TROPECA

Case study for south west coastal Bangladesh

Tropeca Case Study 1

Muhammad Abdur Rouf

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A collaboration between:

- Fisheries and Marine Resource Technology Discipline, Khulna University, Bangladesh
- Uttaran (NGO), Bangladesh
- Nautilus Consultants. Ltd. (UK)
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- Hambrey Consulting

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ABSTRACT

It is commonly assumed that expansion of coastal aquaculture in Bangladesh poses risks in exceeding environmental capacity. TROPECA, a DFID-funded international research project involving Nautilus Consultants and Stirling University (UK), Fisheries and Marine Resource Technology Discipline, Khulna University and University of Dhaka (Bangladesh) and RIA1, The University of Fisheries and the University of Agriculture and Forestry (Vietnam) investigates this issue with case studies in Bangladesh and Vietnam. From 2002-2004 the team in Khulna has been working closely with an NGO (UTTARAN) studying an aquatic system comprising a river (Semi diurnal tidal system), a canal and 10 shrimp ponds as well as verified the results by wider area survey.

Shrimp culture practices were mostly extensive to improved extensive system. Shrimp were being produced without proper pond preparation, fry nursing, stocking or feed management due to a lack of technical knowledge and also concern about the risks associated with higher levels of investment. Consequently production rates were low, averaging only 191 Kg/ha in the study area. Very high mortality of shrimp was reported in some of the farms using shallow ponds immediately after heavy rainfall. The team encouraged farmers to report conditions leading to a variety of potential indicators being tested (reddish colour, oily layer and salt bubble of water, as well as bad odour of soil) to indicate poor water and soil quality prior to shrimp mortality events.

Estimation of overall nutrient mass balance per hector indicates that fertilizer was the highest nutrient contributor both for TN and TP giving a rate of 60.2% and 82.4 % respectively. Feed was the second highest contributor, estimated 21.1% N and 9.3% P. The total inputs of nitrogen and phosphorus were 48.7 kgha^{-1}cycle^{-1} and 328.95 kgha^{-1}cycle^{-1} respectively. Among the inputs, only 33.4% of nitrogen and 6.1% of phosphorus were removed as harvested form. A large portion, 39.1% N and 92% P were remained in the sediments and unaccounted for. According to the estimated nutrient dynamics, N and P are not exceeding the environmental quality standard. However there is possibility of nitrite spike, well account for some of the moralities, due to water exchange or fertilization from May to June.

Year round water quality observations indicated that there was no major differences among the river, canal and pond water which might be due to the high water flushing rate (468% per cycle). The water quality in shrimp ponds during grow-out period in this experiment were in acceptable range.

It may be concluded that the aquatic environment is able to accommodate the present level of aquaculture practice. The assimilative power of aquatic environment is in danger of being degraded with the intensification of shrimp culture areas. Given the poor yields investment in more intensive culture has been slow to materialize. On the other hand, salinity intrusion problem of soil reflects the vulnerability of environmental capacity due to that culture practice. Such cumulative impacts must be considered in planning aquaculture and other development if environmental capacity is not to be exceeded.

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This is not really an environmental capacity issue – is it linked to intensification in any way?
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Contents

LIST OF TABLES

LIST OF FIGURES

1 Introduction

1.1 Project structure

Sustainable aquaculture development can bring real and lasting benefits to rural and coastal communities. But the environmental consequences of inappropriate or excessive development will adversely impact on the wider communities and the farmers themselves through poor farm performance or failure. There is therefore an increasing need for planning and management of aquaculture in developing countries. Environmental capacity is being used in some progressive developed countries to inform the management of aquaculture as it provides a more objective basis on which to plan and regulate aquaculture operations, recognizing the cumulative impacts of resource users and the assimilative capacity of the environment. TROPECA, a DFID-funded international research project involving Nautilus Consultants and Stirling University (UK), Fisheries and Marine Resource Technology Discipline, Khulna University and University of Dhaka (Bangladesh) and RIA1, The University of Fisheries and the University of Agriculture and Forestry (Vietnam) investigates this issue with case studies in Bangladesh and Vietnam. From 2002-2004 the team in Katahaltala, Dumuria, Khulna has been working closely with an NGO (UTTARAN) studying the environmental capacity of an aquatic system comprising a river (Semi diurnal tidal system), a canal and 10 shrimp ponds.

The project tried to estimate the environmental capacity of an aquatic system as well as to develop a guideline for the management of shrimp aquaculture to stay within the environmental capacity.

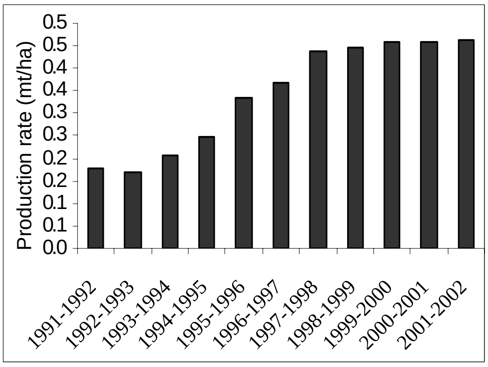
Introductory chapter of the report focuses on brief description of the project, importance of the study and brief description of the status of Aquaculture in Bangladesh. Second chapter highlights review of some literatures. Third chapter represents the case study area, detailed materials methodology including framework of the study. Fourth chapter highlights the primary stakeholder (local shrimp farmer) main concerns and issues. This chapter also describes the institutional aspects. One-year water and sediment quality records as well as biological and farmers indicators, recorded and noticed during the study period, are focused on the fifth chapter. Sixth chapter covers the results and description of water exchange, mass balance per hector, nutrient dynamics and description of the environmental capacity assessment. Management implications and dissemination are placed on the 7th chapter. Finally conclusions and recommendations are made at the last chapter.

1.2 Aquaculture in Bangladesh

Since the early seventies shrimp culture in the coastal region of Bangladesh has been expanding significantly. In the fiscal year 2001-2002, shrimp culture area and production reached to 141,353 hectare and 65,579 Mt., which were only 115,088 hectare and 20,335 Mt. respectively in the fiscal year 1991-92 (Table1).

Table1: Farm area and production of shrimp in Bangladesh

Year	Area (ha)	Production (mt)	Production rate (mt/ha)
1991-1992	115088	20,335	0.177
1992-1993	137996	23,530	0.171
1993-1994	137996	28,302	0.205
1994-1995	137996	34,030	0.247
1995-	13799	46,223	0.335



Source: Shrimp farm survey, DoF

Semi-intensive and intensive methods were initiated after 1990's followed by traditional extensive methods. Hussain (1994) estimated that 70% of the total area under cultivation was 'extensive' culture (100-200 kg shrimp ha^{-1}), 25% was 'semi-intensive' culture (500-1000 kg shrimp ha^{-1}) and 5% of the area was 'intensive' culture systems (1000-2000 kg shrimp ha^{-1}). Despite rapid expansion and intensification of shrimp farming in Bangladesh, water and sediment qualities and their implications in shrimp production as well as the impacts of farm effluents on the receiving ecosystem remains poorly understood (Islam *et al*., 2004*).* So, as an obvious affect of rapid unplanned expansion of shrimp farming in Bangladesh, especially with high level of intensification based on high input, the industry has faced severe disease problems and at present very few semi-intensive farms exists.

The environment in the culture system is dynamic and complex, and the quality of this environment has profound influences upon production. Effective manipulation of the environment to favor greater production requires an understanding of basic physical, chemical, and biological processes (Boyd, 1986).

Physical and chemical properties of water in shrimp farms are useful indicators of the farm environment (Dierberg and Kiattisimkul, 1996) and also properties of effluent waters are important to understand the impacts of farm effluents on the receiving environments (Chua *et al*., 1989). To understand the chemical process, information on the fate of the added nutrients, particularly the major nitrogen and phosphorus, is essential. The establishment of nutrient budgets in pond is the basic step for the quantitative study of food utilization efficiency, pond fertility, water quality and process in the sediments (Avinmelech and Lacher, 1979).

Many problems and needs appear to be linked to the number and intensity of farms in a given coastal area, or the ability of the area to assimilate waste materials (Macintosh and Philips, 1992). Moreover, the excessive amount of dissolved nitrogen and phosphorus resulted from shrimp farms would give problem when there are many aquaculture operations at a unique coastal site. So, information on effluent loading or nutrient budget will be needed for development of modeling the environmental capacity. Site selection and management with due consideration for the capacity of the environment to sustain shrimp culture area needed for effective planning.

Environmental capacity of a particular coastal area depends on tidal flushing, current and assimilative capacity of the water body of pollutants. Overall and specific assessment of the environment capacity for coastal ecosystem (upland, estuary, nearshore), and for individual aquaculture system (pond, cage, raft, pen) respectively with different rate of intensification has evolved as an important necessity for sustainable and environment friendly or at least, environment neutral aquaculture (Chowdhury *et al*., 2000).

Coastal brackish water shrimp farms are claimed to exert substantial impacts on the surrounding environment. Therefore, shrimp farming industries have been under increasing pressure to reduce environmental impacts and improve sustainability (Wu *et al*., 1994). One of the most widely accepted criteria for sustainable development is that activities should not exceed the carrying capacity of the environment. Despite this, there has been little research on what constitutes carrying or environmental capacity, and how this relates to specific developments or sectors, especially in tropical countries (Chowdhury *et al*., 2000).

Chemical or nutrient budgets have been studied in freshwater fish cultured in raceways (Worsham, 1985); in ponds (Avinmelech and Lacher, 1979; Boyd, 1985; Chiba, 1986; Green and Boyed, 1995) and in marine fish ponds (Korn *et al*., 1985; Korn and Neori, 1989). The nutrient budgets were estimated on shrimp ponds in Thailand (Briggs and Funge-Smith, 1994; Thakur and Lin, 2003), extensive shrimp farms in Bangladesh (Wahab *et al*., 2003), semi-intensive shrimp farms in Mexico (Paez-Osuna *et al*., 1997) and in Bangladesh (Islam et al., 2004) and intensive shrimp farms in Australia (Jackson *et al*., 2003). However, more study is required on coastal shrimp farm, especially on the improved extensive shrimp farms in Bangladesh.

In the present study, the effluent loading of nitrogen and phosphorus, water quality and managerial operation of some coastal shrimp (*Penaeus monodon)* ponds were investigated. It is tried to estimate the environmental capacity of an aquatic system as well as to develop a guideline for the management of shrimp aquaculture to stay within the environmental capacity. Sampling was conducted in a local system for whole culture cycles. At the same time it was worked with volunteer farmers to record farmer practice and farm performance. Simple mass balance models were estimated to establish primary nutrient sources and the potential limiting factors in systems. These were then compared with farm practice and performance information before being discussed with the farmers involved. The study also sought to identify simple and locally meaningful environmental indicators to validate/test and monitor assessments and predictions of environmental capacity.

2 Literature Review

2.1 Environmental capacity concept

Environmental capacity refers to "a property of the environment, defined as its ability to accommodate an activity or rate of activity without unacceptable impact" (GESAMP, 1986). Environmental capacity describes an inherent property of the environment to assimilate or process waste and minimizes the impact of any natural or anthropogenic activities.

Industry makes use of marine environmental capacity by discharging effluents directly into the sea. Consent to discharge is usually given closely tied in with careful monitoring which ensures that environmental capacity is not exceeded. The difficulty with this (monitor-response) approach is that monitoring will often show an impact only once the finite environmental capacity has been exceeded. This means that efforts to reduce discharges of potentially damaging effluents may only be implemented once environmental damage has occurred (Gray, 1998).

As a result of the inadequacy of the "monitor-response" approach, there is increasing interest in more precautionary based approach to environmental management. In order to be of value in a regulatory and policy framework environmental capacity must be determined in advance to ensure that it is not exceeded. It should used in a proactive or anticipatory rather than a reactive or retrospective fashion.

2.2 Environmental capacity models

Modelling can be described as an interdisciplinary approach to problem solving. Models can be used to help understand natural events, answer questions and predict future impacts. The value of a model is dependent upon the knowledge and understanding that goes into it and all interpretations or conclusions must take full account of the assumptions implicit in model construction.

All models whether simple or complex must go through the same process of model formulation and validation. Typically this pathway involves identifying the problem or question to be studied, determining the availability of suitable data and undertaking system structural analysis to enable model construction. At this point the model should undergo extensive validation and behavioural tests by reconciling with empirical data. Ideally the modelling process should be fully iterative and any lessons learned in validation should be continually fed back into the model design. Only at this point can the model be taken forward for practical use and policy design.

Biological systems tend to be non-linear, which immediately rules out certain kinds of models for use in ecological modelling. In spite of this there remain a wide variety of models that can be used and each is appropriate to different situations or different levels of information. The more common types of model used in ecology include time trend models, regression models, bio-energetics models, mass balance models, and simulation models.

In biological modelling it is important to consider the impact of random and unpredictable events. The difficulty that remains inherent with this approach is in determining a suitable scale and frequency for events, which by their very nature are random.

Models for environmental capacity in aquaculture

To use models in the strategic development and environmental management of aquaculture, the complexity of a marine environment have to consider first. Even within a closed production system such as shrimp ponds there are complex biological, physical and chemical pathways and interactions which must all be considered in any attempt to model cause and effect. In the open marine environment these pathways become more numerous and complex and the level of information required to construct a valid model increases.

As the level of aquaculture production and associated research have increased in recent years the understanding of these complex systems and the associated data bank have increased. The understanding has begun to reach a stage where it is reasonable to expect accurate and informative models to begin to provide valuable information to the producer and regulator alike. At its most simple this may be in predicting impacts of one particular nutrient.
When looking at the fates of aquaculture wastes, there are a number of different pathways to be considered. Uneaten food and fish faeces can be dispersed into the environment in either particulate or soluble form (Chen et al 1996). These two main pathways are influenced by vast numbers of factors. The physical and chemical characteristics of the receiving water will have a huge influence on the scale of impact of aquaculture production and the relative importance of these two main pathways.

Models have become more complex over time, evolving from initial simple mathematical equations which give an idea of waste build-up, to more complicated ecological models which take account of dispersion and assimilation processes. This evolution has enabled more complicated effects of aquaculture to be estimated including different production levels, variation of feeding regimes and treatment with chemotherapeutants.

A large proportion of the modelling over the last thirty years has focused on the question of particulate deposition on the local benthic community. Studying this area of aquacultural impact has the advantage of being observable and models can be readily verified with field measurements. Smaller but significant numbers of studies have either incorporated or concentrated upon the fate of soluble fraction of the waste product. This is more complicated to model and considerably harder to test and improve models in the ideal iterative fashion.

With advances in the modelling capability, much recent research has begun to consider the impact of increasingly small and numerous chemical reactions associated with aquaculture production. This field of modelling is more complex than prediction of either particulate or soluble wastes. Chemical processes occur on minute scales and many are poorly understood. Numerous interactions within the environment further complicate the accurate prediction of chemical fates over wide distances.

All the models require varying amounts and complexity of information and approach the problem from different angels.

In the present study simple mass balance/flushing rate models is adopted for the estimation of environmental capacity. This model gives an overview of the feeding interactions in the ecosystem, and the resources it contains. This enables analysis of the ecosystem and simulation of various levels of exploitation, and thus allows evaluation of the relative impact of fisheries and environment. This model may be used indirectly to estimate the effects of pressure on native stocks from anthropogenic impacts, such as aquaculture, but not directly in the calculation of the carrying capacity.

2.3 Application of environmental capacity models

Aquaculture systems in developing countries range from highly extensive to highly intensive, and they are often much more closely integrated with agriculture and in some cases forestry systems.

Concerns that pond aquaculture, especially shrimp farming, is exceeding environmental capacity are frequently voiced, and it is often assumed that the high disease incidence in shrimp farming is related to environmental degradation.

Developing countries have lower capacity to develop and apply complex models, but may nonetheless benefit from some level of modelling. The present study seeks to explore the possible application of environmental capacity concepts and models to improve environmental management of aquaculture in practice.
In all cases environmental impact and capacity estimations are being addressed with the relative emphasis on different methods being determined through an evolving and adaptive approach to research dependent on local problems, conditions, and technical capacity. The four basic approaches are:

1. Identification of farmer level indicators of environmental health and capacity to sustain aquaculture production; and monitoring of corresponding nutrient conditions over the production cycle;
2. Development of gross nutrient budgets;
3. Development of simple mass balance/flushing rate models to determine maximum environmental capacity assuming perfect mixing within a defined aquaculture system and/or sub-system;
4. More detailed assessment of hydrodynamics and nutrient/organic matter dispersion and dilution within a defined aquaculture system or sub-system

The utility of the different approaches will be assessed according to their likely cost-effectiveness in generating:

- Improved understanding of the links between management practices, water quality, sediment quality, and farm performance;
- Improved understanding of the relationships between water quality in ponds, in the defined aquatic system, and in the wider aquatic environment;
- Improved understanding of the nature and value of simple indicators of environmental quality and their use for routine water quality management
- Guidance on management of ponds and/or wider aquatic systems to generate optimal conditions for aquaculture and other productive activities;
- Estimates of possible limits to intensification or increased production for aquaculture (and agriculture where relevant) within the defined aquatic systems;
- Guidance as to system changes (e.g. canal design; water gate protocols) which would lead to improved water quality and or potential for increased production without compromising the quality of the wider environment

Testing of these approaches has already begun and will be developed further over the coming year. The four approaches are described in more detail below.

Farmer level indicators of environmental health and nutrient status

The indicators which farmers already use to assess water quality and growing conditions are identified and discussed. Other possible practical indicators (such as watercolour, sediment colour, smell, presence or absence of common organisms), or refinements of existing indicators are developed with the farmers. In parallel with observations of these indicators, records are kept of management interventions (stocking, fertilisation, feeding), climate and water events (such as heavy rain or water exchange), and measured water quality parameters (typically relating to salinity, N, P, BOD).

Information on indicators, salinity and nutrient levels is then plotted over the production or annual cycle, along with major management and other events. The relationships suggested in these plots are discussed with farmers to determine the utility of indicators in pond or water management.

For some case studies questionnaire surveys of a larger number of farmers are being used to test out these possible relationships on a wider scale, and/or identify other important relationships between indicators, water quality, natural events, management interventions and overall farm performance.

Gross nutrient budgets

Total inputs to individual ponds, cages and the shared aquatic system of nitrogen, phosphorus, and in some cases organic matter are estimated. Outputs in the form of harvested organisms, and nutrients and suspended matter in water remaining in the system or exchanged with the wider environment (in open systems) are also estimated. The balance of nutrients retained within the system or lost to sediments and/or atmosphere can then be estimated. These estimates will immediately provide an indication as to whether the system is a nutrient sink or source.

For those systems that are used for rice production as well as aquaculture, the nutrient budget associated with rice cultivation is also estimated and possible nutrient exchanges between the two farming systems assessed.

In determining the nutrient load of a farm, if the nutrient composition of total input (feed, fertiliser, supply water), output as harvested products, discharged water are known, then the release of nutrients to the environment can be calculated easily.
It is also important to understand the fate of the nutrients released in the environment. They may remain within the farm system, be deposited in sediments or enter the wider environment in solution or as fine particles. The quantity may vary greatly over the production cycle, and this can be used to improve the effectiveness of environmental management measures.

Significant quantities of nutrients and chemicals are released to environment from pond aquaculture, though generally at relatively low concentrations. The quantity and quality of these releases are very variable between species and culture systems. Dissolved material from farm effluent enters the water column and may be widely distributed. Solid wastes on the other hand accumulate mainly in the pond bottom, or in the immediate vicinity of the farm. Previous estimation by GESAMP (1996) suggests that around 85% of the phosphorus and around 50% of the nitrogen will be lost to the sediments.

Simple mass balance / flushing rate models to estimate fate of nutrients

The nutrient budget estimations of the distribution of nutrients between the defined system and the wider aquatic environment and between sub-components of the system may be refined and/or cross-checked through the use of mass balance or flushing rate calculations. If nutrient concentrations within system components are known (or can be estimated from inputs), if flushing rate (water exchange/water volume) can be estimated, and if perfect mixing is assumed, then the total flux and balance of nutrients between sub-components can be calculated simply. Water exchange may be estimated based on tidal height differences or on the actual flow of water into and out of system components where this is controlled at a sluice gate.

2.4 Impacts of N and P to the connected water system

To determine the impact of nutrients to the connected water system, the surface area of the connected canal or unit area of the wider water body have to be estimated. The tidal amplitude and water-flushing rate is also required. If the surface area of the water body, depth and water exchange rate and flushing rate is known, then the effect of N and P to the water system can be estimated.

Ambient nitrogen and phosphorus concentrations should not change by more than 5% of pre-development ambient concentrations (GESAMP, 1996). According to Doson (2004) the standard level of nitrogen and phosphorus is 0.4 and 0.2 gm/m^3 respectively. Nutrient analyses carried out in four scooping surveys indicate mean nutrient levels of 25 ug/l total phosphorus and 150 ug/l total nitrogen in a coastal lagoon water (GESAMP, 1996).

Compared to ambient or standard nutrient levels, by a mass balance calculation result it can easily be predicted whether overload of nutrients has occurred or not. If not exceeded the standard level then it can therefore be suggested that the proposed shrimp farm development will not cause significant impacts on nutrient concentrations within the wider aquatic environment.

Various studies have shown that the amount and concentration of effluent from aquaculture is far below that of many other domestic, agricultural and industrial sources. The quality of shrimp pond effluent is compared with domestic sewage in the table-2. Standard domestic wastewater treatment is reasonably effective at removing solids and BOD but less efficient at removing N and P. Even after secondary treatment, domestic effluent is of significantly lower quality than that from intensive aquaculture except in respect of solids (Beveridge et al. 1997).

Table 2. Characteristics of shrimp ponds effluent in comparison with domestic sewage (mg l^{-1})

Effluent characteristics (mg l^{-1})	**Shrimp** pond effluent	**Domestic water**		
		Untreated	Primary treatment	Secondary treatment
BOD_5	4.0-10.2	300	200	30
Total N	0.03-3.4	75	60	40
Total P	0.01-2.0	20	15	12
Solids	30-225	500	-	15

2.5 Major source and impact of nutrients in shrimp aquaculture

Shrimp farming is a rapid growing industry in Bangladesh. Although, culture technique is mostly extensive, semi intensive culture technique based on high input and high output was initiating in this country. But was failed due to a crash for viral disease. However, intensive cultures may have significant influence upon the environment.

Feed as a source of nutrients

A wide variety of feedstuff was employed in fish and shrimp culture to increase production (Boyd, 1986). Feed, uneaten feed and metabolic waste products (faeces, pseudo-faeces and excreta) in intensive culture provide the largest source of nutrients causing pollution (Seymour and Bergheim, 1991). The nutrients in feed not only directly consumed by culture species but also leached into the culture system; unconsummated particles were decomposed by heterotrophic activity, affecting all levels of nutrient availability and organism growth in such system (Moore, 1986).

Feeds applied to pond usually do not consume completely by fish. The conversion of feed to fish or shrimp i.e., the pond conversion value or Food conversion ratio of 2.0 or less are commonly achieved with high quality feeds, but FCR become higher as food quality decreases. In highly intensive shrimp production, feed conversion ratio was usually between 2.0 to 3.0 (Boyd, 1989). One of the reasons of high conversion ratio is overfeeding. Feed constituents which are not incorporated into fish standing crop are excreted into the water as metabolic waste (Muthuwan, 1991). Tsutsumi et.al (1991) reported that approximately 90% of the feed given to fish results in organic discharge to the environment around the fish farm.

Beveridge (1984) reported that 244 kg/ha of nitrogen and 53 kg/ha of phosphorus were applied to pond in feed, but only 94 kg/ha of nitrogen and 35 kg/ha of phosphorus were utilized by fish. The nitrogen and phosphorus contribution to ponds in water was 150 and 18 kg/ha. The nutrient load from feed to the environment was variable, depending on the nutrients content and the digestibility of the feed used.

In the extensive shrimp farms in Bangladesh are supplied with small amounts of nutrients. Extensive system rely on natural food, moderately stimulated by input of manure and fertilizers and may be a net removers of nutrients from coastal environment (Wahab et al., 2003).

But in the intensive or semi-intensive culture system the scenario is different. A survey of shrimp ponds in southern Thailand showed that 77.5 % of nitrogen and 86 % of phosphorus added to intensive ponds was lost to the environment (Macintosh and Phillips, 1992). Wang (1990) stated that up to 5 t/ha of feed is given to intensive shrimp ponds during the last 45 days of growth and up to 50% of the feed is not immediately eaten by the shrimp.

There were reports of changes in benthic fauna in terms of species number, species diversity, faunal abundance, and biomass in waterbodies near fish farms (Brown, 1987). A decrease in shellfish production or mass mortalities at Jinhae Bay, Korea was caused by a high level of eutrofication, which resulted from both waste discharge from an industrial complex and organic deposits from aquaculture (Cho, 1992).

Inputs from fertilizers and chemicals

The use of fertilizers and chemicals in aquaculture was widespread because no legal registration was required for their use (Lin, 1989). Lime and chemical fertilizer like urea and TSP are highly applied in aquaculture. In the extensive culture system, ponds rely on fertilizer rather than supplemental feeds. Wahab et al. (2003), estimated that in the extensive culture system, fertilizer constituted 67% of N and 71% of total P input. Various drugs and antibiotic are also applied in the shrimp culture. Casavas (1992) described that in Southeast Asian shrimp culture over use and abuse the antibiotics and other drugs to avoid massive mortality.

Nutrients in pond water column

When feed was applied into the pond, some nutrients were leach out from feed before consuming by culture species and part of feed consumed eventually enters the water as metabolic waste (Boyd, 1986; Moore, 1986). In channel catfish ponds, concentration of total phosphorus and total nitrogen in the water increased over time with greater feeding rates (Boyd, 1985).

In intensive fish pond with circulatory moving seawater, an averaged 50 % and 46 % phosphorus and nitrogen inputs respectively were found in the particulate phase of the water column (Krom and Neori, 1989). Considerable amount of nitrogen and phosphorus entered into the gher through inlet water is entrapped into the gher (Islam et al., 2002). Wahab (2003), estimated that in the extensive shrimp culture about 70% of phosphorus and 40% of nitrogen entering the gher with the inlet water become trapped in the system. Most of the nitrogen and phosphorus were apparently contained in plankton cells and other particulate matter (Daniels and Boyd, 1989).

Effluent from shrimp culture

In composition, shrimp pond wastes consists of (a) solid matter, mainly a mixture of uneaten food, faeces, phytoplankton and colonising bacteria; and (b) dissolved matter, such as ammonia, urea, carbon dioxide and phosphorus (Macintosh and phillips, 1992). The waste include amino acids, proteins, fats, carbohydrates, fibre, minerals and bacteria (Boyd, 1989). The discharge water from the intensive system were rich of nitrogen and phosphorus, both were important factors involved in eutrophication of water (Worsham, 1985). Effluents from ponds removes accumulated nutrients and organic matter (Boyd, 1989).

Shrimp farming practice in Bangladesh is still extensive to improved extensive. Farmers use low amount of lime and fertilizers and the application of feed is rare to absent (Islam et al., 2002). Traditional extensive system for shrimp farming is not expected to provide any significant loading of organic matter and nutrients to the surrounding coastal environment (Phillips et al., 1993). Unlike the significant effluent load from artificial feed-supplied intensive shrimp ponds with high water exchange rate (Hopkins et al., 1993), the extensive shrimp culture in Bangladesh seems to act as a sink for solids and nutrients in river water led to the system (Wahab, 2003).

Nutrients in sediment

In extensive and semi-intensive systems, typically a major part of nitrogen and phosphorus is accumulated in the sediments (Edwards, 1993). Only a minor part of accumulated sediments is resuspended and flushed out of shrimp-cum-rice producing systems through the outlet at the end of shrimp production cycle. The accumulation of sediments year after year is causing siltation at the bottom (Wahab, 2003).

The solid organic matter (nutrients remain as uneaten food or excreted with the feces) is accumulated in the sediment and for decomposed, principally by microorganisms in the water column and in the sediment (Krom et. al., 1985). The pond bottom soil reacted with water and influence water quality (Boyd, 1989).

Avinmelech and Lacher (1979) determined nutrient accumulation in sediment in intensive fishpond. The data showed a clear profile of nutrients accumulation. The top 20-cm was very loosely packed, as reflected by the low fluid density and high moisture content. This layer contained high concentrations of organic carbon, nitrogen and phosphorus by comparison to deeper layers in the pond as well equivalent layers of the surrounding soil.

3 Methodology

3.1 Study site

A reconnaissance survey was made to select the study site. Finally, the approved study area located on the southwest coastal part of Bangladesh (Fig.3.1) in the Kulbaria Union under the Upazilla Dumuria in the district of Khulna. Ten shrimp farms were selected around a river named Teligati (Semi diurnal tidal system) flowing towards the Bay of Bengal and a canal connecting the river. Four stations from river and canal and ten stations from farms were considered for weekly data collection (Fig.3.2).

3.2 Working methods

Local workshop and training

: Several local workshops were conducted for identifying key issues, selecting volunteer farmers, discussing the progress and taking decisions during the study period. A farm record manual was developed and trained the farmers to record the farm management practices regularly. Additionally, NGO representative was in close monitoring to record the farm management practices. Management equipment such as secchi disk was provided to selected farmers for fulfilling the farm record manual.

Description of the study ponds

In the present study, 10 brackish water shrimp ponds based on improved extensive systems (inputs used for shrimp farming, the management practices, the level of production and the culture technique of the selected farms) were in consideration. In contrast to the traditional extensive methods, improved extensive shrimp farming in the present study relied on higher stocking density (average, 13,782 ha^{-1}), introduction of nursery pond practice, application of fertilizer and supplementary feeding. In addition, the total production of the shrimp farms (average total 384.1kg $ha^{-1}yr^{-1}$) indicates a level that can be termed as improved extensive as classified by Jenkins *et al*., (1999). The average pond size was 0.98 ha and the average depth of plain and deeper (*tob*) portion of the ponds was 0.81 m and 1.17 m respectively. Integrated (paddy cum shrimp) culture was practiced in 6 of the ponds (A1-A4) and solely shrimp in 4 farms (B1-B6). The details of the ponds are presented in table-3.

Table: 3. The detail of the study ponds during the study period (stocking density, survival rate and average weight are only for *P. monodon*)

Pond no	Pond area (ha)	Depth (m)	Stocking density (ha^{-1})	Survival rate (%)	Average Wt (g)	Gross production (kg $ha^{-1}yr^{-1}$)			
						P. monodon	M. rosenbergii	Fin fish	Total
A1 (Ramp'd)	0.5	0.6-0.9	18,525	46	31.3	288	37	112	437
A2 (Bimol)	0.4	0.9-1.2	9,880	45	28.6	129	164	120	413
A3 (Ranjit)	2.4	0.9-1.2	8,398	44	28.0	105	49	34	188
A4 (Dulal)	1.5	0.6-0.9	10,868	48	25.2	156	27	62	245
B1 (Samiron)	2.0	0.9-1.8	18,525	40	24.4	244	186	134	564
B2 (Ramen)	0.6	0.9-1.2	7,410	52	27.0	112	16	22	150
B3 (Chitta)	1.3	0.6-0.9	16,055	50	29.0	264	31	228	523
B4 (Naraon)	0.2	0.9-1.2	9,880	47	24.3	132	184	12	328
B5 (Nitta)	0.6	0.9-1.2	8,645	46	26.4	156	14	25	195
B6 (Susanko)	0.3	0.9-1.2	29,640	49	32.0	323	290	185	798

Average	0.98	0.8-1.17	13,782	46.7	27.62	190.9 (49.7%)	99.8 (26%)	93.4 (24.3%)	384.1 (100%)

Description of farming systems and farm management

Ten shrimp ponds were selected for the experiment. Culture techniques or farm activities like pond preparation, stocking density, water quality management, feeding management were managed by the farmers and were not interrupted by the present study. The quantity and quality of inputs (feed, fertilizer and water exchange) and production were determined and recorded during the study period. Various issues related to management, growth and disease were closely monitored and observed with a participatory approach. Some local workshops also conducted to find out farmer-level issues or indicators like color, smell of water or sediment, shrimp behavior and growth performance. Each of the issues was closely related with other, so it was very difficult to isolate and identify one from another. Farmers kept all the records in our prescribed format. The disease and growth related issues were then cross-checked and verified by wider area survey.

Pond preparation began in mid February to early March. A canal near the border of the farms was made and the soil was used for making dike to store water to their farm. That particular canal used as nursery pond (*Tob*) for shrimp fry. The farmland was ploughed and left for 7-10 days under sunshine after liming and fertilization. Lime (CaO) was applied at the rate of 200-300 kg ha^{-1}. Inorganic fertilizer used were mainly Urea and TSP at an equal rate of 60-80 kg ha^{-1}. Cow dung was the most common among organic manure, applied at the rate of 500-1000 kg ha^{-1}.

After 7-10 days of fertilization water was introduced by allowing the water level of high tide to enter into the ponds during the new or full moon. No particular stocking density was maintained. Stocking varied with farm to farm. For better benefits farmers stocked much. Monoculture of shrimp was not observed in the site. Though tiger shrimp, *Penaeous monodon* was the target species, some other shrimp, especially fresh water prawn, *Macrobrachium rosenbergii* (during rainy season) and finfish species like tilapia, *Oreochromis mossambicus* and persia, *Liza parsia* used to stock. A number of other shrimp and finfish species also enter into the ponds accompanied with tidal inflow of water. In one year they stocked tiger shrimp post larvae in 6-8 spells from March to June with every lunar phase and stocking of completed before the rainy season. Prawn and finfish also stocked at different times based on farmers' ability and availability of seeds.

Fry nursing in nursery pond (locally known as *tob*) was a common practice. Duration of nursing was varied and usually it was for one month. At the time of stocking to the nursery pond (*tob*) farmers did not acclimatize shrimp post larvae properly.

Supplementary feeds were used irregularly without estimating the amount based on shrimp biomass. Formulated feed was used rarely. Mostly used feeds were boiled rice, rice bran, wheat, wheat bran, Vegetables, boiled potato and fishmeal. Some of the farmers were solely depended on natural feeds. Frequent fertilization to produce natural food and liming to prevent diseases was common among farmers.

There were inlet and outlet facility used for receiving and discharging the water. Most of them use the same gate for inlet and outlet, spring tide for water inlet and neap tide for water outlet. Most of the river or canal side farms exchange farm water frequently with tide, but there was few that change the water very rear. Some farmers only added river water allowing high tide occasionally to maintain water level in the ponds.

Frame survey in the wider area

Surveys in the wider area (3 coastal district - Khulna, Satkhira and Bagerhat) carried out with a view to compare the managerial issues of the study area with the wider area. In addition, wider area survey was important to find out management, growth and disease related indicators in shrimp culture. For this a questionnaire was made and surveyed in 50 randomly selected shrimp farms in that area.

Water sampling and monitoring

Weakly water quality monitoring throughout the year was conducted in 10 selected shrimp ponds and 4 stations of water supply canal (station 3 and 4) and river (station 1 and 2) to observe water quality dynamics. Separate sampling during both high and low tide was also considered. The parameters studied weekly were temperature (^{0}C), depth (cm), salinity (ppt), pH, dissolved oxygen (DO)(mgl^{-1}) and biological oxygen demand (BOD) (mgl^{-1}). Monthly data to determine the variation of total ammonia nitrogen (NH$_3$-N) (mgl^{-1}) and total phosphate (TP) (mgl^{-1}) was also recorded both in culture period and non-culture period. Monthly rainfall data was collected from the nearby weather station located in the Khulna city.

To prepare nutrient budget, 3 shrimp farms (A3, B3 and B6) among the 10 primarily selected farms were considered. Water samples were collected fortnightly from pond inlets and outlets throughout the shrimp growing cycle to determine nitrate nitrogen (NO$_3$-N) (mgl^{-1}), nitrite nitrogen (NO$_2$-N) (mgl^{-1}), ammonia nitrogen (NH$_3$-N) (mgl^{-1}), total nitrogen (TN)(mgl^{-1}) and total phosphorus (TP) (mgl^{-1}). Total nitrogen is the sum of the three forms of nitrogen (NO$_3$-N, NO$_2$-Nand NH$_3$-N).

The inflow water samples were collected just at the time of entering river or canal water into the ponds through the inlet and outflow samples from outlet at discharging period. The amount of nutrients in inflow and discharge water was used to calculate the total nutrient gain by and loss from the system.

Water pH was recorded directly by using a digital pH meter (pHep+ by HANNA). Salinity was measured by a hand refractometer (ATAGO S/Mill-E). Dissolved oxygen (DO) was measured on the spot by a digital DO meter (DO-5510, Lutron). NO$_3$-N, NO$_2$-N, NH$_3$-N, TN and TP were measured by using a water test kit (HACH). Biological oxygen demand (BOD$_5$) was analyzed in the lab by Winkler titrimatric method.

