Environmental Capacity Management of Shrimp Culture Based Aquatic System in the Southwest Coastal Region of Bangladesh.

Fisheries and Marine Resource Technology Discipline
Khulna University, Khulna
Bangladesh

August, 2005

Environmental Capacity Management of Shrimp Culture Based Aquatic System in the Southwest Coastal Region of Bangladesh.

A Thesis

By

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Examination Roll No: MS-030604

Session: 2002-2003

The Thesis submitted to the Fisheries and Marine Resource Technology Discipline in partial fulfillment of the requirements for the Degree of

Master of Science

In

Fisheries and Marine Resource Technology

August, 2005

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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.

In the shrimp culture, a large amount of feed and fertilizer is applied to pond to increase production. A large portion of this feed and fertilizer eventually enters the water as metabolic waste (Boyd, 1985). 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

DECLARATION

The results submitted in this thesis are entirely of the candidate's own investigation and no part of the results has been accepted for any degree, nor it is being concurrently submitted for any degree.

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ACKNOWLEDGEMENT

It is my gratification for being able to complete this thesis, so first of all, all my appreciation and indebtedness go for the creator of the universe, the omnipotent, omniscient, omnipresent Allah.

There are many people who helped me in various ways to complete this study successfully. I wish to express my thanks to all of them, specially:

I am pleased to express my deepest sense of gratitude, heartfelt indebtedness and profound respect to my honorable supervisor M. A. Rouf, Associate Professor, Fisheries & Marine Resource Technology Discipline, Khulna University, Khulna for his scholastic guidance and continual effective help to execute this thesis successfully.

I would like to express my deepest sense of gratitude and profound respect to Professor Dr. M. S. Shah, Former Head, Fisheries and Marine Resource technology discipline, Khulna University, Khulna for his valuable suggestions and providence of all necessary facilities.

Special thanks are extended to DFID and Nautilus Consultant Ltd (UK) for providing funds to carry out this extensive research work.

I am also indebted to the shrimp farmers of study area for their sincere co-operation and all-round support during the observation period.

Finally, I would like to convey special thanks to all my teachers, friends and well wishers for their kind co-operation, encouragement and inspiration to complete this thesis.

The Author

ABSTRACT

It is commonly assumed that expansion of coastal aquaculture in Bangladesh poses risks in exceeding environmental capacity. Therefore it is very essential 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. A study was conducted under a DFID-funded research project involving Nautilus Consultants Ltd. (UK), to investigate this issue. The study was done in an aquatic system of the upazilla Dumuria under the district Khulna comprising a river, a canal and 10 shrimp ponds as well the results were verified by wider area survey. Shrimp culture practices were mostly extensive to improve extensive without proper pond preparation, fry nursing, stocking or feed management. Consequently production rate were low, averaging only 191 $kgha^{-1}$. High mortality of shrimp was reported immediately after heavy rainfall in some of the shallow ponds. The study encouraged farmers to report conditions leading to a variety of potential indicators being tested 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 28.95 $kgha^{-1}cycle^{-1}$ 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 capacity standard. Year round water quality observations indicated that there were no major differences among the river, canal and pond water, which might be due to the water-flushing rate of 468% per cycle. The water quality in shrimp ponds during grow-out period in this experiment was in acceptable range. It may be concluded that the aquatic environment is able to accommodate the present level of aquaculture practice. But, the assimilative power of aquatic environment is in danger of being degraded with the expansion of shrimp culture areas. Given the poor yields investment in more intensive culture has been slow to materialize. On the other hand, Saline water logging continuously for long time in shrimp farms resulted in salinization, scarcity of freshwater and destruction of various freshwater species. Such cumulative impacts must be considered in planning aquaculture and other development if environmental capacity is not to be exceeded.

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LIST OF ABBREVIATIONS

Abbreviation	Elaboration
BRAC	Bangladesh Rural Advancement Committee
DFID	Department for International Development
FAO	Food and Agricultural Organization
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Pollution
ha	Hector
HT	High Tide
LGED	Local Government and Engineering Department
LT	Low Tide
PL	Post Larvae
TN	Total Nitrogen
TP	Total Phosphorus
TSP	Triple Super Phosphate
UK	United Kingdom
WSSV	White Spot Syndrome Virus

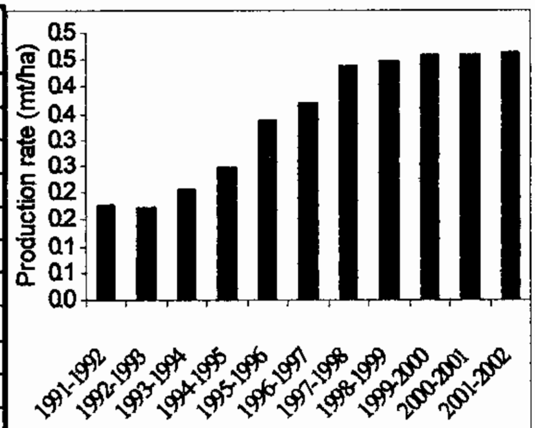
Chapter-1
INTRODUCTION

Shrimp farming has become one of the Asia's fastest growing industries (Chang, 1990). The world cultured shrimp production increased steadily and reached 600,000 mt. by 1990 (Csavas, 1992). The Asia-Pacific region continued to dominate the worlds cultured shrimp production with its 80.6 % contribution in 1991 (Csavas, 1992). More than 85% of world's farmed shrimp is produced in coastal areas of the Asia-Pacific region and Bangladesh was the fifth largest producer in the world (FAO, 2002).

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 115088 hectare and 20,335 mt. respectively in the fiscal year1991-92 (Table1).

Table1: Shrimp farm area and Production 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
1995-1996	137996	46,223	0.335
1996-1997	141353	52,272	0.369
1997-1998	141353	62,167	0.439
1998-1999	141353	63,164	0.447
1999-2000	141353	64,647	0.457
2000-2001	141353	64,970	0.459
2001-2002	141353	65,579	0.464



Source: DoF, 2003

Before early 1990's, brackish water shrimp farming in Bangladesh mostly involved traditional extensive methods. After that, semi-intensive and intensive methods were initiated. 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 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 (Korm *et al.*, 1985; Korm 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 farms of Bangladesh.

In the present study, the effluent loading of nitrogen and phosphorus, water quality and managerial operation of some coastal shrimp (*P. 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 was estimated to establish primary nutrient sources and the potential limiting factors in the system. 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.

However, the specific objectives of the present study were:

- To know about management and environment related issues of shrimp culture in the southwest coastal region.
- To understand the involvement, interaction and influence of institutions and organizations on fisheries.
- To estimate nutrient mass balance and dynamics.
- To assess the environmental capacity coastal in shrimp culture based on nutrient mass balance and dynamics.
- To develop a guideline for the management of shrimp culture to stay within the environmental capacity.

Chapter-2

LITERATURE REVIEW

2.1 Environmental capacity concept

Environmental capacity is defined by GESAMP 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).

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

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, 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 in aquaculture

Modelling can be described as an interdisciplinary approach to problem solving. Models can be used to help understanding natural events, answer questions and predict future impacts. All models whether simple or complex must go through the same process of model formulation and validation. The more common types of model used in ecology include time trend models, regression models, bio-energetics models, mass balance models, and simulation models.

To use models in the strategic development and environmental management of aquaculture, the complexity of a marine environment has 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 be considered in any attempt to model cause and effect. In the open marine environment these pathways become more numerous and complex. 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).

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.

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.

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 described in the next page.

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.

2.3 Farmer level indicators of environment 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.

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

2.4 Gross nutrient budgets

Total inputs to individual ponds, 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 cum 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 is 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. 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 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, 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.

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 has 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 (table 2). The quality of shrimp pond effluent is compared with domestic sewage in the table-1. 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 ponds effluent in comparison with domestic sewage (mg l^{-1})

Effluent characteristics (mg l^{-1})	Shrimp	Domestic water		
	Pond effluent	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

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 that 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 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. Food Conversion Ratio (FCR) 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, FCR 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 N and P contribution to ponds in water was 150 and 18 kg/ha.

In the extensive shrimp farms in Bangladesh are supplied with small amounts of nutrients. Extensive system relies on natural food, moderately stimulated by input of manure and fertilizers and may be a net remover 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.

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 overuse and abuse the antibiotics and other drugs to avoid massive mortalities cause.

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 intensive fishpond 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 throughinlet 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 wastes include amino acids, proteins, fats, carbohydrates, fiber, minerals and bacteria (Boyd, 1989). The discharge water from the intensive system was rich of nitrogen and phosphorus; both were important factors involved in eutrophication (Worsham, 1985). Effluents from ponds remove 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 shrimp farming is not expected to provide any significant loading of organic matter and nutrients to the surrounding coastal environment (Macintosh and Phillips, 1992). Unlike the significant effluent load from artificial feed-supplied intensive shrimp ponds with high water exchange rate (Boyd, 1989), 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 re suspended and flushed out of shrimp-cum-rice producing systems through the outlet at the end of shrimp production cycle. The accumulation of sediments year with year is causing siltation at the bottom (Wahab, 2003).

The solid organic matter (nutrients remain as uneaten food or excreted with the feaces) 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).

Chapter-3
MATERIALS AND METHODS

3.1 Study site

A reconnaissance survey was made to select the study site, located on the southwest coastal part of Bangladesh (fig. 3.1) in the Kulbaria Union under the Upazilla Dumuria in the district of Khulna. Two stations from river (named Teligati, Semi diurnal tidal system), two from canal (river connected) and ten were considered for weekly data collection (fig.3.2). Surveys in the greater Khulna region (Khulna, Satkhira and Bagerhat) were also conducted to verify the issues.

3.2 Shrimp farming techniques and management

In the present study, 10 brackish water 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.

The average size of the study ponds was 0.98 ha (table 3). Pond preparation began in early January after completion of paddy culture (from August to December). 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 (locally known as *tob*) for shrimp fry. The average depth of the *tob* was 1.17 m, but the average depth of plain land was only 0.81 m. The farmland was ploughed and left for 7-10 days under sunshine and lime (CaO) was applied at a rate of 200-300 kg ha^{-1}. After 7 to 10 days of liming inorganic and organic fertilizer was applied. Inorganic fertilizer, mainly Urea and TSP was used 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}.

