowding of farms, lack of pond for reservoir and ETS, use of bore well and low stocking density were not adopted fully (Fig). Though these BMPs are not directly concerned with the productivity, they are very essential for the long-term sustainability and marketability of the produce.

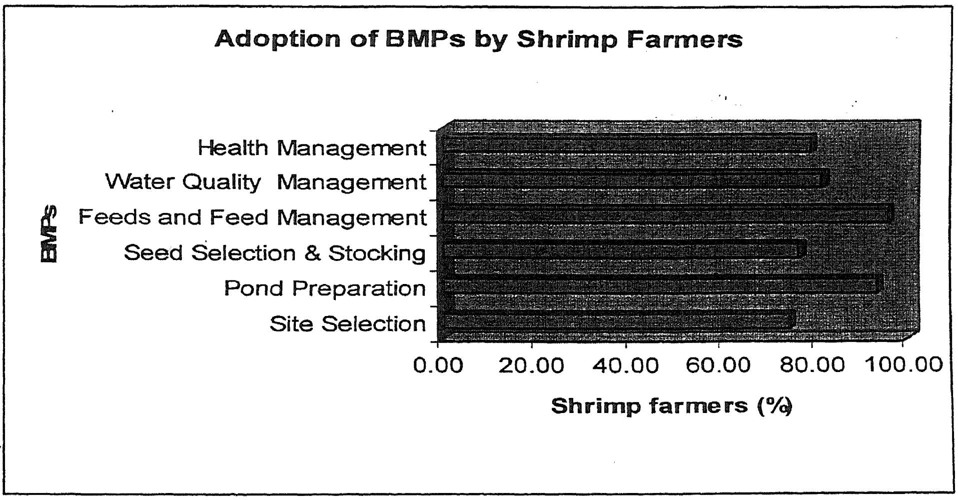


Table 7. Extent of Adoption of Shrimp Production guidelines in AP and TN

Sl. No.	Shrimp Seed Production Guidelines	Level of Adoption (%)	
		AP	TN
1	Overall Extent of Adoption	67.62	69.06
2	Overall Adoption Gap	32.38	30.94

Prevention of	Prevention of	Prevention of	Ensuring Food	Ensuring

Table 8. BMPs in shrimp farming

vertical transmission of diseases	horizontal transmission of diseases – Pathogen transfer	Stress to Shrimps	safety	Environmental safety
1. Screening of mother brooders 2. Select of seeds of single spawning 3. Select seeds of single mother 4. Quality seed – Colour, activeness, uniform size, muscle gut ratio, length, MBV & PCR tests 5. Optimum seed packing density 6. On-farm nursery	1. Initial chlorination of pond water 2. Filtration of inlet water to prevent vectors 3. Reservoir-chlorination-water exchange to prevent vector 4. Crop scheduling 5. Synchronized stocking 6. Restriction of movement of people, equipments etc 7. Disinfection of people, equipments and vehicle 8. Bird scaring & crab fencing 9. Remove and burry moribund/dead shrimps 10. Non-draining of disease affected pond water 11. Emergency harvest and bleaching of the disease affected pond 12. Disease attack - Information to nearby farmers	1. Removal of bottom black soil ,drying, ploughing etc 2. Drying and ploughing to remove bottom algae and gastropods 3. Acclimatization of seed before stocking 4. Maintenance of optimum soil and water quality parameters (pH, salinity, temp, bloom, oxygen, bottom) 5. Feeding and feed management-type of feed, rationing, scheduling, method of feeding, place of feeding, 6. Aeration-position and orientation 7. Maintenance of optimal blooming and optimum water depth in the pond 8. Removal of floating algae and weeds 9. Appropriate water exchange – using reservoir 10.Chain dragging 11.Prevent the development of benthic algae 12.Monitoring for soil and water quality, animal behaviour 13.Do not feed shrimps with by catch crustaceans	1. Sites free from industrial polluted area – prevent residue heavy metals 2. Non-use of harmful/banned drugs, pesticides, antibiotics 3. Appropriate harvesting time & method 4. Do not feed shrimps 6 hours prior to harvest to keep the gut empty to improve shelf life 5. Separate hand picked shrimps from bag net harvested shrimps. Thoroughly wash the hand picked in clean water and pack them separately. 6. quality ice- Ice dipping of harvested shrimps in freshwater ice slurry for freshness &additional weight 7. Do not use any chemicals while washing & chilling the harvested shrimps 8. Pack the harvested shrimps in transport tubs with ice 1:1 ratio for better preservation 9. Maintain cleanliness while packing and stacking 10. Separate any dead, discoloured shrimps from the quality shrimps	1. Proper site selection-guidelines 2. Shrimp farm-minimum distance from human settlements, etc 3. farming do not affect other traditional activity 4. WSA 60:40 area for other purposes 5. ETP 6. Separate inlet & outlet 7. Mangrove plantations in the bunds to prevent erosion. 8. Non-use of bore well water