Partial mass budget

In the present study an area of 303.5 ha (pond area) was considered to estimate a rough overall nutrient budget and dynamics of that area. There were 3 types of pond in terms of water exchange. One type directly connected with the river, which exchange water using the tidal level of river, another type exchanged water with canal and the other through other ponds. The proportionate area of those farms was 15%, 30% and 55% of the total area respectively. Three representative ponds, A3 connected with river, B3 with canal and B6 with other ponds were considered for nutrient mass balance (input and output). Firstly, individual budget (ha^{-1}cycle^{-1}) of each type of ponds considering those representative ponds was made. Then the overall mass budget was made as well. The flushing rate both of individual pond and the overall system was estimated calculating exchange frequency and amount per time and month.

In estimating the rough nutrient budget of the 3 shrimp farms (A3, B3 and B6), total amount of nutrient (N and P) from input (feed, fertilizer and post larvae), output (harvest), inflow and discharged water and sediment was estimated. Feed samples from each of the type applied were collected and analyzed for nitrogen and phosphorus contents. To estimate the amount of nutrients input from feed, the type and amount of feed input were recorded. After terminated the experiment, total amount of feed inputs were used to estimate the feed conversion ratio (FCR) of shrimp and the total amount of nutrient input from feed in each pond. Nutrient input from fertilizer and manure was calculated assuming 46 % N in urea and 20 % P in TSP (BARC, 1997) and 1.65 % N, 0.70 % P in cowdung (Jeyabal and Kuppuswamy, 2001). Nutrient inputs and outputs from stocked and harvested shrimp were estimated in the laboratory (total N by Kjeldal method and total P by digestion followed by direct spectrophotometric reading).

Input and discharge of nutrients through water were calculated on the basis of exchange volume and the respective nutrient concentrations (determined from pond inlet and outlet). By calculating the amount of nutrient exchanged per day and number of exchange day per month, the total amount in a month was calculated.

Total amount of nutrients in sediment was estimated. For this initial soil sample before stocking and final sample at the end of culture period was taken. The samples were analyzed in the laboratory and from their difference the amount of N and P in the sediment was calculated. Inputs of nutrients through atmospheric precipitation, runoff, and loss through seepage were neglected.

Water Exchange

The water exchange volume and flushing rate both for shrimp and paddy was made considering area, depth from water exchange frequency and rate of exchange. Flushing rate was determined by dividing the water exchanged volume by total volume of water. The flushing rate of each type of ponds was made separately. An area of 404.7ha was considered to estimate the flashing rate of the aquatic system of the study site.

Nutrient dynamics

Nutrient dynamics of the system was determined to know whether the environmental capacity exceeded or not. The following equation was considered to determine nutrient dynamics.

Nutrient dynamics = mass balance total / water exchange total

$$C = N / FU,$$

where, C = The elevation of nutrient concentrations caused by fish farms (or any other source of nutrient input)

N = The rate of nutrient input

F = The flashing rate

U = the volume of water

4 Issue and institution analysis

4.1 Farmer Issues

Farmer workshop

TROPECA was an adaptive research project. In view of the approach, Farmers Issues or perception at various stages were in consideration through out the project period. Among the various aquaculture practices in the coastal area of Bangladesh, shrimp culture was the most dominant culture practice applied by farmers. Hence, at the very beginning of the project, the shrimp farming was in consideration for estimating the environmental capacity.

At the first workshop, farmers indicated that the shrimp productivity of farms (*ghers)* has declined significantly over the last 10-20 years. Rice and dyke crops also seem to be declining. Prime problem identified in the local workshop include low yield due to disease [Sudden death of shrimp due to unknown disease (people called as virus)] and other associated problem such as

- Soil problem
- Water quality problem
- Inadequate water quality management
- Lack of knowledge
- Illegal operation of power

In addition to that there were some important areas of ignorance in the aquatic systems at broader level such as .

- Seepage in surrounding farms and lands
- the siltation of the channels as well as land, raised the land areas outside the polder causing drainage congestion in the area,
- water logging during monsoon,
- high water table,
- creation of unauthorized sluice gates or channels through perimeter of the polders along the riverbanks.
- empoldering is one of the factors responsible for increases in surface salinity in the region particularly during winter months,
- non-availability of good quality of water for irrigation during dry winter season

The risk of flooding seems to be increasing, especially in the SW of the area. Salinity of water/soil seems to be increasing overall, but causes are complex. Polders, shrimp farms, waterlogging, climate change, loss of river water flow (upstream barrier, shrimp farms in rivers) may all be contributing factors.

Local peoples are assuming that the total shrimp production will be collapsed by five year if the problem sustain like the present.

A local “chingri committee” operates at Upazilla level is charged with the regulation and management of shrimp culture.

The workshop identified many general research needs, including the following:

- On farm research (Demo farm)
- Identification of causative agents of shrimp mortality
- Fish Diseases
- Introduce and adoption of Integrated culture techniques
- Selection of Stocking period
- Proper Nursing system
- Carrying capacity / Stocking density
- Investigation on water quality and soil quality (most concern on soil quality)
- Chemical and fertilizer application on different zone (Zone wise testing)
- Differentiate the zones on the basis of chemical and fertilizer application.
- Indigenous Knowledge

In addition to the above mentioned issues the workshop also

- Identified both the formal and informal land and water management systems,
- Assess the strengths, weaknesses, opportunities and threats of their management systems

After having through and continuous discussion at the subsequent local workshops, the following points come to the front:

- Production levels are low and moralities are frequent occurrences.
- Most ponds appear to be below optimal depth – farmers recognize this but digging deeper ponds means additional costs.
- A variety of water quality indicators are recognized.
- The practice of rice culture including fertilizing the pond and leaving six-inches of leaf material following harvest is likely to be impacting significantly on nutrient levels for shrimp culture.
- The paddy culture surrounding the shrimp ponds and upstream of the shrimp ponds is also thought to be impacting on the quality of water used for shrimp culture. Shrimp ponds in this instance may be acting as a nutrient sink for the system. This requires further investigation.

Management and yield related issues

Some management and yield related issues were revealed from the study area during study. Inadequate depth was reported as a problem for shrimp culture. Farm and tob depth was ranged between 0.6-0.9 m and 0.9-1.17 m respectively (table. 2.2). But water depth at the plain land was very less (<0.3m) in the month of June-July, when salinity (11-15 ppt) and temperature (>30^{0}c) was high. At that time sudden heavy rainfall caused huge shrimp mortality in the farms A3, B4 and B5 of the study area. It may be due to reduction of water pH and fluctuation of temperature and salinity.

The optimum production of a farm depends on effective managerial operation of stocking, feeding, fertilizer using and water quality monitoring. As, they did not manage all these properly, the shrimp production of these farms was very less (most cases, 100-200 Kg/ha). Most of the cases stocking density were very less. The present study shows that the stocking density of 7,410-10,868 piece ha^{-1} produced 105-156 Kg ha^{-1}yr^{-1}of shrimp. But optimum density of stocking is 15,000-20,000 piece ha^{-1} for extensive method. In some cases where the stocking density was between 13,782-18,525 piece ha^{-1}, the production was 191-288 Kg ha^{-1}yr^{-1}.

Optimum production also depends largely on feed and fertilizer using. But the farmers did not maintain that properly. Some of the farmers did not use feed and fertilizer at all. Some used fertilizer without following any recommended dose. So natural feed did not grow usually in these farms. In addition, the feed that they used was not balanced and adequate. They used very limited number of supplementary feed ingredient like rice bran, boiled rice and wheat bran, which do not contain all the nutrients. Some of them use fishmeal occasionally, which were not adequate. So malnutrition was a common phenomenon which used to cause various disease and lower growth. The stocking density of 29,640 piece ha^{-1} and uses of minimum level feed and fertilizer resulted in a good production of 323 Kg $ha^{-1}yr^{-}$1in the farm B6.

Most of the farmers reported that frequent water exchange from river and canal is a major problem. This river and canal water may contain microbes and pollutants which may causes diseases in the shrimp farms. Shrimp mortality used to occur not only for viruses and microbes, but also for less depth, frequent filling river water, malnutrition and fluctuation of water pH, temperature, dissolved oxygen and salinity. All these disease and management related issues were then cross-checked and discussed with the farmers of wider area to reveal more new indicators.

Farmers issues in wider area

Most of the farmer's used to exchange farm water traditionally using tidal level of the adjacent river (70%) and canal (12%) (Fig.4.1.1). As no or very limited supplemental feed was used, they were obliged to fill ponds with river or canal water as a source of natural food. In addition, they did not have any other options except river water to fill up the evaporation and leaching loss.

But some of the farmer's (8%) (Fig.4.1.6) reported that supply water may be responsible for shrimp mortality and they were not willing to fill the farms with river water now a day. There was evidence that disease occurrence was less in those farms that did not exchange or occasionally exchange river water. Farmers reported that huge mortality was occurred just after 2-3 days of water filling from river. Some farmers also reported that during water filling when shrimp come in contact with tidal water it become weak and consequently death occurred. During the month of April-May the initial reddish tidal water causes mortality. They suggested that farm should be filled with river water just after ending high tide or just after initiating low tide, so that precipitation or settle down of

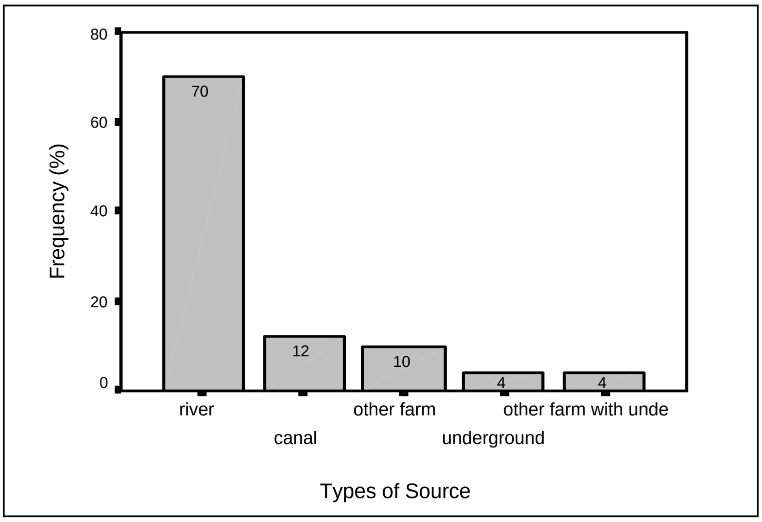


Fig.4.1.1**.** Sources of water exchange

waste could be taken place. They were also favored to have a reservoir to reserve river water for filling, if it could be managed.

The reddish colors and off odor/smell of water was considered to be bad farm water and an indication to change water. On the other hand greenish water and availability of hydrophytes was considered to be good. It was reported that mortality occurrence was less in the farms having hydrophytes (cata saola), as it was a wonderful source of food and shelter in the dry season.

One of the prominent indicators for farmers was to observe the direction of shrimp movement during water entry. If shrimp move in favor of water flow than it indicates probability of disease. Locally, it terms as "Joyan". There was a size consideration for the effect of that occurrence. Hundred (100) - fifty (50) grade shrimp was more vulnerable than lower (less than 44) grades.

It was reported that 2.5-3 ft depth optimal for shrimp culture. But most of the farmers did not able to maintain it. Because, they had to lease land for few years. So, they could not change the depth. Excessive salinity with less water depth in the dry season used to cause shrimp mortality. Occurrence of saline bubbles and salt coagulation in the pond bottom was reported as a cause of shrimp mortality. There was evidence that after a heavy rain huge mortality occurred, especially in the less deep pond. It may be due to the reduction of water pH and fluctuation of water temperature and salinity for sudden heavy rainfall.

Muddy soil was considered to be good, as a source for feed and shelter, where as hard bottom substrate and sandy soil was considered to be bad for absence of those.

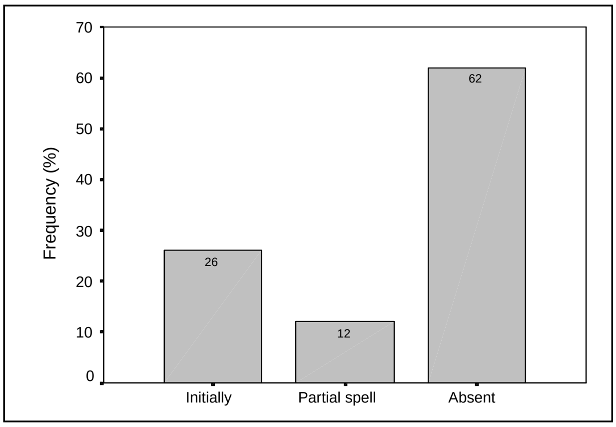


Fig: 4.1.2 Fry nursing practice

Farmer's used to stock fry in multiple spells. They used to stock 20-25 PL/dm in a spell and after few days when these fry got bigger size, another spell of stocking was done. Thus 5-6 spells of stocking was done per year. Fry nursing was mostly absent (62%) and 26% of the farm's nursing was done at initial stage of culture cycle (Fig. 4.1.2). Production was higher in the farms where fry nursing was applied (Fig. 4.1.3). Fry acclimatization was practiced in almost all the cases (94%).

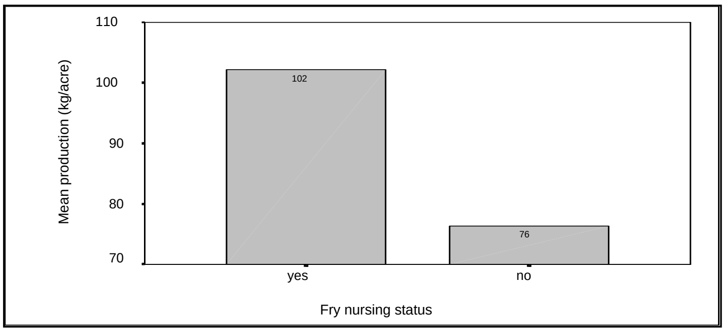


Fig. 4.1.3. Relation of fry nursing with production

Harvesting was mainly batch and grade based. After harvesting a batch another spell of fry was stocked. Disease incidence, management difficulties and lack of adequate funding as well as risk involved in higher investment were the main constraints of higher stocking. In the extensive culture technique, shrimp production was 120-200 kg/ha. In the improved extensive system where lime and fertilizer was used production became higher in some extent (Table 4.1). But disease occurrence used to reduce 80-90 percent of the production. Generally 90-100 days were required to get a good size (30-50 gm). In the present study 48% of the respondent practiced alternative paddy-shrimp culture and 50% practiced only shrimp (Fig. 4.1.4). Salinity regime was noticed as a considerable factor for types of culture practices. Moreover, most of the farmers reported that monoculture of shrimp in a segmented small farm is good for higher production and easy to manage as well.

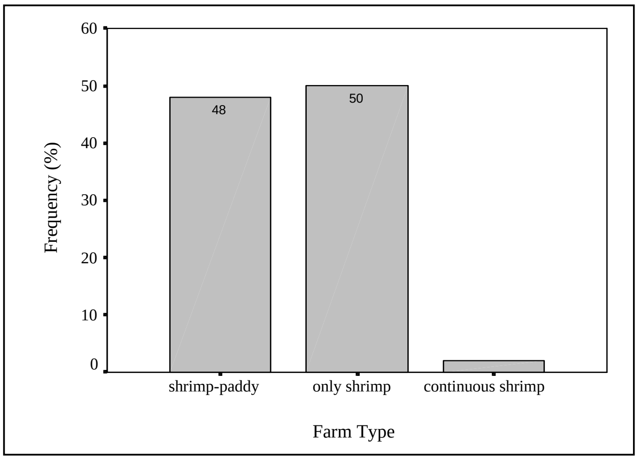


Fig. 4.1.4. Use of Culture farms and their frequency in wider

Shrimp mortality used to occur at any stage and any season. But most of the farmers (60%) observed that 44-66 grade shrimp (15-23 gm) was more vulnerable than lower (less than 44) grades (fig. 4.1.5). Forty percent of the farmers reported that mortality occurrence was frequent in the month of May-June (Fig.4.1.6). Farmer's were unable to find out the actual causes of mortality. Some farmers (10 %) reported that hatchery produced shrimp PL might be a source of microbes, because source of water and feed was common (fig. 4.1.7). In addition, disease occurs usually after 45-60 days of stocking. As virus can remain in a dormant state in animal body up to 45 days, it may be a clue. Some blame river water for mortality. Uses of expired dated waste feed were reported as a cause shrimp mortality.

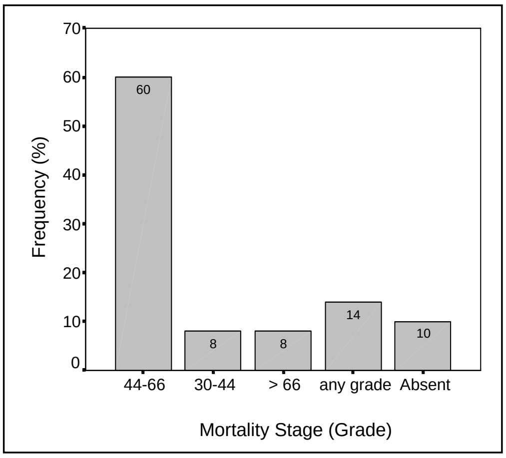


Fig. 4.1.5. Stage of shrimp

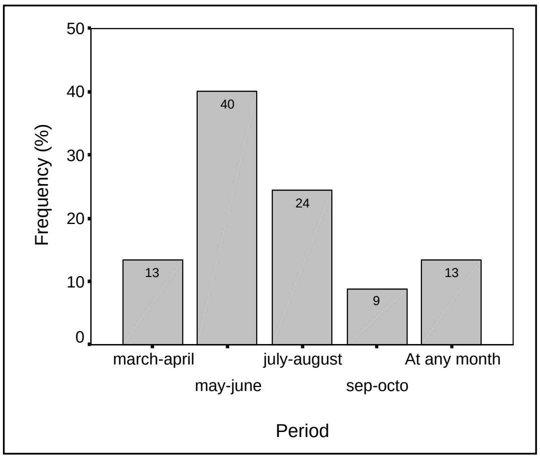


Fig. 4.1.6. Period of shrimp

In addition, 68% of the surveyed farms did not use any supplemental feed (fig. 4.1.8). It was widely acceptable fact that lack of feed and malnutrition is the main causes of mortality. Shrimp getting very less or no food become weak and is susceptible to disease. Fluctuation of water temperature, DO, pH, salinity etc also causes mortality. White spot, lesion in body, spoilage of appendices and reddish color was observed in a shrimp after death. Some time no detectable symptom was observed in a dead shrimp.

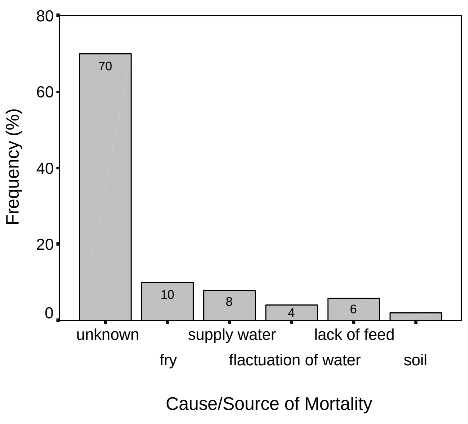


Fig. 4.1.7. Cause/source of shrimp

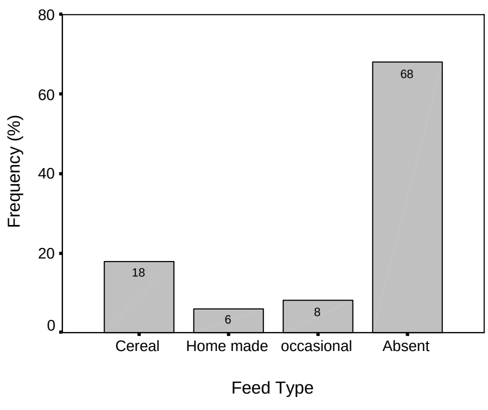


Fig.4.1.8. Type of feed

During grow out stage, use of Lime+urea+TSP+Cowdung provides highest production (110 kg/acre). Uses of Lime+Urea+TSP also provide nearly similar production. But a negligible percent (8%) only practice. On the other hand medium level production (81.20 kg/acr) found without use of any fertilizer during that stage. And 50% respondent prefers not to use of fertilizer during grow out stage.

Table 4.1. Descriptive Statistics of the farm performance in relation to fertilization and production

Fertilizer type	Percentage of farm	Total production (kg/ha)	Mean production (kg/ha)
Lime	8	805	201.3
Urea	2	148	148.2
Urea+TSP	24	1954	162.8
Lime+Urea+TSP	8	991	247.3
Lime +Urea+TSP+Cowdung	8	1094	273.6
Absent	50	5014	200.6

Generally organizations or associations of shrimp farmers were absent in the village level. But in the Upazilla and district level farmers associations, consist of large-scale farmers, were present. However, small-scale farmers favor to have an association among them.

4.2 Institutional structure

Institutional analysis is the identification of various resource users, stakeholders and organizations involved in a particular management system. It also involves an examination of the institutional arrangements, the set of rights and rules for a particular resource management in a community.

External institutional and organizational arrangement

There is a National Fisheries Policy developed by The Bangladesh Government during 1998. Coastal shrimp and its culture policy are a part of the policy. The following points are highlighted on the policy:

1. Committee develop – national and other level
2. Nature conservation – Integerated/alternative culture, Polders
3. Culture intensification with natural sustainability
4. Establishment of Demonstration farm and training
5. Encouragement of hatchery at private level
6. Sanctuary declaration and closure regulation for brood in ocean
7. Infrastructure development and security provide by Government in the culture areas.
8. Encouragement of manageable small unit farmer
9. Training and infrastructure facility for quality product
10. Development of quality control laboratory
11. Strong marketing network
12. Extension of central shrimp cell to field level
13. Area zoning for shrimp farming

14. Encouragement of Joint venture cooperation for environmentally sustained semi-intensive shrimp culture
15. Insurance program for shrimp farming

Other than Coastal shrimp and its culture policy, there are some additional related policies such as Fisheries credit policy, Fisheries relevant environment policy, Research-extension and training policy, Transport-export-quality control policy.

Acts and Rules

There are several acts and rules related to shrimp culture are mentioned below:

5. The marine fisheries ordinance-1983
6. The marine fisheries rules-1983
7. The Fish and Fish products (Inspection and quality control) ordinance – 1983
8. Shrimp culture Obhikar act- 1992
9. Shrimp culture Obhikar rules –1993
10. Bangladesh Fisheries development corporation act - 1973
11. Bangladesh Fisheries development corporation ordinance - 1984

Government Administrative agencies

Fisheries Department: Structure of the administration ranged from National level to Upazilla level. In terms of shrimp culture management the responsibilities are following:

- License allocation and registration
- Training
- Water and soil test
- Quality control

Specially, large size farmers have registration and getting government facilities through the cooperation of Shrimp farmer association. Small size farmers are not registered and not getting any Government facilities.

In addition to Fisheries department under the Ministry of Fisheries and Live stock, there are some other organizations are also, in some extent, involved with shrimp culture management such as Ministry of Land, LGED, Ministry of Forest and Environment. The following table-4.2.1 briefly indicates the nested organizational arrangement of shrimp culture management in Bangladesh with reference to the study area.

Table 4.2: Listed organizational and institutional arrangement for shrimp culture in Bangladesh with reference to the study area

Administration level	Government agencies	NGO	Local people organization
National	Ministry of Fisheries and Livestock Ministry of Land LGED Ministry of Forest and Environment	BRAC,	Shrimp farmer association Frozen foods association Hatchery
Regional and district level	Administration (Commissioner Office) Fisheries department (Regional or District Fisheries Office) Department of Environment LGED	UTTARAN, PIONEER, SETU and BHUMIJA Processing plant	Shrimp farmer association Frozen foods association Shrimp processing agent association Hatchery
Upazilla	Administration (Upazilla Office) Fisheries department (Upazilla Fisheries Office) Department of Environment LGED	UTTARAN, BRAC	Shrimp farmer association Shrimp processing agent Fry agent Chingree committee Water committee
Union and Village level	Administration (Union Porishad)	UTTARAN, BRAC, MUKTI and CHANDA – Union level	Dipo association Shrimp fry business association – Union level Furias Individual dipo Cooperative society (around 10)

Community Organizational and Institutional arrangement

There were broadly two pattern of arrangement, one for small-scale shrimp farming and another for large-scale shrimp farming noticed in the wider area of Southwest region. Study area mainly focused on the small-scale farmers.

Shrimp fry business association

A Union level organization developed during 1985. There are seven executive members and twenty-five members on the association. Main responsibility is to sell fry by getting commission (30-40 tk per 1000 of fry sell). There is no technical manpower but the association is providing training related to fry transport, fry acclimatization and some other awareness creation activities.

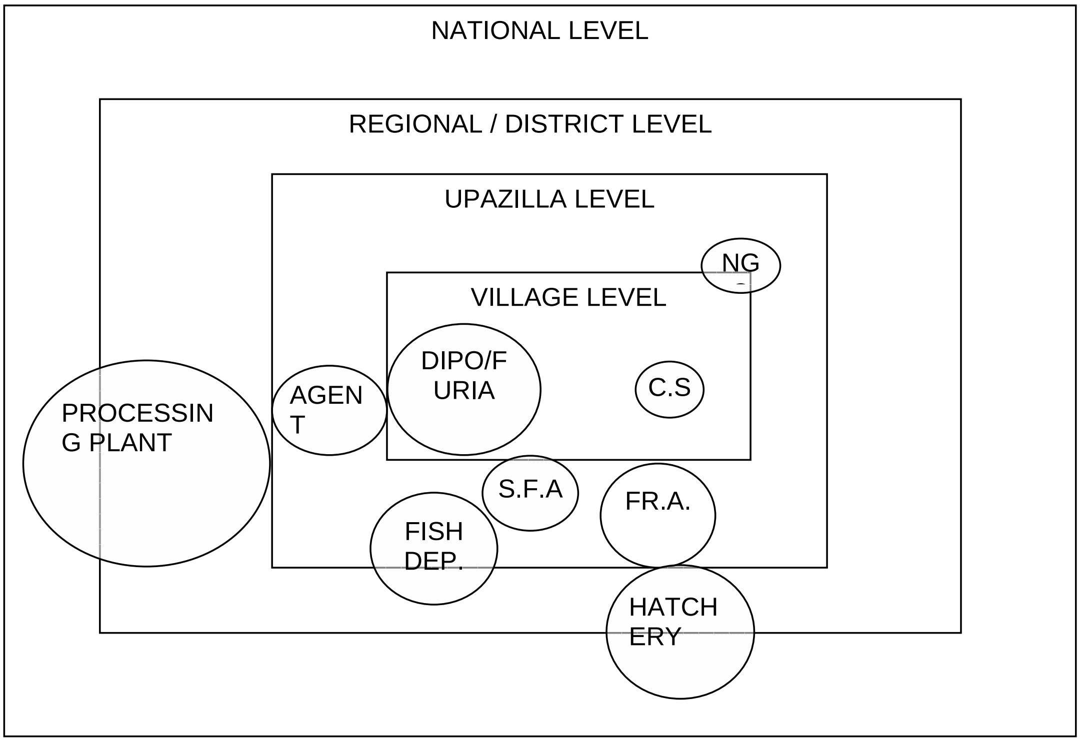


Figure 4.2.1 Venn diagram for small scale shrimp farm management

Legend:

C.S. = Cooperative society
FISH. DEP. = Fisheries Department
FR.A. = Fry agent
S.F.A. = Shrimp farmer association
FURIA = Small scale trader, DIPO = Medium scale trader,
Agent = Large scale trader

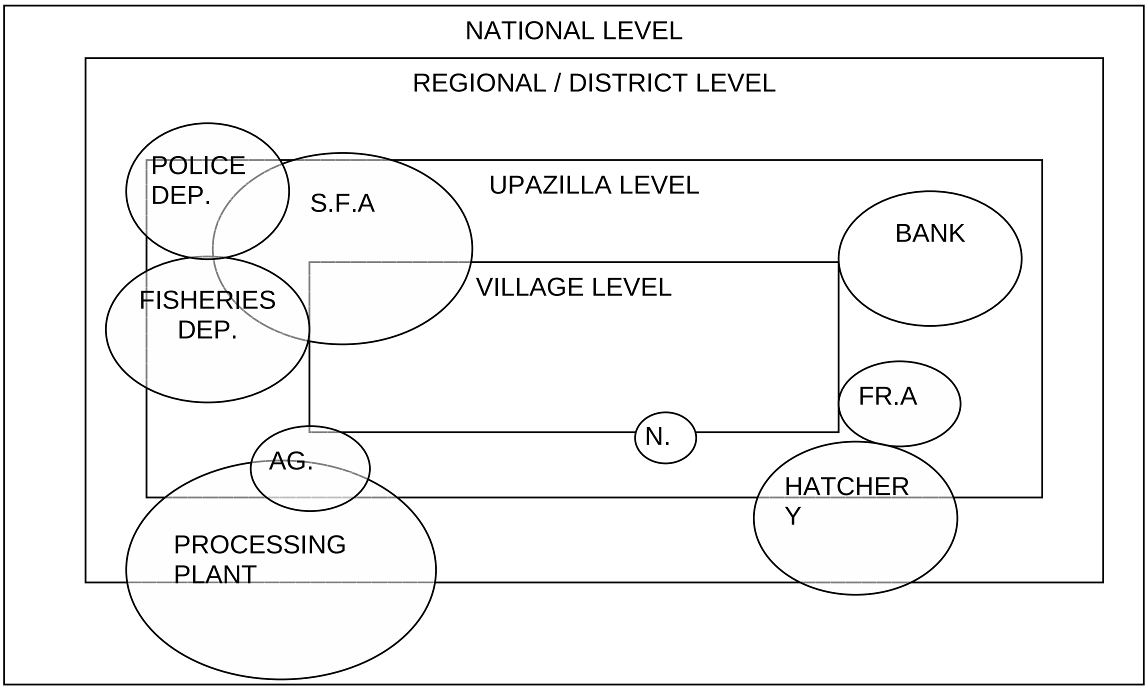


Figure 4.2.2 Venn diagram for LARGE scale shrimp farm management

<u>Legend:</u>

S.F.A. = Shrimp Farmer Association
FR. A. = Fry Agents

AG. = Shrimp Distribution Agent
N. = NGO

Note:

- *The larger the circle the more influence the group represented by that circle has on the issue.*
- *Size is relative to other circles.*
- *Circles representing institutions that influence each other is placed overlapping each other depending on the degree of influence or number of similar membership.*
- *Circle inside the boundary represents the internal group*
- *Circles overlapping the boundary are external groups with presence in the community or activities.*
- *External institutions but with some degree of influence in the community will be placed outside of the square; its relative distance from the square will depend on the link or effect of the institutions identified.*

Shrimp farmer association

Structure is ranged from Upazilla level to national level. The association started at Dumuria during 2003 and registered through National Shrimp farmer association. There are 31 executive members and 310 members on the Upazilla level association. Objective of the association is to increase the shrimp production level with the awareness of all shrimp farmers. Association has a very good relation with local Fisheries department for providing technical service to registered shrimp farmers. The association has plan to extent the structure up to Union level and to create awareness raising program by 2004.

Processing plant

Most of the processing plants are in region or district level with few exception at Upazilla level. Processing plant used to provide loan to agent with the condition of getting all harvested shrimp.

Shrimp Agent

It is usually at Upazilla level. Collect the shrimp from Dipo or large farms and process according to the order of processing plant. Agent used to provide loan to Dipo owner with the condition of getting all harvested shrimp.

Dipo association

It is at Union level and started during 1993. There are 50 dipo under the association. main responsibilities are to grade wise price set up and to control the purchase and/or selling price. There are fine system with the violation of fixed purchase / selling price.

Dipo

Dipo is at the local level. Main responsibility is to collect the shrimp and to supply to the agent. They used to provide loan to farmers with the condition of getting all harvested shrimp. Dipo owners have right to bargain with Agents.

4.3 Conflict Resolution Mechanism

Village member or local influential persons usually solve conflicts. Influential person used to have a very good network with wider level stakeholders and provide loan to different stakeholder. Shrimp farmer organization is also an important organization to solve the conflicts of large level farmers those who are the member of the organization. The organization is also worked for coordinating Fisheries department, Administration and Police authority for farmers training, getting government facilities –such as licensing, registration, water and soil test, and safety.

Farmer can make himself general level management decision but major and wider (price) decisions have a relation with the monitory channel. Processing plant and Hatchery owners are the major source of fund provider and they make the major decisions (Price). Farmer association, Dipo association and agent association has a role to control the marketing channel.

4.4 Management Issues

Identification of management issues were one of the prime important part of the TROPECA project. Key management issues for aquaculture both at individual farm level and for the wider aquatic systems are pointed out on the following figure-4.3. The figure also reflects the importance of environmental and waters quality issues relative to other management issues.

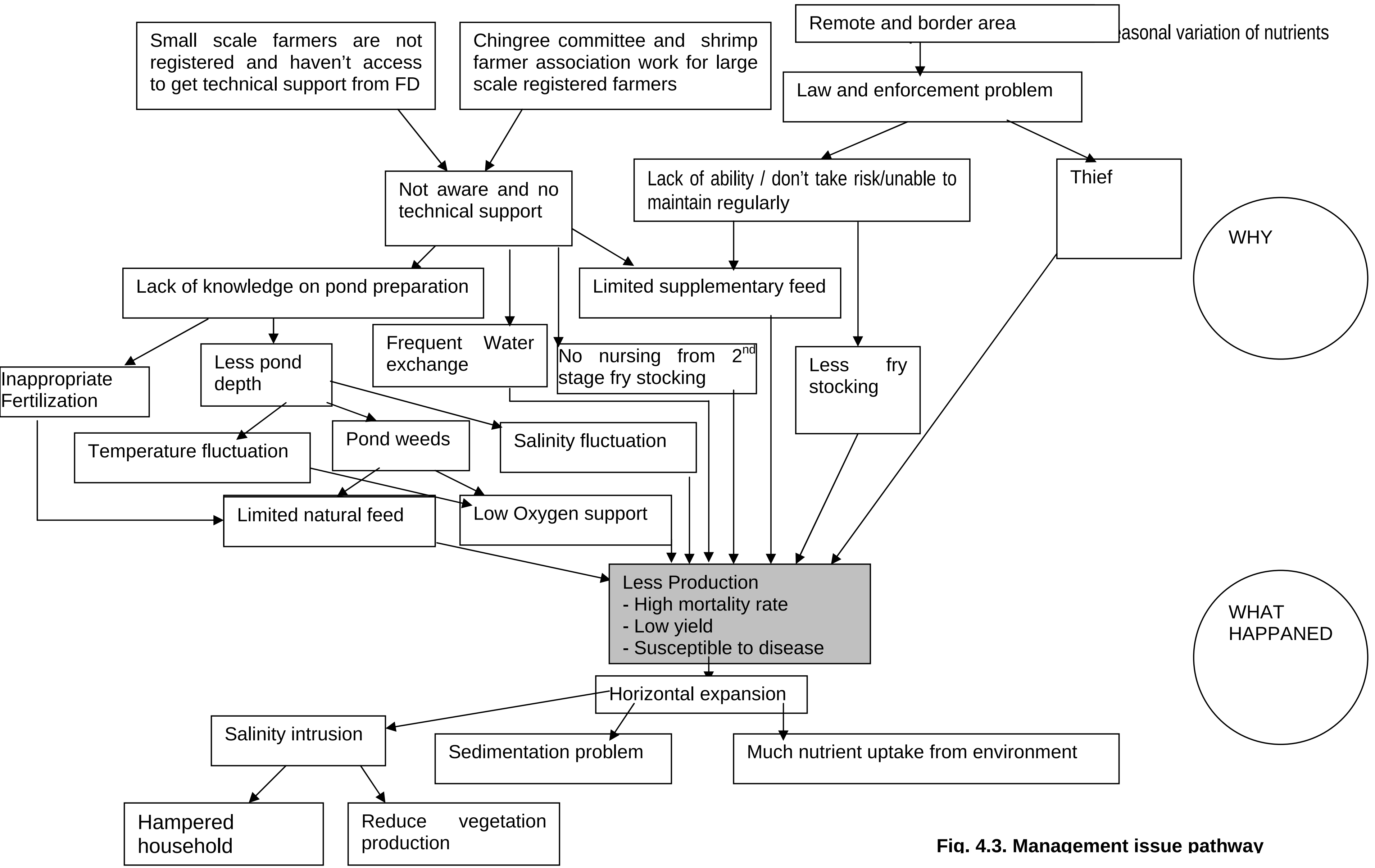


Fig. 4.3. Management issue pathway

5 Indicators and seasonal variation of nutrients

5.1 Water quality parameters

Temperature, Salinity, dissolved oxygen (DO), pH and biological oxygen demand (BOD) did not show significant variation among river, canal and ponds (Fig. 5.1.1). In the month of January salinity was 0 ppt. Significant gradual increases of salinity in the water was recorded from February (1ppt) to June (15 ppt), consequently it was decreases gradually and 1 ppt was recorded in December. The average salinity of the 10 ponds remained relatively less from January to June and became higher after June than that of river and canal (Fig. 5.1.1A). The weekly salinity data indicated no significant variation with tides (Fig. 5.1.2).