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
1(Ram'd)	0.5	0.6-0.9	18,525	46	31.3	288	37	112	437
2 (Bimol)	0.4	0.9-1.2	9,880	45	28.6	129	164	120	413
3 (Ranjit)	2.4	0.9-1.2	8,398	44	28.0	105	49	34	188
4 (Dulal)	1.5	0.6-0.9	10,868	48	25.2	156	27	62	245
5 (Samiron)	2.0	0.9-1.8	18,525	40	24.4	244	186	134	564
6 (Ramen)	0.6	0.9-1.2	7,410	52	27.0	112	16	22	150
7 (Chitta)	1.3	0.6-0.9	16,055	50	29.0	264	31	228	523
8 (Naraon)	0.2	0.9-1.2	9,880	47	24.3	132	184	12	328
9 (Nitta)	0.6	0.9-1.2	8,645	46	26.4	156	14	25	195
10(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%)

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. However, average stocking density was 13,782 PLha^{-1}(1.37 PLm^{-2}). 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 (*tob*) was a common practice usually at few early spells. After the initiation of rainy season, when rain water inundated the whole farms fry nursing could not possible. 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.

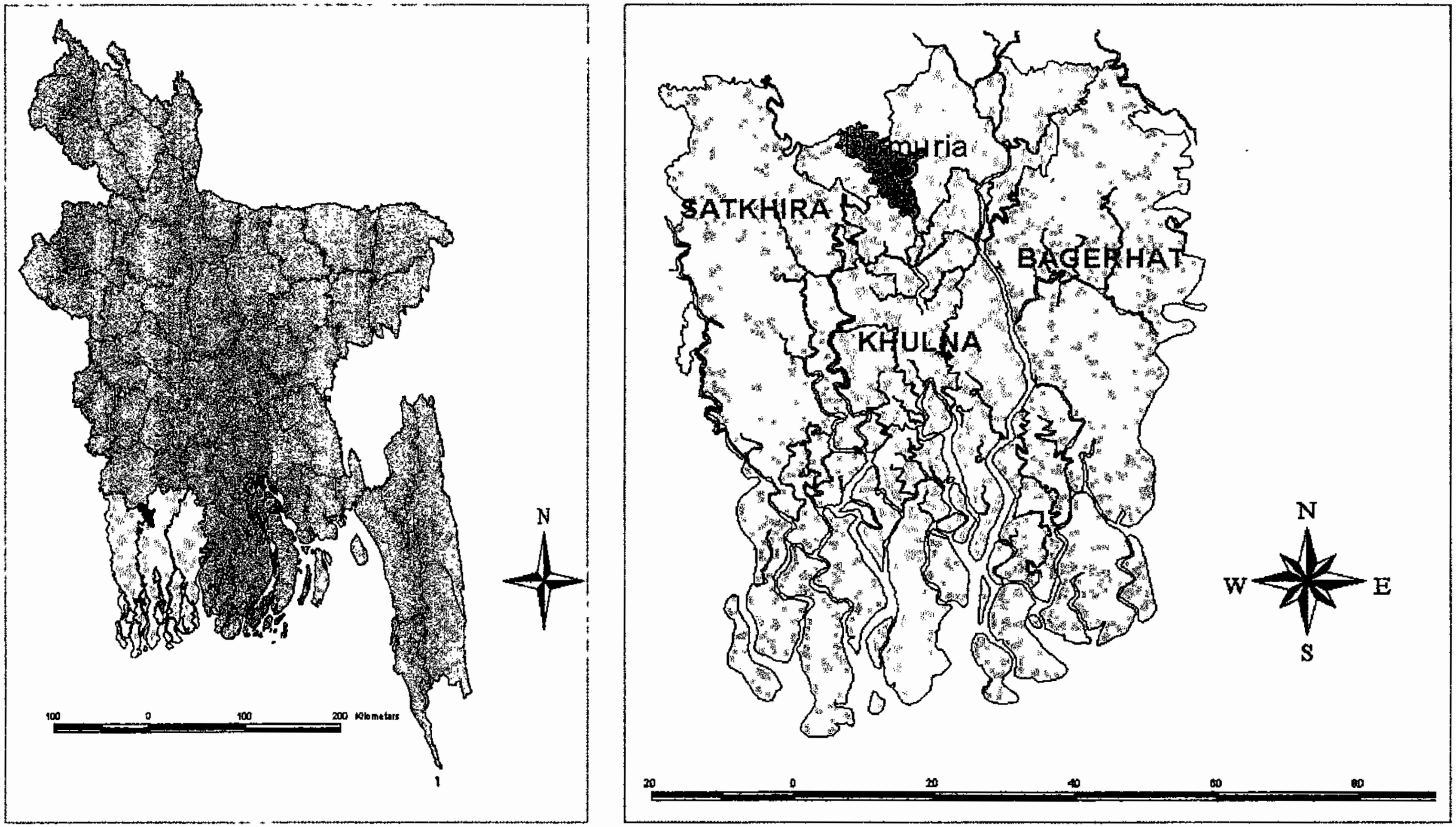


Fig. 3.1. Geographical location of the study area

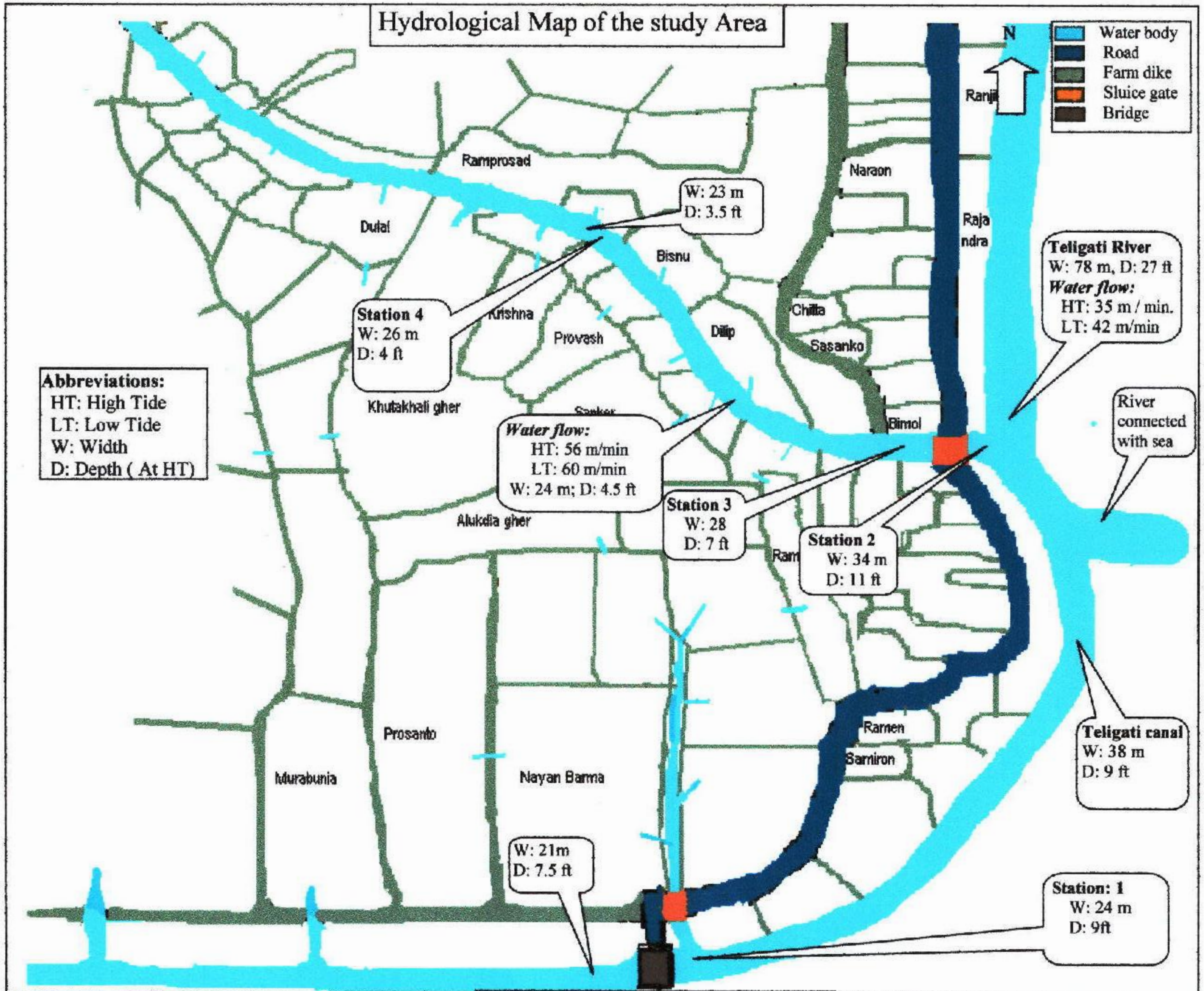


Fig. 3.2. Hydrological Map of study area

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 water exchange was rare in the farms located far from the river or canal. Some farmers only added river water allowing high tide occasionally to maintain water level in the ponds.

3.3 Frame survey in the wider area

Surveys in the wider area (3 coastal districts - 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 (appendix-1) was made and surveyed in 50 randomly selected shrimp farms in that area.

3.4 Institutional analysis

The various types of institution and organization involved in fisheries, their interaction and influence were studied in the study area.

3.5 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 (^0C), 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 near Khulna city.

To prepare nutrient budget, 3 shrimp farms (farm 3, 7 and 10) 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.

3.6 Partial mass balance

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 exchanges 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 farms, farm 3 connected with river, 7 with canal and 10 with other farms, 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 (farm 3, 7 and 10), 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. 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 was estimated by micro Kjeldahl method (AOAC, 1980) 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.

3.7 Water exchange assessment

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 404.7 ha was considered to estimate the flashing rate of the aquatic system of the study site.

3.8 Nutrient dynamics assessment

Nutrient dynamics of the system was determined to know whether the environmental capacity exceeded or not. The following equation (Doson, 2004) 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

Chapter-4
RESULTS

4.1 Growth and yield performance

According to the information obtained from the farmers, it was found that in all the selected farms the methods applied for shrimp farming was extensive to imoroved extensive. The average stocking density of *P. monodon* in the 10 farms was 13,782 post larvae (PL) ha^{-1} and average yield was 190.9 kg ha^{-1}. The survival rate of *P. monodon* fry was between 40 and 52 % (mean, 46.7%) and the individual weight at harvest ranging between 24.3g and 32g (mean, 27.62g). The range of total production was 150-798 kg ha^{-1} with an average of 384.1 kg ha^{-1}. The main target species, *P. monodon* constituted 49.7 % of the total yield. The average production of fresh water prawn species, *Macrobrachium rosenbergii* was 99.8 kg ha^{-1} (26%), where as average production of the finfishs (tilapia, *Oreochromis mossambicus*, persia, *Liza parsia* etc.) was 93.4 kg ha^{-1} (24.3%) (table 3).