BMPs are dynamic and continuously being updated in tune with the emerging requirements. Initially BMPs were developed to prevent the vertical entry of pathogens in to the farming system. Later BMPs like filtration, reservoir, chlorination, WWTS, bird fence, farm fence, restriction of movement of personnel, material and vehicles are also included. Of late BMPs on food safety, environmental and social safety aspects are also being included in response to the market demands. A comprehensive list of BMPs recommended in line with the international principles of sustainable shrimp farming is listed in Table-8. Profit is the ultimate aim for adoption of any farm management practice by the farmers. Today the price of the shrimp is all-time low and the inputs costs are soaring hence it is very difficult to convince the farmers to adopt BMPs. Hardly 50% of the developed farm facilities are under operation at present. Presently farmers are aiming for large sized shrimps (40-50gm) which fetch them better price, for that, they have reduced the stocking density to the lowest level i.e. 3-4/m^2. Except feed and lime most of the external inputs are stopped. Of late, feed companies and experienced professionals advocating application of organic manures, organic juices and yeast based productions in lieu of formulations of input companies to reduce the production cost. Zero water exchange cultures are also being advocated and practiced extensively.

Group Approach for Collective Compliance of BMPs

Shrimp farming is being practiced mostly along the brackishwater creeks and canals in clusters of farms drawing and draining water from the same source. Shrimp culture has been beset with frequent disease outbreaks mainly due to 'self pollution' arising out of poor farm management, negligence and lack of cooperation among the fellow farmers. Unless all the farmers in the cluster adopt all the BMPs prevention and transfer of pathogens cannot be achieved by random adoption of BMPs by some farms. Hence, it is necessary that all the farmers in a shrimp cluster should organize themselves as a society and enforce collective compliance of BMPs by every farm. The primary advantage of group approach to shrimp farming is that it enables the cluster to organise the scheduling of water exchange and harvesting regimes, contributing to substantial reduction in the intra cluster horizontal transmission of the deadly virus. This collectiveness would also lead to many benefits, such as quality seed procurement and collective stocking dates, purchase of feed and other crop inputs and procurement of soil, water and health management kits together minimizes the cost and assures quality. Another critical advantage is enabling optimum utilization of financial resources of members of the cluster in setting up of common facilities such as reservoir ponds and effluent treatment ponds. Farmers' groups can negotiate with buyers and get a premium price for the high quality shrimp produced in their cluster. Experiences have amply proved that aqua farmer groups, as an effective institution, ensure responsible and sustainable aquaculture development (Kumaran *et al.* 2003; Kumaran,2009; Kutty *et al.* 2003; MPEDA/NACA,2003), empowered farmers through collective decision making (Kristin Davis, 2006; MPEDA,2006 and Umesh,2008), offered opportunities to link with markets and ensured social, environmental and food safety responsibilities (Umesh,2008), could take care of farm extension service too and guarantee sustainability of the shrimp farming in the long run (Krishna,2000; Franzel *et al.*'2003; Omoyeni and Yisa, 2005; Kumaran,2007). The National Centre for sustainable Aquaculture (NaCSA) the extension wing of the MPEDA has been working in this direction in organizing farmers societies to mobilize the farming community for collective compliance of BMPs.

CONCLUSION

Adoption of BMPs at the hatchery and farm level is must to prevent the entry and spread of pathogens in shrimp culture systems. Selective adoption of BMPs by the farmers as well as random adoption by some farms in a shrimp farming conglomeration would do more harm than good. However, certain BMPs may not be adopted individually due to space constraints needs collective effort. The Government through it promotional schemes could facilitate the farmers groups in establishing common facilities like reservoir and WWTS. The day has come that adoption of BMPs would be mandatory for sale of shrimps in the global market through certification. Hence, capacity building of farming community on BMPs and motivating them for a collective compliance of BMPs is necessary to ensure adoption of BMPs. Case studies on group approach to shrimp farming in selected sites have proved that cluster based group managed shrimp farming ensures sustainability and better prospects for the farmers.

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