The dissolved oxygen concentrations fluctuated mostly between 5 and 7.5 mg/l. Dissolved oxygen concentrations of pond was usually higher than that of river and canal, except January to March, when 4 of the ponds were dried for pond preparation and little amount of water was found in other 6 ponds (Fig. 5.1.1B).

The pH value of river, canal and ponds were relatively higher (7.5 to 8) during April to October than rest period of the year. The average water pH in the culture ponds was slightly higher in most period of the year than river and canal (Fig. 5.1.1C).

The average biological oxygen demand (BOD) of the river, canal and ponds varied mostly between 1.7 to 2.5 mg/l (fig. 5.1.1D). The highest BOD level 4 mg/L was recorded from the pond B1 in November and the lowest value of 0.8 mg/L was found at river (station 1) in December. The average BOD contents of the river, canal and ponds water was 2.1± 0.88 during the study period.

The monthly patterns of salinity, temperature and rainfall are show in the figure 5.1.3. Temperature showed a trend of increasing in the summer and gradually decreasing with the onset of rain and winter. In summer temperature and salinity was high and rainfall was low.

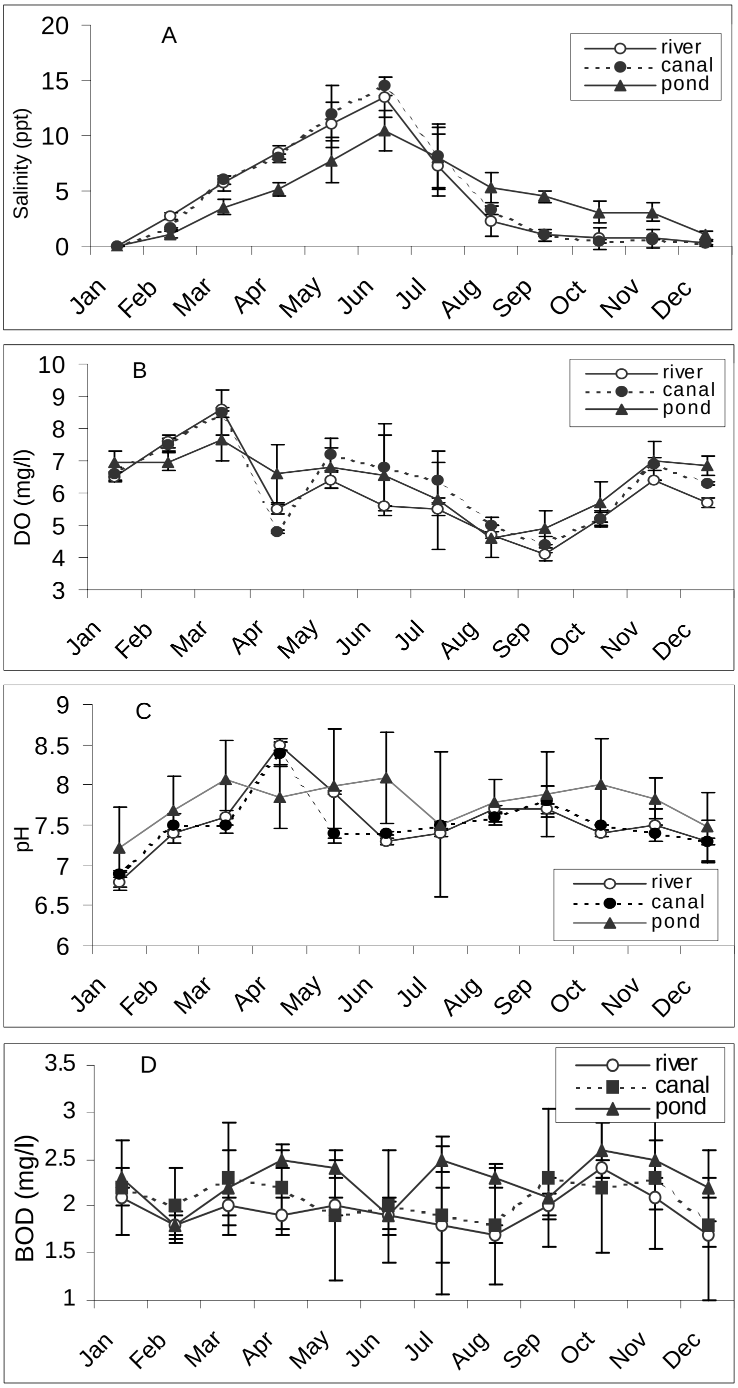


Fig. 5.1.1. Changes of physico-chemical parameters (mean ± SD) of water throughout the year in river, canal and culture pond.

A for salinity (ppt), B for dissolved oxygen (mg/l), C for pH and D for biological oxygen demand (mg/l). Weakly water samples (from high and low tide for river and canal) were recorded and average monthly value was calculated. Final values are mean (± SD) of 2 stations of river, 2 stations of canal and 10 grow out shrimp ponds. Data was not recorded at 4 of the ponds from early January to mid February due to pond preparation.

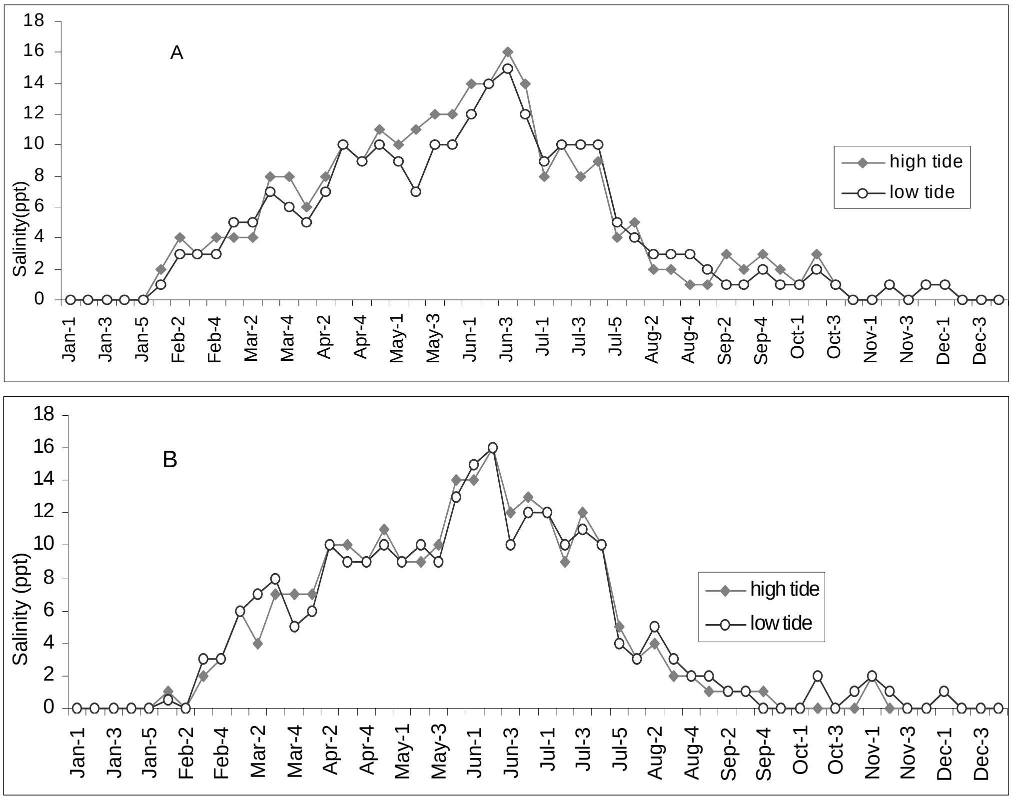


Fig. 5.1.2. Weekly variation of salinity (ppt) with tidal variation throughout the year. A for river and B for canal

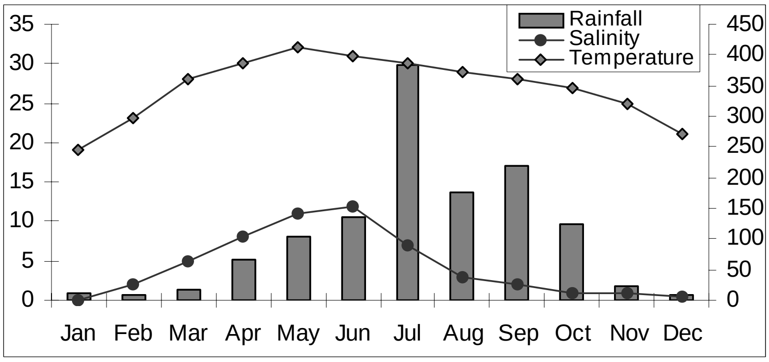


Fig. 5.1.3. Seasonal variation of salinity, temperature and rainfall.
Values of salinity (ppt) and temperature (^{0}C) are in Y axis and rainfall (mm) in Z axis. Salinity and temperature values are the average from river, canal and ponds. Rainfall data are taken from the nearby weather station.

The salinity of pond water showed a general trend of gradual increase from 3 ppt at initial stage (March) of farming to 11 ppt at June and subsequent decrease towards the later part of the grow-out period. The dissolved oxygen concentrations throughout the grow-out period fluctuated mostly between 6 and 7 mg/l. Slight decrease of DO (4.62 mg/l) was observed at the end of grow-out period. The pH value of pond water was relatively stable during most of the grow-out period ranging from 7.5 to 8. The average BOD value of pond water was mostly stabled fluctuated between 2 to 2.6 mg/l (Fig. 5.1.4).

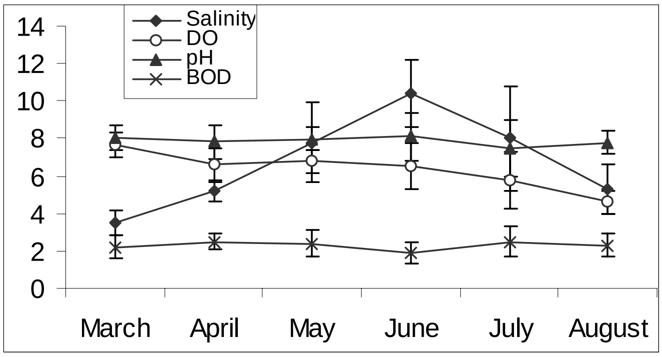


Fig.5.1.4. Changes in physico-chemical parameters of water in 10 shrimp ponds throughout the growing cycle.
Values (mean ± SD) are for salinity (ppt), DO (mg/l), BOD (mg/l) and pH.

The total Phosphate and total Ammonia Nitrogen concentration did not show significant variation among river, canal and ponds (Fig.5.1.5). Total Phosphate concentrations were mostly between 0.5 to 0.7 mg/l with the exception of the month of October, where slightly increased values were recorded (0.73 to 0.96 mg/l). The concentrations of total Ammonia Nitrogen were ranged between 0.5 to 0.8 mg/l during non-culture period of the month of October to February. Significant gradual increases (up to 2.2 mg/l) were recorded from March to September. The highest value 2.2 mg/l was recorded from the canal.

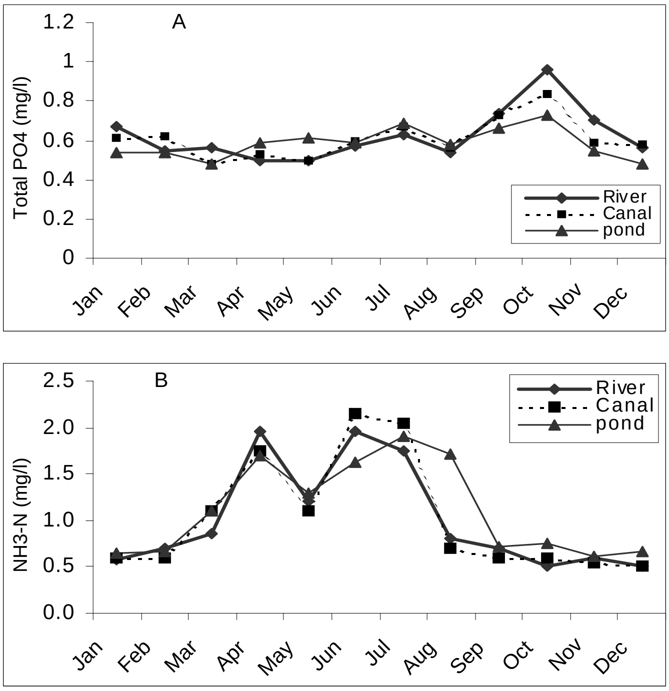
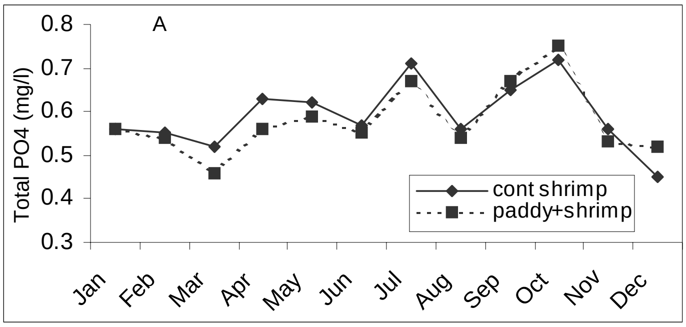


Fig. 5.1.5. Fluctuation of water nutrients throughout the year in river, canal and ponds.

Average monthly data of A for Total Phosphate (mg/l) and B for Total Ammonia Nitrogen (mg/l). Mid February to September shrimp culture period and the rest are paddy cultivation period. Data was not recorded at 4 of the ponds from early January to mid February due to pond preparation.

The total Phosphate and total Ammonia Nitrogen concentration did not show significant variation among continuous shrimp and paddy cum shrimp ponds (Fig.5.1.6). Total Phosphate concentration of paddy cum shrimp ponds were low than that of continuous shrimp ponds in most of the period of the year.



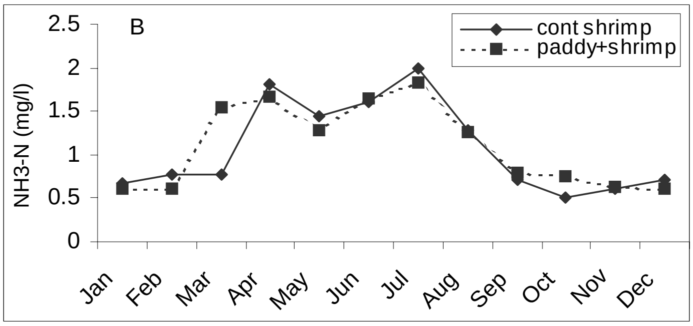


Fig.5.1.6. Fluctuation of water nutrients throughout the year (average monthly value) in different culture system. A for Total Phosphate (mg/l) and B for Total Ammonia Nitrogen (mg/l). Mid February to September shrimp culture period and the rest are paddy cultivation period.

The concentration of total Nitrogen (TN) and total Phosphorus (TP) showed the same pattern over the growout period of the 3 ponds (A3, B3 and B6) studied for mass balance. The concentrations were low during first two months (February and March). Then the concentration increased from 0.15 mg/l to 0.25 mg/l for total phosphorus and from 1.3 to 4.3 mg/l for total nitrogen (Fig. 5.1.7). The concentration of TN and TP were higher in the supply (inlet) water than discharged (outlet) water in first few months of culture cycle. Consequently, in the later months TN and TP were higher in outlet than inlet water. The average TN and TP concentration of inlet or supply water was slightly higher than that of outlet or discharged water (excluding of final harvest drainage) are shown in the table 5.1. However, the lower outlet concentration of N and P indicate a net retention of nutrients in the pond ecosystem from the surrounding aquatic system.

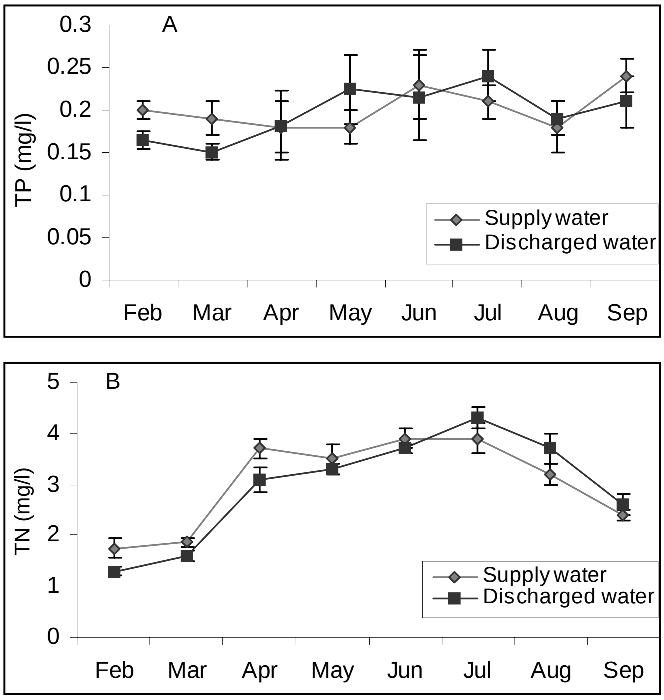


Fig.5.1.7. Changes of water nutrients in 3 shrimp ponds (A3, B3 and B6) throughout the growing cycle. Values (mean ± SD) are for Total Phosphate (mg/l) and Total Nitrogen (mg/l).

Lindsay and Vlek, (1977) mentioned that the various processes governing precipitation and remobilization are probably most importantly influenced by acidity (pH). Below ~pH 5.7, increasing pH is likely to increase available P as it inhibits co-precipitation with Al_3^+; above ~pH 5.7 (found in the study area), increasing pH reduces available P by promoting precipitation of $Ca_5(PO_4)_3F$. It is obvious that increasing pH (alkalinity) will tend to decrease P availability (ie the soluble P pool) in the surface water, while decreasing pH (acidity) will tend to increase it. The (small) labile P pool acts to buffer the system against any short-term change, the (large) stabilized P pool against longer-term shifts. Management additions to the system will generally be of organic or soluble P, which will be converted relatively quickly into the labile forms, and more gradually into the stabilized ones. The consequences of under-supply and over-supply will both take considerable time to be manifest in the background levels of the indicator pools (organic and soluble P). So it is clear that P does accumulate in sediments, but is very well buffered, and is unlikely to be re-mobilized in large quantities in a form available to plankton etc.

There is a possibility of nitrite "spike" which is likely to occur after fertilization (equal amounts of NH_4^+ and NO_3^- added to the oxic zone); top-water exchange (reoxygenation of the oxic zone coupled with addition of active (readily-oxidisable) organic matter and inorganic N); and residue addition (active organic C and N added to the oxic zone, as fertilizer or feed), followed after a few days by a lesser increase in N_2O. In every case this is due to denitrification in the sediment (of NO_3^- diffusing down from above) followed by upward diffusion of its products. Chen & Chen, (1992) stated that the Nitrite (NO_2^-) is toxic to shrimp and might well account for some of the moralities.

Table. 5.1. Nutrient concentration (mg/l) in different shrimp ponds

parameters	Months																Mean	
	Feb		March		April		May		June		July		Aug		Sep			
	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet	inlet	outlet
Pond A3																		
NH3-N	0.80	0.50	0.80	0.90	1.45	1.30	1.20	1.30	1.90	1.80	1.75	1.80	0.80	1.10	0.70	0.80		
NO3-N	1.00	0.70	1.10	0.80	2.10	1.70	2.20	1.90	2.40	2.10	2.10	2.20	2.10	2.30	1.80	1.90		
NO2-N	0.002	0.001	0.002	0.001	0.003	0.002	0.004	0.003	0.004	0.003	0.004	0.004	0.003	0.004	0.003	0.003		
TN	1.80	1.20	1.90	1.70	3.55	3.00	3.40	3.20	4.30	3.90	3.85	4.00	2.90	3.40	2.50	2.70	3.028	2.890
T PO4	0.55	0.46	0.56	0.42	0.50	0.40	0.5	0.48	0.57	0.48	0.63	0.58	0.54	0.62	0.74	0.58		
TP	0.183	0.153	0.187	0.140	0.167	0.133	0.167	0.160	0.190	0.160	0.210	0.193	0.180	0.207	0.247	0.193	0.191	0.168
Pond B3																		
NH3-N	0.65	0.6	0.95	0.70	1.40	1.60	1.25	1.40	1.95	1.70	2.00	2.20	0.75	1.20	0.60	0.90		
NO3-N	1	0.7	1.00	0.80	2.10	1.80	2.20	1.90	2.30	1.90	2.10	2.20	2.0	2.30	1.80	1.90		
NO2-N	0.002	0.001	0.002	0.001	0.002	0.003	0.004	0.003	0.004	0.003	0.004	0.004	0.003	0.004	0.003	0.003		
TN	1.652	1.301	1.952	1.501	3.502	3.403	3.454	3.303	4.254	3.603	4.104	4.404	2.753	3.504	2.403	2.803	3.009	2.978
T PO4	0.64	0.56	0.56	0.42	0.53	0.56	0.50	0.68	0.72	0.66	0.67	0.72	0.56	0.62	0.73	0.64		
TP	0.213	0.187	0.187	0.14	0.177	0.187	0.167	0.227	0.24	0.22	0.223	0.24	0.187	0.207	0.243	0.213	0.205	0.203
Pond B6																		
NH3-N	0.8	0.6	0.85	1.10	1.80	1.85	1.30	1.40	1.60	1.60	2.00	2.10	1.9	2.10	0.80	0.90		
NO3-N	1	0.8	0.90	0.80	2.10	1.90	2.30	2.00	2.30	2.10	2.10	2.20	2.00	2.20	1.60	1.40		
NO2-N	0.002	0.001	0.001	0.002	0.003	0.004	0.003	0.004	0.004	0.003	0.003	0.004	0.003	0.004	0.003	0.003		
TN	1.802	1.401	1.751	1.902	3.903	3.754	3.603	3.404	3.904	3.703	4.103	4.304	3.903	4.304	2.403	2.303	3.172	3.134
T PO4	0.64	0.46	0.62	0.34	0.62	0.68	0.68	0.86	0.72	0.8	0.67	0.88	0.58	0.48	0.73	0.72		
TP	0.213	0.153	0.207	0.113	0.207	0.227	0.227	0.287	0.24	0.267	0.223	0.293	0.193	0.160	0.243	0.240	0.219	0.218

5.2 Biological indicators

In the study area water mainly supplied from river and canal for shrimp culture. About 47% of farms exchanged water from river, 38% from canal and the rest 15% from other farms. The status of planktonic abundance and primary productivity of river water was considered to determine the food value of natural water.

Islam *et al*. (2002) studied on the planktonic abundance and primary productivity of a shrimp farm and adjacent river in Khulna district from February to September. The average phytoplankton abundance and primary productivity of inlet or river water was less than that of pond outlet, but in case of zooplankton scenario was different (table. 5.2.1).

Table 5.2.1. Average planktonic abundance and productivity in Paikgacha, Khulna

Item	Inlet (river)	Outlet (pond)
Phytoplankton (cell/l)	225	429
Zooplankton (unit/l)	598	309
Primary productivity (gC/m^3/hr)	0.071	0.296

Mamun (2003) also studied on the planktonic abundance of four main river system (Passur-Sibsa, Bleswar-Selagang, Arpangasia-Balta and Jamuna-Malancha) of the southwest coastal region from April to December. The study revealed the average phytoplankton cell abundance and net primary productivity in summer, monsoon and winter (table. 5.2.2). A total of 15 genera of phytoplankton and 11 genera of zooplankton were recorded (table. 5.2.3). Chlorophyceae, Myxophyceae and Bacillariophyceae were the 3 class of phytoplankton. The zooplankton population mainly consisted of copepods, cladocerans, crustaceans, crab larvae, decapoda and mysidacea.

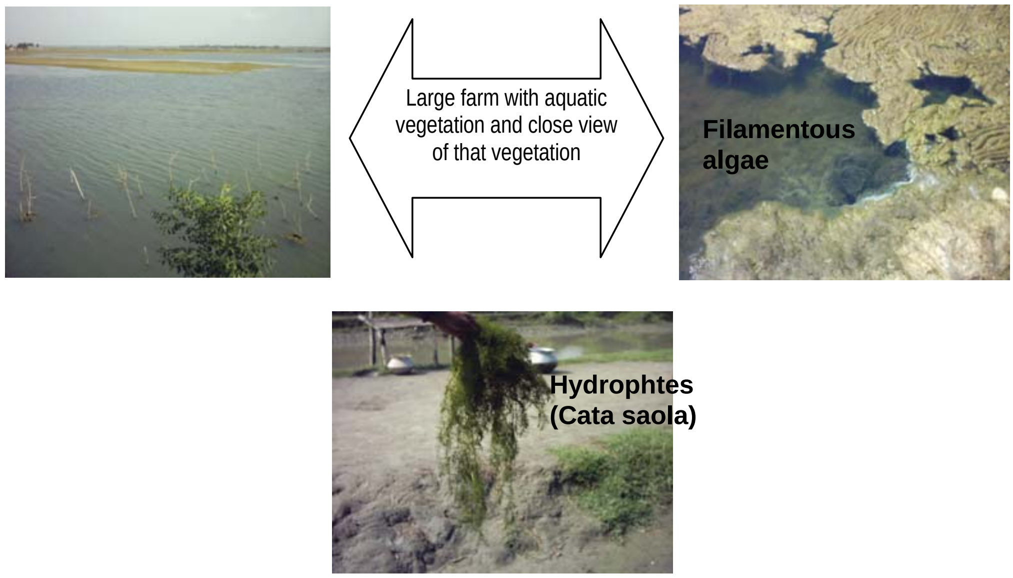
Table 5.2.2. Average planktonic abundance and productivity in 4-river system of south-west coastal region

Item	Summer	Monsoon	Winter
Phytoplankton (cell/l)	2510	1786	2550
Zooplankton (unit/l)	2038	1260	1206
Primary productivity (mgO_2/l/hr)	0.1 - 1.1	0.1 - 1.1	0.1 - 1.1

Table. 5.2.3. Total number of phytoplankton abundance for the 4 river system.

Phytoplankton			Zooplankton	
Sl.	Class	Identified species	Class	Genus
1	Chlorophyceae	Gloeotrichia pisum *Coscinodiscus Rhizosolenia* *Treubana setigerum* *Echinosphaerella limnetica* *Pediastrum simplex*	Crustacea	*Merocyclops* sp *Mesocyclops* sp *Cyclops* sp *Diaptomus* sp *Daphnia sp* *Bosmina* sp *Diaphasomqa* sp *Lucifer sp* Praunus sp *Mysidella sp* *Brachyuran sp*
2	Myxophyceae	*Microcystis robusta* *M. elongata* *Apharothece gelotinesa* *Chroococcu disperse* *Holopedium irregulare* *Dactylococcopsis sp* Aphanizomenor sp		
3	Bacillariophyceae	*Gloeotrichia echinulat* *G .pilsum* *Schizothrix tinctoria* *Thalassiora Subtilis* *Cyclotella. bodarica* *Coscinodiscus granil* *C. tumidus* *C. marginatus* *Rhizosolenia truneat*		

Hydrophytes availability in the study area was common. A special type of filamentous algae (species not identified) was grown rapidly in some of our selected ponds are shown below. It prohibits normal movement of shrimp. We not yet identify it as vector of viruses. But it is found in most of the large farms. Availability of another type of hydrophyte (cata saola) was reported good as it reduces the rate of mortality as well as a wonderful source of food and shelter in the dry season.



5.3 Farmer indicators

Water color and Smell: Usually the water color looks whitish but it may tends to reddish and in some extent water looks oily layer which indicate the possibility of disease attack. Disorder of smell is also an indicator to change water.

Watercolor was varied from gher to gher. Color used to change during the crop cycles. Color changed from Green » Blue Green » Muddy. Tealeaf color (tannin rich water) may protect mortality (further study is needed).

Soil quality: Most of the soil were gray in color and origin is sandy loamy. Black and red soil found less in this site. No evidence found that soil is the source of microbes. Bottom sediment of the nursery canal did not dig out every year. Excessive waste sediment may produce Sulfur dioxide gas, but not all the farmers do this. Although we have not found any gas occurrence in our selected farms this year.

Water exchange: There was evidence that disease occurrence is less in those farms that do not exchange or occasionally exchange river water. Farmers reported that huge mortality was occurred just after 2-3 days of water filling from river. Some farmers also reported that during water filling when shrimp come in contact with tidal water it become weak and consequently death occurred. During the month of April-May the initial reddish tidal water causes mortality.

Some of the farmers suggested that farm should fill with river water just after ending high tide or just after initiating low tide, so that precipitation or settle down of waste could take place. Favorably it is good to have a reservoir to reserve river water for filling.

Shrimp behavior and performance: Tendency of shrimp to float. One of the prominent indicators for farmers is to observe the direction of shrimp movement during water entry. If shrimp move in favor of water flow than it indicates probability of disease. Locally, it terms as "Joyan". There is a size consideration for the effect of that occurrence. Hundred (100) - fifty (50) grade shrimp is more vulnerable than lower (less than 44) grades.

Three days after releasing the fry, farmers used to check the movement capacity of the fry. Test the proportionate density and continue. Two-inch size indicates better future production. If there is any disease or any problem, shrimp come to the side of the pond and keep their mouth open at the surface water. People like to use urea if a shrimp body seems hard. After the use of urea it seems soft. Hard body means no change of shell i.e., no growth.

Rain: There is evidence that after a heavy rain huge mortality occurs. It may be due to the reduction of water pH and fluctuation of water temperature and salinity for sudden heavy rainfall. Farmers also reported that huge mortality occurred after 2-3 days of heavy rainfall.

Salinity and depth: Excessive salinity with less water depth in the dry season causes mortality. Occurrence of saline bubbles like material causes less production and mortality.

Fry: Some farmers reported that shrimp fry might be a cause of disease because source of water and feed is common. In addition, disease occurs usually after 45-60 days of stocking. As virus can remain as a dormant state in animal body up to 45 days, it may be a clue.

Feed: Uses of expired dated waste feed causes shrimp mortality. It is widely acceptable fact that lack of feed and malnutrition is the main causes of mortality. Shrimp getting very less or no food become weak and is susceptible to disease.

Hydrophytes: Availability of hydrophyte (cata saola) reduces the rate of mortality, as it is a wonderful source of food and shelter in the dry season.

Grass: Vegetation on the pond reflects good soil condition and less vulnerability for shrimp disease or death.

5.4 Observed situation of a pond during mortality

- Water quality was good enough. No bad smell and color observed but water was too transparent (three feet). Inadequate natural feed observed.
- One of the farmers observed that water found red when decomposition of root system of paddy occurred (previous crop). It may be harmful for shrimp.
- No spot observed (>90%) except few. Most of the shrimp behave inert before death.

5.5 Correlation between Indicators

The following table represents the correlation of the nutrients with different physical, chemical and biological parameters.

Table 5.3: Correlation between indicators

Nutrients		Physical		Chemical		Biological				
TN	TP	Temp	Water supply	Salinity	pH	BOD	Phytoplankton	Zooplankton	Primary Productivity	Disease Occurrences
High (May-Aug)	Relatively low	High	Frequent supply	High	Relatively high >7.5	NSD*	1786-2510 cells/l	1206-2038 cells/l	0.1-1.1	Prominent
Low (Sep – April)	Relatively High	Low	less supply	Low	Relatively low 6.5-7.5	NSD*	2550 cells/l	1206 cells/l	0.1-1.1	Less

* Not Specifically Detected

6 Environmental capacity issues

6.1 Water Exchange

Volume of water in system: The project considers the case study area as 1000 acre in that particular case. There are two crop cultivated on the study area such as shrimp (February-July) and paddy (October-December). Among the total area, 5% treated as canal area, 20% as no-production area and 75% as pond/paddy field area. Respective water volume for shrimp and paddy as well as total water volume showed in the following table – 6.1.1.

Table - 6.1.1: Respective water volume in the study area.

Types	Dimensions (m2)	% area	Water volume (m3) (Shrimp culture)	Water volume (m3) (Paddy cultivation)
canal area	202350	5%	505875	505875
non-production area	809400	20%		
pond area	3035250	75%	2306790	910575
Total	3237600		2812665	1416450

Note: Canal depth = 2.5 m, Pond depth for shrimp = 0.76 m, depth of paddy farm = 0.3 m

Water exchanged each time both for shrimp and paddy followed by the average canal water depth difference showed in the following table-4.1.2. For shrimp, the water exchange rate was around 40% and for paddy it was around 20%. In terms of calculating total period/ cycle, for shrimp, it was considered as 10 times per month and total period as 6.5 month whereas for paddy 6 times per month and total period as 4 months.

Table 6.1.2: Flushing rate of water for shrimp and paddy cultivation

	Shrimp		Paddy	
av. max height (m) of water depth	2		1.75	
av. min height (m) of water depth	1		1.25	
difference (m) of water depth	1		0.5	
water exchanged each time (m3)	202,350	40%	101,175	20%
water exchange (m3/cycle)	13,152,750		2,428,200	
Flushing rate	468%		171%	

Note: Flushing rate = water exchanged/volume of water in system

So flushing rate of canal water for shrimp was 468% and for paddy, 171% per cycle.

Category-wise individual water exchange was also calculated to develop the category wise and overall mass balance model. Water exchange of the river sided ponds (pond type 1) carried out for 4 to 6 days at new and full moon in every fortnight. Though water exchange was not done at every fortnight routinely. Sometime it was avoided to escape from disease, as they believe supply water may be a source of disease occurrence. Besides, the frequency of water exchange was changed on the basis of season and harvest. So, average 6 times per month is considered pond type1. Canal sided pond's (pond type 2) exchanged water fortnightly using highest high tide of the canal. Ponds that are far from river or canal (type 3) usually filled water at initially with occasional exchange. Water exchange of each type is mentioned on the following table-6.1.3:

Table 6.1.3: Category wise flushing rate in the study area

Types	Frequency /month	% per time	Volume per pond (m3)	Water exchanged (m3)	Flushing rate
pond 1: direct with river	6	11%	455287.5	300489.75	66%
pond 2: direct with canal	2	15%	910575	273172.5	30%
pond 3: through other ponds	0.5	20%	1669387.5	166938.75	10%
Paddy farm	0.5	10%	910575	45,529	5%

6.2 Mass balance

A rough estimation of the nutrient mass balance ($ha^{-1}cycle^{-1}$) has been made first for 3 different types of ponds. Then the overall mass budget per hector of land has been made. The overall average yield of harvested shrimp and other finfishes were estimated 258 and 237 $kgha^{-1}cycle^{-1}$ respectively.

In the present study ponds were supplied with small amount of feeds mostly homemade cereals with more reliance on fertilization. So the overall nutrient mass balance (Table. 6.2.4) of the present study indicated that fertilizer was the highest nutrient contributor (60.2% TN and 82.4 % TP), which can be best compared with Wahab et al. (2003) who reported 67% TN and 71% TP contribution from fertilizer in extensive shrimp farm of Bangladesh.

However, Wahab et al. (2003) reported intake water as the second largest source of TN (33%) and TP (29%) in contrast to our study where feed (21.1% N and 9.3% P) was the second highest contributor. But the individual budget (Table 6.2.1) of the present study shows that water-born nitrogen is the highest contributor of the total nitrogen budget, both for input (51.2%) and output (49%).

The overall budget shows that nutrient input through supply water and disposal through discharged water were approximately same. The input and output value for TN was 14.9% and 14.5 % as well as for TP 2.2% and 2.0% respectively. The total inputs of nitrogen and phosphorus were 48.7 $kgha^{-1}cycle^{-1}$ and 28.95 $kgha^{-1}cycle^{-1}$ respectively. Wahab et al. (2003) reported that 13% of TN and 21% of TP was discharged through effluent as net loss to the surrounding water, which supports the present study in terms of total nitrogen (14.5%), but different scenario has found in terms of total phosphorus which is very low in our estimation (2.0%).

Only 33.4% of nitrogen and 6.1% of phosphorus were removed as harvested shrimp and fish that is supported strongly by Muthuwan (1991), who estimated 24.8 % N and 9.1% P removed as shrimp harvested.

A large portion, 39.1% N and 92% P, which accounts for 20.6 kg N and 26.66kg P $ha^{-1}cycle^{-1}$ were remained in the sediments and unaccounted for. According to Edwards (1993), in extensive and semi-intensive systems, typically a major part of nitrogen and phosphorus is accumulated in the sediments. This also strongly supports the findings of the present study. In the present study nitrogen removed through denitrification and ammonia volatilization is assumed 13% according to Doson's MB diagram.

The present study shows that large amount (20.6 kg N and 26.66kg P $ha^{-1}cycle^{-1}$) of total output was apparently trapped in the pond bottom. A significant part of the removed nutrients must have been trapped by settling of solids, algae and detritus on the bottom of the ponds (Edwards 1993). A minor part of the accumulated sediments are flushed out at the end of culture cycle. So year by year the accumulated sediment results in rise of bottom level. So, sediment management has potential to reduce environmental impacts. Farms should not be allowed to drain the washing sediments directly to the nearby canal or river. There is a need to dig out the pond bottom after few years and this nutrient rich sediment can be used in agricultural lands.