High rate (average 60%) of mortality often noticed in the study area. Most of the farmers thought that virus was responsible for shrimp mortality. Frequent filling of river water, malnutrition and excess salinity were also reported by some of the farmers as a cause of shrimp mortality. But they did not know the actual cause of mortality. It was reported that during the last week of June huge mortality occurred after heavy rainfall in 3 (farm 4, 8 and 9) of the study farms. All these disease and management related issues were cross-checked and discussed with the farmers of wider area to reveal more new indicators.

4.2 Farming issues in wider area

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. Most of the farmer's used to exchange farm water traditionally using tidal level of the adjacent river (70%) and canal (12%). As no or very limited supplemental feed was used, most of the farmers were obliged to fill ponds with river or canal water as a source of natural food and to fill up the evaporation and leaching loss. But some of the farmer's (8%) (fig.4.2.5) 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 considering the supply water as a cause for shrimp death. There was evidence that disease occurrence was less in those farms that did not exchange or occasionally exchange river water. It was also reported that huge mortality occurred just after 2-3 days of water filling from river. Sometimes when shrimp come in contact with tidal water it becomes weak and consequently death occurred. During the month of April-May the initial reddish tidal water causes mortality.

The reddish color of water and presence of oily layer in water may be a cause of disease attack. 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, *Ruppia maritima* L. (locally named as 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.

Inadequate depth was also reported as a problem for shrimp culture. Most of the farmers did not able to maintain optimum (2.5-3 ft) depth for shrimp culture considering the high expense. Excessive salinity with less water depth used to cause shrimp mortality. Occurrence of saline bubbles and salt coagulation in the pond bottom was reported as a cause of shrimp mortality. After a heavy rain huge mortality occurrence was reported, especially in the less deep pond.

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.

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.4.2.1). Fry acclimatization was practiced in almost all the cases (94%). 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. Production became higher (table 4.2) in some extent in the improved extensive system where lime and fertilizer were used. But disease occurrence used to reduce 50-80 percent of the production. Generally 90-100 days were required to get a good size (30-50 gm).

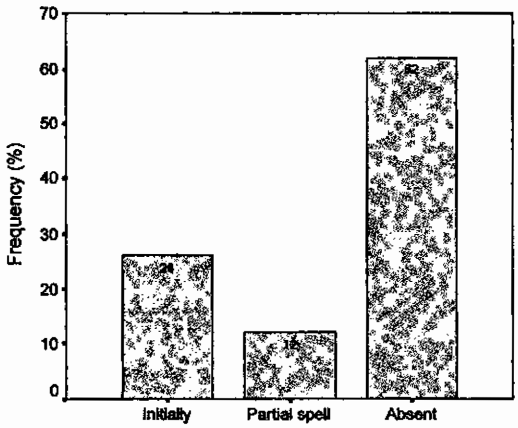


Fig. 4.2.1 Fry nursing practice

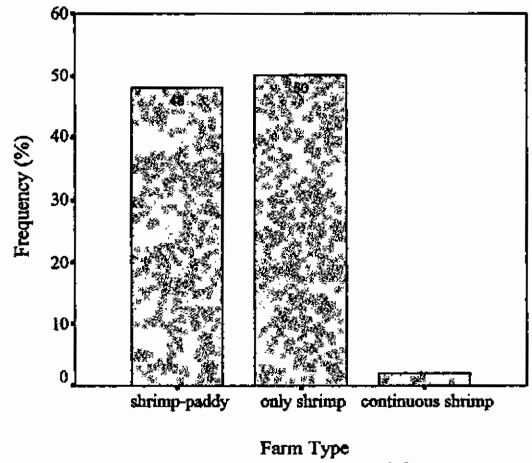


Fig. 4.2.2 Culture type of farms

In the present study 48% of the respondent practiced alternative paddy-shrimp culture and 50% practiced only shrimp (fig. 4.2.2). 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.

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. 4.2.3). Forty percent of the farmers reported that mortality occurrence was frequent in the month of May-June (fig. 4.2.4). 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. 4.2.5). They also reported that, disease occurs usually after 45-60 days of stocking.

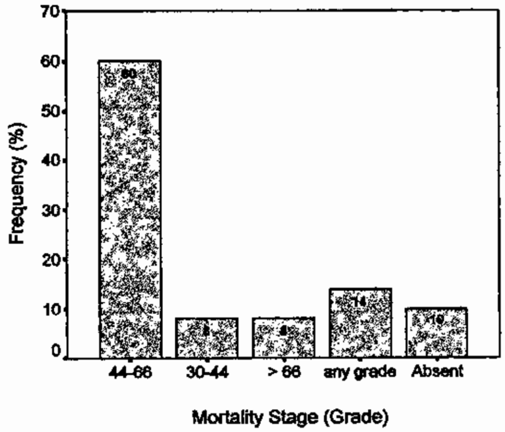


Fig. 4.2.3 Stage of shrimp mortality

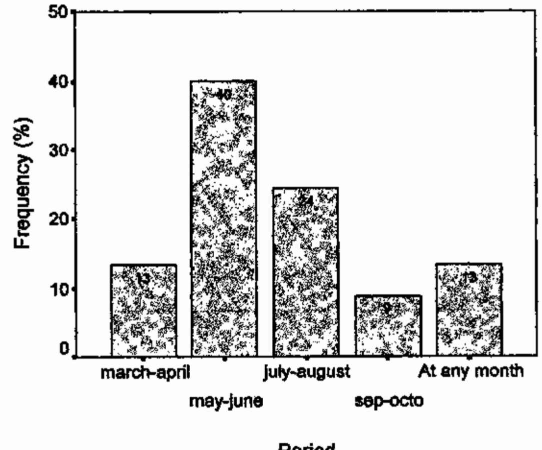


Fig. 4.2.4 Period of shrimp mortality

In addition, 68% of the surveyed farms did not use any supplemental feed (fig. 4.2.6). 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. In most cases no detectable symptom was observed in a dead shrimp. Sometime, white spot, lesion in body, spoilage of appendices and reddish color was observed in a shrimp after death.

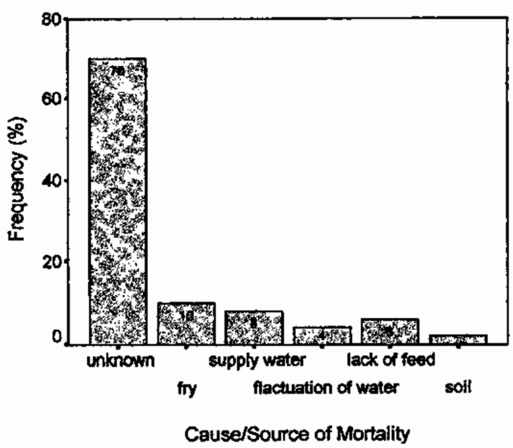


Fig. 4.2.5 Cause/source of shrimp mortality

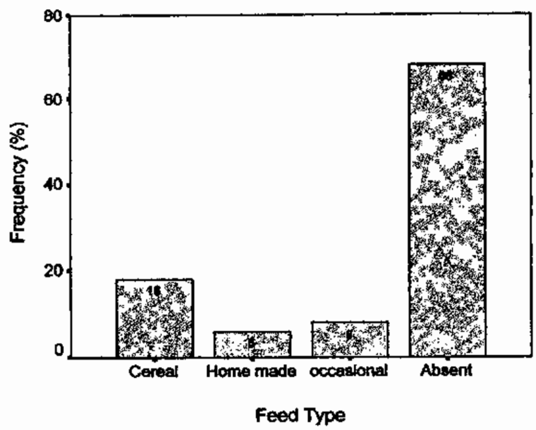


Fig.4.2.6. Type of feed using

During growout stage, use of Lime+urae+TSP+Cowdung provides highest production (273.6 kg/ha) (table 4.1). Uses of Lime+Urea+TSP also provide nearly similar production. But a negligible percent (16%) of farm applied that. On the other hand medium level production (200.6 kg/ha) found without use of any fertilizer during that stage. And 50% respondent prefers not to use of fertilizer during growout stage.

Table 4.1. 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 were present. However, farmers favor to have an association among them.

4.3 Institution and association

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 – Integrated/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 provided by Government
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:

1. The marine fisheries ordinance-1983
2. The marine fisheries rules-1983
3. The Fish and Fish products (Inspection and quality control) ordinance – 1983
4. Shrimp culture Obhikar act- 1992
5. Shrimp culture Obhikar rules –1993
6. Bangladesh Fisheries development corporation act - 1973
7. 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 briefly indicates the nested organizational arrangement of shrimp culture management in Bangladesh with reference to the study area.

Table 4.2. Nested 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 Forias 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.