The overall mass balance of paddy (per hector basis) has also been made to compare it with shrimp. The culture area for paddy was considered 3,035,250 m^2. The nutrient mass balance paddy (Table. 4.2.5) of the present study indicated that fertilizer was the major nutrient contributor. About 58% of nitrogen and almost 100% of phosphorus has come from fertilizer. The total nutrient removed from harvest was 78% for TN and 74% for TP. The rate of nitrogen and phosphorus accumulation in sediment is 22% and 26%, which accounts for 20.57 kg N and 4.71 kg P ha respectively. Nutrient input through supply water and disposal through discharged water were very less, nearly zero percent.

So from the overall mass balance of shrimp and paddy it can be observed that water born nutrient contribution and discharge to aquatic system as well as sedimentation rate is comparatively higher in case of shrimp.

In chemical aspects, rice plant roots create an oxic rhizosphere within largely anoxic sediment that enhances their ability to exploit sediment N (as NO_3^- instead of NH_4^+). Rice plant roots also acidify their rhizosphere by oxidizing Fe^{2+} that enhance their ability to exploit (mobility and uptake) sediment P (Kirk et al., 1994; Saleque & Kirk, 1995).

MASS BALANCE PER HECTOR BASIS

Table. 6.2.1. Direct from river [comprised 15% of total culture area]

Inputs	Type	Volume used (kg)	Nitrogen			Phosphorous		
			N % per kg	kg N / cycle	% of total	P %per kg	kg P / cycle	% of total
feed	homemade	52	1.9	0.988	3.3%	0.43	0.224	2.3%
	MOC	0	0	0	0.0%	0	0	0.0%
	Fish meal	0	0	0	0.0%	0	0	0.0%
fertilizer	Urea	17	46	7.82	26.4%		0	0.0%
	TSP	28		0	0.0%	20	5.6	56.5%
	Cow dung	210	1.65	3.465	11.7%	0.7	1.47	14.8%
seed		0.1	9.1	0.0091	0.0%	0.4	0.0004	0.0%
paddy stubble		278	0.61	1.7	5.7%	0.52	1.4456	14.8%
water supply		5,016,000	0.0003028	15.188448	51.2%	0.00001916	0.9610656	9.7%
rainfall		929000	0.000052	0.483	1.5%	0.000023	0.214	1.9%
Total inputs per cycle		5,945,721	59.2603548	29.6	100%		9.914335	100%
Outputs								
crop								
shrimp	harvested	105	3.01	3.1605	11%	0.27	0.28	2.9%
	mortalities	30	3.01	0.903	3%	0.27	0.08	0.8%
fish	harvested	83	2.48	2.0584	7%	0.45	0.3735	3.8%
	Mortlities	10	2.48	0.248	1%	0.45	0.045	0.5%
denitrification				3.85	13%			
Total nutrient removed				10.22	34%		0.8	7.9%
water	exchanged	5,016,000	0.000289	14.50	49%	0.00001671	0.84	8.5%
	harvest drainage	7,600	0.001	0.076	0%	0.0003	0.02	0.2%
Total outputs in water				14.57	49%		0.86	8.7%
stays in sediment				4.85	16%		9.05	91%
Total outputs		5,023,828		29.65	100%		9.91	100%

Table. 6.2.2. Direct from canal [comprised 30% of the total culture area]

Inputs	Type	Volume used (kg)	Nitrogen			Phosphorous		
			N % per kg	kg N / cycle	% of total	P %per kg	kg P / cycle	% of total
feed	Home made feed	365	1.9	6.93500	16%	0.43	1.5695	5.1%
	MOC	65	5.4	3.51000	8%	1.8	1.1710	3.8%
	Fish meal	35	4.7	1.64500	4%	3	1.05	3.4%
fertiliser	Urea	48	46	22.0800	51%		0	0.0%
	TSP	124				20	24.8	80.6%
	Cow dung	0	0	0.00000	0%	0	0	0.0%
seed		0.1	9.1	0.00910	0%	0.4	0.0004	0.0%
paddy stable		280	0.61	1.95200	4.5%	0.52	1.664	5.4%
water supply		2,280,000	0.0003009	6.86052	16%	0.00002045	0.46626	1.5%
rainfall		194800	0.000052	0.10130	0.2%	0.000023	0.044804	0.1%
Total input per cycle		2475847.1	67.7103529	43.1	100%		30.76	100%
outputs								
crop								
shrimp	harvested	323	3.01	9.7223	23%	0.27	0.8721	2.8%
	mortalities	90	3.01	2.709	6%	0.27	0.243	0.8%
fish	harvested	275	2.48	6.82	16%	0.45	1.2375	4.0%
	mortalities	27	2.48	0.6696	2%	0.45	0.1215	0.4%
denitrification				6.2362	13%			0.0%
total nutrient removed				26.1571	59%		2.4741	8.0%
water	exchanged	2,280,000	0.0002977	6.78756	16%	0.00002025	0.4617	1.5%
	harvest drainage	1000	0.001	0.01	0%		0	0.0%
Total output in water				6.79756	16%		0.4617	1.5%
stays in sediment				10.77	25%		27.83	90%
Total outputs				43.09	100%		30.76	100%

Table. 6.2.3. Through other ponds [comprised 55% of the total culture area]

			Nitrogen	Phosphorous

Inputs	Type	Volume used (kg)	N % per kg	kg N / cycle	% of total	P %per kg	kg P / cycle	% of total
feed	Home made	470	1.9	8.93	15.6%	0.43	2.021	6.1%
	MOC	66	5.4	3.564	6.2%	1.8	1.188	3.6%
	Fish meal	0	0	0	0.0%	0	0	0.0%
fertiliser	Urea	58	46	26.68	46.7%	0	0	0.0%
	TSP	114	0	0	0.0%	20	22.8	68.5%
	Cowdung	840	1.65	13.86	24.3%	0.7	5.88	17.7%
seed		0.1	9.1	0.0091	0.0%	0.4	0.0004	0.0%
paddy stable		210	0.61	1.281	2.2%	0.52	1.092	3.3%
water supply		790,000	0.0003184	2.51536	4.4%	0.00002193	0.173247	0.5%
rainfall		516000	0.000052	0.26832	0.5%	0.000023	0.11868	0.4%
Total inputs per year		1308251.1	66.02037	57.1	100%		33.27	100%
Outputs								
crop								
shrimp	harvested	264	3.01	7.9464	13.9%	0.27	0.7128	2.1%
	mortalities	60	3.01	1.806	3.2%	0.27	0.162	0.5%
other	harvested	259	2.48	6.4232	11.2%	0.45	1.1655	3.5%
	mortalities	25	2.48	0.62	1.1%	0.45	0.1125	0.3%
denitrification				7.424	13.0%			0.0%
total nutrient removed				24.219	42.4%	1.44	2.1528	6.5%
water	exchanged	790,000	0.0003159	2.49561	4.4%	0.00002175	0.171825	1%
	harvest drainage	1000	0.001	0.01	0.0%	0.0003	0.003	0%
Total outputs in water				2.50561	4%		0.174825	1%
stays in sediment				30.38	53%		30.95	93%
Total outputs				57.1	100%		33.27	100%

Table. 6.2.4. Overall mass balance [per hactor basis]

			Nitrogen			Phosphorous		
Inputs	Type	Volume used (kg)	N % per kg	kg N /cycle	% of total	P %per kg	kg P / cycle	% of total
feed	Homemade	375	1.9000	7.140	14%	0.43000	1.616	5.2%
	MOC	58.35	4.5900	3.013	5.9%	1.53000	1.004	3.1%
	Fish meal	14.7	1.4100	0.494	1.2%	0.90000	0.315	1.0%
fertiliser	Urea	77.8	46.0000	22.47	45.1%	0.00000	0.000	0.0%
	TSP	99.915	0.0000	0.000	0.0%	20.00000	20.82	70.5%
	Cowdung	503.7	1.1550	8.143	15.1%	0.49000	3.455	11.9%
seed		0.1	4.8430	0.004	0.0%	0.44950	0.000	0.0%
								0.0%
paddy stable		274.35	0.6100	1.4713	3.3%	0.52000	1.254	5.4%
water supply		1870900	0.0003	5.7199	14.9%	0.00002	0.3793	2.2%
rainfall		481590	0.0001	0.2504	0.6%	0.00002	0.1108	0.6%
Total inputs per year		2819303.1	65.513	48.706	100%	0	28.954	100%
Outputs								
crop								
shrimp	harvested	257.85	3.0100	7.761	16.1%	0.270	0.696	2.1%
	mortalities	64.5	3.0100	1.941	4.1%	0.270	0.174	0.5%
fish	harvested	237.4	2.4800	5.888	12.0%	0.450	1.068	3.2%
	mortalities	23.35	2.4800	0.579	1.2%	0.450	0.105	0.3%
denitrification		0	0.0000	6.653	13.0%	0.000	0.000	0.00%
total nutrients removed				22.502	46.3%	0.792	2.044	7.2%
water	waste water	1,870,900	0.0003	5.583	14.51%	0	0.359	2.0%
	harvest drainage	1,990	0.0010	0.020	0.1%	0	0.005	0.0%
Total outputs in water				5.603	14.5%		0.364	2.0%
stays in sediment				20.606	39.1%		26.664	92%
Total outputs				48.711	100%		28.955	100%

Table. 6.2.5. Paddy mass balance [per hactor basis]

Inputs	Type	Volume used (kg)	Nitrogen N % per kg	kg N / cycle	% of total	Phosphorous P %per kg	kg P / cycle	% of total
fertilizer	Urea	120	46	55.2	58%		0	0%
	TSP	90			0%	20	18	100%
					0%			0%
water supply/Irrigation		150000	0.0003009	0.45135	0%	0.00001954	0.02931	0%
rainfall (Dry season)		1000	0.000052	0.00052	0%	0.0000023	0.000023	0%
N2 fixation				40	42%		0	0%
Total inputs per year		151210	46.00035	95.7	100%		18.03	100%
outputs								
crop								
paddy	grain	1200	2.98	35.76	37%	0.59	7.08	39%
	Straw	1200	0.61	7.32	8%	0.52	6.24	35%
Percolation				10	10%	1	0	0%
denitrification				21.9999	23%			
total nutrients removed				75.0799	78%		13.32	74%
water	waste water			0	0%		0	0%
	harvest drainage			0	0%		0	0%
Total outputs in water				0	0%		0	0%
stays in sediment				20.57	22%		4.71	26%
Total outputs				95.65	100%		18.03	100%

6.3 Nutrient dynamics

The following equation was considered for the determination of nutrient dynamics.

Nutrient dynamics = mass balance total / water exchange total

$$C = N / FU,$$

where

C = The elevation of nutrient concentrations caused by fish farms (or any other source of nutrient input)
N = The rate of nutrient input
F = The flashing rate
U = the volume of water

Table 6.3.1: Nutrient dynamics for shrimp and paddy cultivation in the study area.

	Shrimp		Paddy	
	Phosphorus	Nitrogen	Phosphorus	Nitrogen
N the rate of nutrient input (kg)	28.9	48.7	24.27	131.5
F the flushing rate	4.68	4.68	1.71	1.71
U the volume of water in case study area (m3)	2812665	2812665	1416450	1416450
Nutrient Concentration (g/m3)	0.002	0.004	0.010	0.053
Water Nutrient Concentration (g/m3)	0.2	2.5	0.2	2.5
*Standards**	2	4	2	4
Overload	-1.8	-1.496	-0.2	-1.447

- Vietnam

6.4 Environmental Capacity assessment:

Environmental capacity is defined by GESAMP[i] as " a property of the environment and its ability to accommodate a particular activity or rate of an activity…without unacceptable impact". The concept is therefore central to the promotion of sustainable aquaculture development and the implementation of the FAO Code (Article 9.1.2 of the FAO Code of Conduct for Responsible Fisheries). Importantly, it requires us to address the cumulative impacts of the whole sector (and in its most comprehensive form all economic activity) on the ecosystem within a specified area. To date these wider cumulative and dispersed impacts have not been effectively addressed by conventional regulatory approaches such as EIA or individual farm consents[ii].

The application of the concept of environmental capacity to the planning and management of aquaculture development relies on two aspects:

1. The ability to measure the rate of environmental change and relate this to activities such as aquaculture
2. The determination of what amount of environmental change is acceptable, i.e. developing an environmental quality standard (EQS)

A recent GESAMP report suggests environmental capacity in relation to aquaculture may be interpreted as:

- The rate at which nutrients are added without triggering eutrophication; or
- The rate of organic flux to the benthos without major disruption to natural benthic processes.

More practical interpretations are of particular relevance to the situation in developing countries. These might include for example:

- The rate of organic (or nutrient) flux into a defined aquatic system without reducing aquaculture productivity
- The rate or organic (or nutrient) flux into a defined aquatic system without negatively affecting the interests of other resource users

The concept of environmental capacity can be expanded to include impacts that are more difficult to quantify such as reductions of natural habitat or even loss of scenic value due to visual impacts.

Status of Coastal shrimp aquaculture in Bangladesh – TROPECA case study

The present study (Table-4.3.1) reveals that minor level of nutrient enrichment (0.002 g/m3/year TP and 0.004 g/m3/year TN) within the system for shrimp farming. Minors difference of TN and TP (Fig-5.1.7) among the supply and discharge water in the present study support the minor level nutrient enrichment within the system. There is no TN and TP standard setup for Bangladesh coastal water. Hambrey et al. 1999, referred the Effluent standards for coastal water in Asia-Pacific countries where the Ministry of Agriculture, India, 1995 mentioned the TN as 2 mg/l (as N) and Phosphate as P (0.2-0.4 mg/l). But it is observed that nutrient level particularly NH_3N (0.5-2.0) at the system (Fig-5.1.5) is comparatively higher than the standard level declared by the Department of Environment of Bangladesh (1.2 mg/l), NEB 1991 (<0.4mg/l) and the Ministry of Agriculture, India, 1995 (0.5-1.0 mg/l free ammonia (as NH_3-N)) from March to August. i.e., during the peak shrimp culture period. Is it indicating that the Environmental Capacity is exceeding? DO record of the present study may provide the chemical indication in that respect. Access nutrients usually hinder the DO level in a system. But through the shrimp culture period DO was more than 5 mg/l. It implies that nutrient level within the system is in such stage that there is no question of eutrophication during the shrimp culture period. Additionally 468% flushing rate per cycle in the aquatic systems (River-Canal) and 15-66% flushing rate in the Canal-Farm systems may also pave the control of eutrophication within the system. BOD range (1.7-2.5 mg/l) in the system also represents the acceptable environmental status for living organisms. In that respect it may says that the environmental capacity may not exceeding in that period.

There are some standard set up in Vietnam (`4 mg/l N and 2 mg/l P). Even though, it is assumed that significant portions of the nutrients are trapped to the shrimp farms due to the existing water management systems.

According to the more practical interpretations (mentioned at above) relevance to developing countries, Nutrient input in terms of feed is significantly lower that results the low aquaculture production. It is also wide accepted that saline water trapping in shrimp farm affecting the paddy cultivators and other home yard activities.

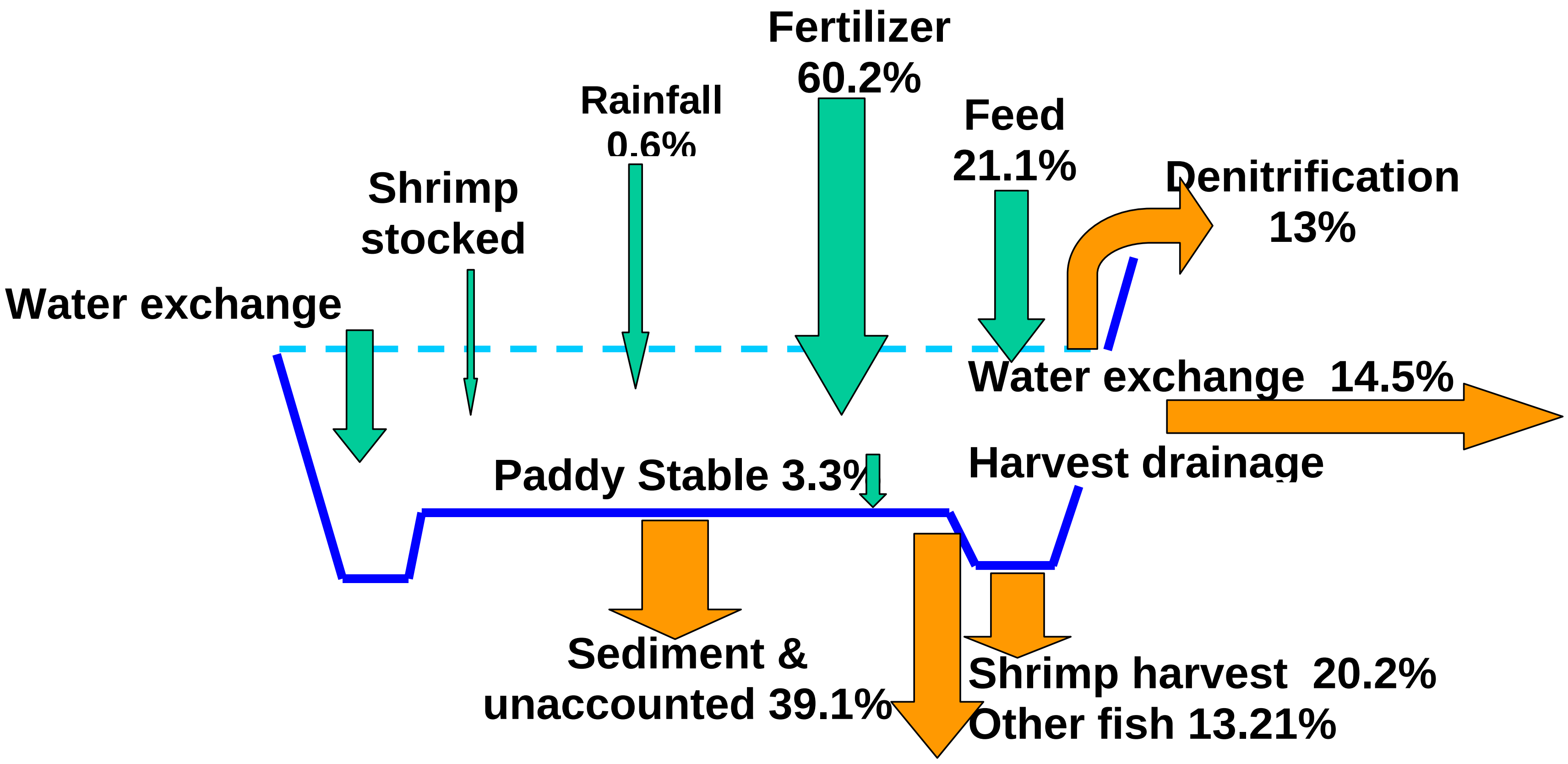


Fig. 6.1. Overall mass balance of Nitrogen in shrimp farm

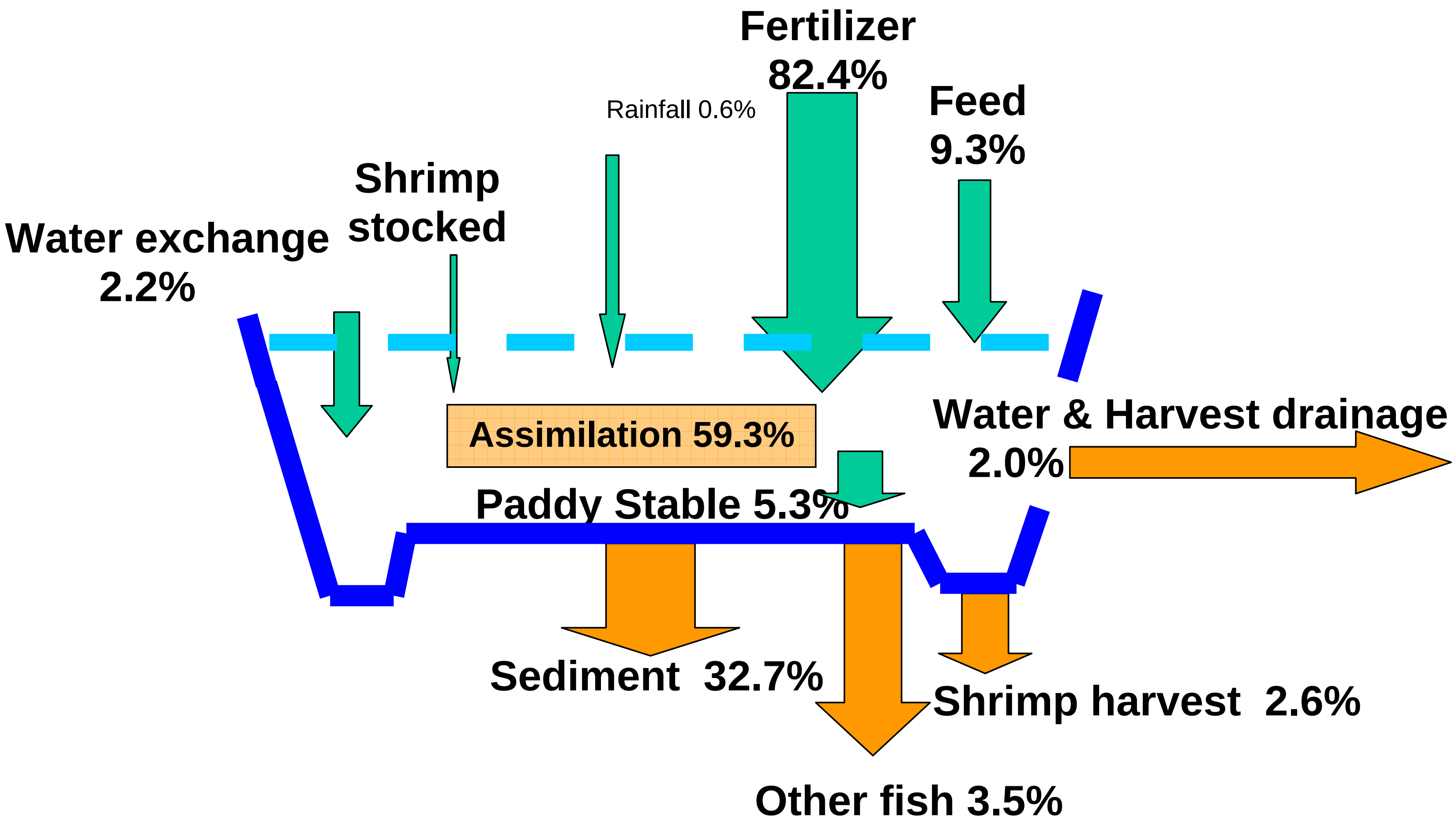


Fig. 6.2. Overall mass balance of Phosphorus in shrimp farm

7 Socio-economic impacts:

Though the present study has revealed several management and operation related drawbacks that are prevalent in the culture technique adopted by the farmers, it is very difficult to afford the amount of money (Table 7) required for shrimp farming by the poor farmers. Dike and nursery pond maintenance should be performed every year but is costly. Specially to maintain optimum pond depth by excavating the large size farm is costly and time consuming. In addition, farmers usually get lease of land on few years (3-5) basis. So they do not want to spend money in excavating land of others which may be taken back. They are producing shrimp traditionally depending on nature. They don't want to take risk involved in high investment. So, though there are some recommendation given from the present study, how many farmers' will be managed to adopt that, is still a question.

Table 7. Cost analysis for inputs required in traditional shrimp farming

Head	Unit	Unit cost (Tk.)	Cost / decimal (Tk.)
Dyke & canal purpose (initial cost, once in life)	Tk./labour	50	266.67
Dyke & canal purpose (re excavation every year)	Tk. /labour	50	13.33
Fry (hatchery produced P. monodon)	1000	0.5	20
Fry (wild P. monodon)[1]	1000	1.3	1300
Fertilization (phosphate)[2]	Kg	13	600
Total cost in each year			633.33
Total cost once in initial cropping			886.67

The present study tried to explore Socio-economic and environmental impact of shrimp farming through wider area survey. The major causes of rapid unplanned horizontal expansion of shrimp cultivation in the study area are the increased demand and price of shrimp in the international market, higher return in compare to paddy cultivation and low crop yield due to presence of high salinity in soil.

In the study area a large number of large scale shrimp farmer have made quick economic return by producing and trading shrimp. But most of the middle and small farmers and the landless day labours have lost their economic base due to shrimp culture. These classes of people live on hand to mouth over the year, being associated with agriculture, household servant and other works. As agricultural land is converted to shrimp farming, their income options have become limited and become totally dependent on shrimp farming. On the other hand the fishermen of the concerned areas cannot catch fish because of the restriction of fishing areas and also the crisis of various fishes in the water bodies of that area. Shrimp

[1] Surveyed ghers not stocked wild fry but here added for perception.
[2] Varied from one to another, some one uses fertilizer and some not.

culture has also taken away their right of access to open water bodies. Thus, social environment is becoming unstable leading to increase social unrest.

However, the impact of shrimp culture on income distribution and employment generation may not be negative, as it appears to be. Although shrimp farming itself is less labor intensive than rice cultivation, the overall labor requirement centering shrimp production and processing is likely to be higher (Islam, 2003). The emergence of commercial shrimp farming and related activities has also opened up new dimension for the woman folk whose activities were earlier confined to household duties. Karim and Aftabuzzaman (1995) reported that women representation in the shrimp depot and processing plant were 73 and 65 percent respectively.

Saline water logging continuously for long time in shrimp farms resulted in salinization, scarcity of freshwater and destruction of various freshwater species. The soil characteristics of the study area deteriorated substantially due to gradual accumulation of salt deposits over the years (Rahman, et al. 1992). Once the soil became saline, subsequent monsoon rainfalls can not leach out salt completely. There always remains residual soil salinity, which increases with time. The progressive accumulation of salt in the soil is now threatening permanent soil fertility in most of the area surveyed during the study. Salinity is the important factor to hamper the growth of crops at germination and early vegetative stages of growth (Shah and Karim, 2001). Vegetable production of the study area is sharply declining due to increase of soil and water salinity.

The present study reveals that with the increase of shrimp cultivation the populations of domestic animals have decreased. The causes may be scarcity of grass, straw, grazing lands, non-availability of pure drinking water.

Fish production in the southwest region has been drastically reduced over the years due to unplanned extensive shrimp cultivation. The recent increase of soil and water salinity has upset natural equilibrium of the delicate ecological balance for the flora and fauna of the study area. If this phenomenon allows continuing, the natural aquatic fish resources would face imminent extinction (Shah and Karim, 2001). The fresh water species, specially the capture fishes face the possibility of extinction due to loss of spawning ground or habitat caused by drying up of river, change in regime and intrusion of saline water, the factors acting individually or in combination with each other.

The shrimp farmers do not follow government rules and regulations. The large influential farmers sometime forcefully take lease of cropland from the poor people. They sometime do not pay the contract money to the poor landowners. This problem does not only create social imbalance but creates ferocious fighting, collision and sometimes murder. Social crimes are also spreading centering shrimp farms.

8 Management initiatives

TROPECA recognized some environmental issues related to the environmental capacity of the system. Issues and necessary steps are mentioned below:

Problem	Necessary step
Sedimentation and Water logging	Flushing rate should be **maximum** at the sluice gate (Present flushing rate 20 - 40% each time) Flushing rate should be **minimum** at the farm level water exchange gate (Present flushing rate 15-66%)
Salinity intrusion	Preparation of compact dyke Net set up (V shaped) (2-p24) at the sluice gate of farm and canal to discard crab and other predators Clean the net every week
Placement of sediment waste	Need to keep on the dyke and compact
Water management conflict	Agreement of small scale farmers and large scale farmers
Formation of small-scale farmer association and negotiation of large and small-scale farmer association is prerequisite to take the above mentioned necessary steps.	

TROPECA identified a crucial problem at the farm level

Events	Specific information	Outcome	Necessary Step
Month	May-June	Abrupt shrimp mortality may reflect exceed of Environmental capacity (possibility of Nitrite spike).	Water depth must maintain from 2.5 ft to 3.5 ft according to temperature. Lime should be stocked to use immediately after rain. At time water exchange (entrance) must be minimum. Use of urea and cow-dung should be avoided at that period. If necessary, at time addition must be very minimum. Use a holding tank/pond to “clean” top water exchange.
Salinity	High (around 15 ppt)		
Temperature	High (around 32-34 ^{C} at day time)		
Pond water depth	less (average 1 feet)		
Rainfall	Sudden		
Disease outbreak period	45-60 days after harvesting		
Grade (maximum Mortality occurred)	44-66		

There are also few routine problems inside the farm:

Problem	Reason	Necessary steps

Water become transparent	Death of plankton Lack of natural feed	Water exchange and fertilization
Water color become white (foamy)	Death of plankton	Water exchange
Water color become red	Access Plankton (bloom)	Water exchange
Water color become Light Green	Access Plankton (bloom)	Water exchange Fertilization and feeding need to stop
Maintenance of water depth from 2.5 ft to 3.5 ft according to temperature reduce the occurrence of the above mentioned problems.		

According to the estimate of nutrient budget, TROPECA identified that major proportion of nutrient comes from fertilization in the system and maximum proportion goes to sediment or in unaccounted form. There are two ways to prepare or maintain a cultivable pond

1. Organic fertilization
2. Inorganic fertilization

1. Organic fertilizer application		
Time of application	Dose (kg/hac)	Primary consideration
1st dose: One or two days after organic and inorganic pesticides application	1000 - 3000	Pond depth need to maintain 10-15 cm
2nd dose: 8th day	200-400	Pond depth need to maintain 30 cm
3rd dose: 14th day	200-400	Pond depth need to maintain 100 cm
4th dose: 21st day	according to secchi disk reading	pond depth need to maintain 100 cm and need to check plankton density by secchi disk
Until shrimp harvest	according to secchi disk reading	pond depth need to maintain 100 cm and need to check plankton density by secchi disk

2. Inorganic fertilizer			
Time/ objective of application	Dose (kg/hac)		Primary consideration
	Type	Amount	
Lablab production at the pond	Urea TSP Potash	30 60 10	Need to apply according to the existing level of lablab on the pond by organic fertilizer
Plankton production	Urea TSP Potash	30 60 10	Need to apply according to the existing level of plankton on the pond
Consistency of plankton on the pond	Urea TSP Potash	30 15 05	According to the existence of plankton on the pond determined by secchi disk.

However, there are some specific management guidelines:

- Large size farms should be divided into small unit (1-5 ha) for convenient management and renovated properly to increase the water depth at an optimum level. Multiple pond depth ranged should be kept to reduce sudden shock.

- The following step may be considered for pond preparation due to wide acceptance by farmers.

  Paddy Harvest→ Canal digging→ Dyke preparation → land ploughing → Liming and Fertilization → Water intake → Fry stocking

- There should have seperate nursing pond with a farm. Ponds that use tob (farm surrounded canal) initially for fry nursing, can also be used for subsequent fry nursing by seperating a part from the tob.
- Single stocking instead of multiple stocking is preferable to avoid disease.
- Alternate shrimp–rice farming could be adopted instead of only shrimp.
- Frequent water exchange should be avoided. Moreover, farm should be filled with river or canal water just after ending high tide or initiating low tide, so that precipitation or settle down of waste could be taken place. If it is possible, a reservoir to allow river or canal water to precipitate for further use is also preferable.
- Farmer may reserve lime to use urgently after heavy rainfall. Dolomite at a rate of 50gm per decimal is recommended which can increase soil pH rapidly.
- Considering the less production and having less to no chance of environmental capacity degradation (as less nutrient load to the wider aquatic system), farm should be provided with adequate fertilizer and feed to increase shrimp production.
- Farm effluent should not discharged into freshwater areas or on to agricultural land.
- Accumulated sediment of ponds need to dig out and can be put into pond dike or low lands to use as earth-fill up.
- A well managed water exchange system should be developed considering the benifit of both small and large scale farmers.
- Develop integrated drainage systems for supply of saline water and drain out water from the farms.
- Small scale farmers may form a association, so that they may avoid information gap, water management problems, marketing complexity and local threats.
- Shrimp culture should be developed under integrated coastal zone management plan.
- Government should develop a convenient way for small-scale farmers to registrar and get training.

9 Management Implications

Small-scale local farmers realized about the formation of association at local level to run the shrimp culture as well as water management in a convenient way. They also realized some of the management drawbacks throughout the involvement of the project and willing to follow the recommended solutions. Involved farmers already familiar with wider area's farmer level indicators considered as threat to the shrimp culture.

Formation of cooperative association for small-scale farmers, as like as large scale farmer association, should be done additionally. So that they may avoid information gap, water management problems, marketing complexity and local threats. Community based cooperative associations may follow the existing polder management program of Fourth Fisheries project (FFP) and LGED based water management program to pave the way of implication.

Small-scale farmers are not interested to registrar. Government should develop a convenient way for small-scale farmers to registrar and get training.

10 Dissemination:

Since local farmers and, local NGO local involved with the project from the very beginning. So, results and information has already disseminated to the selected local farmers and local NGO. Local Fisheries department officials and other stakeholder also informed about the progress of the project due to the subsequent workshop held on the study area. Results of the project were also presented on a seminar "Demand led Fisheries Research – Present perspective" held at Khulna University, Bangladesh dated 13th October 2004. A presentation was made at the 7th Asian Fisheries Forum held on 29th November to 4th December 2004 at Malaysia. Estimation of environmental standards for Bangladesh was pointed out at the forum. Experiences of the TROPECA project was also addressed at the International workshop "Policy issues for sustainable shrimp farming in Asia" Organized by Policy Research for Shrimp farming in Asia (PORESSFA project) [www.port.ac.uk/departments/economics/cemare/project_poressfa.htm] dated 13-14th December 2004 in Dhaka, Bangladesh.

A regional and national level workshop will be appreciable and be effective to disseminate the results at the policy maker level. Demonstration and environmental management leaflet will be effective to disseminate the results at the farmer level. Article submission at the Newsletter such as Aquaculture in Asia, NACA may provide international focus of the project results.

11 CONCLUSIONS

Sustainable aquaculture development can bring real and lasting benefits to rural and coastal communities. But the environmental consequences of inappropriate or excessive development will adversely impact on the wider communities and the farmers themselves through poor farm performance or failure. There is therefore an increasing need for planning and management of aquaculture in our countries. Environmental capacity is being used in some progressive developed countries to inform the management of aquaculture as it provides a more objective basis on which to plan and regulate aquaculture operations, recognising the cumulative impacts of resource users and the assimilative capacity of the environment. The present study has investigated the potential to apply the environmental capacity concept to aquaculture.

Results of the present study suggest that the present level of culture practice no longer risk of exceeding environmental capacity. The water quality in shrimp ponds and aquatic system during culture cycle in this experiment was also in acceptable range. Elevation of nutrient (TN and TP) concentration for shrimp farming is reasonable and the aquatic environment is able to accommodate the present level of aquaculture practice. In case of more extensive shrimp systems the study has highlighted the dominance of rice agriculture in the local nutrient budget, and potential for exploiting these nutrients in aquaculture – rather than suffering adverse consequences. According to the study, nutrient input in terms of feed is significantly lower that results the low aquaculture production. Considering the less production and having less to no chance of environmental capacity degradation (as less nutrient load to the wider aquatic system), farm should be provided with adequate fertiliser and feed to increase shrimp production.

But, the assimilative power of aquatic environment may be a potential of being degraded with unplanned intensification of shrimp culture areas. On the other hand, salinity intrusion problem of soil is affecting the paddy cultivators and other home yard activities. Additionally, existing water management system influences the sedimentation and water logging problem as well as deprives small-scale farmers. Initiation of a community-based management, training programs and dissemination of short advisory leaflets may create a room to overwhelm those environmental problems.

Comment: Page: 1
This is not really an environmental capacity issue – is it linked to intensification in any way?
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TROPECA

Case study for Dosun, Northern Vietnam

Tropeca Case Study 2

This paper is available in Vietnamese

By Vu Dung and Nguyen Thi Thu Hien
Email: thuhien_1977@yahoo.com

Centre for Brackish Water Fisheries Research
Research Institute for Aquaculture No.1
Dosun, Haiphong, Vietnam

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Contents

1 Introduction

Where environmental capacity is exceeded problems in terms of disease and poor performance arise. The need to control the use of potential aquaculture sites to stay within environmental capacity has resource allocation and access implications.

The project team reviewed existing and potential approaches to estimating environmental capacity and developing associated environmental management systems. The application of assessment and management techniques to a range of tropical aquaculture systems in Bangladesh and Vietnam that are likely to see increased pressure from future aquaculture development have been explored. This phase of the work involved a number of case studies in Vietnam and Bangladesh.

Practical guidelines for planners and aquatic sector professional in tropical developing countries have been be developed, based on the lessons learned from the project case studies and reviews of international experience. It is hoped that these guidelines, will help to increase the sustainability of aquaculture development in these countries.

Note that some of the data and analysis in this report has been superseded by analysis feeding into the final project technical report.

Status of aquaculture in North of Vietnam

Current culture techniques: Poor investment with 99% improved-extensive culture. Poor culture techniques.
Quality of feed: Most of feed are low-quality home made feed: fresh bivalves, trash fish ...
Origin of Juvenile shrimp: Middle part of Vietnam (65%), China (30%), in house production (5%) with price: 35-40 VND/1 Ind.
Quality of seed: China- originated juvenile is not as good, therefore, farmers prefer in-country made seedlings. However, it is not easy to distinguish between the two.

Table 1.1a: Coastal aquaculture area in Haiphong 2000 - 2003

Model	**2.000**	**2.001**	**2.002**	**2003**
Semi-intensive and Intensive	1.829,0	2.091,0	2.200,0	2.100
Improved-extensive + Extensive	7.394,5	8.629,0	8.620,0	8.800
Total area (ha)	9.223,5	10.720,0	10.820,0	10.900,0

(Source: Haiphong Fisheries Depart's report, 2003

Table 1.1b.Shirmp culture model and its production in Haiphong

Culture model	Year 2000			Year 2001			Year 2002		
	Area (ha)	**Yield (ton/ha)**	**Prod. (ton)**	**Area (ha)**	**Yield (ton/ha)**	**Prod. (ton)**	**Area (ha)**	**Yield (ton/ha)**	**Prod. (ton)**
Extensive	5.459	0,12	655	3.950	0,14	553	4.251	0,12	510,12
Semi-intensive	600	0,34	204	2.091	0,27	556	1.900	0,25	475,0
Intensive	0	0	0	18	0,51	9,18	8	0,60	4,8
Total	**6.059**	**0**	**859**	**6.059**		**1.118**	**6.159**		**990**

Table 1.3: Yield and production in the year 1999 - 2003 in the 1st crop *(excl. fish & seaweed prod.)*

Year	**Yield (Ton/ha)**	**Total produc. (Ton)**
1999	0.50-0.55	381.7
2000	0.45-0.50	312.3
2001	0.15-0.20	104.1
2002	0.15-0.25	133.9
2003	0.20-0.25	173.5
Grandtotal		1.110,4

Function and task of Centre for Brackish Water Fisheries Research (CBWFR).

- To study, experiment and consultation econo-technical studies, complete model technology aquaculture and produce shrimp seed, and seed for fish that has high economic in the North Vietnam.
- Research, monitoring and warning environmental and epidemic disease in the coastal districts of North Vietnam.
- Train farmers and encourage adoption of appropriate technology and improved environmental management.
- Cooperate with international organisations, institutes, universities in order to promote technology and management for sustainable aquaculture.

2 Case study area

Location of study area

A case study was carried out at DoSon – Haiphong, adjacent to the Bachdang estuary with an area of 683 ha located inside a major sea dyke. The farmers here mainly culture shrimp by semi-extensive model. In rainy season, waters fall to sea from headwater with high siltation resulting in accretion and extension of tidal area. These silts have been created sediment soil of muddy sand, sandy mud with small beads grade, and transparency of water is rather low.

Characteristics of climate

Wind regimes

There are two wind seasons: From September to April northeast wind is dominant, and from May to August is southwest wind is dominant. The northeast monsoon is associated with cold climate and low sea temperatures. The southwest wind blows over the continent, and is typically hot and rainy.

Rainy regimes

In terms of rainfall there are also two clear seasons: dry season from October to April, wth low rainfall (average is 30-70mm); rainy season from May to the end of October, with total rainfall above 1500mm, and average 300-350mm.

Tidal regime

Tide mode in Hai Phong - Thai Binh coastal research is regular frequencies of daily tides. Most days in month have single daily tides).

General characteristic of aquaculture

Close to Dosun town is a large area which has been under aquaculture for many years. Collective or group management is coordinated by Do Son aquaculture service Enterprise and Kien Thuy aquaculture Enterprise.

Figure 2.1a. Map of study areas - TROPECA in Doson - Vietnam

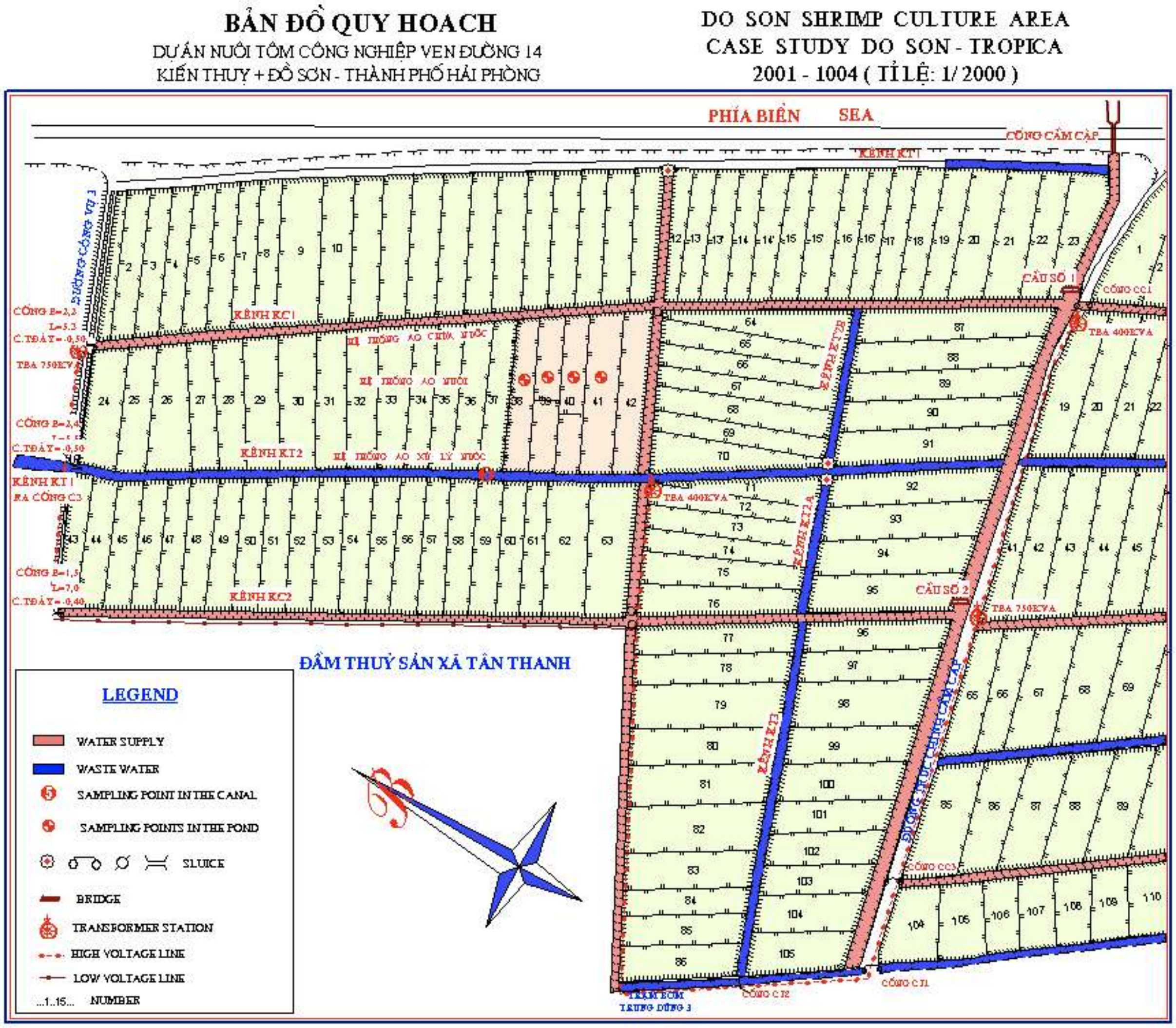


Figure 2.1b: Characteristic of canal system and cultured ponds in Doson -Vietnam

Culture area

Total area of collected aquaculture is 683ha with 574 culture ponds. They belong to 574 households with average area of each pond typically in the range 0.8-1.4ha. They are divided into 3 parts of different characteristic:

- **Part 1:** They border on sea dike with area of 230ha. Pond depth 1.2 – 2m, sediment is muddy sand, and many roots of *aegiceras* (mangrove). Such big depth is not only by slope of tidal zone but also dike.
- **Part 2:** This is the middle of part with area of 230ha and average depth of water level is 0.8 –1.2 m. Sediment is muddy sand and low organic matter.
- **Part 3:** They border on line of traffic with total area is 220ha, high bottom pond, low water level of 0.5 –0.8m. Their poor condition is due to the changing from agriculture to aquaculture.

3 Methodology

The immediate problem in the case study area is disease. Its relationship or otherwise with environmental quality and management is less well understood by all stakeholders. The current focus of the case study Doson is pond management to improve water quality and thereby increase carrying capacity.

The research is designed to facilitate awareness and knowledge of water quality and pathogen occurrence within the canals, and their relationship with individual farmer behavior and practice. This knowledge and awareness in turn should underpin management/communication initiatives which lead to improved environmental management of the water resource more generally-such as farmer agreements to certain practices: or farmer support for higher level infrastructure initiative (canal design, reservoirs etc).

Research elements

1. Detailed mapping of water supply/effluent system, including initial rough estimates of water flow/exchange/dynamic at critical points; impact of pond water exchange on these characteristic; sink and sediment issues
2. Survey and characterise nutrient budget in ponds and canals in the project area. Recruit volunteer farmer to form groups of farmers to join in research on environment management, and to collect practical data on management and activities, so that lead farmers can improve environmental management effectively through by discussing with each other, with RIA1's scientists, and with officer of local fishery extension.
3. Workshop with farmer to present these findings and discuss disease and water quality issues.

Key questions to be addressed in discussions, meetings and workshops:

- Where is the disease coming from?
- What are the key indicator of water soil quality readily available to farmer?
- Can any of these indicators - used in relation to supply water or pond water - also be relate to disease incidence?
- Is supply water quality a major issue?
- What are the major influences affecting the quality of the water and disease incidence in the canals?
- How can water quality and disease incidence in supply canals be improved?
- How does the increased use of chemical affect water quality, natural productivity and assimilation, antibiotic resistance, profitability, etc?

4. Estimate levels and dynamics of nutrient concentrations in water source, water in canal, at sluice gate, and inside pond in semi-extensive in shrimp culture through water and sediment sampling and analysis, including total phosphorus, total nitrogen, BOD.
5. To establish environmental capacity model with nutrient budget, flushing rate/nutrient exchange with wider environment and dispersion and dilution.
6. Water samples were collected at different states of the tide. Sample were collected about 08:00 - 09:00 at the morning (end tide) and 17:00 - 18:00 (flood tide).

Analytical methods

Parameters monitored included:
temperature , pH, DO (mgl^{-1}), Nitrate (N -NO3) (mgl^{-1}), Nitrite (N -NO2) (mgl^{-1}), BOD (mgl^{-1}) total Nitrogen (TN) (mgl^{-1}), Total phosphorus (TP) (mgl^{-1}) .

Temperature, salinity, dissolved oxygen and pH measured with quality meter.

Nitrate (N -NO3) (mgl^{-1}), Nitrite (N -NO2), total Nitrogen (TN), Total phosphorus (TP) water sample were taken from inside ponds, source and canal. Sample preserved with concentration H_2SO_4 1ml with 500ml sample in PVC plastic bottles and placed in ice then transported to the lab for analyses.

The parameter N -NO2 were determine Griess method, N -NO3 - cadimi column method, P-PO4 - molybdate complex. TN determine Keldalh, TP determine acid ascorbic - molybdate complex. All of them direct is reading spectrophotometer HITACH 2100.

4 Disease and disease management

The major concern of farmers in the area is disease.

Establishment of ponds

Early in 1996 a system of ponds was built by Hai Phong people committee, Kien Thuy aquaculture enterprise, Do Son aquaculture service enterprise. After they improved and operated the system, workers in these enterprise joined action of aquaculture and paid taxes annually to their organization.

The main species cultured are tiger shrimp, *Penaeus monodon*, and crab, *Scylla*

Culture methods

Seed

Demand for black tiger shrimp seed in Northern Provinces is rather high but local supply is limited, so most seed are imported from central Vietnam and China.

Culture method and productivity:

Extensive and improved extensive culture is dominant and semi intensive gain small area with 0.1% of total. Productivity fluctuates from 300-1000kg/ha/crop. Some other places, mainly pilot case or model of sampling production, have achieved 3000-4000kg/ha/crop.

Food

Shrimp food is of 3 kinds

1. **Natural food:** phytoplankton, zoobenthos and detritus in pond; they depend on nutrient level of each pond and tidal source. Natural food is only significant with extensive and advance extensive culture
2. **Live food/trash fish:** include shrimp, trash fish, fiddler crab, bivalves, etc. These food are easy to seek and develop rapidly, shrimp are interested them much. However, supply is inadequate and unpredictable and large quantitiesl cause pollution and may bring pathogens into ponds.
3. **Artificial food:** pelleted industrial feed, convenient and easy to use but its quality variable. Pellet feed has been popular in all northern provinces for example: Hai Van and KP 90 (§a Nang); CP (Thai lan) and Ha Long (Hai Phong) and some other foods of Taiwan (Grobest), China, etc.

Equipment:

Most farmers are culturing with low productivity, and do not use paddle wheel aeration. When seepage through the pond dyke is excessive, they regularly use oblique axle axis pump to maintain pond depth.

Disease treatment

Chemicals added to the water, pro-biotics, and specific medicines are used to manage disease throughout the shrimp culture area.

Cropping cycle

Stocking normally takes place in March/April with growout through to September/October. This time is rainy season with high temperature; it is good for black tiger shrimp growth but heavy rain causes decreased and/or variable salinity, and pollution may be associated with run-off from other activities into the rivers and supply water. Therefore, environmental management to reduce disease is very necessary.

Problem of disease and environment.

A workshop organized in the end of 2003 addressed "*Environmental-disease management in area of collected shrimp culture*" with target of assessing status and opportunities for environmental management. Disease at farm level and local level, and development of a suitable production and management model based on the result of Tropeca in 2003-2004 were discussed. Participants included farmers in research area, experts and aquaculture researchers in northern area of Viet Nam.

The result of workshop assessed in particular the following issues:

Disease appeared in 3 ways:

1. White spot disease appeared in shrimp seed from local sources
2. **Poor quality seed** were imported from the Central provinces and from China. In 2001-2002, many seed consignments imported from different sources were checked and showed that shrimp seed imported into northern provinces in stage of P_{10} - P_{13} , 0,8-1.4 long, 0.019-0.021 weight/a was infected luminous disease, MBV, WSBV. 31 specimens of seed shrimp in P_{15} imported from Central Provinces and from China were checked and result are shown in Table 1.
3. **Water Environment**: According to the result of Vu Dung, Tran The Muu, research work 2002, after pathogen appeared in water sources, it developed and spread very rapidly throughout the area of culture ponds.

Although percent of disease infection is lower than previous years, it caused serious damage, in some cases resulting in complete crop loss in many farm in Ha Tinh, Nghe An and so on.

Factors associated with disease development

- After early rain or rainy months.
- High stocking density
- Narrow ponds
- Poor quality of food or fresh food.
- Have no contain pond and paddle wheel.
- Algae die a lot in bottom pond.
- Import uncontrolled shrimp.
- Culture area without planning.

Quality of supply water

The main difficulties for shrimp culture in northern Vietnam are temperature and salinity. In winter, high salinity and low temperature, and in summer the reverse - rain and storm, so they are not good for black tiger shrimp.

The research area is affected by many external factors from the estuary such as decreased salinity, sweetener of supply water, high turbidity in rainy season (July, August). Shrimp in the final stage of culture cycle require high level of water exchange, and this exacerbates the problems of environmental management.

The lower section area of Lach Tray, Van Uc river system are affected by domestic, agricultural and industrial waste. Moreover, dumping ground of City lies adjacent to river shore; waste is released to the river, which has a big affect to quality of water (Showed in "Quality of supply water" in appendix).

Supply - Waste system

Because the water is loaded with silt, sediment deposition is substantial rapidly reducing depth of supply and waste water systems with problems arising after only one or two crops. Gaining adequate supply water and effective discharge of waste becomes problematic.

When disease occurs in pond, it spreads rapidly because of seepage through banks and dykes (related to poor quality of soil, limited grant and inadequate annual maintenance). On the other hand, culture ponds have not treated pathogen before discharging into environment.

The use of chemicals and antibiotic has not only failed but also leaves residues in soil, water and shrimp flesh.

- Resistant bacterial strains arise after using antibiotic and reduced effective of treatment.
- Using chemical also destroys environment, sediment becomes hard, some links in cycle of matter transformation like Chlorine, $CuSO_4$, etc.

Upgrade quality of supply water

1. Install pre-treatment pond for whole culture area to clean water, eliminate suspended matter in pond and diminish pathogen in supply water.
2. Upgrade and maintain pond dykes in order to avoid seepage and limit disease transmission
3. Remove accumulated sediments from supply and waste canals annually in order to enhance water quality and water exchange opportunities.

Manage environment.

Management of shrimp culture environment is very important in order to diminish risk and improve production. Although farmers were equipped with knowledge of aquaculture, they still meet many difficulties in culture of shrimp and fish.

Farmers lack of equipment of checking quality water. However, they regularly assess water quality based on their experience using mainly water coloration and shrimp activity, though written records are rare.

Scientific knowledge presented in simple practical terms relating to species characteristics and water quality management is greatly appreciated by the farmers.

Conclusion

- Coastal water in Do Son shrimp culture area is being polluted by industrial waste, agriculture waste and domestic waste. On the other hand, mangrove forests are being reduced annually by shrimp culture ponds, affecting the natural bio-filtering system.
- Sediments are accumulating in canal-pond system; pathogens are latent throughout and treatment is ineffective;
- There is widespread interest and the will to improve conditions and thereby production amongst farmers, managers and experts, etc.

5 Environment capacity models

Water exchange

Total area shrimp culture about 638 ha. 40% (262.6 ha) of the area is allocated to culture shrimp, and 60%(393.96 ha) for the culture shrimp and crab. Canal system occupies about 26.4 ha area. Main water canal has length 6 km, width 30m, depth 2m. Canal supply water for ponds culture has length 3 km, width 4 m, depth 1.7 m; in some places depth is only 0.3m. Total area of canals about 26.4 ha.

Supply water source is from tidal zone through national dike in two supply gates or drains; they are Thuy Giang No1 drain and Cam Cap No2 drain. Do Son drain is waste water one. There are 3 main supply drains with total length of 6km and 7 branch supply drains leading to culture pond with total length of 21km. Beside, there are 2 main supply drain and 1 waste one.

At Doson the tidal range varies over the month with 2 peaks per month. The highest range is 3.5 - 3.8m, the lowest is 0.7 - 0.8m. Water in canal has depth about 1.7m. Thus, water exchange depth 1,4m. Water exchange volume is roughly 8,870,400m3, flushing rate 153% per year.

Ponds only culture shrimp *P.monodon* has flushing rate averaging 21% per month. The water exchange volume 13,007m^3 per ha per year. Ponds culture shrimp and crab have flushing rate averaging 14.5% water exchange volume for 1 ha lµ 11,571m^3 per year.

Main supply water system:

There are 3 supply water canals with total length of 6000m.

Table 5.1: Canal system

Component	Amount	Length (m)	Width (m)	Area (ha)
Main supply water ditch	03	2000	30	18
Supply water ditch into pond	07	3000	4	8,4
Total				**26,4**

Drain water from tidal zone in Lach Tray estuary through 2 supply canals, they are Thuy Giang-supply drain No1 and Cam Cap-supply drain No2. Thank to 2 main supply canals, water is lead into culture pond through 7 subsidiary canals.

Main supply canals

- 3 canals
- Length: 2000m
- Width (average): 30m
- Total area: 180.000m^2

Subsidiary canals:

- 7 canals
- Length: 3000m
- Width (average): 4m
- Total area: 840.000m^2

Water exchange

- Height of water in supply water ditch
  - High littoral: 1.7m
  - Low littoral: 0.3m
- Level of changing: 1.4m
- Number of time changing water in month: 02 times.

Water in culture pond is discharged into Do Son waste according to waste system. Monthly water amount depend on tide, it changes 2 times/month with ratio of 15 - 21%

4.2. Mass balance (nutrient budget)

***P.monodon* pond**

Size average of shrimp ponds is 0.88ha, depth average of 0.91m. Pond preparation began in February to March. Bottom of pond dry about two weeks under the sunshine. Organic fertilizers (manure) is most of commonly used in order to generate appropriate color water (and therefore food for seed). Information showed table 4.2a.

Water is introduced to the pond one week after fertilization. Shrimp fry (P20 - 20days postlarvae) are collected from nurseries in Haiphong and DaNang (Vietnam) transferred to rearing ponds.

Main species is tiger shrimp (*Penaeus monodon*) but a number of the other shrimp and finfish found their way to the ponds during tidal inflow of water.

Shrimp culture techniques were evaluated from degree of management applied throughout the production cycle from the initial stage of pond preparation to haversting of shrimp.

Table 5.2a: Generalize scenario of management regimens in selected shrimp *P.monodon* ponds

Issues	Unit	Application
Area	ha	262.6
Pond size	ha	0.88
Pond dikes		Stable and well-maintained
Water control	%	Tidal exchange (20% per month)
Depth	m	0.91
Source of fry (Major)		Danang - Vietnam
Stocking density	ind/m2	12.2
Rearing period	month	4.63
Crop/year	crop	1.3 (March - August)
Feed used (KP and Win)	kg	165.22
Trashfish	kg	0
Fertilizers - Ure - NPK	$kg\ ha^{-1}\ year^{-1}$	 39.34 88.92

Fertilizer (Manure)	kg ha^{-1} $year^{-1}$	221.28
Aeration		No aeration
Survival rate	%	10-15
Lime used	(kg $ha^{-1}year^{-1}$)	1081.78

P.monodon and crab ponds

Size average of shrimp ponds is 1.43ha, depth average of 0.78m. Pond preparation began in February to March. Bottom of pond dry about two weeks under the sunshine. The most of commonly use organic fertilizers (manure) in order to make color water.

Water introduced to pond one week after fertilization. Shrimp fry (P20 - 20 days postlarvae) are collected from nursery in Haiphong and DaNang (Vietnam) transferred to rearing ponds and stocked in the ponds one week after stocking with seed of *P.monodon*. Seed crab are stocked when shrimp about 3 months old. The production parameter and other standard assumptions show in table 4.2b.

Main species is tiger shrimp *(Penaeus monodon)* and Crab but a number of fish found their way to the ponds during tidal inflow of water.

Table 5.2b. Production parameter and other standard assumption in P.monodon and Crab

Issues	**Unit**	**Application**
Area	ha	393.96
Pond size	ha	1.43
Pond dikes		Stable and well-maintained
Water control	%	Tidal exchange (20% per month)
Depth	m	0.78
Source of fry (Major)		Danang - Vietnam
Stocking density of shrimp	ind/m2	6.26
Rearing period	month	4.36
Crop/year	crop	1.3 for shrimp (March - December) and 1.03 for crab
Feed used (CP and Win)	kg	165.22
Trashfish	kg	0
Fertilizers - Ure - NPK	kg ha^{-1} $year^{-1}$	 39.34 88.92
Fertilizer (Manure)	kg ha^{-1} $year^{-1}$	221.28
Aeration		No aeration
Survival rate	%	10-15
Lime used	(kg $ha^{-1}year^{-1}$)	1081.78

The inflow of nutrients to Doson area culture is defined as the sum of nutrients in all food supply for species culture consumption, nutrients in fertilizer (Ure, NPK, Manure), its used order to growth of algae, seed, water supply and rain fall, run off.

The outflow of nutrient from Doson area culture is more difficult to estimate than inflow. It include product (shrimp, crab, fish, seaweed, et.), accumulation in sediment, waste water, atmospheric deposition.

In the balance for study area, this definition implies that total nutrients inflow minus total nutrient outflow.

Table 5.3: Nutrient content of inputs and outputs

Nitrogen (N) content shrimp	%	2.89
Phosphorus (P) content shrimp	%	0.28
N content feed	%	6.4
P content feed	%	1.7
N content trashfish	%	2.72
P content trashfish	%	0.5
N content Snail	%	2.4
P content Snail	%	0.3
N content Fertilizer	%	16
P content Fertilizer	%	16
N content ure	%	45

Table 5.4 Calculation of nutrient input and out put for two type culture (*P.monodon* ponds and *P.monodon* and crab ponds)

1. P. monodon			
	type	**kg N /ha/ year**	**kg P /ha/ year**
Inputs			
Feed	Winer		
	CP	10.00	1.56
	trashfish	0.00	0.00
Fertilizer	URE	17.70	
	NPK	14.23	7.44
	manure	3.01	1.08
Seed		0.02	0.004
Water supply		0.17	0.06
Rainfall		0.004	0.00
Run off		0.00	0.00
Total inputs per year		45.14	10.44
Outputs			
Shrimp	Harvested	6.14	0.72
	Mortalities	3.42	0.52
Fish	Harvested	2.54	0.24
	Mortalities	0.67	0.07

Seaweed	Harvested	6.03	0.57
Plantlife	Weed		0.00
Animals	Jellyfish		0.00
	Snail		0.00
Water	Waste water	0.22	0.79
	Harvest drainage	3.00	0.40
	Denitrification	3.00	0.00
Sink in sediment		4.77	1.82
Total outputs per year		*29.79*	*3.50*
2. P. Monodon and crab pond			
Inputs	type	kg N /ha/ year	kg P /ha/ year
Feed	Winer	0.00	0.00
	KP	16.13	2.52
	trashfish	0.00	0.00
	Snail	9.25	1.16
Fertilizer	NPK	26.57	14.45
	manure	1.96	0.70
	Ure		0.00
Seed		0.01	0.00
Water supply		0.19	0.01
Rainfall		0.00	0.00
Run off		0.00	0.00
		0.00	0.00
Total inputs per year		*54.12*	*18.84*
Outputs			
Shrimp	harvested	4.97	0.75
	mortalities	1.45	0.22
Crab	harvested	2.30	0.35
	mortalities	0.00	0.00
Fish	harvested	3.29	0.31
	mortalities	0.00	0.00
Seaweed	harvested	5.04	0.55
Plantlife	weed	0.00	0.00
Animals	jellyfish	0.00	0.00
	snail	0.00	0.00
Water	waste water	0.23	0.09
	harvest drainage	3.00	0.40
	denitrification	3.00	0.00
Stays in sediment		4.77	1.82

Total outputs per ha per year	*28.05*	*4.474*
Balance (inputs - outputs)	*26.06*	*12.55*

Calculation for total area culture

P.monodon pond culture is 40% area and *P.monodon* and crab pond culture is 60%. When we calculate nutrient for total area Doson is 40% of *P.monodon* pond multi 60% *P.monodon* and crab pond. Nutrient only calculated with Nitrogen and Phosphorus. Mass nutrient of inflows and outflows for overall Doson area culture as below:

Nutrient input:

1. Calculate mass food supply to system	**kg.ha^{-1}.year^{-1}**
Food	213.65
Fertilizer	
Ure	18.17
NPK	135.22
Manure	174.83
2. Calculate nutrient input system	
Nitrogen	50.53
Phosphorus	15.48

Nutrient out put:

3. Calculate production (harvest + mortalities)	**kg.ha^{-1}.year^{-1}**
Shrimp	239.17
Fish	102.9
Crab	69.1
Seaweed	147.04
4. Calculate nutrient in production and other out put of system	**kg.ha^{-1}.year^{-1}**
Nitrogen	29.94
Phosphorus	5.15

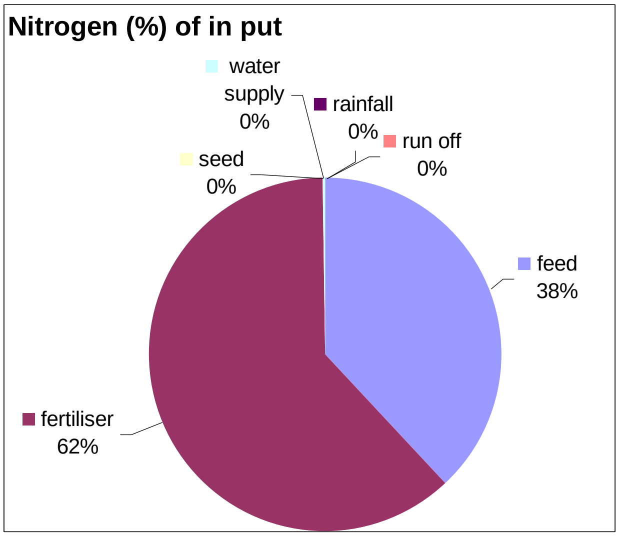
Mass balance:

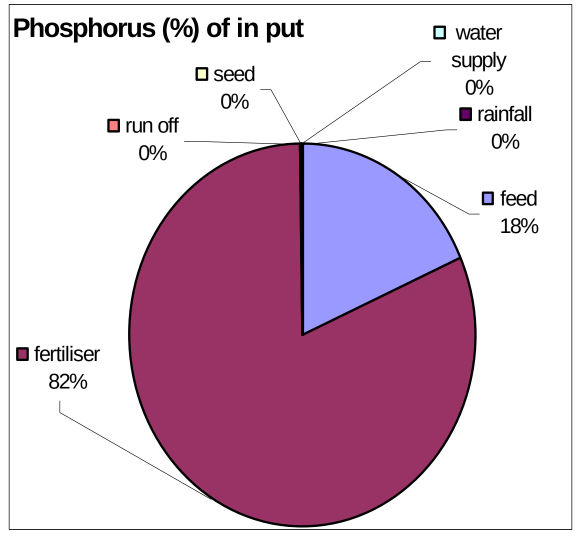
5. Balance of nutrient in system	**kg.ha^{-1}.year^{-1}**
Nitrogen	20.58
Phosphorus	10.33
6. Estimate nutrient waste to environment of Doson area	**tones.year^{-1}**
Nitrogen	13.52
Phosphorus	6.78

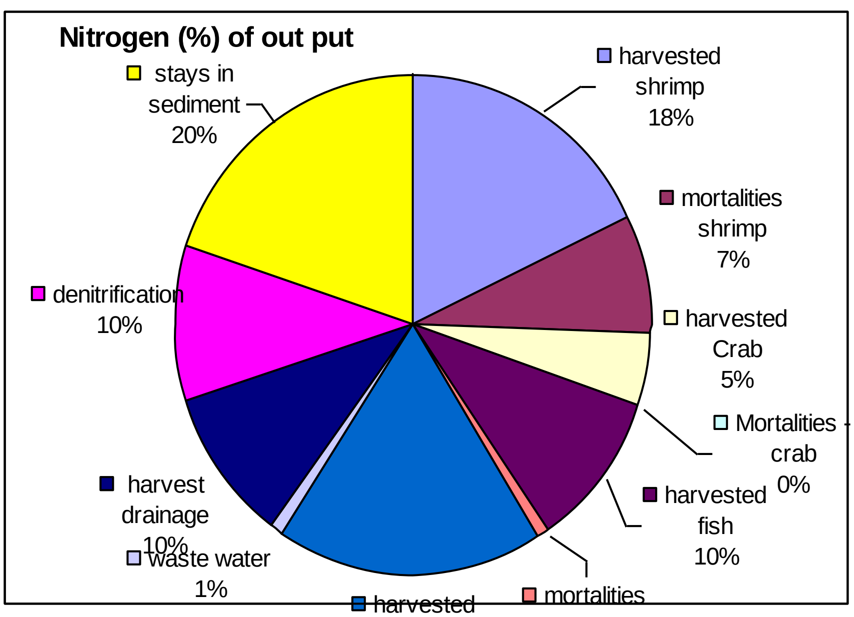
For more detail and data of inflows and outflows see appendix II

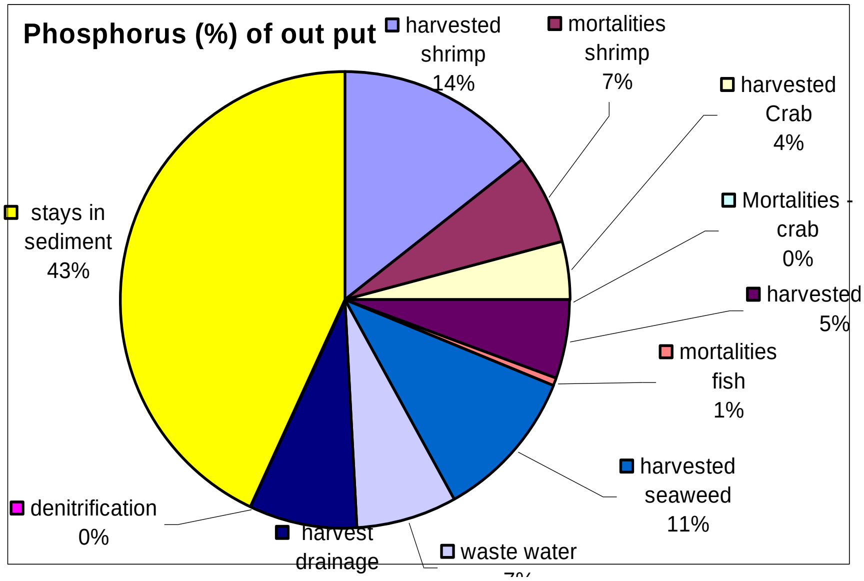
Major nutrient input is food and fertilizer. N in food about 38.06% and P is 18.28%. N in fertilizer is 61.55% and P is 81.53%. Inflows and outflows of system show by pie chart below (further reading appendix)

Figure 5.1a. Nitrogen and Phosphorus of inflow at Doson area culture, Vietnam









Picture 5.1b. Nitrogen and Phosphorus of outflow at Doson area culture - Vietnam

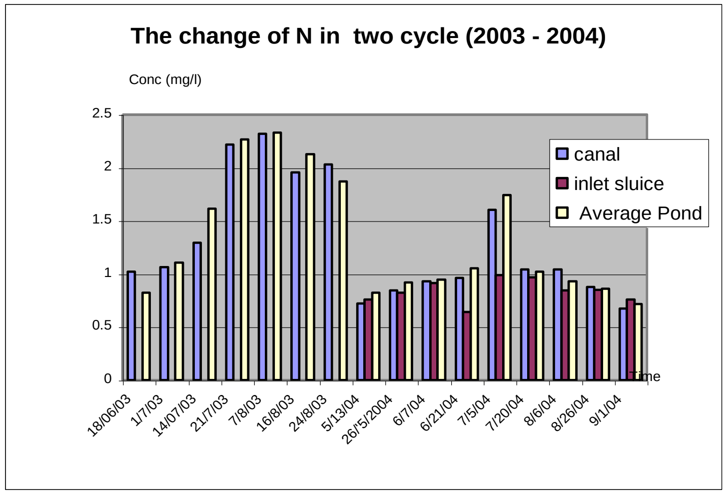
A large amount of nutrients and chemicals are contributed to environment from pond aquaculture, which varies according to culture intensity, level of chemical use and species cultured. Dissolved material from farm effluent are mixed with the water column where as, *largest proportion of solid wastes accumulated in the pond bottom or in the immediate vicinity of the farm*. Higher amount and proportion of discharged nitrogen remain in water in compare to phosphorus, most of which accumulated into the sediment.

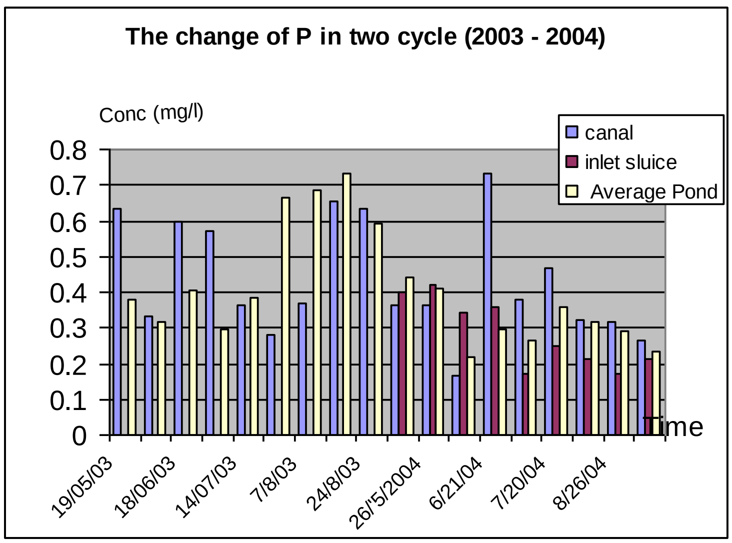
Nutrient dynamics

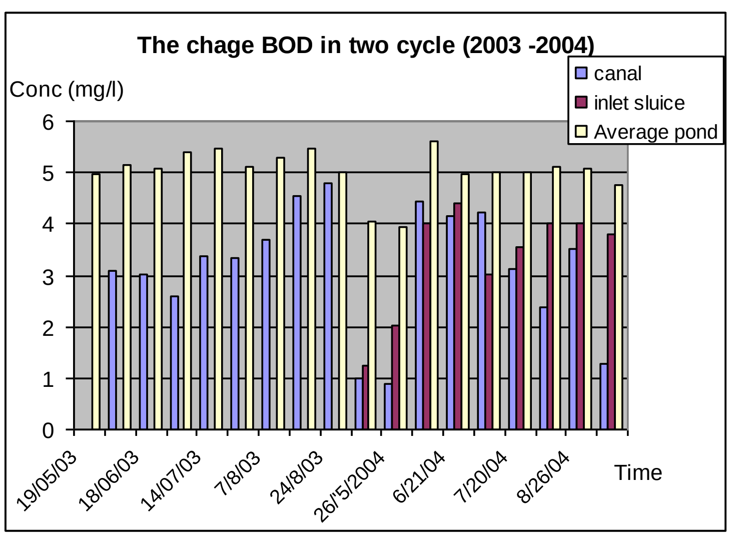
The trend of nutrient in system change from water supply, in ponds to wastes water. Nutrient concentration increases at middle the crop cycle, as the rate of growth and increase in mass is high, so farmers add more food and fertilizer. However, excretion rate of shrimp increases also Nutrient concentration tend to reduce at end of the crop. This change show with diagram below (picture 4.3). Nutrient concentration of system change but not exceed standard (Vietnamese Environment Quality Standard for water Aquaculture for BOD is 10mg/l, N is 4mg/l and P is 2mg/l).