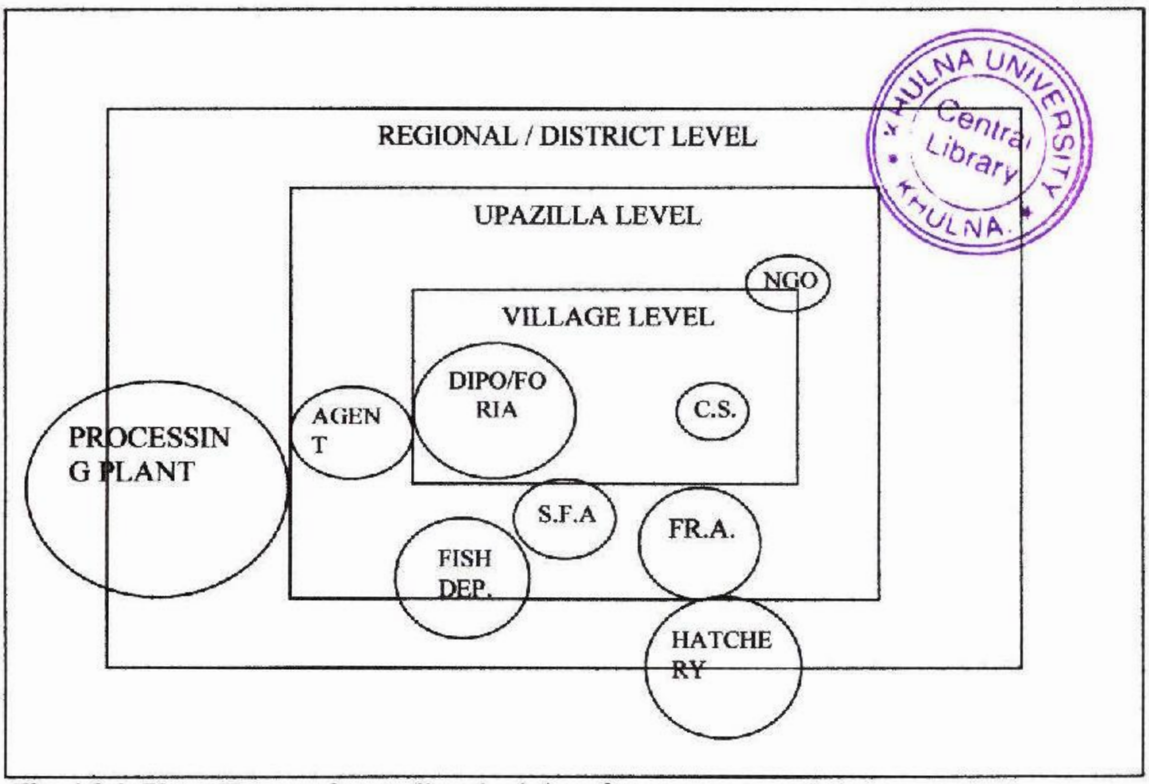


Fig. 4.3.1: Venn diagram for small scale shrimp farm management

Legend:

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

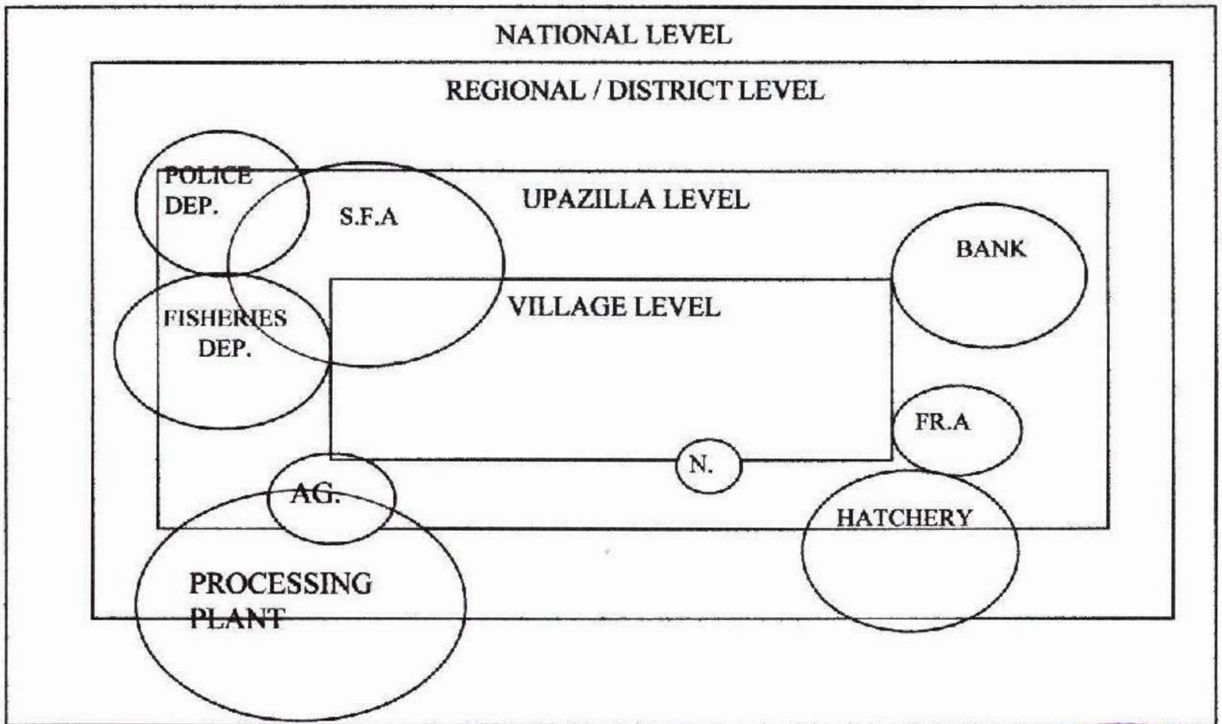


Fig. 4.3.2: Venn diagram for LARGE scale shrimp farm management

Legend:

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 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.

Processing plant: Most of the processing plants are in region or district level with few exceptions to 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 is good 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.

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 Water quality parameters

4.4.1 Seasonal variation

Temperature, Salinity, dissolved oxygen (DO), pH and biological oxygen demand (BOD) did not show significant variation among river, canal and ponds (fig. 4.4.1). 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. 4.4.1A).

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. 4.4.1B).

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. 4.4.1C).

The average biological oxygen demand (BOD) of the river, canal and ponds varied mostly between 1.7 to 2.5 mg/l (fig. 4.4.1D). 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 of river, canal and ponds are shown in the figure 4.4.2. 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.

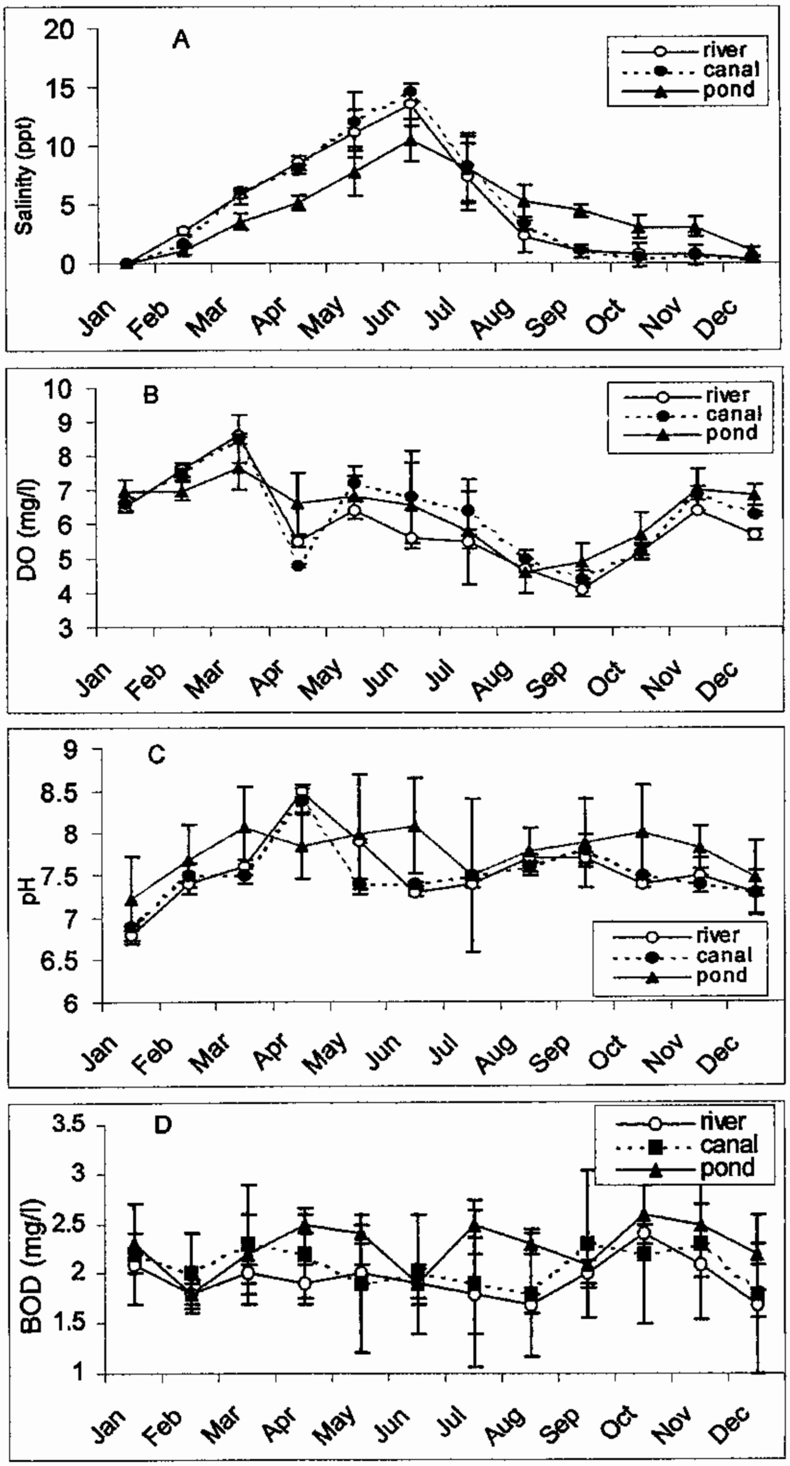


Fig.4.4.1. Changes of physico-chemical parameters (mean ± SD) of water throughout the year in river, canal and culture pond. A for salinity (ppt), B for dissolved oxygen (mg/l), C for pH and D for biological oxygen demand (mg/l). Weakly water samples (from high and low tide for river and canal) were 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.

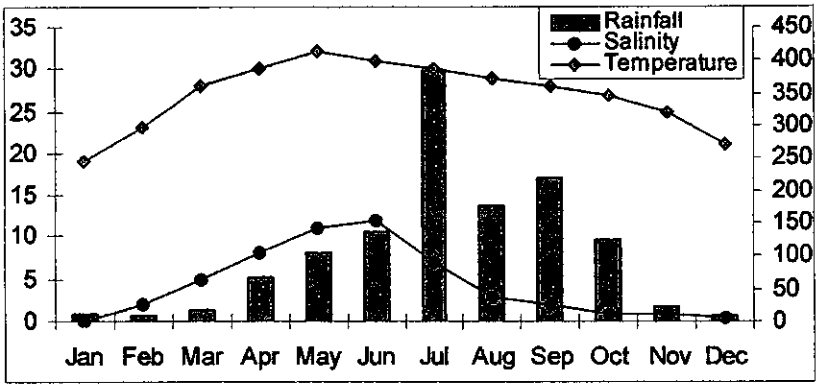


Fig. 4.4.2. Seasonal variation of salinity, temperature and rainfall. Values of salinity (ppt) and temperature (^{0}C) are in Y axis and rainfall (mm) in Z axis. Salinity and temperature values are the average from river, canal and ponds. Rainfall data are taken from the nearby weather station.