In 2003, canal supply water system same wastes water, too. In 2004 the local authority set up new canal system with separate canal for supply water and waste water canal but the system not complete yet. Some of the pond use this new canal system but other ponds have to use old canal.

Figure 5.2. The change of nutrient in system aquaculture DoSon – Vietnam







Calculate the elevation of nutrient concentration (C = N/FU)

C is the elevation of concentration caused by pond culture shrimp (any other source of nutrient input). N is the rate of nutrient input. F is flushing rate and U is water volume exchange.

We calculate for 656 ha pond culture at Doson. The flushing rate is 0.722. Water volume exchange estimate as 5,818,179m^3. The rate of nutrient input estimate as 15.48 kgP per ha and 50.53 kgN per ha. C calculated equal 0.004 gP/m^3 and the overload estimate as -0.165 gP/m^3, nutrient concentration equal 0.012 gN/m3 (0.12mg/l) and the overload estimate -0.324 gN/m3.

6 Indicators

Water & Sediment Sampling

Basic parameter showed table 5.1.

Table 6.1: Basic parameter of environment in pond Doson - Vietnam

Parameter	Temperature (^oC)	Salinity (‰)	pH	DO (mg/l)
Pond 1	30,8 29.0 - 31.60	14,2 8.3 - 19.5	8,39 8.05 - 8.58	6,21 5.54 - 7.50
Pond 2	31,3 30.2 - 31.7	14,5 9.0 - 20.0	8,31 7.88 - 8.62	6,11 4.94 - 8.10
Pond 3	31,7 31.2 - 30.6	14,3 8.3 - 20	8,34 8.23 - 8.50	6,22 5.18 - 7.60
Pond 4	31,5 30.9 - 31.9	14,5 8.7 - 20	8,56 7.89 - 8.98	6,64 5.34 - 7.80
Average	***31,3***	***14,3***	***8,40***	***6,30***

Nutrient concentration (total N, total P, BOD) in water at area culture shrimp Doson show below:

Table 6.1b. Total nitrogen concentration (ppm) in study area (Doson -Vietnam)

Place	Location	Average	Min	Max
Doanh pond	sample 1	1.424	0.720	2.420
Doang pond	sample 2	1.439	0.716	2.387
Long pond	sample 4	1.526	0.720	2.556
Quyet pond	sample 5	1.467	0.688	2.427
Outlet sluice	sample 3	1.042	0.736	1.812
Further from inlet	sample 8	1.081	0.684	2.176
Canal	sample 6	1.508	0.672	2.317
Inlet sluice	sample 7	0.839	0.640	1.792

Table 6.1c. Total phosphorus concentration (ppm) in study area (Doson -Vietnam)

Place	Location	Average	Min	Max
Doanh pond	sample 1	0.438	0.199	0.802
Doang pond	sample 2	0.425	0.108	0.802
Long pond	sample 4	0.423	0.108	0.687
Quyet pond	sample 5	0.539	0.128	0.856
Outlet sluice	sample 3	0.380	0.246	0.462
Canal	sample 6	0.489	0.164	0.734
Further from inlet	sample 8	0.346	0.184	0.700
Inlet sluice	sample 7	0.283	0.174	0.420

Table 6.1d. BOD concentration (ppm) in study area (Doson -Vietnam)

Place	Location	Average	Min	Max
Doanh pond	sample 1	3.48	1.60	4.20
Doang pond	sample 2	3.72	1.98	4.92
Long pond	sample 4	4.26	0.40	5.63
Quyet pond	sample 5	4.17	0.75	4.80
Outlet sluice	sample 3	2.91	1.23	4.50
Canal	sample 6	3.34	0.88	4.80
Inlet sluice	sample 7	3.34	1.26	4.02
Further from inlet	sample 8	2.57	0.37	3.45

This is results of sediment concentration (2003, 2004)

Nutrient concentration (%) in sediment at areas culture shrimp Doson			
2003	2004	Min	Max
1 Total Nitrogen			
0.249	0.238	0.201	0.288
2 Total Phosphorus			
0.118	0.091	0.075	0.147
3. BOD			
-	0.459	0.372	0.576

Biological Indicator

In order to assess quality of water environment, beside chemical-physical standard, biological standard can be used or called species indicator.

Pollution of surface water has been assessed by sensitive organisms or species adapted to different water quality conditions.

- Some species are sensitive to levels of nutrient or dissolved oxygen. Nutrient levels can therefore be assessed through presence or absence of these species.

- Other indicator organisms can survive long term in heavy polluted environment. However, they have to stand some detrimental effects, for example decreasing rate of growth, changing spawn ability and changing habit.

Using indicator organism to assess quality of water is simple, quick, practical method. They are ideal for farmers who normally lack water quality testing equipment, and they also offer a better picture of long term conditions. Bio-indicator and multi-biology can be used in more sophisticated assessment of water qualify but requires group of professionals with expertise in ecology and environment monitoring.

Some indicator organisms for water quality assessment are simple, plain and are shown in farmer's handbook:

- Zooplankton and Phytoplankton
- Zoobenthos
- Higher level plants
- Some manifestations of hydro-physicochemical such as color, taste, etc.

Phytoplankton in culture pond

Organism-plankton but mainly phytoplankton is the first and indispensable member of ecological system in water. They play an important in oxygen supply, absorbing nutrient salt, pH stability, reducing transparence and is a part of food of shrimp.

When algae develop in pond, they remove nutrient and reduce toxicity in compound of Nitrogen: NH_3, NO_2 and colorful water.

Algae species occur in pond consist of *Chlorophyta, Bacillariophyta, Pyrophyta* and *Cyanophyta*

Among above algae, *Chlorophyta* is 50 to 80%, Bacillariophyta is 10 to 30%. The rest belong to other algae branch. Moreover, Cyanophyta only occurs under conditions of low salinity – in this case usually in July, August.

Common *Cyanophyta* are *Ceratium furca* (Ehrenberg) *Dujardin, Alexandrium sp*. They will appear when nutrient content is high at the end of culture crop. They poison shrimp – mass mortality of shrimp occurs when *Cyanophyta* die in pond. *Cyanophyta (Microcits* sp, *Anabena*) will be present in pond with low salinity, and water with high organic mater content. When *Cyanophyta* develops rapidly, they discharge poison, make blue water. Fishes die, shrimps show swollen gut, refuse food, develop blue shell, and in some cases die.

A balance needs to be maintained. Too low density of algae will cause high transparency, zoobenthos growing up shocking shrimp. If algae overdevelops, ecological elements in pond will be unstable and high amplitude of fluctuation of day and night.

Relationship between algae density and water coloration, pH changing

Transparency and water coloration are considered as a ecological element in culture pond. In aquaculture, transparency is a simple indicator in order to assess quickly quality of environment. In shrimp culture pond, transparency and water depend on organism-plankton, amount of suspended organic matter and muddy soil from supply water source or from shore flowing into pond after rains

Index of transparency not only show limit of dark or light water but also reflect quantitaties of object contain in it. When algae have not developed or perished, watercolor is light or colorless but after they develop strongly, watercolor or dark, reduced transparency of water. In sunny period, transparence of water depends on amount of organic matter and dissolution of muddy soil.

Data in table 1 shows that transparency reduces gradually over the culture period.
In the third and the fourth month of culture, transparency is too low because of overdevelopment of algae. This is general situation for culture ponds; they are affected directly to fresh source in estuary in flood season.

Table 6.2. Relationship between transparence (Tr) of water and density of plankton (x10^{4a}average/ml) in shrimp culture pond.

Culture month	**I**		**II**		**III**		**IV**	
Quota	Trans	Alga	Trans	Alga	Trans	Alga	Trans	Alga
Shrimp pond	43,3	256	38	375	35	433	32	425
Shrimp-Crab pond	51,3	215	40,3	354	25	625	22	783

Low transparency makes reduced photosynthesis layer in environment. Only 20-30cm of surface water is photosynthesis layer in order to create oxygen in culture pond. Middle and bottom layer are consumption layers. If low transparency status lasts, oxygen source in pond will be exhausted and shrimp health will be affected. Phenomenon of shrimp floating on surface layer, swimming toward shore in the morning indicates serious lack of oxygen.

Development of algae causes fluctuation of pH in culture pond. Relationship of fluctuation between algae and pH degree is shown in figure 6.1.

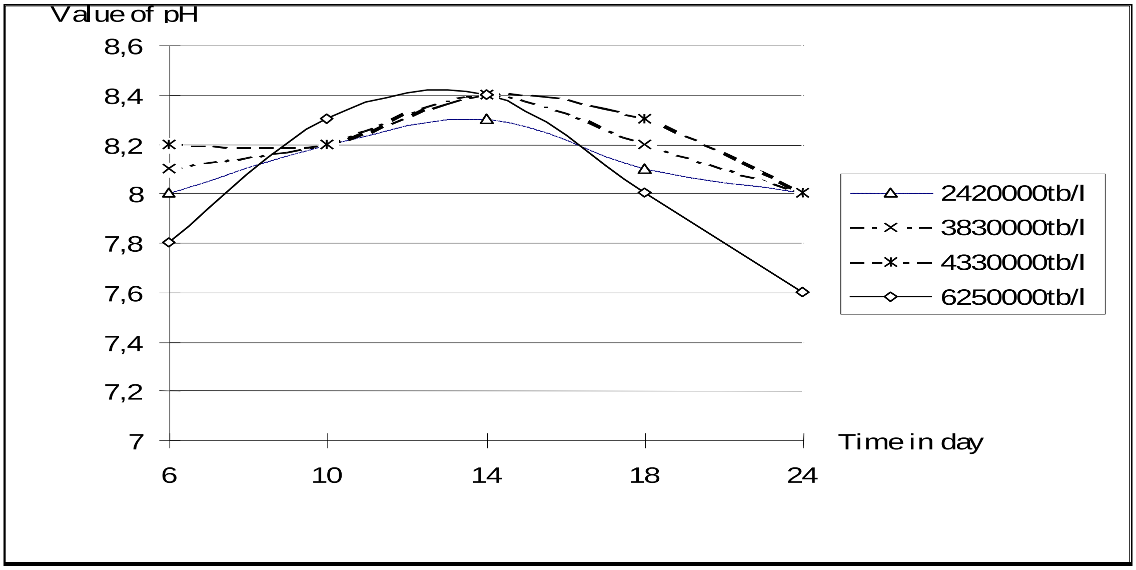


Figure 6.1: Fluctuation of pH following time in day in shrimp culture pond with different algae density.

Figure 6.1 shows that: If culture environment with algae density is 2,420,000, 3,830,000 and 4,330,000 cell/l, amplitude of fluctuation in day will be in narrow space (0.2 degree). If algae density is 6,250,000 cell/l, amplitude of fluctuation of pH will be higher threefold than above algae density (0.4 degree). All the above demonstrate that algae-plankton affects to pH stability in culture pond.

Zooplankton

Zooplankton is an important component in food chain of surface water. White spot disease has recently caused widespread damage in shrimp culture industry and natural crustacean s are suspected to be one of host spreading WSSV virus.

C*opepoda* occupied 50-60% in structure of zooplankton area in tidal zone. After that is *Cladocera* 14 species and other groups such as: *Siphonophora, Chaetongatha, Amphipoda, Tunicata, Ostracoda, etc.* Specific species in tropical tidal zone consist of: *Brachionus plicatilis (Rotatoria), Acetes spp (Sergestidae)*.

Common Protozoa: Zoothamnium, Epistylis, Vorticella, Acineta, Tocophrya, Podophrya, Lagenophrys. They occur when waterbody is polluted by organism, stagnant water, and when they develop strongly, they live as parasite on shrimp and make shrimp develop slowly and die.

Relationship between zooplankton, phytoplankton and quality of water pond:
Beside protozoa, some pest as zooplankton, suitable protozoa maintain balance of ecology of water pond, after that water matter is preeminent, ecology status is shown following formula:

$$\text{Ecological balance in shrimp pond} = \frac{\text{Zooplankton (below protozoa is the same) amount is 1}}{\text{Number of phytoplankton with one billion cell}}$$

Ratio of 1:100 always has arising and altering ability their rule because zooplankton gains initiative and phytoplankton remains passive. If they in that way: increased zooplankton and decreased phytoplankton, water matter will become bad with different rate in 3 periods:

- Before changing bad: zooplankton 1,1 - 1,2 per billion phytoplankton of individual, in this time, zooplankton rather increase but water sample unchanged, pond water still maintain available color.
- Changing bad: zooplankton 3 – 10 per billion phytoplankton has been increasing clearly; watercolor has been changing white due to small zooplankton with white light, dim grey.
- Entire changing bad: zooplankton 0,8 – 1 per 100 phytoplankton. In this time, zooplankton grows up strongly, phytoplankton die massy or watercolor was faded by zooplankton, water change into milky white. Pond is in floated status and shrimp will die after few days.

Zoobenthos

Biological indicator in polluted water-body, zoobenthos is used to define level of pond water pollution. Base on structure of species element, organic density of endemic species to water pollution.

Table 6.3: Structure of zoobenthos element in Kien Thuy - Do Son.

Animal group	Total of species	Shrimp pond	Shrimp, crab pond
Anlenida	(12)		
Polychaeta	12	5	11
Crustacea	(1)		
Amphipoda	1	1	1
Insecta larvae	1	1	1
Mollusca	(1)		
Gastropoda	1		
Total	15	7	13

Among indicator zoobenthos of water matter, 2 organisms shown to be related to quality of water clearly:

Cerithidea cingulata

There are many *Cerithidea cingulata* in culture pond. Especially in ponds with low salinity, sediment of muddy sand, rich in nutrition. When they develop rapidly, they are associated with reduced alkalinity in water, and shrimp will be infected soft shell disease. On the other hand, *Cerithidea cingulata* will compete for food and dissolved oxygen in water.

Fluctuation of oxygen content of culture pond in research area showed that when content of dissolved oxygen decreased of 2mg/l, shrimp began swim on surface but not die and near 100% *Cerithidea cingulata* individual living in bottom layer crawl to water surface and lie scattered around shore. In production, *Cerithidea cingulata* can be used as a indicator species in order to define amount of dissolved oxygen in low threshold of culture pond.

Treatment: Eliminate all *Cerithidea cingulata* in pond before stocking seed, use industrial lime periodically ($CaCO_3$, $MgCO_3$) in order to increase Alkalinity in culture pond.

Polychaeta

They are often present in water-body with high levels of organic enrichment. In early crop, if sediment has high nutrient content, *Polychaeta* will appear. They are good food for black tiger shrimp. It is said that food can be recover shrimp' liver-pancreas when they infected MBV virus. The other said that *Polychaeta* is object of white spot pathogen in shrimp culture, they also recommend *Polychaeta* should be eliminate out of sediment of shrimp culture pond

Animal-plant of high class

Seaweed

In shrimp culture pond,bottom growing seaweed often appears in water-body with high transparency, and micro-algae develop badly. The presence of seaweed causes some difficulties in shrimp culture. It removes nutrients, blocks ability of catching prey of shrimp, and decay will create polluted water-body and make shrimp die.
Some seaweed pest:

- Rong khÐt (..........)present when water in pond is colorless, low salinity; their development rapidly remove all mineral in water and after they perish, they discharge toxic affected badly to shrimp culture. *Treatment*: When they appear in culture pond, take them out of pond and stimulate development of micro-algae to avoid high transparency and light reflect to bottom pond.
- - Rong kim (.....) commonly seen in water-body of sediment with muddy sand, high transparency; they grow up quickly and cover with bottom of pond. Development of Rong kim rapidly will decrease alkalinity in pond, remove mineral, block ability of catching prey of shrimp. When they die, they will create mass waste and make water-body heavy polluted.
- - Rong ®u«i chã (..........) often appears in culture pond with low salinity, lower than 10‰, they develop rapidly, covering pond surface. When they grow up to water surface, the above seaweed layer is perish but the below develops make quality of water become worst
- - Rong nhít (..............) occur mainly in water-body with high transparency, sediment of muddy sand, high content of nutrient salt. When they develop to maximum, they will block catching prey of culture and after die, environment will be degraded rapidly. Main managed measure if water coloration before stocking seed. They should be taken out of pond at the same time of water coloration. Color chemical should be used aim to block radiation of sunlight to bottom culture pond.
- - Rong c©u (*Gracilaria*. sp) In brackish water lagoon, there are many *Gracilaria* in shrimp culture pond. If Gracilaria develop moderately, quality of water always improve. However, with thick density, lack of nutrient, culture lagoon will be polluted.

Invertebrates

Hydromedusa

Commonly found in March, April annually, they penetrate into culture pond through supply water sources. When conditions are suitable (plenty of food) they will grow up and discharge poison checking development of shrimp. If density of jellyfish is too thick, water environment will be polluted rapidly with opaque color, Analysis of viscid degree in the lab showed that environmental index such as NO_2, NH_3 in level higher tenfold than standard of shrimp culture water. When environment is changed jellyfish will die massy, cause polluted environment and shrimp will also die. *Treatment*: Filter water carefully before supplying water into culture pond. When jellyfish appears in pond, they must be moved immediately out of pond. Chemical should not be used to annihilate jellyfish because if they die, environment will pollute quickly.

Wild Crustacea

Wild *Crustaceae* is intermediate host taken white spot disease pathogen into culture pond. They include many species, whereas, common and carried main pathogen species are fiddler and so on. When in culture pond, they not only compete but also spread disease to shrimp

Uca annulipes

Often found in brackish water area. *Uca annulipes* digs hole in pond bank. Their food is organic detritus, Polychaeta, bivalve larva. They belong to *crustaceae*, are object of carried pathogen WSSV virus, infected to black tiger shrimp. *Hemigraphsus tenuicrustatus.*

Hemigraphsus tenuicrustatus

Similar to *Uca annulipes*, they carry WSSV pathogen into shrimp culture pond. Measure of their limit presentation is filtering water carefully before supplying into culture pond, making fence with net around pond bank to prevent *Hemigraphsus tenuicrustatus,* fiddler into culture pond.

5.3 Farmer indicators

Farmers have no equipment of environmental monitoring; they only define quality of water by their eyes through color, taste, and shrimp activities.

Common quality of water in pond.

Water color.

- *Brown-yellow:* It occurs in initial crop when farmer fertilized, water coloration. Water color is formed by community of *Bacillariophyta*. They are "wild grass" in the sea, they are also preeminent food, good quality to organism in the sea. Pigment of *Bacillariophyta* has chlorophyll A, E when it growth strong water have brown yellow.
- *Green color:* Farmer usually see, it appear when ponds fertilized and this color exist long-time. This color appear due to algae green species. Ponds with green color are favourable for shrimp growth.

- *Turbid brown-yellow*: Shrimp culture ponds usually appear turbid brown - yellow in the corner. At the night, when shrimp swim usually has light blue color. This color due to "t¶o gi¸p" create. This usually in the ponds and may result in mass mortality.
- *Deep blue - brown*: At the end corner wind make layer and due to *Bacillariophyta* , not good for ponds shrimp. When they collect at the corner pond so easy create H_2S and CH_4. This algae develop suitable at high temperature, much nutrient. This ponds shrimp usually float at pond edge, leave food, soft skin and die when algae growth strong.
- *Milky white*: Due to protozoa. When they grow strongly and eat all algae then water become milky while, occasionally brown and red.

Table 6.4 Correlation between indicators:

Environment	Key species	Tolerance	Scientific sampling result	Farmer observation
Low N,P	Skeletonema costatum - *Nitzschia* and *Chaetoceros* - *Chlorophyta*	Begin the crop - Salinity > $15^0/_{00}$ - Clear 30 – 35 cm.	Optimum	Water clean, color yealow ligh brown, clear 30 - 35 cm Shrim strong, clean bowel gut and full food. -Water have green color .
Low N,P	Seaweed (*Gracilaria. sp)*	- Salinity > $15^0/_{00}$ - Clear 30 – 35 cm. - Temperature > 20^0C		Water clean, Shrimp strong.
	Seaweed of bottom (rong t¹p)	- Salinity < $10^0/_{00}$ - Clear > 50cm		Water clear, seaweed of botom growth. Shrimp black color, less growth. Seaweed die, appear scum lap – lap, sediment black color, stinking smell. Shrimp die.
High N,P	*Ceratium sp*	Salinity 10 -$20^0/_{00}$ Temperature > 28^0C	BOD > 5mgO/l	Water change yealow black brown. shrimp not strong, the mass of shrimp die. Water have stinking smell when algea die. At the night the water has photogenic color blue.
High N,P	Algae deep blue color *(Microcitis anabena)*	Salinity <10 Temperature > 28^0C	H_2S > 0,03mg/l and high CH_4	- Water has black, the coner of pond algae die with water red brown, stinking smell. Shrimp weak, driff on edge of the pond, leave eat, excreta of shrimp has white color. If heavy more, shrimp can die all.
High N,P	Rotifer (Branchionus.sp)		COD, BOD high.	Color water green change ligh red
High N,P	Protozoa (*Zoothamnium, Epistylis, Vorticella, Acineta, Tocophrya, Podophrya, Lagenophrys*.)	Temperature > 28^0C		Water white milk color. Shrimp is stick mud, leave eat and difft on edge of pond, not growth.
Low oxygen	Polychaeta	DO < 3mg/l		Shrimp fload head at
	Helices (Cerithidea cingulata)	DO < 3mg/l	Alkalinity decrease < 60mg/l	Water exchage high brown. Shrimp is soft skin

7 Environmental capacity assessment

Environmental capacity is a more general term for “a property of the environment and its ability to accommodate a particular activity or rate of an activity...without unacceptable impact” (GESAMP, 1986).

Environmental capacity measures the resilience of the natural environment in the face of impact from human activities, and must be measured against some established standard of environmental quality. In the case of shrimp ponds, environmental capacity in relation to a specified estuary area

- The rate at which nutrients can be added without triggering eutrophication;
- The rate of organic flux to the benthos without major disruption to natural benthic processes; or
- The rate of dissolved oxygen depletion that can be accommodated without causing mortality of the indigenous biota (GESAMP 1996)

If environmental capacity can be determined, this opens the door to controls on effects, rather than activity. Furthermore, there arises the possibility of allocating or selling a share of environmental capacity, or a share of something which affects it (e.g. total acceptable pollution loading; total quantity of feed inputs) to a particular user or user group. This is likely to offer an incentive to producers to modify technology or management so that production may be increased without exceeding the environmental target. This contrasts with the use of area or production limits, which are directly restrictive, and offer no such incentive.

The success of aquaculture depends on the ability of the market to absorb increased production. It also depend on the capacity of the environment to absorb wastes or remove disease organisms. The environment has limited capacity to absorb wastes from pond aquaculture. This is commonly referred to as *environment capacity*. If this capacity is exceeded, water quality declines, disease organisms thrive, and aquaculture production may decline and collapse. Many people in Vietnam have lost money and become indebted as result.

We can estimate the capacity of the environment for aquaculture activity. The theory is calculate waste production per unit area aquaculture.

Method 1

There are three main steps involved in the estimate of environment capacity:

1. Define environment quality Standard - in terms of nutrient concentration
2. Measure the current (Flushing volume) of the water exchanged
3. Assess the total loading from system to the EQS.

Table 7.1. Rough calculation of carrying capacity: maximum acceptable nutrient load and corresponding shrimp aquaculture production for shrimp ponds system

Calculate parameters	P	N
Mass balance per year	6780	13520
Volume of canal system	369600	369600
Flush volume per year (m3)	13571712	13571712
Environment Capacity (kg per year) (EQS - ambient*flushed volume)	2714.342	5428.685
Overload (g/m3)	0.162	0.315

We have estimated capacity of environment for Doson - Vietnam as roughly 2,714 kg P/year and 5,429 kg N/year.(table 6.1) suggesting that the existing system is overloaded. If this process continues then the farmer and the country will suffer. Not only will production be under threat but quality of environment generally will decline.

This overload is related to both the driving force for increased production and the lack of knowledge and awareness of the build up of nutrients – and therefore likely future problems. Fertilizer input to ponds is too much, and water exchange volume limited so excreta of shrimp, residua fertilizer deposit to sediment or disperse the waste to environment. As a result, survival rate only 10 - 15%, shrimp die scattered every where, and in many ponds all shrimp die. Food for crab is usually raw trash fish and this compounds the dangers to the pond and canal environment. For this reason, Doson aquaculture environmental exceeded carrying capacity.

Method 2

Table 7.2a. Morphometric, hydrologic and other parameter of the selected canal water exchange

Flushing rate per year (F)	1.52
water standard d (m)	1.4
surface S (m^2)	264000
Nutrient retention coeffcient (R)	0.52
R= 1/(1 +0.747*F power 0.507)	

Table 7.2b Calculate of carrying capacity

Parameter	Fomula	Min case		Max case	
		N	P	N	P
N content in water canal (mg/m3)	Nonconservative	640	178	1792	420
Environment quality standard (mg/m3)	N2	4000	2000	4000	2000
N loading from pond culture (mg/m3)	N3= N2-N1	3360	1822	2208	1580
result of solid deposition (x)%	x	0.3	0.4	0.3	0.4
Mass of nutrient lost in sediment coeffient	R1 = x + (1-x)*R	0.664	0.712	0.664	0.712
Carring capacity of nutrient in canal (kg)	M =N3*1.4*F*S/(1-R1)	5618	3554	3692	3082

Pollution of ponds culture at Doson exceeded carrying capacity of environment due to almost ponds inside breakwater, system exchange limit, canal system not fully complete.

As much as 80% of the nitrogen in the feed and 90% of the phosphorus is wasted in ponds shrimp culture. Of waste nutrient generated, 70 - 90% may end up in the sediment of ponds. If we keep the sediment in the pond, and treat (dry) it between crop or remove it to a safe place, we can increase carrying capacity fivefold.

Alarm signal of exceeded capacity where heavy seaweed growth in the ponds, and when bottom has many snail, helices. Mud of bottom pond thick (15 - 20 cm) and has black color.

8 Socio-economic impacts

Socio-economic context

- 584 households have jobs with thousands people.
- Production: Estimate product about 200- 300 tonne shrimp, 100- 200 tonne crab, and ten tonne fish, seaweed, etc.
- Our research suggests that 20% household attain profit about 10 millions VND/ha/year. About 60% household combine culture shrimp and crab, 70% household lose 5 –10 millions VND/ha/year. 10% household break even.

Trends

- Disease and quality of environment declining, production of aquculture decrease strongly in last two years. In 2000 average production was 300 - 500kg/ha then in 2003 – 2004 only 100- 200 kg/ha. While spot disease damage for 90% household.
- Environment polluted so shrimp less growth and low survival rate, shrimp harvest small so low sale price (50%).
- Ponds older and older, spent money much for improve pond as take sediment, chemical, etc. (*Special lot 1 and ponds culture shrimp combine crab)*
- Following on from recent poor performance, money to make essential improvements and maintenance is now lacking (*improve pond, treat water, et..*) so environment pollute, shrimp die, farmer is loss.

9 Management implications

Plant and improve technology

Design and plan for sustained and successful culture over a long period; improve canal system; enhance understanding of nutrient accumulation and its effects; initiate better pond and system management.

Program for main pond area:

- Areas concentrate aquaculture.
- Storage ponds, settling ponds and system treat supply water for ponds.
- Treat waste water ponds.
- System canal supply water and waste water
- Transport road and system electric and other infrastructure.

Table 9.1. Main zones of areas culture in Doson Vietnam

No	**Zones**	**Rate (%)**
1	Pond storage, treat water supply	21
2	Ponds culture	61
3	Ponds treat waste water	18
	Total	**100**

- Promote diversification and multispecies: Shrimp (*Metapenaeus ensis*), Red fish (*Sciaenops ocellatus*), *Tilapia (Mosambica*), shrimp (*P.orientalis*), Mud crab *(Scylla serrata)*
- Develop farmer groups to exchange technology and knowledge (this has begun under Tropeca).
- Training, guidance, dissemination initiatives relating to disease and environmental management for all farmers.

We can increase the carrying capacity of environment for aquaculture activity.

1. *Decrease the wastes per ha pond culture:* Better quality feeds and improved feeding practices improve food conversion efficiency (food give/weight of production). Better water quality reduces stress, disease, and also improve food conversion efficiency.
2. *Reduce the amount of waste that is discharged to the environment*. Water can be discharged to a settling pond before being discharged to the wide environment. This may only be necessary toward the end of a production cycle when most of the organic matter and nutrient are released. Pond mud can be removed at the end of a production cycle and sold or disposed where nutrients are not a problem, or where they are needed. Pond mud can be treated by drying and turning between crop.
3. *Disperse the wastes more widely*. Farm can be site in areas where wastes are rapidly flushed away. Farmer and /or government can design water canals to make sure that there is plenty of flushing and that wastes are not recycled to themselves or other farmers.

4. *Mangrove forest and other wetland plant* absorb low concentration organic wastes very effectively. Government, authority local and farmer groups should strive to conserve significant areas of these natural treatment beds and make sure that waste water from shrimp ponds is dispersed at acceptable concentration.
5. *Treat waste* and recycle to production pond.
6. *A combination of settling, sediment remove and heavy aeration* may allow water to be recycled to production ponds with the added benefit of reducing the like the likelihood of introducing disease organisms in the water supply.

What should be done additionally – is there more that should be changed?

Ensure that those using the capacity of the environment for aquaculture and other productive activities are aware of its value and limits, and are made responsible for it. Introduce initiatives to promote the practices described above, which will effectively increase carrying capacity.

Set in place simple monitoring schemes (based ideally on simple and easily observed indicators) so that the accuracy of environment capacity estimate can be improved and precautionary measure introduced in good time to prevent environmental damage and production collapse.

10 Dissemination

- Research on bio-technology in order to decease pollution of environment. We take sediment in bottom then research microbiology species for product bio-fertilizer. Use pro-biotic, limit use chemical.
- Set up programs monitoring, warning environment and disease in order to communicate for farmer and other areas give methods treat quickly.
- Research new technology for aquaculture and transfer for farmer.
- Organize training course for farmer: 01 course at CBRFA -RIA1, 02 course at Doson with 300 farmer more. Organize workshop at ponds for conclusion, exchange experiment between farmer and sciences.
- Leaflets on technology for aquaculture then share out free for farmer.
- Document on ‘ *Indicator in ponds’ is in preparation*. This document will guide farmer to check quality water by indicator most simple.

11 Conclusions and recommendations

Conclusion

1. Study area belong to BachDang estuary in Vietnam that has surface estimate 683 ha. System has dike outside and major culture species are shrimp and crab.
2. Water exchange volume per year estimate 8,870,400 m3. The flushing rate estimated at 152%.
3. For area only culture *P.monodon* the flushing rate about 166%. Water exchanged per year calculate overall is 20,832.81m^3 per year. The similar for area culture P.monodon and Crab estimate about 107% and 2,2373.74m^3.
4. The inflows to system are food and fertilizer. Mass of Nitrogen in food is 38.06%, P is 18.28%. Mass of N in fertilizer is 61.55% and P is 81.53%. Mass of N and P in production is 18%N and 14%P.
5. The carrying capacity of environment calculate by two ways. The way 1st calculated 2,714 kgP/year and 5,429 kgN/year. The way 2nd calculated in max case of N is 5,618 kgN/year and 3,554 kgP/year, and mix case of N is 3,692 kgN/year and 3,082 kgP/year.
6. The current system is significantly overloaded and large amounts of nutrient are accumulating within the system. Strategies must be developed to address this long term problem

Recommendations

1. Vietnam government and local authority should develop suitable polices for shrimp culture development. Suitable policies should enhance and support farmer initiative. Better planning and infrastructure will encourage the farmer to invest and maximize use and returns from ponds. Development of aquaculture should be friendly to the environment.
2. Aquaculture should combine with conservation of natural resources, tidal environmen, and prevent disease in order to sustainable development aquaculture.
3. Invest, enlarge and develop aquaculture at main point areas that have areas wide, many high economic culture species.
4. Should develop detailed plans for aquaculture development, that is set up training course on technology and management for sustainable aquaculture development. The farmer need to understand that they have responsibility and interest to manage and protect environment in order they will have max profit. An important issue here is integrating higher level government policy with local initiative.
5. Improve quality water by biological methods: recover mangrove forest.
6. Research new technology for aquaculture and transfer for farmer.

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Case study for Can Gio, southern Vietnam

Tropeca Case Study 3

This paper is available in Vietnamese

By Nguyen van Tu, University of Agriculture and Fisheries, Ho Chi Minh City, Vietnam nvantu@hcmuaf.edu.vn

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Contents

1. Introduction

Can Gio is the only coastal district of Ho Chi Minh City. It is located 50 km southeast of Ho Chi Minh City in Southern Viet Nam. Before the Vietnam War, Can Gio mangrove forest covered an area of approximately 40,000 ha. During the War, the forest was almost destroyed by defoliant chemicals. After the War, Can Gio mangroves have been totally recovered with efforts of reforestation of the city government.

Shrimp culture operation has been linked with mangrove development. During 1970s and 1980s, extensive shrimp culture system was practiced, in which production was mainly based on wild stock availability. Early 1990s, due to the decline of wild seed resource leading to low yield some farmers carried out trials of shrimp culture in ponds with artificial seed. In late 1990's, the city government launched a program of shrimp culture development in Can Gio as a new form of income generation for local farmers. As a result, shrimp culture area has been increased very fast during recent years. Shrimp culture systems in Can Gio District can be classified as follows.

Improved extension system

This system was practiced in small reservoirs (10-15 ha) made by embarking dykes across river branches. Addition to wild seed of shrimp, crab and finfish, farmers stocked artificial post larvae (PL) of black tiger shrimp (*P. monodon*) with low density and provided shrimp with low quality feed. The shrimp was harvested monthly based on tides.

Shrimp culture in rice fields

This system was commonly practiced in Binh Khanh and An Thoi Dong communes. Rice was planted in rainy season (from July to October) and black tiger shrimp was cultured in dry season (from January to April). Stocking density was less than 9 PL/m^2. The shrimp was fed with pelleted feed.

Shrimp culture in salt fields

This system has been recently developed in Ly Nhon, Can Thanh and Thanh An communes. Salt production was practiced in dry season (from January to April) and black tiger shrimp was cultured in rainy season (from July to October). Stocking density was less than 9 PL/m^2. The shrimp was fed with pelleted feed.

Semi-intensive and intensive shrimp culture systems

These systems were commonly practiced in Binh Khanh, An Thoi Dong, Ly Nhon and Tam Thon Hiep communes. Black tiger shrimp could be stocked two to three crops per year. Stocking density of semi-intensive system was 10-20 PL/m^2 and intensive system was more than 20 PL/m^2. The shrimp was fed with pelleted feed. Besides the difference of stocking density, in the semi-intensive system the culture pond water was exchanged directly with outside environment while in the intensive one the culture pond water was exchanged through a treatment pond.

The rapid growth of shrimp culture area without planning has caused problems of environmental degradation leading to uncontrolled diseases of cultured shrimp. The aim of the study was to determine water quality and identify indicators of environmental capacity based on perception of shrimp culture farmers to create cooperation among them for sustainable shrimp culture development.

2. Materials and methods

2.1. The study area

Fig. 1 Study area

Shrimp farming in Can Gio District has been developed in four north communes of Tam Thon Hiep, An Thoi Dong, Binh Khanh and Ly Nhon. The present study was undertaken in a brackish water shrimp culture area with a total area of 28 ha in An Hoa hamlet of An Thoi Dong commune throughout a production cycle from April to July 2004. The selected shrimp culture area was isolated and bordered by mangrove forest, residential land and inter-communal road (Figure 1). All the ponds were located at and fed by a small canal connected to Soai Rap River. The ponds were similar in configuration, basin and contour type, well-exposed to sunlight and natural air flow. The mean size of the ponds was 5000 m^2 with a mean depth of 0.80 m throughout the growing cycle (Table 1).

2.2. Shrimp culture techniques and farm management data

Shrimp culture system selected was semi-intensive from the degree of stocking density and management applied (Table 1). Two representative ponds were selected for the study. Farm records were inputs used (shrimp fry, lime, supplemental feeds), shrimp harvests and information on the management practices applied. Shrimp yields were calculated from the final biomass obtained in each individual pond. Biomass of other crustacean species as well as the finfish species was small to be negligible. Gross yield was expressed as production in kg/ha.cycle. The farmers were interviewed for detailed information husbandry and management practices.

Pond preparation began in early March to mid July with draining water, applying lime (carbonate calcium, $CaCO_3$) at an average rate of 200 kg/ha and then drying under the sunshine for few days. Water was introduced in the ponds during high tide by pumping one week after liming. A fine-mesh size nylon net was set at the end of inlet pipe to prevent entering of other shrimp and finfish species from inflow of water. Shrimp fry (15 days old postlarvae-PL15) of *P. monodon* were stocked directly into the ponds without nursing one week after watering the ponds. Farmers usually buy shrimp fry from local hatchery without disease check. Industrial shrimp pelleted feed was supplied on a regular basis. The amount of feed supplied was not based on a calculation of the shrimp biomass. The other forms of post-stocking management included only frequent liming as a measure of disease prevention and exchanging pond water as a measure of pollution control of the ponds. For first 30-45 days after stocking, the ponds were added water to compensate for water lost by evaporation. After that the pond water were exchanged at an average rate of 10-20% volume at high tide of new moon or full moon every month. However, the exchange rate was increased after rain.

Table 1. Detail of management regime of selected shrimp system

Issues	Applications
Average pond size (m2)	5,000 (ranged between 3,000-6,000)
Average pond depth (m)	0.8
Water control	Pumps and pipes of outlets
Water exchange	Pumping and tidal exchange (20% every time)

Source of fry	Imported from local hatcheries
Stocking density (PL/ha)	10,000-15,000
Rearing period	4-5 months
Crops/yr	2 (March-July and August-December)
Lime used (kg/ha.cycle)	100-400
Feed used (kg/ha.cycle)	700-900
Aeration	Natural air flow
Survival rates (%)	20-70
Production (kg/ha.cycle)	900 (ranged between 400-1200)

2.3. Water quality parameters

Water samples were collected monthly at high tide followed tidal regime to investigate the chemical parameters. The inside samples were collected just before draining and after adding water from two spots from inside the ponds. The outside samples were collected at the mouth, middle and end (at entrance into the ponds) of the canal. The first sampling was done one day before stocking and the final sampling during harvesting. The parameters studied were salinity (ppt), pH, dissolved oxygen (DO) (mg/l), total suspended solids (TSS) (mg/l), total ammonia nitrogen (NH3-N) (mg/l) total nitrogen (total-N) (mg/l), total phosphorus (total-P) (mg/l), biochemical oxygen demand (BOD_5) (mg O_2/l) and chemical oxygen demand (COD) (mg O_2/l).

Water pH was measured on the spot by a pH-test kit and DO by a DO-test kit. Salinity was recorded with a refractometer and expressed as the part per thousand (ppt).

To determine NH_3–N, TN and TP water samples were taken from the ponds from two spots inside the ponds as well as from the canal. Water samples in PVC plastic bottles were placed in dark container with ice. The samples were then transported to the laboratory for analyses. NH_3–N was determined with Phenate method, TN with Kjeldahl method and TP with acid ascorbic method (APHA, 1998).

TSS concentrations, BOD_5 and COD were determined using standard methods (APHA, 1998).

2.4. Sediment quality parameters

Sediment samples were collected from two randomly selected spots on each pond. Samples were taken using a 400-cm^2 sampler, which was designed to trap a column of mud 5 cm deep from the soil–water interface. Samples were preserved in black nylon bags placed in dark container with ice and were transported to the laboratory. Samples were oven-dried, digested with H_2SO_4 and determined NH_3-N, TN and total-P with methods mentioned in 2.3.

2.5. Partial mass budget

The sampled shrimp ponds had an average surface area of 5,000 m^2 with one outlet point. A part of the water volume of the ponds was routinely exchanged every month at full and new moon. During water exchange intervals, water was added into the ponds about 2 cm in depth to compensate for evaporation. Stocking rate (15 PL/m^2) and feeding followed the procedure for semi-intensive ponds formerly described. The shrimp feed was purchased from the Tom Boy Company and was labeled to contain 6.1-6.72% N and 1.5% P. Input and discharge of nutrients through water were calculated on the basis of the added and exchanged volumes and the respective nutrient concentrations. Nutrient inputs and outputs from stocked and harvested shrimp were analysed assuming 2.9% N and 0.34% P (Jackson et al., 2003; cited by Islam et al., 2004). Nutrients gained through other sources such as atmospheric precipitation, runoff, rainfall, nitrification or nitrogen fixation by algae and loss through denitrification, volatization or seepage were considered negligible (Jackson et al., 2003; cited by Islam et al., 2004).

2.6. Statistical analysis

Due to unexpected reasons, some water and mud quality parameters were not available. During the study, one selected pond was infected with WSSV and early harvested. These problems have caused difficulties of statistical analysis.

3. Results

3.1. Current situation of shrimp culture in Can Gio District

During 1990s, shrimp culture was expended to northern communes of Can Gio District followed a program of plant and animal husbandry conversion of the city government. Particularly, since late 1990s shrimp culture included improved extension, semi-intensive, intensive and rice-shrimp systems has been developed very fast (Table 2) and contributed significantly for income generation for local households.

Table 2. Shrimp culture development in Can Gio district during 2000-2003

	2000	2001	2002	2003
Area (ha)	2,733	3,779	4,076	4,648
- improved extension	2,283	2,283	2,283	2,283
- semi-intensive	73	166	189	448
- intensive	10	263	422	570
- rice-shrimp	367	1,067	1,182	1,347
Production (tones)	760	2,700	3,200	5,400
Shrimp culture households (hhs)	1,212	1,620	2,334	2,930

3.2. Survival and yield parameters

For the first farm, with the stocking density of 70,000 PL15 for 5,000-m^2 pond (14 PL/m^2), the harvest was 620 kg of shrimp at the average size of 25 g (equally, the yield of 1,240 kg/ha.crop). The survival rate was 44%. Meanwhile, the second farm got problem of WSSV infection and had to harvest the shrimp earlier. With the similar size and stocking density (16 PL/m^2), the harvest was 350 kg.

3.3. Water quality parameters

Dissolved oxygen and pH did not show significant difference between months of growing out period, being 4-5 mg/l and 7-8, respectively. Salinity was reduced from the beginning (8-9 ppt) to the end of the crop (5-6 ppt). The values of TSS, BOD_5, COD and NH_3-N in the ponds were higher those in the canal. These outside values varied irregularly by months and at low and high tides. In the pond, these values were reduced after adding water (Table 3).

Table 3. Water quality parameters of the pond and canal

Parameters	Site		Day/month/year					
			7/4/04	25/4/04	6/5/04	25/5/04	22/6/04	16/7/04
TSS (mg/l)	Canal	LT	n.a.	n.a.	n.a.	24.3	44.3	21.2
		HT	n.a.	n.a.	n.a.	32.0	52.0	29.7
	Pond	Before	n.a.	n.a.	33.5	50.0	44.0	28.6
		After	n.a.	n.a.	32.5	43.5	46.0	28.7
BOD (mgO_2/l)	Canal	LT	n.a.	n.a.	n.a.	6.5	7.7	5.3
		HT	n.a.	n.a.	n.a.	5.4	5.6	5.1
	Pond	Before	n.a.	n.a.	4.7	12.7	10.1	9.4
		After	n.a.	n.a.	4.1	8.9	7.8	7.9
COD (mgO_2/l)	Canal	LT	n.a.	n.a.	n.a.	30.7	22.3	25.5
		HT	n.a.	n.a.	n.a.	27.3	33.0	24.5
	Pond	Before	9.6	12.0	n.a.	62.0	63.0	44.0
		After	8.8	10.0	n.a.	48.0	55.0	39.5

NH_3–N (mg/l)	Canal	LT	n.a.	n.a.	n.a.	0.05	0.48	0.16
		HT	n.a.	n.a.	n.a.	0.05	0.61	0.14
	Pond	Before	0.03	0.22	0.32	0.27	0.09	0.1
		After	0.03	0.21	0.33	0.19	0.13	0.13

Some of the parameters showed poor quality of the water for optimum growth of the shrimp. DO values were frequently low for good feed intake. NH3-N and COD values were almost over acceptable ones of 0.1 mg/l and 45 mgO_2/l, respectively.

3.4. Sediment quality parameters

Variations in volumetric composition of pond sediment tended monthly increase (Table 4). In contrast to pond water, NH_3-N remained high in sediment while this parameter in water tended reduces by the end of the cycle (Table 3).

Table 4. Sediment quality parameters of the pond

Pond	7/4/04	25/4/04	6/5/04	25/5/04	22/6/04	16/7/04
Total-N (%)	n.a.	n.a.	0.26	0.27	0.28	0.30
NH_3-N (mg/100g)	n.a.	n.a.	8.10	8.35	6.52	7.06
Total-P (%)	n.a.	n.a.	0.12	0.13	0.15	0.15

3.5. Partial mass budget

A yield of 1,240 kg/ha.cycle of shrimp at an average individual weight of 25 g was recorded. Based on farm management a rough estimation of the nutrient mass balance of the pond was made. The water-borne budgets of TN and TP were calculated by combining the volume of intake and discharge of water and the available data of the nutrient concentrations in the canal and pond. Feed was the highest contributor of the total nitrogen and phosphorous budgets for input, giving a value of 74.69% and 90.95% respectively (Table 5). The net nitrogen exported from the farm in effluent was 11.20 kg/ha.cycle, accounting for 8.82%. Similarly, the net TP exported in effluent was 1.60 kg/ha.cycle, accounting for 5.77%. The total input of nutrients to the ponds was 126.98 kg TN/ha and 24.74 kg TP/ha (Table 5).

Table 5. Partial mass budget for total nitrogen and phosphorous of the pond over a growing cycle of 110 days

	Total nitrogen		Total phosphorous	
	kg/ha.crop	%	kg/ha.crop	%
Gains				
Shrimp stock	0		0	
Initial loading	9.52	7.50	1.20	4.85
Water adding	22.62	17.82	1.04	4.20
Feed	94.84	74.69	22.50	90.95
Losses				
Shrimp harvest	35.96	28.32	4.22	15.21
Effluent	11.20	8.82	1.60	5.77
Draining	5.36	4.22	1.28	4.61
Unrecovered	74.46	58.86	17.64	63.59

Only 28.32% N and 15.21% P were recovered in harvested shrimp (Table 5).The unrecovered nutrient budget (58.86% N and 63.59% P) was over-estimated. At the end of the cycle, the pond water became poor and the shrimp showed infection of WSSV. The pond water was actively exchanged for a few days before harvesting. This performance resulted in low inside water quality parameters (Table 3). The nutrient discharged through effluent water these days might be high and unaccounted for.

3.6. Indicators of water quality

At the end of this crop, only 20% of shrimp culture farmers got profits. The poor harvests of the farmers caused by white spot disease. The farmers believed that the problem was due to poor quality of water but they could not relate the environmental problem to shrimp culture performance. Perception of indicators of poor water quality was based their own experiences as follows.

3.6.1. Canal water

Good quality water was indicated with transparence (less suspended solid materials) and appearance of small fish (such as fingerlings of mugil fish), and no effluents from other shrimp culture ponds discharged.

3.6.2. Pond water

Good quality was indicated with green color and transparency of 30-40 cm. In good quality water the cultured shrimp was moving healthy with clean gill. Poor quality water was indicated with slimy and dark green color or orangish, transparency low (< 20 cm), high suspended solid materials, floating ferrous layer, black mud and appearance of small snail. In poor quality water the shrimp was moving near pond banks with black gills or algal growth on shell.

4. Discussion

There was a close relationship between water quality of the shrimp pond and canal. Inside water quality became poorer during the process of growing cycle. There was an accumualtion of nutrients in the pond followed current farm management. It required a collaboration among farmers to reduce impacts of outside environment to shrimp culture ponds

Case study of spiny lobster cage culture, Xuan Tu lagoon, Van Ninh district, central Vietnam

Tropeca Case Study 4

This paper is available in Vietnamese

By Le Anh Tuan, University of Fisheries, Nha Trang, Khanh Hoa Province, Vietnam

leanhtuan@dng.vnn.vn

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Contents

Introduction

The spiny lobster (*Panulirus*) cage farming is one of the most important aquaculture industries on the Southern Central coast of Vietnam. In Vietnam, there are approximately 35,000 lobster cages of which approximately 20,000 cages are located in the coastal waters of the Khanh Hoa province. These marine cages are responsible for approximately 1,500 metric tonnes of products and valued more than US$40 million in 2003.

The Xuan Tu lagoon belonging to Khanh Hoa province is a water where lobster farming developed originally in Vietnam. Cultured lobsters in this area are fed exclusively with fresh whole or chopped fish and shellfish. Food conversion ratio for lobster using this diet is high at around 28 (fresh weight basis).

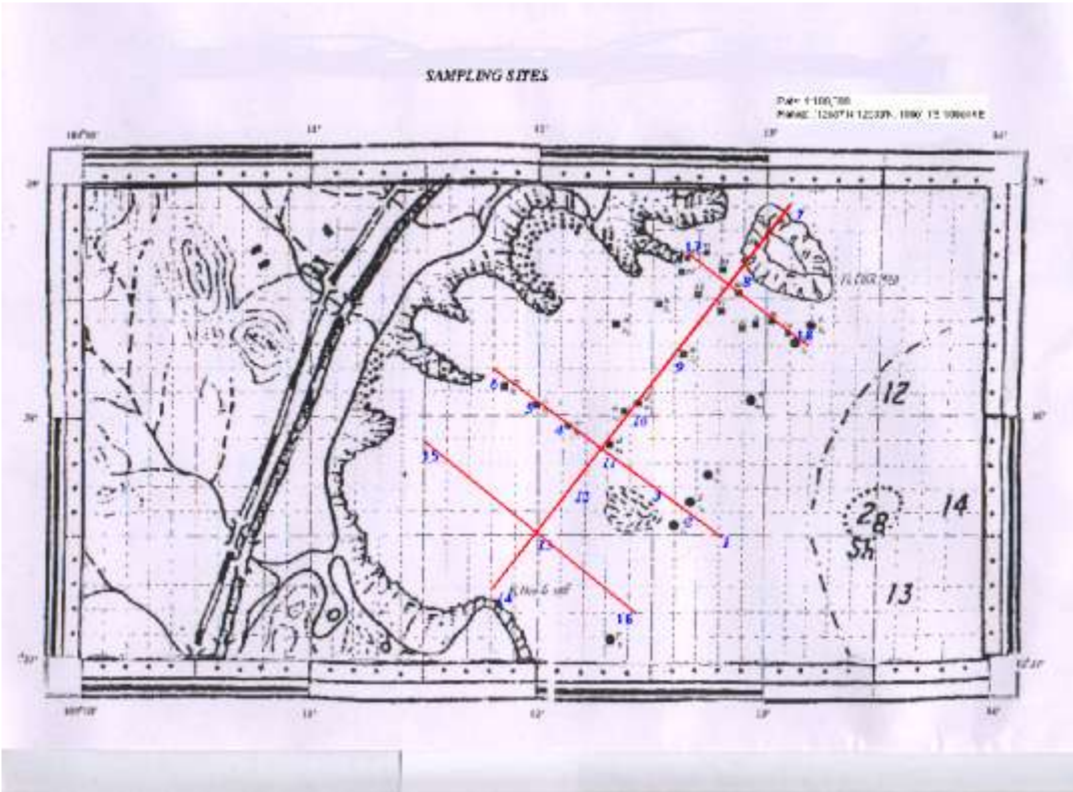
Although these cages have been operating for more than a decate, there recently are no studies on *environmental capacity* associated with the operation of lobster cages. Therefore, there is a need to determine what impacts lobster cages have on the environment and vice versus.

Methodology

The study area

The Van Phong bay is located between the latitude 12°29' N and 12°48'N and between the longitude 109°10' and 109°26' E. It is one of the large, deep and relatively closed bays in Vietnam. The total area of the bay is 503 square km with the areas of its islands of 5000 ha. The bay area with the depth less than 10 m is approximately 30% of the total water surface area (Fig 1). Those made it suitable for cage mariculture, especially for lobster culture.

Figure 1. Map of the Van Phong bay and Xuan Tu sea



The Xuan Tu lagoon is in the west side of the Van Phong bay. The sea area is approximately 472 ha with the tidal range of 0.8-1.2 m and the average depth of 3.8 m. The water current is maily south-west with the average velocity of 20-30 cm/s.

The village population increased over the time. The major population live on lobster farming in recent years. Lobster cage farming started in Xuan Tu lagoon in 1992 and it was profitable and prosperous. Since then many fishermen have invested in lobster cage culture. Lobsters are fed exclusively with fresh whole or chopped fish and shellfish. The most commonly used species/groups for feeding lobster are Lizardfish (*Saurida* spp); red big-eye (*Priacanthus* spp); Pony fish (*Leiognathus* spp); pomfret; snails, oyster and cockles; small swimming crab, other crabs and shrimps. Finfish comprizes about 70% of the diet, with 30% shellfish. The preferred fish (comprizing 38% of fishes in diet) was lizardfish. Food conversion ratio for lobster using this diet is high at around 28 (fresh weight basis).

Table 1. Status of population and aquaculture production in Xuan Tu village in recent years.

	1998	*1999*	*2000*	*2001*	*2002*	*2003*
Population	4582	4720	4829	4915	4996	5100
Lobster farmers/households	395	420	557	560	653	700
Snail farmers/households				10	40	71
Shrimp farmers/households	155	120	90	20	20	20
Lobster production (mt/yr)	39.2	45	85	129.6	170	176
Snail production (mt/yr)				0.8	20	35
Shrimp production (mt/yr)	95.2	78.2	68	57.8	54.4	54

The snail cage culture has developed in the Xuan Tu sea since 2001. The number of snail cages and the productions for the years of 2001 and 2002 were 30 and 200 cages, and 3 and 20 tones, respectively. The spontaneous development of snail farming caused problems with the water and sediment quality in the area. There was an outbreak of disease that detroyed many snail farms. As a result, there are only 5 snail farmers in the village now in 2004. Similar to lobster farming, snail was fed only trash fish and the FCR was as high as 15.

Shrimp farming (*Penaeus monodon*) has developed for long time due to high profit. However, it wasn't paid more attention by the local people because of high investment, lacking of land and high risk. There are 20 shrimp farms with an area of 16 ha recently in the Xuan Tu village (Table 1).

Key issues

Lobster and snail (*Babylonia*) farming have developed rapidly in the project area. Disease (which until 2000 was not a problem) has increased rapidly in recent years. Water quality has declined, especially close in shore and around the snail cages. Lobster farmers have responded by into deeper water, but are still highly aggregated. Cages in deeper water are more expensive and less convenient, and this has resulted in some conflict with snail farmers. Water and bottom quality are now key concerns for both lobster and snail farmers. There is also some concerns about on-going shrimp farm development. More general concerns include cost, quality and supply of seed for both snail and lobster farmers, lack of technical support for all the new enterprises. Awareness of environmental issues has been greatly raised through the (on-going) work of an IMA funded project, which has created and seeks to protect a marine protected area (the coral reef in the centre of the Bay) for fisheries conservation/enhancement. There has been significant local support for this initiative, and there seems to be a consensus that benefits are arising. The first local workshop showed that there was strong support for the objectives of *Tropeca*, and farmers were keen to get involved. Key issues to be addressed by the project included water quality and its relationship with feeding regime and production; and practical guidance on water quality management (snail, lobster, shrimp farmers).

Water quality parameters

Water samples were collected monthly to investigate the chemical parameters. Samples were collected between 08:00 and 09:00 h at the morning, from two spots: surface and bottom, and inside and outside of each cage. The parameters studied were temperature (C), depth (cm), secchi disc transparency (SDT)(cm), salinity, pH, dissolved oxygen (DO)(mg l^{-1}), total nitrogen (total-N) (mg l^{-1}), total phosphorus (total-P)(mg l $^{-1}$). Water temperature, dissolved oxygen (DO), water pH, and salinity were recorded directly on the spot by a Portable equipment-TOA Water Quality Checker, model WQC-22A (Japan, 1998). Water transparency values were measured by a simple secchi disc. To determine total N and total P, water samples were taken from the cages randomly from a number of spots inside and outside the cages. Water samples were preserved with concentrated H_2SO_4 in 200 ml PVC plastic bottles and placed in dry ice. The samples were then transported to the laboratory for analyses.The parameters were determined by using a HACH water analysis kit, a direct reading spectrophotometer (DR6000). Standard calibration was plotted and used to validate.

Sediment quality parameters

To determine the sediment particle size distribution, sediment samples were taken from inside and outside of the cage. For chemical analyses, sediment samples were collected from four randomly selected spots on each cage. Samples were taken using a core sampler, which was designed to trap a column of soil 5 -10 cm deep from the soil-water interface. Samples were preserved in wide-mouthed black bottles and are transported to the laboratory on dry ice. Samples were oven-dried and results were expressed as the total dry matter,T-DM (mg/kg). The soil texture was determined by using Hydrometer method (After Boyd, 1995). Sediment pH was determined from a soil suspension in distilled, de-ionized water (soil:water ratio of 1:5, using a digital pH-meter. Total-P (mg/kg) was measured by the method provided by Olsen (After Boyd, 1995). To determine the total nitrogen, samples were oven dried at 45^{o}C for 2 h and crushed with a mortar.The total nitrogen was determined by using the Kjeldahl method (Nelson and Sommers,1980,1982). The organic content of the sediments (also called loss of ignition) was determined by combustion of samples in porcelain crucibles at 550^{o}C for 12 h in a muffle furnace and the final product of the combustion was expressed as the ash content of the sediment (Clesceri et al.,1989).

Nutrient budgets/system hydrodynamics

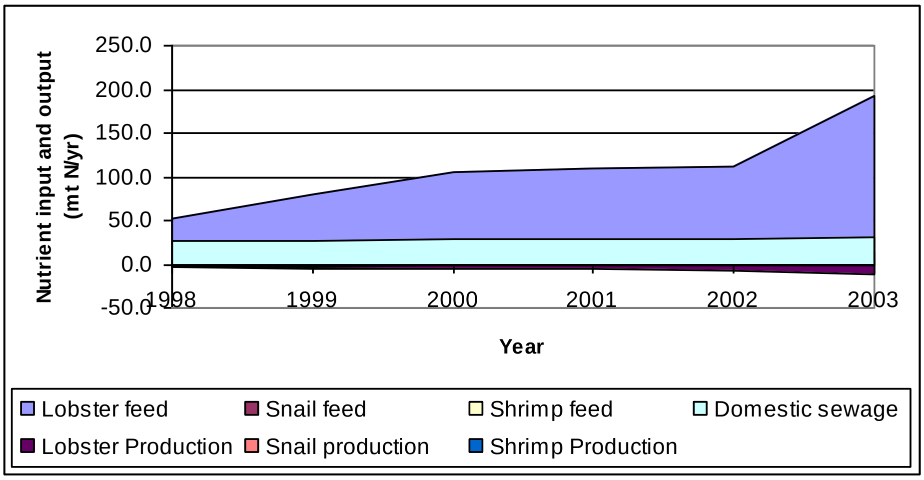
The lobster's feed including trash fish, ark, clam and crab was calculated assuming 2.10% N and 0.17% P. The snail's feed including trash fish and crab was calculated to contain 2.54% N and 0.21% P (Boi, 2000). The shrimp grower feed was purchased from Long Thang Company and was labeled to contain 6.62% N and 1.66% P. The estimation of waste load from local households was based on discharge coefficients for solid waste (Sorgreah, 1974), domestic sewage (Padilla, J., L. Castro, A. Morales, C. Naz, 1997), and detergent (Work Bank, 1993). The coefficients of Nitrogen per person per year were 1.86, 4, and 0 for solid waste, domestic sewage and detergent, respectively. Input and discharged of nutrients through water were calculated on the basis of the exchange volume and the respective nutrient concentrations. Nutrient inputs and outputs from stocked and harvest lobster, snail, shrimp were calculated assuming 3.59%N and 0.3%P (Boi, 2000), 1.42% N and 0.11%P (Binh, Pers. Comm.), and 2.9% N and 0.34% P (Jackson et al., 2003), respectively. Inputs of nutrients through atmospheric precipitation, runoff, rainfall, nitrification or nitrogen fixation by blue-green algae and loss through denitrification, volatization or seepage were considered negligible (Briggs and Funge Smith, 1994; Jackson et al., 2003; Md. Shahidul Islam et al., 2004).

Results

What is coming in, what is going out of the lagoon?

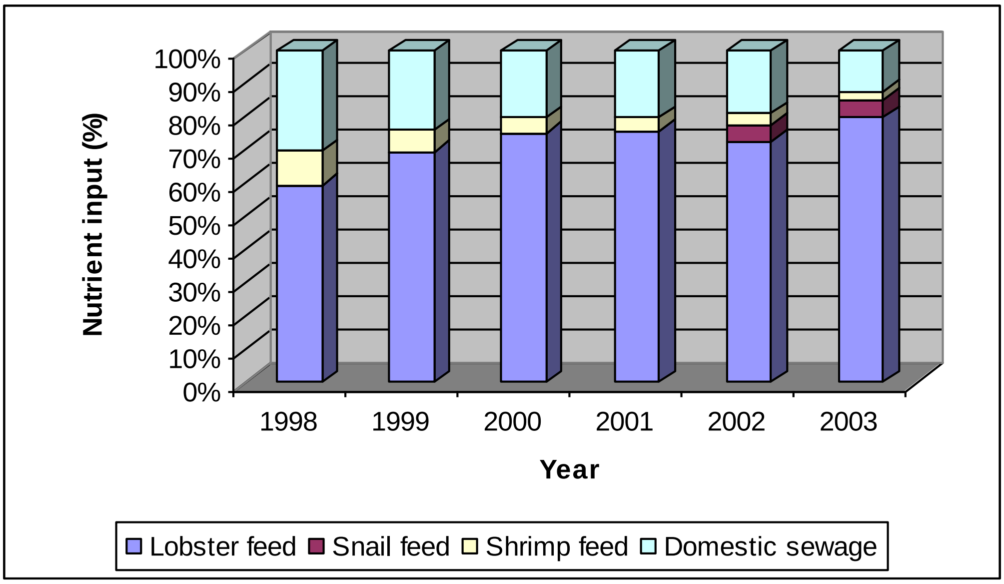
The major nutrient inputs (sources) were the feeds for lobster, snail and shrimp and the domestic sewage while the nutrient outputs were mainly final products including lobster, snail, and shrimp (Fig. 2). The nutrient concentration in ambient water was treated together with the acceptable nutrient concentration in relation to the flushed volume and the environmental capacity.

Figure 2. Major nutrient inputs and outputs in the Xuan Tu lagoon



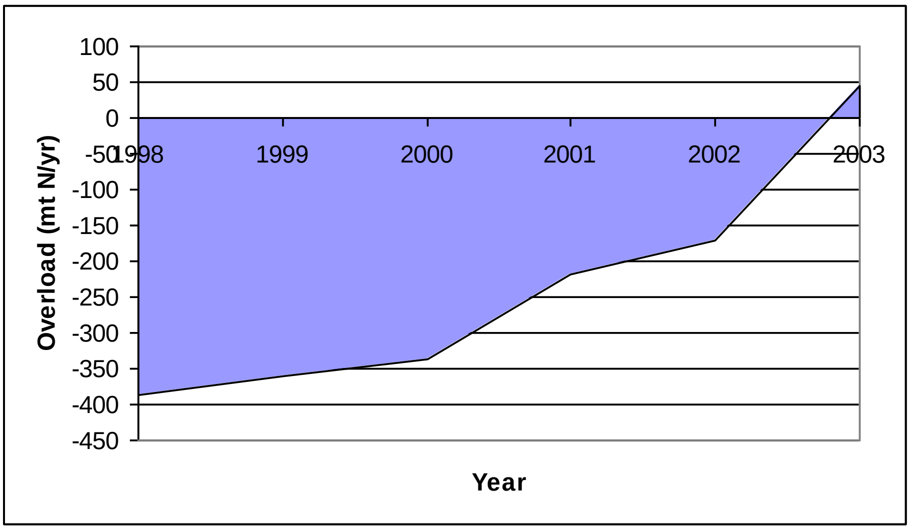
The lobster feed and domestic sewage accounted for 59-80% and 30-12% of the nutrient inputs in the lagoon. The contribution of the lobster feed tends to increase over the time (Fig2, Fig. 3), especially in late 2002 and 2003. In general, the nutrient input increased markedly during this time, not only due to lobster feed but also from the snail feed (Fig3).

Figure 3. Contributive percentages of different sources



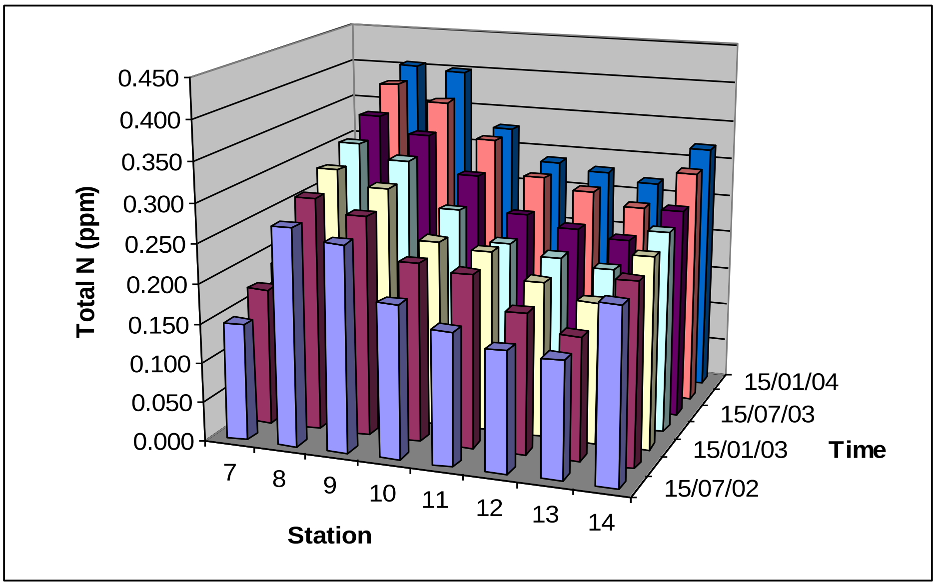
Compared with the significantly increasing nutrient inputs, the nutrient outputs was still at a modest level, and mainly from the lobster prodution (Fig. 2). That is why the environmental capacity of the lagoon for Nitrogen could be exceeded in late 2002 and early 2003 (Fig. 4).

Figure 4. The overload of Nutrient (Total Nitrogen) in Xuan Tu lagoon by year



This prediction based on calculations using a simple mass balance model seemed to be supported by our surveyed data (Fig. 5). Due to the environmental capacity was exceeded during the time between late 2002 and early 2003, from then on the lagoon could not assimilate all of nutrient inputs.

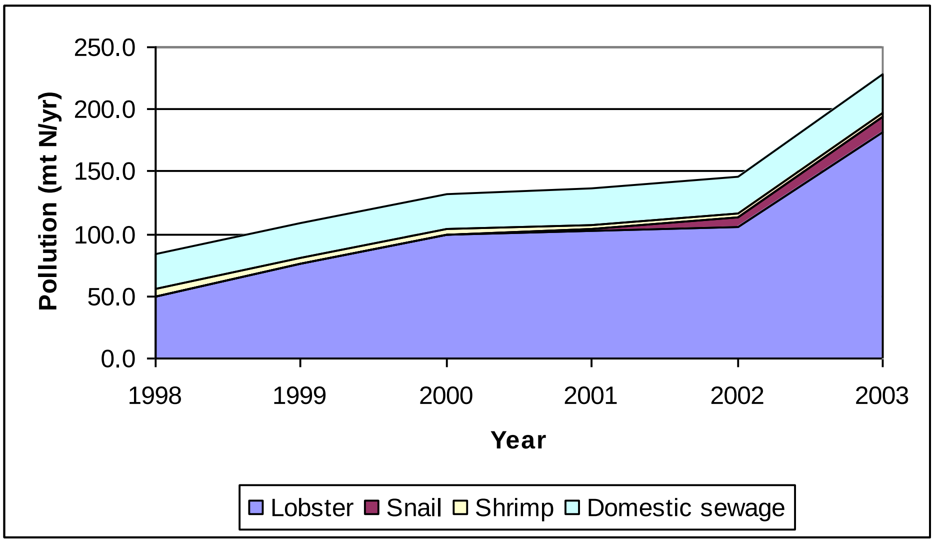
Figure 5. Concentration trends of total nitrogen in Xuan Tu lagoon over time



How significant is the lobster farming relative to other activities and natural nutrient cycling?

The pollution rates, which are expressed as kg N/mt production or per person, for the production of lobster, snail, shrimp and the domestic sewage were 586.34, 366.58, 70.36, and 5.86 (Adapted from Sorgreah, 1974; Work Bank, 1993; Padilla, J., L. Castro, A. Morales, C. Naz, 1997; Boi, 2000; Jackson et al., 2003; Binh, pers comm., 2004), respectively. The pollution caused by the farming of lobster, snail, and shrimp and the domestic sewage over the time was shown in the figure 6 below.

Figure 6. The pollution caused by aquaculture activities and domestic sewage in Xuan Tu lagoon



Oviously, lobster farming was the major factor contributing to the pollution of the lagoon with a nutrient (total nitrogen) loading more than 150 tones a year recently. Additionally, the pollution contribution from the local population was as high as approximately 30 tones a year. Shrimp and snail farming contributed small parts to the pollution. However, the increasing of snail farming in the period of 2002-2003 sped up the exceeding of the environmental capacity in the lagoon.

Is there a problem? – for the lobster farmers; for others sharing/using the water

In the past, lobster diseases rarely occurred. Recently however, culturing in poorer quality water (due to rapid increase in number of cages) have resulted in some diseases in cultured lobsters in the lagoon. The common diseases were black gill, shell necrosis, and red body. Some preliminary studies showed that the main pathogens occurring in infected lobsters were: 2 bacteria *Aeremonas hydrophyla* and *Proteus rettgeri*, 2 fungi *Fusarium solari* and *Lagenidium sp*; and some parasites *Baranus spp, Zootharinium, Vortiella* (Lieu, P.T.T, 2003). Besides, the growth rates of the cultured lobster were reduced markedly compared with those in previous years (Muoi, pers. Comm., 2004). Water and bottom quality are now key concerns for both lobster and snail farmers.

Management implications: individual farms; groups of farms; other activities

The lobster farms in Xuan Tu lagoon may be divided into two groups: failed cages and successful cages. The management regimes and some other characteristics showed that there were some differences between the two groups (Table 2). Therefore, regarding to improving the environmental capacity of the lagoon, there are some management implications as follows:

- Cage design: larger and off-bottom cage seemed to be better;
- Location: should be far from shore and in deeper area where there is good flushing rates;
- Feeding practice: should be improved through reducing feeding frequency and feed amount if possible;
- Left over: the un-eaten feed should be removed out of the lagoon instead of out of their own cages but still in the lagoon, and in a shorter duration instead of overnight time as usual;
- Practical indicators: lobster cages should not operated if their sediment has a darker colour, and very off-flavor, especially when the bottom organisms are mainly polychaet.
- Groups of farms: should be re-arranged in a way that facilitates better flushing rates;
- Other activities: snail farming practices in the lagoon were similar to those of lobster farming, therefore, snail farmers may improve their management through lobster farmers. Improve the common environment, the shrimp farmers need to treat the sludge discharged from shrimp ponds before releasing into the lagoon. Additionally, domestic sewage should be treated in the same way.

Table 2. Generalized scenario of management regimes in selected lobster cages

Issues	**Applications**	
	Failed Cages	*Successful Cages*
Cage type	Fixed cages	Fixed and floating cages
Cage shape and size (m)	Rectangular, 3 x 3 x (1.5-4), 3 x 4 x (1.5-4);	Rectangular, 3 x (3-4) x (1.5-4), 3.5 x 3.5 x 3.5, 4 x 4 x 4
Frame	Salt-resistant wood, vertical wood: ϕ = 15-20 cm; horizontal: ϕ = 7-15 cm	Salt-resistant wood, vertical wood: ϕ = 15-20 cm; horizontal: ϕ = 7-15 cm and buoys (if floating cages)
Net bag	outer net: 2a = 20-50mm; inner: 2a = 2-4mm (fixed)	outer net: 2a = 10-15mm (floating) or 20-50mm; inner: 2a = 2-4mm;
Bottom	On or off-bottom (~ 0.5 m)	Off-bottom (> 0.5 m)
Depth (m)	< 4 m	> 4 m
Distance from shore	Close (<1000 m)	Far (>1000m)
Source of fry	Wild	Wild
Stocking density (individuals/cage)	100	100
Rearing period	18 - 20 months	18 - 20 months
Feed used	Trash fish, ark, clam, crab	Trash fish, ark, clam, crab
Feeding regime	≤ 200g-lobster: twice a day; feed with out shell > 200g-lobster: 1-2 times/day: 30% in the morning, 70% in the afternoon; feed with shell	≤ 200g-lobster: twice a day; feed with out shell > 200g-lobster: 1 time/day; 100% in the afternoon; feed with shell
FCR	28-30	20-30
Sediment colour	Darker	Brighter
Sediment smell	Off-flavor	Normal
Bottom organisms	Mainly polychaet	Mainly molluscs
Cumulative mortality	30 -100%	05 - 30%
Survival rates	0 - 70%	70 - 95%

Production (kg /cage)	< 70	> 70

- Management agreement: should be established among the local communities because aquaculture contributed 90% to the village's economy.