4.4.2. Variation in grow-out period of ponds

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 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. 4.4.3).

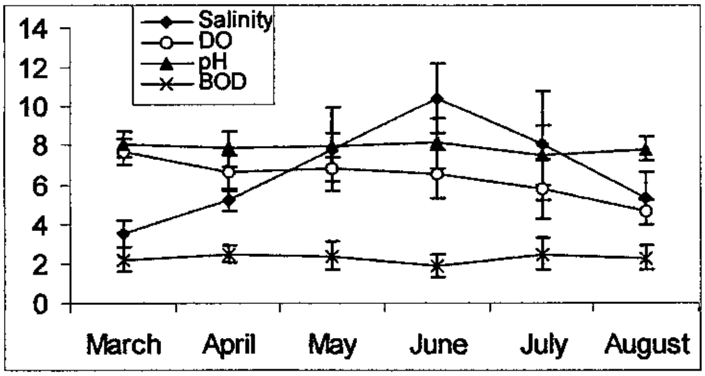


Fig. 4.4.3. Changes in physico-chemical parameters of water in 10 shrimp ponds throughout the growing cycle. Values (mean ± SD) are for salinity (ppt), DO (mg/l), BOD (mg/l) and pH.

4.5 Nutrient dynamics

4.5.1 Seasonal water nutrient variation

The total Phosphate and total Ammonia Nitrogen concentration did not show significant variation among river, canal and ponds (fig. 4.5.1). 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.

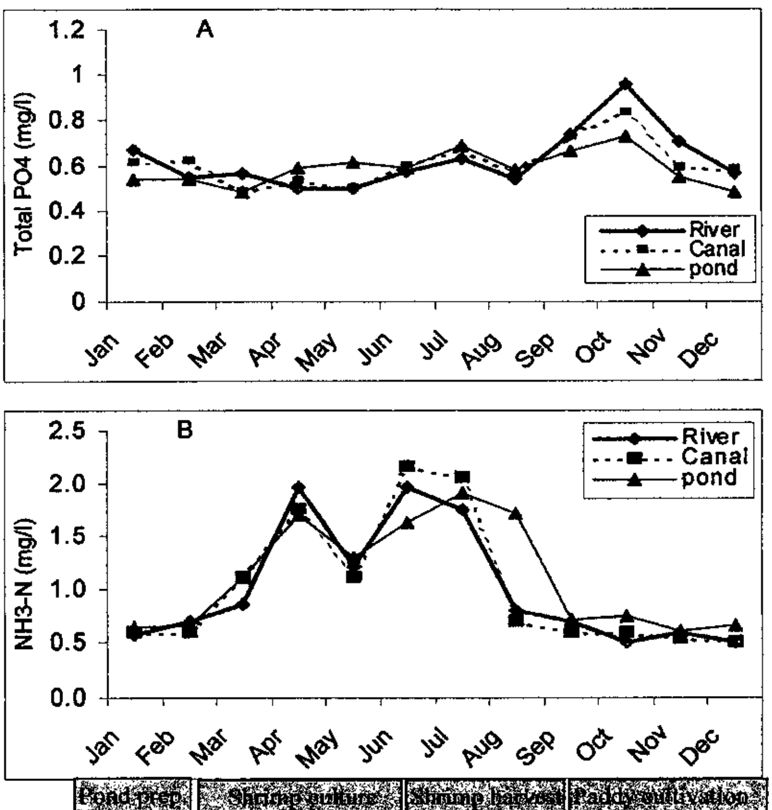


Fig. 4.5.1. Fluctuation of water nutrients throughout the year in river, canal and ponds. Average monthly data of A for Total Phosphate (mg/l) and B for Total Ammonia Nitrogen (mg/l). Mid February to September shrimp culture period and the rest are paddy cultivation period. Data was not recorded at 4 of the ponds from early January to mid February due to pond preparation.

4.5.2. Fluctuation of nutrients in grow out ponds

The concentration of total Nitrogen (TN) and total Phosphorus (TP) showed the same pattern over the growout period of the 3 ponds (3, 7 and 10) 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. 4.5.2). 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 (table- 4.5) than that of outlet or discharged water (excluding of final harvest drainage). The concentration of ammonia nitrogen (NH_3-N) and nitrate nitrogen (NO_3-N) in the culture ponds were increasing with culture time. The concentrations ranged from 0.5-2.2 mg/l for NH_3-N and 0.7-2.3 mg/l for NO_3-N in the ponds outlet. The concentration of nitrite nitrogen (NO_3-N) was very less (0.001-0.004 mg/l) in the ponds inlet and outlet (table- 4.3).

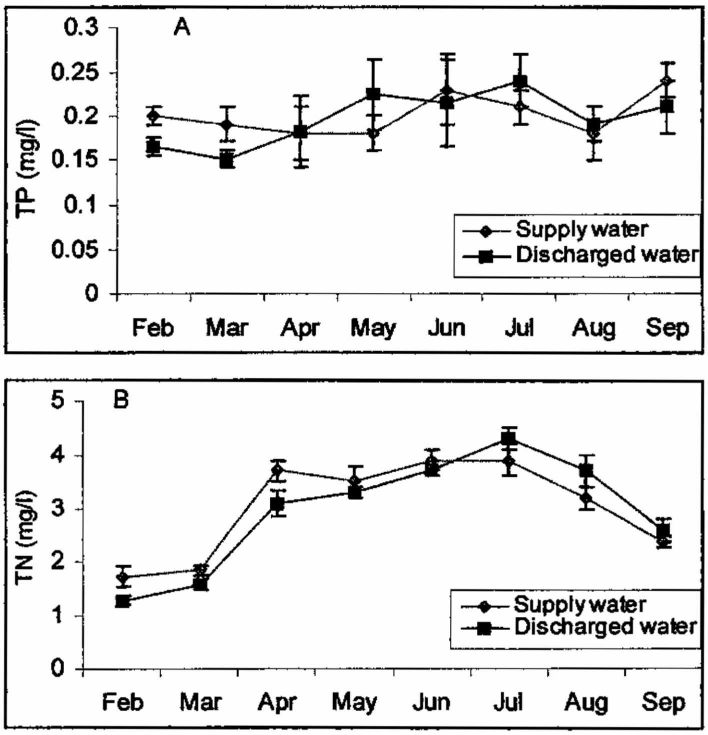


Fig.4.5.2. Changes of water nutrients in 3 shrimp ponds (3, 7 and 10) throughout the growing cycle. Values (mean ± SD) are for Total Phosphate (mg/l) and Total Nitrogen (mg/l).

Table 4.3. 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 3																		
NH_3-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		
NO_3-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		
NO_2-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 PO_4	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 7																		
NH_3-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		
NO_3-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		
NO_2-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 PO_4	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 10																		
NH_3-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		
NO_3-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		
NO_2-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 PO_4	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

4.6 Environmental capacity issues

4.6.1. 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 total water volume showed in the following table-4.4

Table 4.4. Respective water volume in the study area.

Types	Dimensions (m2)	% area	Water volume (m3)
Canal area	202350	5%	505875
Non-production area	809400	20%	
Pond area	3035250	75%	2306790
Total	**3237600**		**2812665**

Note: Canal depth = 2.5 m, Pond depth for shrimp = 0.76

Water exchanged each time followed by the average canal water depth difference showed in the following table-4.5. For shrimp, the water exchange rate was around 40%. In terms of calculating total period/cycle, for shrimp, it was considered as 10 times per month and total period as 6.5 month.

Table 4.5. Flushing rate of water for shrimp farming

Av. max height (m) of water depth	2	
Av. min height (m) of water depth	1	
Difference (m) of water depth	1	
Water exchanged each time (m3)	202,350	40%
Water exchange (m3/cycle)	13,152,750	
Flushing rate	**468%**	

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

So flushing rate of canal water for shrimp was 468% 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. In fact, 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-4.6.

Table 4.6. 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%

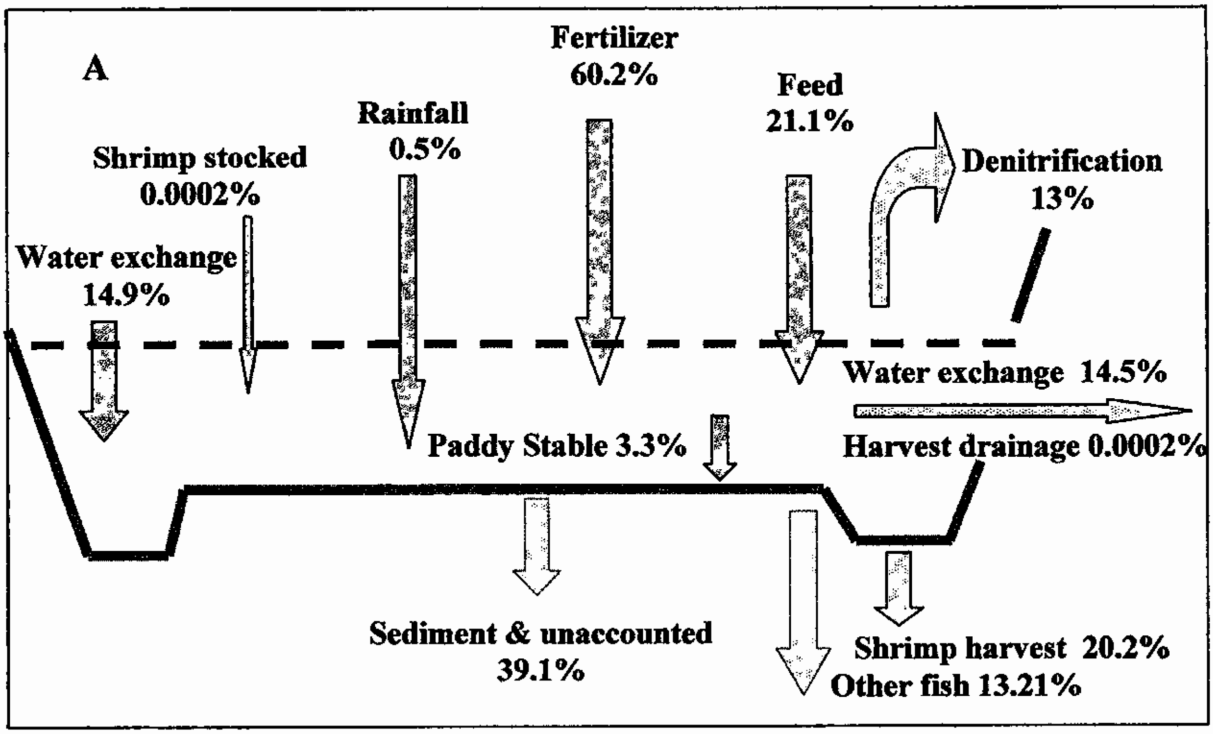
4.6.2 Nutrient Mass balance

A rough estimate of the nutrient mass balance ($ha^{-1}cycle^{-1}$) has been made first for 3 individual ponds (appendix-2) followed by the overall budget. The overall average yield of harvested shrimp and other finfishes were estimated 258 and 237 $kgha^{-1}cycle^{-1}$ respectively. The overall nutrient mass balance (table. 4.7) 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 % N and 9.3% P.

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% (5.72 $kgcl^{-1}$) and 14.5 % (5.6 $kgcl^{-1}$) as well as for TP 2.2% (0.38 $kgcl^{-1}$) and 2.0% (0.36 $kgcl^{-1}$) respectively. The total inputs of nitrogen and phosphorus were 48.7 $kgha^{-1}cycle^{-1}$ and 28.95 $kgha^{-1}cycle^{-1}$ respectively. Only 33.4% of nitrogen and 6.1% of phosphorus were removed as harvested form. A large portion, 39.1% N and 92% P, which accounts for 20.6 kg N and 26.66 kg P $ha^{-1}cycle^{-1}$ were remained in the sediments and unaccounted for. The overall mass balance pathway of nitrogen and phosphorus in a shrimp pond are shown in the figure 4.7.

Table 4.7. Overall mass balance (per hactor basis)

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	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%
Fertilizer	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								
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%**



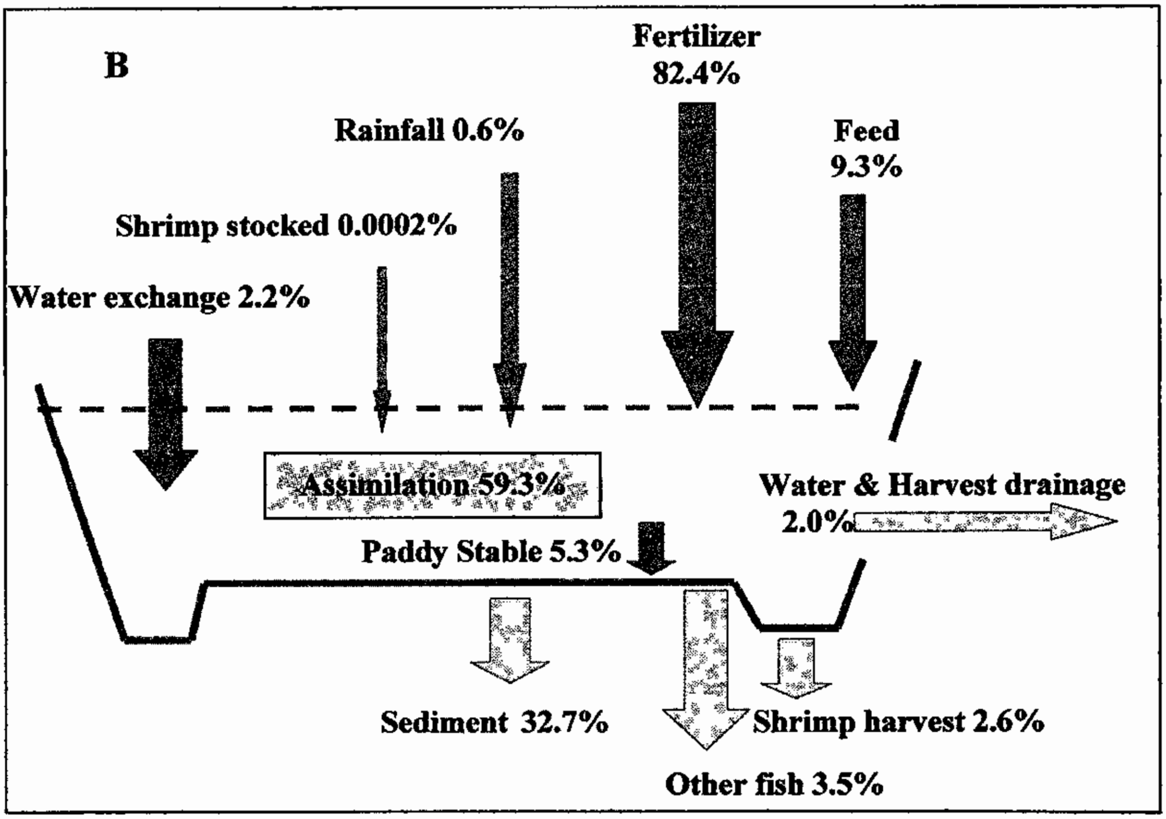


Fig. 4.6.2 Overall mass balance of Nitrogen (A) and Phosphorus (B) in shrimp farm

4.6.3. Environmental capacity assessment

The study focused on a particular defined aquatic system comprised of river, canal and shrimp farms. Addition of nutrient (specially nitrogen and phosphorus) through shrimp culture is not triggering the eutrophication [DO level throughout the year (fig. 4.4.1.B), water primary productivity, 0.071-0.296 gC/m^3/hr] in the study area. Excessive flushing rate (468% per cycle) in the aquatic systems are controlling the eutrophication. But 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 also wide accepted that saline water trapping in shrimp farm affecting the paddy cultivators and other home yard activities.

According to the estimated nutrient dynamics (by the equation mentioned at 3.8), N and P are not exceeding the environmental quality standard (table 4.8).

Table 4.8. Nutrient dynamics for shrimp cultivation in the study area.

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

- Vietnam

Overall management and environmental issues

Identification of management issues were one of the prime important part of the present study. Key management issues for aquaculture both at individual farm level and for the wider aquatic systems are pointed out on the following figure-4.7. The figure also reflects the importance of environmental and waters quality issues relative to other management issues.

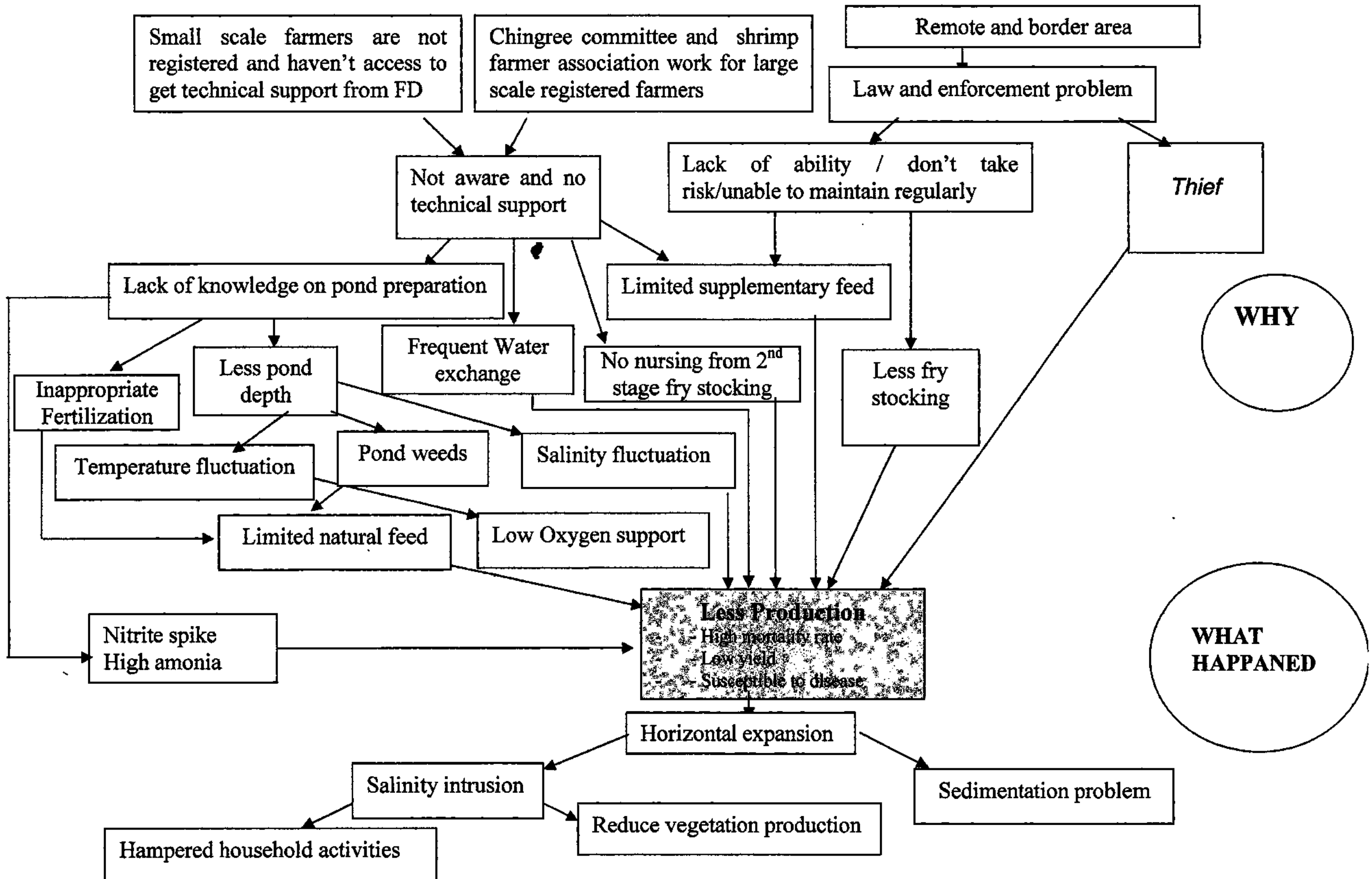


Fig. 4.7. Management issue pathway

Chapter-5
DISCUSSION

5.1 Farming practice and yield

The optimum production of a farm depends on effective managerial operation of stocking, feeding, fertilizer using and water quality monitoring. The shrimp production of the farms was very less (most cases, 100-200 kg/ha) due to the inappropriate management. In most cases of the present study, stocking density was 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 5,000-30,000 piece ha^{-1} for extensive method (Jenkins *et al.*, 1999). In some cases where the stocking density was between 13,782-18,525 piece ha^{-1}, the production was 191-288 kg $ha^{-1}yr^{-1}$. Wahab *et al.* (2001) found a production of 128-273 kg/ha (except a case of 63 kg/ha), where the stocking density was 20,000-25,000 PL/ha. So there was a provision for more stocking in the study farms where improved extensive culture technique was applied. But main constraints of higher stocking were disease incidence, management difficulties, lack of adequate funding source and risk involved in higher investment.