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And????

Multiple use freshwater pond, Rajshahi, Bangladesh

Tropeca Case Study 5

M Niamul Naser
Department of Zoology, University of Dhaka, Dhaka, Bangladesh
Email. mnnaser@yahoo.com
February 2005

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Introduction

Farming in earthen ponds has grown to tremendous acceptance by pond owners in Bangladesh over the past few decades. In semi intensive system many modifications has been made to grow more fish using small water bodies. Fish pond was treated with different inputs such as fertilizer and feed for fish resulting directly or indirectly in the release of nutrients in ponds. To maintain a better aquatic environment is indispensable for achieving sustainable fish production. The aquatic environment is a complex dynamic system. It is subject to constant physico-chemical changes due to natural causes and mans activities. Major deviation from the optimal level may result in stress to the cultured organisms. Stress elicits a series of physiological and behavioral responses in the organisms. If prolonged, the stress may lead to poor growth, reproductive failures, besides rendering them susceptible to disease - every culturists nightmare.

Bangladesh has a long unsuccessful history of cage culture. Unlike other Asian countries, Bangladesh has a limited history of fish culture in cage, and much has been unsuccessful. The only traditional use of cages is for the holding of fish in small bamboo boxes in the Sylhet region. The first documented attempts on cage culture were in research institutes in the 1970s and 1980s. But these were small scale research projects conducted near the campuses of the institutes, and little attempt was made to involve rural farming in cage culture (Haque 1978 ; Islam *et al*. 1988 ; Hossain *et al*.1986). The first serious attempt to introduce cage culture in Bangladesh occurred during the 1980s in the lake Kaptai (Felix 1987). These projects were unsuccessful due to several factors. In 1991 and 1992, the department of fisheries (DOF) and overseas development agency (ODA, now DFID), supported the North-West fisheries Extension project (NFEP) in the conjunction with CARE in piloting small scale cage culture in northwest Bangladesh. Although initially successful, the project failed due to high levels of post-stocking mortalities.

In recent past, NGOs became the driving force behind the development of cage aquaculture in Bangladesh. Poor people of Bangladesh are very much interested about the cage culture. Because this method is easy to them in point of feasibility ,financial , monitoring , profit and marketing . Moreover, this culture has brought about significant change in their livelihood. Cage culture helps the fisherman to supply protein. They can make their own cage by available materials. For the fisherman lacking a pond this technology has created an opportunity. Multi-ownership of ponds is one of the constraints in fish culture in Bangladesh. In these cases, it is very difficult to proper use of the pond; this problem may be overcome by cage aquaculture because this culture suggests that ownership of the fishes go to owner of the cages.

CARE CAGES project has introduced small scale pond cage culture technique for poor. However, majority of these cages were placed in pond which was used for multipurpose uses like fish culture, irrigation and household use. In cage culture system, unused feed and fish feces fall from the bottom of floating net cages on the floor of the water body. Accumulated waste decompose and causes nutrient imbalance of water. Cages also increase deposition of silt on the bottom of the pond. Bangladesh has about 1.7 million ponds and if pond cage culture is adopted by the poor the environmental capacity of ponds for cage culture and other activities should be known.

Objectives

- The overall "umbrella" project was initiated to develop practical guidance for the estimation and allocation of environmental capacity for aquaculture in tropical developing countries, and
- To sustain and increase productive benefits of aquatic resources for poor people through improved knowledge of aquaculture processes and their management

Rationale

- The expansion of aquaculture in developing countries poses risks of exceeding environmental capacity
- The possible need to control the use of sites, in order to remain within environmental capacity, has implications for resource allocation and access

Case objectives

Considering the above stated factors, TROPECA case study in Rajshahi developed the following objectives:

- Identification of problems faced by cage farmers
- Develop nutrient budget in a multi-use pond including cage culture
- Determine the impact of cage culture on water quality and other users
- Refine nutrient management for the benefit of all users

Methodology

Site selection

First CARE cage villages list was taken. The related NGOs were contacted and several visits were made to see the suitable pond site from cage villages of Bangladesh. Most suitable study pond was found in Putia upazilla under Rajshahi district about 300 km from Dhaka. Two ponds were selected for the study. About 15 farmers were selected for the study. The farmers are not the owner of the pond . They have to access to the pond owner by negotiation. The details of the two ponds are given below.

Table 1: pond characteristics

	Pond A	**Pond B**
Size	1.25 Ha	0.35 Ha
Ownership	multiple	Dual
Uses	multipurpose	Multipurpose
Management	Multiple	Dual
Fish culture uses	Carp fry rearing	Carp culture
Cage culture	Additional effort	Additional effort

Problem identification

Rapid rural appraisal (RRA) method has been applied to identify the problem. A workshop had been arranged to exchange views and finalize the issues from all stakeholders of the ponds. This has been described in a previous report.

Nutrient budget

In cage ponds all inputs and outputs were identified. The amount were recorded and the nutrient values of P and N were analysed for further interpretation of nutrient dynamics of the ponds.

Water quality

Some physical and chemical variables of pond- water were studied. The chemical parameters of water measured on spot by using a water analysis kit box (Model no.FF - .2, Cat -2430 -01. HACH, U.S.A.).

Water temperature
Water temperature was recorded directly from the water body by dipping a digital centigrade thermometer into the water body.

Water depth
The depth of the pond - water was measured by setting six permanent sticks at different places and the value was measured with a meter tape in average.

Transparency:

The transparency or the level of light penetration was measured by lowering a “Secchi disc” into the water until it just disappeared and measuring the length of the rope bearing the secchi disc by a measuring tape in cm.

Chemical variables

P^H

pH was determined by digital pH meter of HANNA(Model no -RI -02895.Italy)

Dissolved Oxygen(DO)

The amount of dissolved Oxygen was determined by digital DO. meter of Lutron company ;India (Model no.-D O -5509) . HACH water analysis kit was used in some cases.

Free Carbon dioxide:

Free carbon dioxide was determined by Test Kit. In this method, sample water was titrated with standard 0.3636 N sodium hydroxide using phenolpthaline as indicator.

Hardness:

The sample water treated with buffer solution, Hardness -1 and Manver powder. Hardness indicator solution, Hardness 2 to give a pink solution. Then the titrant Reagent, EDTA added to drop by drop until the solution colour changes from pink to blue.

Ammonia:

Nesler Reagent ammonia test was done by a color comparator method. Rochelle salt was added to the sample to eliminate interference due to Hardness.

Nitrite:

The sample was treated with Nitriver (R) 3 Nitrite Reagent powder pillow and was compared with non-treated sample against color disc, in a colour comparator box.

Phosphate

The sample was treated with phospover reagent powder pillow and was compared with non treated sample against colour disc , in a colour comparator box.

Livelihood of the cage farmers/pond user

A study was undertaken to see how the pond aquaculture impact on the livelihood of the pond users. Any social issues arise also considered.

Farmer Issues

From workshop with farmers and various stakeholders several priority issues were identified.

- Limited availability of good quality fish fry
- Scarcity of supplementary food in local area
- Inadequate knowledge about fish farming particularly in feeding fish and feed ingredients
- Contamination of pond fish with tilapia fry released from cages
- Deterioration of water quality due to plankton bloom causing high fish mortality
- Conflicts of interest among pond owners and cage farmers
- Problem in fish marketing

Nutrient budget

Inputs and outputs

Duck dropping: A good number of duck swims in the pond in average 7-8 hrs daily.

A considerable amount of feaces was released directly to the pond

Cow dung: Pond A was used for household work. Thus cow dung fertilization was prohibited. However, 6-8 cows were housed in the bank of pond whose dung was dumped at one corner of the pond. A regular seepage was evident during this study. Pond B was fertilized with cow manure for carp culture. are usually entered into pond particularly in the rainy days. It also a good source of N,P &K.

Domestic wastes: There were 6 tube wells around the pond A, which release various domestic water to the ponds. However we donot identify any nutrient source added in the pond except soaps.

Toilet: There are 3 toilets . But there is no direct relationship among these and pond water .But when heavy rainfall occurred urine may be mixed with water .

Soap and detergent: The neighboring residents usually use moderate amount of soap. The amount of soaps used was recorded.

Leaves-About 17mango trees are on the bank of pond A and less in pond B. The tree do not shed all leaves in winter. The total amount of leaves was recorded for each pond.

Water exchange: The boundaries were tightly closed .there is no scope of water exchange between pond and surrounding environment.

Mass balance

The total N and P nutrient were calculated regarding all inputs and outputs from each pond (table 2). It was evident there is a net accumulation of N and P of 85.98 kg/ha/y and 56.64 kg/ha/y respectively in pond A. The amount of accumulation was higher in pond B (N 128.36 kg/ha/y and P 81.58 kg/ha/y). In both cases the major contributor for nutrient was the fertilizer, followed by feed.

Table 2 : Nutrient distribution in Pond A and Pond B.

Pond A **1.25 Ha** **11 months** **Total 48 Cages**

Inputs	**Kg**	**Cal wt**	**N% Cont**	**Kg N**	**% N**	**P% Cont**	**Kg P**	**%P**
Tilapia fry	120	120	4.843	5.8116	2.956	0.4495	0.5394	0.729
Carp fry	300	300	4.843	14.529	7.391	0.4495	1.3485	1.822
Fish feed	300	240	1.9	4.56	2.320	0.43	1.032	1.395
Leaf part feed	3470	867.5	1.4	12.145	6.178	0.03	0.26025	0.352
Urea	330	330	46	151.8	77.217	0	0	0.000
TSP	330	330	0	0	0.000	20.64	68.112	92.043
Cow dung	900	801	0.81	6.4881	3.300	0.27	2.1627	2.923
Duck drop	600	120	0.92	1.104	0.562	0.44	0.528	0.714
Leaf	50	10	1.5	0.15	0.076	0.175	0.0175	0.024
			Total N	**196.588**	100	**Total P**	**74.000**	100.000
Outputs								
Tilapia fish	1540	1540	4.843	74.5822	76.049	0.4495	6.9223	76.049
Carp finger	485	485	4.843	23.48855	23.951	0.4495	2.180075	23.951
			Total N	**98.071**	**100**	**Total P**	**9.102**	100

N left **98.517** **N Kg/ha/yr** **85.98**
P left **64.898** **P kg/ha/yr** **56.64**

Pond B **.35 ha** **8 months** **Total 21cages**

Inputs	**Kg**	**Cal wt**	**N% /kg**	**Kg N**	**% N**	**P %/ Kg**	**Kg P**	**%P**
Tilapia fry	45	45	4.843	2.17935	2.795	0.4495	0.202275	0.860
Carp fingerlings	20	20	4.843	0.9686	1.242	0.4495	0.0899	0.382
Fish feed	0	0	1.9	0	0.000	0.43	0	0.000
Leaf part feed	1300	325	1.4	4.55	5.836	0.03	0.0975	0.414
Urea	232	150	46	69	**88.495**	0	0	0.000
TSP	232	110	0	0	0.000	20.64	22.704	**96.483**
Cow dung	150	127	0.81	1.0287	1.319	0.27	0.3429	1.457
Duck drop	100	20	0.92	0.184	0.236	0.44	0.088	0.374
Leaf	20	4	1.5	0.06	0.077	0.175	0.007	0.030
			Total N	**77.971**	100	**Total P**	**23.532**	100.000
Outputs								
Tilapia fish	540	540	4.843	26.1522	54.545	0.4495	2.4273	54.545
Carp	450	450	4.843	21.7935	45.455	0.4495	2.02275	45.455
			Total N	**47.946**	**100**	**Total P**	**4.450**	100

N left **30.025** **N Kg/ha/yr** **128.36**

P left **19.082** **P kg/ha/yr** **81.58**

Physico-chemical parameters:

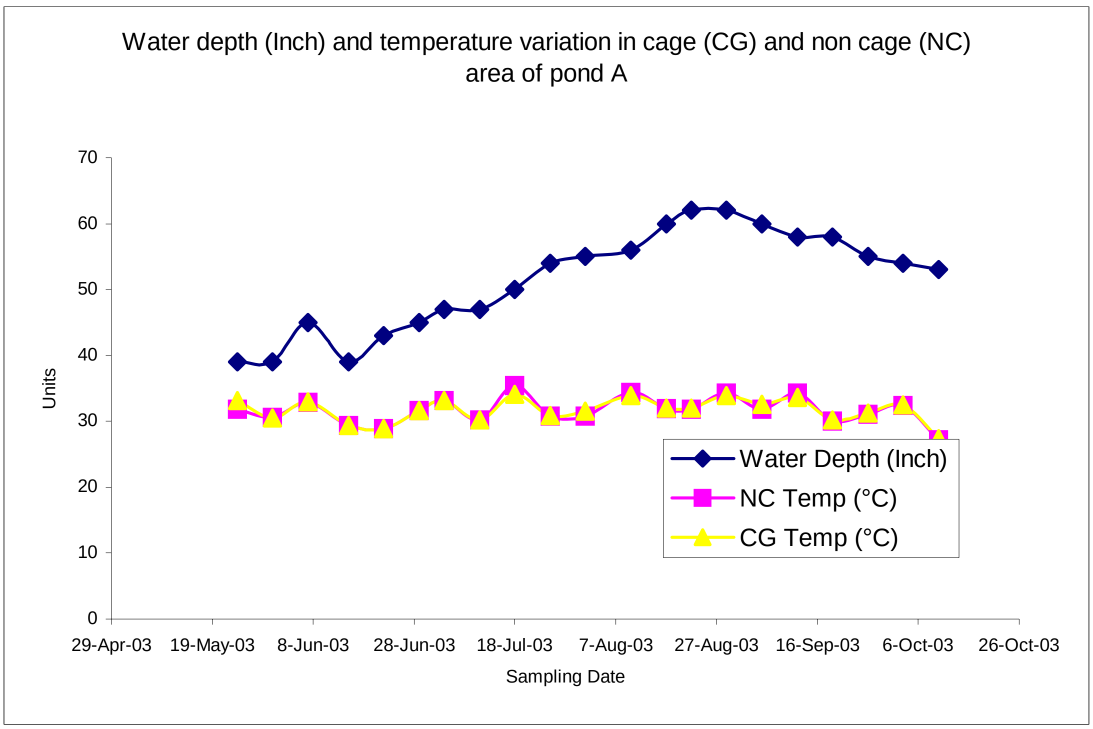
As the physical and chemical parameters having a great role in the species diversity and also seasonal rhythm of various biological factors. Most of the variables showed changes their quality with seasons.

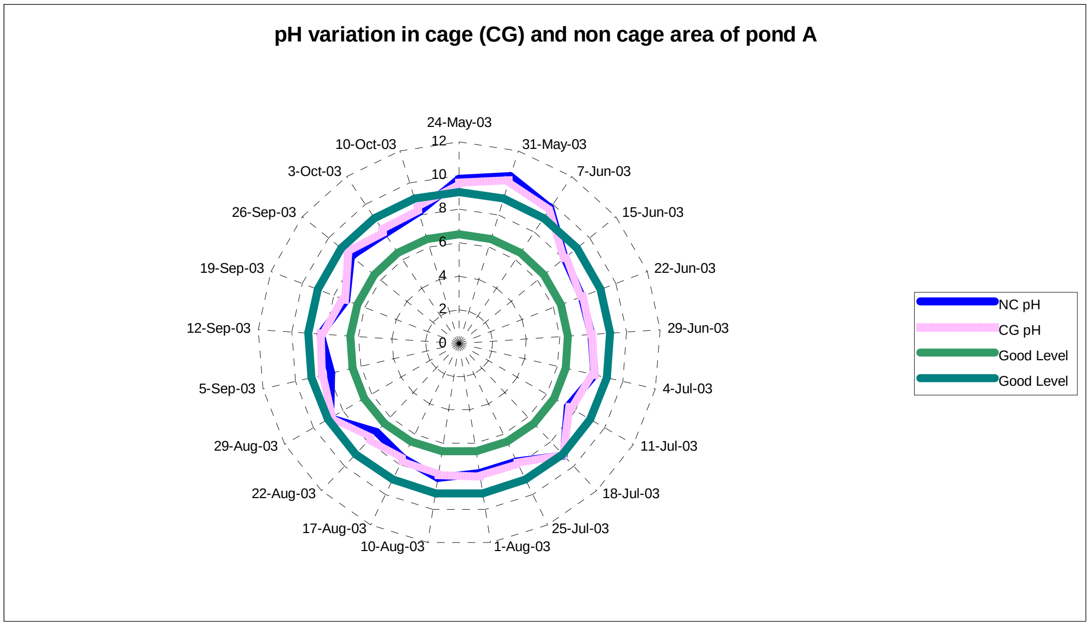
Water temperature and depth

The water temperature of Pond A did not vary much. The water depth showed a trend towards higher level due to the rainy season. The water temperature ranged between 27.2°C and 35.4°C. The maximum water depth of the pond was 62" and minimum was 39".

pH:

The pH value of the water varied between 7.2-10.4 during the present investigation in pond A. The value was higher coinciding to liming in ponds.





Dissolved Oxygen:

Disssolved oxygen varied from 4.5 (oct/sept 03) to 9.2 (may 03) mg/L in pond A. Recommended concentration for aquaculture of dissolved oxygen was 5 mg/L or higher (Boyd, 1992). The lowest value corresponds to fish kill on that week. However, overall DO level showed suitability of fish culture.

Free Carbon dioxide (CO_2):

During the present investigation, CO_2 content was found lowest in rainy season.. The free CO_2 content of pond water showed seasonal changes which increased during summer and declined during autumn and winter . Carbon dioxide was lowest (2.8 mg/L) in July and highest (28 mg/L) in June in pond A. :

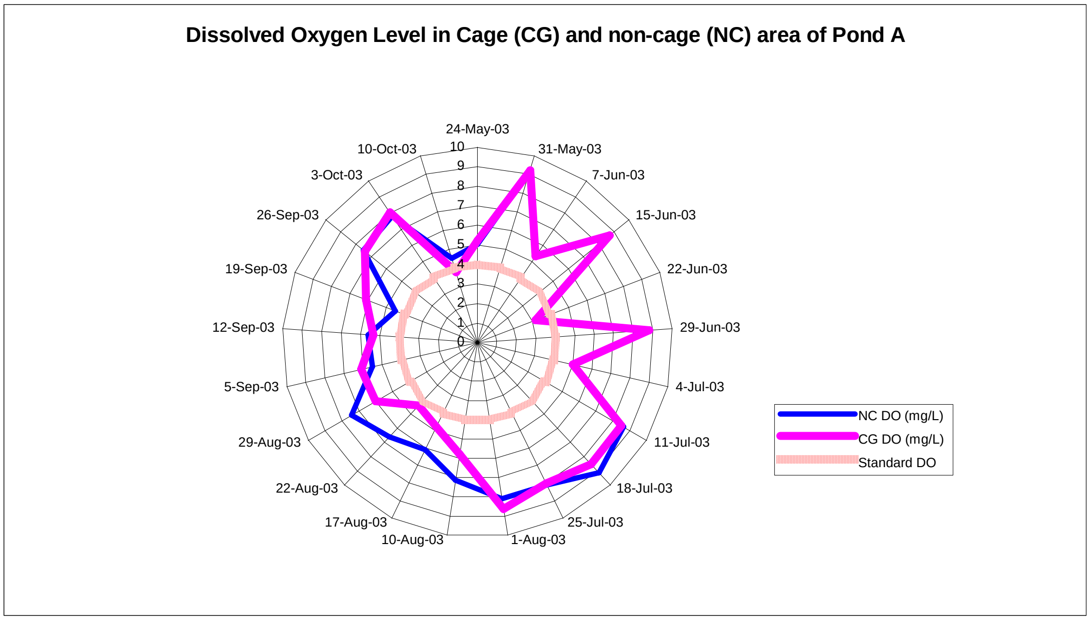
Total Hardness:

Total hardness means the cation concentration and total alkalinity means the anion concentration. It is the dividing line of hard water and soft water. Hardness of water is directly related to biological productivity. A hardness level as 170-220 mg/L is termed as good quality water . During the present investigation, 108 mg/L (Sep 03)to 178 mg/L (May 03) was observed from pond A.

Ammonia:

It is mainly found in water as ammonium ion (NH_{4+}). It is found through the bacterial breakdown of protein and through bacterial denitrification. It is also formed through N_2 fixation by certain bacteria, molds and blue green algae. It is used by plant to some extent as the nutrient. In unpolluted water body its concentration is low (1 mg/L or less). Due to organic pollution, pollution by gases work and very high decomposition, high concentration of ammonia (12 mg/L or more) colour in water which may become detrimental or lethal to fishes and other aquatic animals.

The level of ammonia varied from 0 (May, July 03) to 1.6 mg/L (June 03) in pond A.



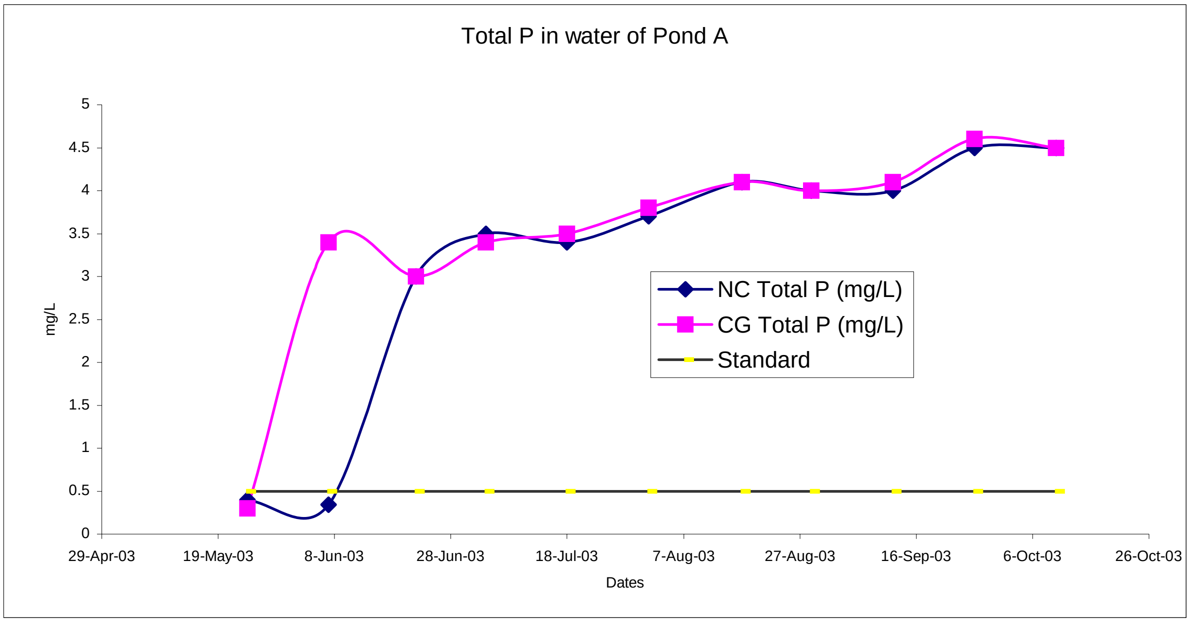
Nitrite

Nitrite, the partially reduced form of nitrate is usually present in insignificant quantities (Goldman and Horne, 1983). Insignificant quantities of nitrite were recorded during the present investigation. Marked monthly seasonal variation was observed but relatively higher values were found in autumn. An imbalance in the nitrification reaction leads to the accumulation of nitrite. Nitrite originates from the reduction of nitrate by bacteria in anaerobic mud or water. When nitrite is absorbed by fish, it reduces the oxygen carrying capacity of blood and causes a Brown Blood Disease to the fish. The nitrite varied from 0 (May 03) to 0.1 mg/L (Oct 03) in pond A.

Dates	24-May-03	7-Jun-03	22-Jun-03	4-Jul-03	18-Jul-03	1-Aug-03	17-Aug-03	29-Aug-03	12-Sep-03	26-Sep-03	10-Oct-03
Pond water parameters (Away from Cages)											
Secchi (Inch)	6.1	5.5	5.7	6.5	6	5.1	6	7.4	5.8	6	8.5
Total P (mg/L)	0.4	0.34	3	3.5	3.4	3.7	4.1	4	4	4.5	4.5
Nitrite (mg/L)	0	0	0.01	0.03	0.02	0.03	0.03	0.03	0.04	0.03	0.1
CO2(mg/L)	4.8	9.5	28	24	2.8	11.5	10.5	4.7	9.1	13.2	19.6
Hardness (mg/L)	178	170	150	112	115	112	114	109	108	120	125
Ammonia (mg/L)	0	0	1.6	0.6	0	0.1	0.5	0.5	0.5	0.6	1.2
Pond water parameters (Where Cages Placed)											
Secchi (Inch)	6.1	5.8	5.6	6.5	6	5.2	5.9	7.5	5.6	6	9
Total P (mg/L)	0.3	3.4	3	3.4	3.5	3.8	4.1	4	4.1	4.6	4.5
Nitrite (mg/L)	0	0	0.01	0.04	0.03	0.04	0.04	0.04	0.05	0.04	0.1
CO2(mg/L)	4.9	9.7	27	15	5	12.3	10.7	7.2	9	13.4	21.3
Hardness (mg/L)	178	137	124	112	112	114	112	112	110	102	104
Ammonia (mg/L)	0		1.3	0.5	0	0.01	0.5	0.5	0.6	0.6	1.1

Total-P

The total phosphorus of water varied from 0.34 mg/L to 4.5 mg/L in pond A. The variation usually depends on fertilization of the pond, i.e. after TSP fertilization the level was found to be highest. However, the ideal is 0.5 mg L. The TP content of water was much higher than recommended levels for aquaculture ponds.



Indicators

The following were identified as indicator of water quality and fish health for pond aquaculture.

- Brownish or yellowish-green color water is suitable for cage culture
- Highly green water is not suitable for fish culture .
- Fish come to the surface of the water indicates poor conditions
- During the winter season fish become weak, lethargic and suffer diseases

A correlation between farmers indicators and water quality is given in table.3

Biological indicators

When the N and P fertilizer were applied to ponds the production of plankton was tremendously increased. This could be used a biological indicator. However, no simple method to identification of plankton was developed.

Indicators could be use as prediction to access environmental capacity of a pond exceeding and well as to understanding the water quality of fish ponds.

Table 3. Indicators and its relationship to water quality of two ponds

Water nutrient	Abundant Plankton group	Tolerance to fish	Water quality	Farmers observation
High N early week	Algae	Ok	OK, Secchi depth ~10 cm	Green pond, low transparency
High N, later week	Filamentous algae	OK	OK, Secchio depth <10 cm	Green pond, moving towards bloom, O deficiency
High N, further progression	Low plankton	Fish kill	NH3 High, DO comparatively low, Secchi depth >25 cm	Fish kill, Water colour blackish, pungent smell, bottom mud smelly
High P	Abundant Rotifera	OK	OK, Secchii depth > 10 cm	Yellowish brown water colour, medium transparence
Low P	Abundant Clodoceran	OK	OK, Sechii depth > 20 cm	Brownish water colour, transparent water
Low nutrients	Less abundant plankton	OK	OK, Secchii depth < 30 cm	Transparent water, brownish water, can see full hand under water
High DO	High plankton /early stage	OK	OK, Secchi depth ~10 cm	Green pond, low transparency
Low oxygen	Low plankton/ later stage	Fish kill	Low oxygen, High N NH3	Fish kill, fish hoping up the pond surface
High N, P	Abundant phytoplankton	OK	High N No2, TP	Framers observe green water. Fertilizer was applied

Livelihood assessment

The villege Chakdadus of Putia, Rajshahi has brief history in cage culture. This village was trained by CARE CAGES project and had an unique physical feature for cage culture. Cage farmer's dominant area and most of the villager were involved in cage culture.

Methodology:

Questionnaires developed to conduct a survey and data collection. Some selected rapid rural participatory research tools such as Venn diagrams, transects, social mapping and semi-structure questionnaire were used.

Age structure

Knowledge of the age structure of fisherman is important to estimate potential productive human resources. The age distribution of farmers has an important tools. Most of the farmers included in the age groups ranges 30-40 i.e. most of the farmers are quite young.

Housing condition

In the study area, houses of the community were of mainly three types:

1. Katcha- houses are made of bamboo and tree leaves with mud flooring
2. Semi pucca - made of wood or /and tin
3. Pucca- made of brick.

The present study revealed that 80% of housing structures were katcha(hat) while 13.33% were semi-pucca(tin shed) and only 6.66% were pucca (building) among the community.

Health facilities

Respondents were asked to state the type of health services they could afford for their family. The study reveals 13.33% were dependent on local kabiraj (Village Doctor) who did not have any understanding of medical science, while 10% and 76.66% dependent on local doctors and Upazilla health complex respectively (Table 4).

Table 4. Health services used by farmer.

Health facilities	No of farmers	Percentage
Local kabiraj	4	13.33
Local Doctor	3	10
Upazilla health complex	23	76.66

Drinking water facilities

The provision of safe drinking water is considered to be the most important elements. The study showed that 90% of cage farmer used tube well and 10% used pond water for drinking . (Table) .

Table. Use of drinking water by farmer.

Drinking water facilities	No of farmers	Percentage
Tube well	27	90
Pond	3	10
Well	0	0

Sanitary facilities

It was observed that sanitary conditions were very poor . In the study area 53.33% oipen or kacha and 33.33 % semi pacca and 13.33% pacca toilet(sanitary latrine) used by the farmers (Table) .

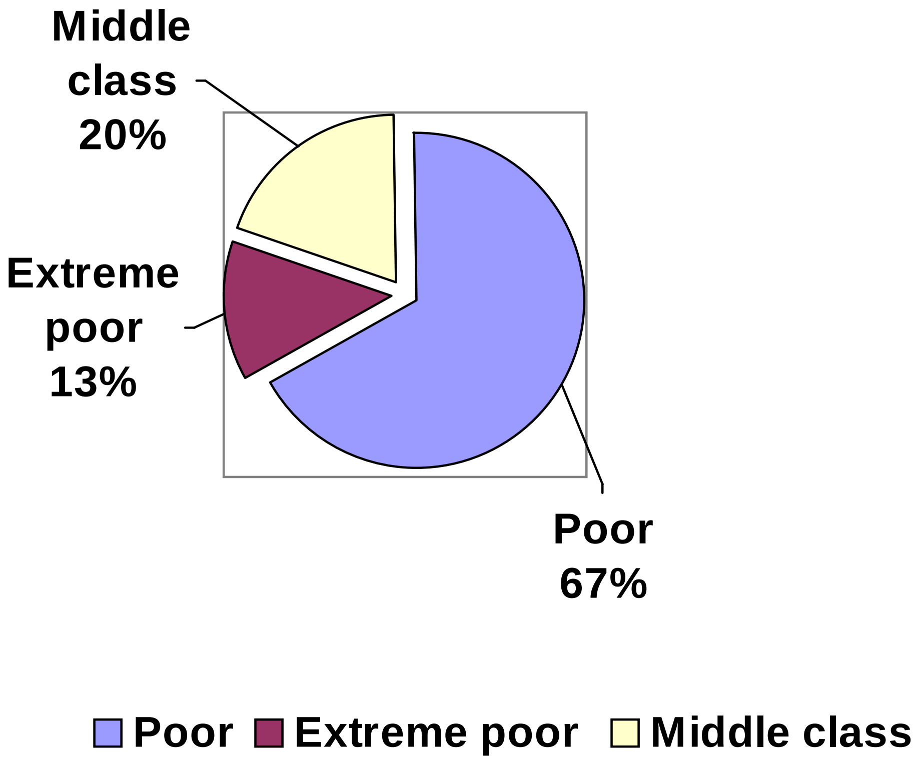
Table. Sanitary facilities used by the farmers.

Types of sanitation	No. of farmers	Percentage
Kacha(non sanitary)	16	53.33
Semi pacca(semi sanitary)	10	33.33
Pacca(sanitary)	4	13.33

Economic class structure of cage farmer

Economic class structure of cage farmer according to wealth ranking categories were 66.66% poor , 13.33% extreme poor, 20% middle class.

Such condition of cage farmer may be described further on the basis of qualitative indicator (Fig)



Cage culture as a tool for improving socio-economic conditions

Though farmers' living conditions are poor , the survey suggests that they have improved their socio-economic conditions through cage culture. Among them 80% of the cage farmers improved their living conditions through cage culture and 20% of cage farmers yet no improved their status. Such improved conditions may be described further on the basis of qualitative indicator. These could include increased food consumption, increased social status, involvement of women in cage culture and associated activities. Study results suggest that cage farmer have broadly improve their standards of living , purchasing power, choice and ability as an economic sector . The drawback of the 20% poor cage farmers were mainly unability of money to investment. Besides, unavailability of pond (failure negotiation), fish mortality, theft and unavailability of fish seed were affect these farmer more than the others.

Management implications

From above it is evident that cage culture in Putia village has good impact on the livelihood means for the poor. However complex management plans like, over doses of nutrient in pond resulting various problem in the ecosystem. It resulted to issues for social conflicts between pond carp culturist and pond cage culturist. Besides various indicators could be used to resolve to overcome the pond nutrients situations. Some of the key management issues are given in Table.

Management Plan for Pond Cage culture

Issues	Objectives	Mechanisms	Institutions
• Green colour pond, moving towards the plankton bloom • Fish kill • Eutropication of the pond • Bottom pond soil stinky smell • Filamentous algae grows • Loss of biodiversity of plants by feeding tilapia • Release of tilapia fry to the culture pond	• Yellow-brown water colour • Stop fill kill • Secchi depth of 10-20 cm • Stop eutropication of pond • Healthy pond bottom soil • Conserve the biodiversity of plants of the area • Stop introduction of tilapia in pond from cages •	• Avoid adding fertilizer in pond • Move cages to other part of the pond • Stop fertilizing the pond • Selling all fish in winter, mix pond bottom well, liming with proper dose • Feeding fish with pellet • Use of mono sex tilapia	• Community formation and discuss various events of nutrients in ponds (simpler form) • Involvement of local NGOs • Involvement of DoF personnel

Dissemination

- **Research/information partnership**: Partnerships with universities, national and international research institutions, agencies involved in development work within and outside the country are developed. These partnerships have been mutually beneficial and will become productive when there are well-defined frameworks. Research scientist had arranged several presentation in the university and FRI.
- **Horizontal scaling (people to people):** This process' major focus is the transfer of information from people to people. For effective upscaling of TROPECA issues this is foremost task to do. TROPECA will arrange workshop with cage culturist for better understanding of the nutrient availability in ponds.
- **Human resource development:** There is no scope for HRD. However, severa;l undergraduate students were developed during this TROPECA porjeect time.
- **Working with farmers:** Working with farmers generally consists of the group approach following a farmer field school strategy, wherein farmers meet at regularly to learn together, through action-oriented educational approaches. With the help of local NGO POSD, group of farmers were formed. Both male sand females were taken. The general principles in farmer field discussion approaches followed CARE model as follow:

    - Learning contract. Each group is encouraged to establish a learning contract in which the commitment of all parties is included.
    - Field is the classroom. Farmers identify the problems and areas where issues have to be addressed. Plans are developed by the farmers to meet their own needs.
    - Curriculum focuses on science, not just technology. Based on the identified needs of the farmers, curriculum is developed to increase their knowledge. Sometimes, progressive farmers are used to develop a curriculum appropriate to the village. Learning sessions could vary in number depending on the importance farmers attach to the issue.
    - Meet on set days and set time. Generally, each group meets at least once in a fortnight and undertakes observations collectively. In addition to these fixed meetings, extension staff also provides follow-up support.
    - Make time for analysis and synthesis. At the end of the session, results are analyzed by the farmers and shared with others. Farmers' science congress is also becoming popular. In these meetings, farmers share and analyze results with other farmers.

- Partnership with government agencies: working with the Department of Fisheries achieves wider coverage. TROPECA will explore the scope of working with DoF to dissiminate the findings.

Conclusion and recommendations

Cage aquaculture can make a significant impact on people. To achieve such an impact, changes are necessary in the extension processes. Following are the major lessons learned from the scaling up processes.

- More care with cages: The present cage culture practice in the pond found to be more careless practice. Cage farmers should be aware of the care of cages. So that fewer escape of tilapia fries to pond occurs. Sale of mature female could help in simple way as well monosex tilapia could help in preventing fish escape to pond.

- Awareness building of uses of nutrient sources in the pond. Farmers should be awarded of the effects of cages on pond environment. Moreover, introduction of nutrient through non-traditional feed like leaf and fertilizer should be avoided.

- The use of various leafs for fish feed causes loss of plant biodiversity. Besides, conflicts between using of leafs for human and fish consumption may arise. Farmers should be encourage grow fish with good FCR feed.

- Pond owner should be aware of natural feeding of carp and its relation to pond productivity.