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, usually natural feed did not grow 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 necessary nutrient. Some of them use fishmeal occasionally, which were not adequate. So malnutrition was a common phenomenon that used to cause various disease and lower growth. The stocking density of 29,640 piece ha^{-1} and uses of some feed and fertilizer resulted in a good production of 323 kg $ha^{-1}yr^{-1}$in the farm10.

5.2 Wider area survey

From wider area survey present study revealed that not only viruses and microbes used to cause shrimp mortality, but also less depth, frequent filling with river water, malnutrition and fluctuation of water pH, temperature, dissolved oxygen and salinity responsible for shrimp mortality.

In the study period, situation of some of the mortality occurred ponds were observed. Water quality was good enough. No bad smell and color was observed but in most of the farms (above 80%) water was too transparent (visibility 3 feet). It indicates the inadequate natural feed availability of the farms. No spot was observed except few cases (less than 10%). Most of the shrimp behave inert before death. It indicates that virus was not responsible for mortality in most cases.

Farm and *tob* (canal) depth (except dry season) was ranged between 0.6-0.9 m and 0.9-1.17 m respectively. It seems good, but during summer (May-June) water depth at the plain land was very less (<0.3m). At the same time salinity (11-15 ppt) and temperature (>30^0c) was high. At such a condition, during the onset of rainy season (June-July), occurrence of sudden heavy rainfall caused huge shrimp mortality (as occurred in the farms 4, 8 and 9). It may be due to reduction of water pH and fluctuation of temperature and salinity. Again, occurrence of nitrite spike is likely to cause shrimp mortality according to Arah, 2001 (described in 5.5).

The above mentioned problem can be avoided by increasing pond depth. But, maintenance of optimum pond depth by excavating the large size farm is difficult for most of the farmers, as it 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 invest money in excavating land of others, which may be taken back. In the traditional farming, farmers don't want to take the risk involved in high investment. The amount of money (table 5) required for shrimp farming is very high. In compare with the average production (190.9 kg/ha) of shrimp, it is not profitable. However, some non-target species like Prawn, tilapia, Persia and paddy in some cases used to save the small-scale farmers.

Table 5. 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
Fertilization	Kg	13	600
Total cost in each year			633.33
Total cost once in initial cropping			886.67

As, inadequate pond depth is highly responsible for shrimp mortality, it is essential to compromise the farmers for maintaining pond depth (2.5-3 ft) with leasing land used for shrimp culture and high investment required for pond preparation.

Many of the farmers reported that river and canal water might cause shrimp mortality, because they observed that sometimes when shrimp come in contact with tidal water it becomes weak and consequently death occur. They also reported that disease occurrence was less in those farms that did not exchange or occasionally exchange river water. Nevertheless, they had to depend on adjacent river and canal as a source of water and natural food. In most cases, they did not have any other option except river water to fill up the evaporation and leaching loss. To avoid this problem, it is suggested and agreed by farmers 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.

Most of the farmers (60%) observed that small sized shrimp (44-66 grade/15-23gm) was more vulnerable than bigger one (fig. 4.2.3). A shrimp fry takes about 45-60 days to attain such a size. In addition, disease occurs usually after 45-60 days of stocking. As virus (WSSV) can remain as a dormant state in animal body up to 45 days, it might supports the ideas of some farmers (10%), who reported that hatchery produced shrimp PL might be a source of virus. They also reported that, although source of water and feed was common, only some of the farms were affected.

5.3 Institution and association

Generally organizations or associations for small-scale shrimp farmers were absent. But large-scale farmer's association was present in the upazilla and district level. For this small-scale farmer's used to face various problem especially information gap, river and canal water management, marketing complexity and local threats. Usually river sluice gates remain in control of influential people. So, small farmers do not able to exchange farm water timely. The large scale 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.

However, Small-scale local farmers realized the necessity of forming an association at local level to run the shrimp culture management in a convenient way. So that, they would able to influence water control through sluice gate, collect information about farming system, market rate as well as control robbery and theft.

5.4 Water quality parameters

The water quality parameters in river, canal and ponds were found more or less similar throughout the year. It may be due to the traditional nature of culture where input is very less as well as high flashing rate of water (468% per cycle) (table 4.5). The river (semidiurnal tidal system), which is connected directly with the Bay of Bengal, might control the canal and ponds water quality.

The water salinity, pH, DO, BOD were more or less acceptable for shrimp farming. According to NACA (1995), the optimum salinity range for *P. monodon* is 10-20 ppt. The water salinity in shrimp ponds during grow-out period in this experiment was in acceptable range. But salinity at initial stage and at the end of culture cycle was less (3 to 6 ppt) than the optimum lower limit recommended by NACA (1995). But it is the ideal practice in this region and did not produce any bad effect in the present experiment. The viability of *P. monodon* in low-saline water has been indicated by Saha *et al.* (1999). They observed, when salinity decreased after 60 days of culture (>5 ppt) to freshwater level (0.16 ppt), the growth rate and feed utilization of the shrimp stock were still satisfactory in semi-intensive pond. Again, Chakraborti *et al.* (1985) reported that high salinities at stocking favour PL survival and Sinderman and Lightner (1988) reported that lower salinities towards the end of the production cycle when shrimp biomass was high reduce the chance of occurrence of *Vibrio spp.* infections.

Dissolved oxygen and pH concentrations were favorable throughout the experimental period as the optimum range (DO, 3.8-5.0 mg/l and pH, 7.5-8) was recommended by NACA (1995). No significant variation in DO and pH among the farms was observed. Chakraborti *et al.* (1995) stated that many variations in pH usually do not occur in shrimp farms owing to the buffering capacity of brackish water.

BOD is another critical factor, which can indicate organic pollution. River water contains BOD more than 10ppm is considered to be moderately and more than 20 ppm as to be highly polluted water (Paul, 1999). Very negligible amount of BOD (mean, 2.1± 0.88 mg/l) was recorded from river, canal and ponds during the study, which generally indicates no organic pollution occurred in the river, canal and ponds water.

5.5 Nutrient dynamics

All forms of nitrogenous nutrients were increased gradually with the progress of culture period. The concentrations of ammonia nitrogen (NH_3-N) in the culture ponds were ranged from 0.5-2.2 mg/l. Wahab *et al.* (2001) recorded the minimum and maximum values of ammonia nitrogen (TAN = NH_4^+-N + NH_3-N) of 1.08 mg/l and 2.43 mg/l.

Ionized ammonia, or ammonium (NH_4^+) is considered non-toxic to fish and crustaceans animals, while the unionized form, ammonia (NH_3) is highly toxic. For successful production of penaeids, the unionized ammonia (NH_3) should not be more than 0.10 mg/l (NACA, 1995). Wahab *et al.* (2000) indicated peak concentrations of unionized ammonia of 0.5-1.0 mg/l in several shrimp farms due to increased pH in the afternoon (pH > 8.5). In an experimental infection trial, addition of 2 ppm of total ammonia nitrogen (TAN) led to 40% mortality among *P. monodon* caused by WSSV (Wang *et al.*, 1997). Allen *et al.* (1990) proved a growth reduction of 5% in *P. monodon* at 0.21 mg NH_3-N/l. Obviously, the ammonia peaks in the afternoon fluctuated within the "sub-lethal" range and consequently might have created stressing conditions for shrimp stocks (Wahab *et al.*, 2001). In the present study, the observed ammonia nitrogen concentration (maximum 2.2 mg NH_3-Nl^{-1}) in the ponds (3, 6 and 10) might have been a cause of disease outbreak, although no such occurrence was reported.

Burford and Longmore (2001) showed that low rate of nitrogen loss from denitrification, relative to high nitrogen input, results in high ammonia concentration in the water column. So, the source of high ammonia concentration in the study ponds might be the input of nitrogen mainly through urea and little from feed.

The concentration of nitrate nitrogen (NO_3-N) in the culture ponds was ranged from 0.7-2.3 mg/l. Deb (1998) reported nitrate range of 0.005-1.54 mg/l in intensive shrimp pond effluent water. NACA (1995) reported that even at concentration of 300 mg/l of nitrate, shrimp could grow normally. So the nitrate value found in the present study was acceptable for shrimp culture.

Nitrite (NO_2^-) is toxic to shrimp and might well account for some of the mortalities (Chen & Chen, 1992). Though, in the present study, the concentration of nitrite nitrogen (NO_2-N) was very less (0.001-0.004 mg/l) in the farms (3, 6 and 10) and no mortality occurrence was reported in those farms, we should careful about nitrite "spike". Because nitrite "spike" 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 (Arah, 2001). 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.

Arah, 2001 stated 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.

However, Nutrient concentrations in water discharged from ponds increased as time of grow out period progressed and reached maximum concentration in the month of August. TN and TP concentration was higher in supply water (inlet) in the first 2-3 months and reduced in the later part of growing cycle than that of outlet. The overall data shows that inlet nutrient value was slightly higher than that of outlet or discharged value that means sink of nutrients to the ponds was occurred. However, the lower outlet concentration of N and P indicate a net retention of nutrients in the pond ecosystem from the surrounding aquatic system.

5.6 Nutrient mass balance

The shrimp farming practice in Bangladesh is still traditional to improved traditional. Farmers use low amount of lime and fertilizers and the application of feed was rare to absent. Present study revealed that traditional extensive system of shrimp farming not provides any significant loading of nutrients to the surrounding coastal environment.

Excessive use of feed and fertilizers in semi-intensive (Paez-Osuna *et al.*, 1997) and in intensive (Briggs and Funge-smith, 1994) culture system causes considerable amount of nutrient discharge in the natural water through the discharge canal. Where as, extensive shrimp culture ponds are supplied with small amount of nutrients. The average input of nitrogen and phosphorus to intensive shrimp culture in Thailand was 858 kg $TNha^{-1}cycle^{-1}$ and 291 $TPha^{-1}cycle^{-1}$ (Briggs and Funge-smith, 1994), which is 15 times for TN and 9 times for TP the estimated average input of the present study.

In the present study ponds are supplied with small amount of feeds mostly homemade cereals with more reliance on fertilization. So the overall nutrient mass balance of the present study indicates 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. However, Wahab *et al.* (2003) reported intake water as the second largest source of TN (33%) and TP (29%) in contrast to feed (21.1% N and 9.3%) that was the second highest contributor in this study. But in the present study, the mass budget of the river connected pond (appendix-2, table 9.2.1), where water flushing rate was high (66%) showed that supply water was the highest contributor of TN (51.2%) which accords with the findings of Islam *et al.* (2004) (water-born nitrogen was the highest contributor, 54.9%), where water exchange rate was 50%. But, when the average mass balance (table 4.7) was calculated it shows different scenario (fertilizer highest contributor) because of different flushing rate (pond exchange water with canal, 30% and through other ponds 10%) (table 4.6).

Only 33.4% of nitrogen and 6.1% of phosphorus was 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.

The effluent loading is strongly affected by the water exchange rate throughout the growth cycle. 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 overall mass budget of 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%). The lower rate of TP discharge may be due to less water exchange in the average mass balance. Because the individual budget of the pond connected with river (table 9.1) having higher flushing rate (66%) in compare to other types (table 4.6) showed higher P discharge of 8.7%.

The intake of nutrients through supply water (TN 5.72 $kgcl^{-1}$and TP (0.38 $kgcl^{-1}$) were slightly higher than nutrient discharged (TN 5.6 $kgcl^{-1}$ and TP 0.36 $kgcl^{-1}$) (table 4.7) through water discharge, which indicates that small amount of nutrient enrichment within the farms was occurred rather load to the river. So it is clear that extensive shrimp farming, is not loading nutrients to the wider aquatic system, rather acting as a nutrient remover from that system.

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. Where, 20.6 kg N and 26.66 kg P $ha^{-1}cycle^{-1}$ accounts for 39.1% of TN and 92% of TP output ended up in sediments and unaccounted for. According to Islam *et al.* (2004) 10 % of nitrogen was estimated as unaccounted. Unaccounted nitrogen may have been trapped in the systems, or lost through denitrification, ammonia volatilization and diffusion at high pH (Briggs and Funge-smith, 1994) and seepage (Boyd, 1985). When calculating nitrogen budgets for shrimp farms, denitrification and ammonia volatilization are two potential losses of nitrogen that are often not measured directly (Jackson *et al.*, 2003). Denitrification and ammonia volatilization in the semi-intensive shrimp farm are reported 10% by Briggs and Funge-smith (1994) and Martin *et al.* (1998). Although Briggs and Funge-smith in other studies reported it 30%, a lower value of 3% was also reported by Jackson *et al.* (2003). In the present study nitrogen removed through denitrification and ammonia volatization is assumed 13% according to Doson, 2004.

So it can be said that a major part of trapped nitrogen may be removed from the system by denitrification and ammonia volatilization. But what about the huge amount (92% of TP in this study) of trapped P in pond bottom? According to Arah (2001), huge sedimented P does not cause any significant problem. Phosphorus 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. Edwards (1993) stated that a significant part of the removed nutrients must have been trapped by settling of solids, algae and detritus on the bottom of the ponds.

However, a minor part of the accumulated sediments are flushed out at the end of culture cycle. So year by year the accumulated sediment may 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.

5.7 Environmental capacity

Present study has revealed that minor level of nutrient enrichment (0.002 g/m3/year TP and 0.004 g/m3/year TN) has been occurred within the ponds for shrimp farming. Minor difference of TN and TP (Fig-4.5.2) 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-4.5.1) 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 be said that the environmental capacity may not exceeding in that period. Additionally, environmental capacity is not exceeding according to the Vietnam standard (`4 mg/l N and 2 mg/l P) (table 4.8).

According to the more practical interpretations (mentioned at above) relevance to developing countries, nutrient input in terms of feed is significantly lower that result in 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), there is still provision for fertilizer and feed input to increase shrimp production.

Nevertheless, the horizontal expansion of shrimp farm in this region is imparting bad effect to the environment. Saline water logging continuously for long time in shrimp farms resulted in salinization, scarcity of freshwater and destruction of various freshwater species.

Chapter-6
RECOMMENDATION

The present study has investigated the sustainable management aspects as well as water quality of shrimp culture systems. According to the study, pond depth is less than 1 ft (a major concern), 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 fertilizer and feed to increase shrimp production. According to Das, 1998 a fertilizer dose of 30 $kgha^{-1}$ of Urea, 60 $kgha^{-1}$ of TSP and 10 $kgha^{-1}$ of Potash is recommended.

Smaller units (1-5 ha) of farm with multiple depth ranges (2.5-3.5 ft) having separate nursing pond is highly recommended. Farms that use 'tob' (surrounding canal) initially for fry nursing can also use them for subsequent fry nursing by separating a part from the tob. Alternate shrimp–rice farming could be adopted instead of only shrimp.

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.

In terms of water exchange, farm should be filled with river or canal water just after high tide or at the beginning of low tide, so that precipitation or settlement of waste could take place. If possible, having a reservoir to allow river water to precipitate is preferable.

As because the assimilative power of aquatic environment may be a potential of being degraded with unplanned intensification of shrimp culture areas, a group management initiative is very much essential in planning and development of coastal shrimp aquaculture. Integrated water exchange system must be developed considering the benefit of both small and large-scale shrimp farmers as well as paddy cultivators.

Present study has revealed some environmental issues related to the environmental capacity of the system. Sedimentation and water logging is one of that. To avoid that flushing rate should be maximum at the sluice gate (present flushing rate 20 - 40% each time) minimum at the farm level water exchange gate (present flushing rate 15-66%).

Farm effluents should not be discharged into freshwater areas or on to agricultural land. Accumulated sediment of ponds needs to be dug out and can be put into pond dike or as earth-fill.

Small-scale farmers may form an association, so that they may access information, and address water management problems, marketing difficulties and local threats. Government should develop a registration system for small-scale farmers with training supports.

Chapter-7
CONCLUSION

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 less 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 in 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 fertilizer and feed to increase shrimp production.

But, the assimilative power of aquatic environment may be a potential of being degraded with unplanned expansion of shrimp culture areas. On the other hand, salinity intrusion problem of soil is affecting the paddy cultivators and other home yard activities. Such impacts must be considered in planning aquaculture and other development, so that environmental capacity not exceed. An effective management initiative is very much essential at that context.

Chapter-8
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Chapter-9
APPENDICES

9.1. Frame Survey Questions

Name of the farmer:

1. Type of farm

Culture type	Duration											
	J	F	M	A	M(b)	J	J	A	S(bh)	O	N	D
Shrimp+paddy												
Shrimp												
Cont. shrimp*												
Others												

*not drying pond in between culture cycles, but continuous restocking

2. Size of pond (acre)

<1	1-3	4-10	11-20	20-50	51-100	>100

What would be suitable categories? Why? (*May be relevant esp for constraints to practice)*

3. Proportion of deeper (tob) area with pond

Absent	<5%	5-10%	11-30%	>30%

4. Depth of pond

Depth	<2 feet	2-3 feet	4-5 feet	>5 feet
Main pond				
Deeper (tob) area				

5. Do you have any separate nursery pond ? Yes & No &
   Area:

6. Ownership structure

Owner-operate	Leased-operate	Owns-managed	Partial owner-leased	Other

7. New / old (*how long have used this pond for shrimp?)*

<1 year	1-3 years	4-10 years	10-15 years	Over 15 years

8. Water exchange regime: Yes & No &

Water source	River	Canal	Other farm	Underground	others
Frequency (time/month)					
Amount (% / discharge)					

9. Potential tidal range they can exploit (water depth in feet)

	River		Supplied canal	
	HT	LT	HT	LT
Spring tide				
Neap tide				

10. Stocking density

Spell	Date	Species	Wild (no)	Hatchery (no)
First		1. bagda		
		2. galda		
		3.		
Second		1. bagda		
		2. galda		
		3.		
Third		1. bagda		
		2. galda		
		3.		

11. Did you acclimatise fry? Yes & No &

Duration	<15 min	15-30 min	30-60 min	> 1 hour
Method				

12. Did you stock fry in the nursery pond? Yes & No &

Frequency	At every stocking	Partial (%)	Initial spell	Others
Duration	< 1 week	1-2 week	3-4 week	>1 month

13. Fry mortality

<10 %	20-30 %	30-40%	40-50%	50-60%	> 60%

14. Feed regime: Yes & No &

Type	Cereal feed (rice bran, rice, wheat bran etc)	Homemade pelted feed	Commercial pelted feed	Household wastes	others
Specific					
Amount/day					
Formula used					

15. Fertilization regime (Kg per hectare)

Growth cycle		No	Lime		Urea		TSP		Cow dung		Pesticide		other	
			kg/biga	frq/cy	kg/biga	frq/cy	kg/biga	frq/cyl	kg/biga	frq/cy	kg/biga	frq/cy	kg/biga	frq/c
Land prepration	Shrimp													
	Rice													
Grow out period	Shrimp													
	Rice													

16. Harvesting regime

Batch	Cull harvesting*	Ad-hoc**	To avoid mortality	other

*net, grade and harvest accordingly** harvest based on need for income at given time
When and what size grades do you usually harvest and why? (Prioritise if more than one response)

17. Production regime

	grade 20	grade 30	grade 44	grade 66
Amount (kg)				
No				

18. Mortality incidence in the last 5 years (*specify extent by proportion of crop lost and type of disease*)

When (month/year)	Stage	Symptoms	Cause/ source	% lost

*physical/behavioural/environment

Water

1. What source of water is good for culture?

River	Canal	Other farm	Underground water

Which one is the best (if you have every choice)? Why?

2. Before exchanging the water are you aware of about quality of the water?

Not aware	Aware	Obligation

3. What do you consider to be good farm water (colour, turbidity, smell, bubbles, presence of bloom, plants, animals/zooplankton etc.)

color type	smell type	bubbles appearence	hydrophytes availability	plankton availability	Bloom occurence

4. What can be done to get to this condition? Will you do it and what do you need to do it *(avoid responses of simply money – if money, what for and what else)*?

5. What do you consider to be bad farm water? (colour, turbidity, smell, bubbles, presence of bloom, plants, animals/zooplankton etc.)

color type	smell type	bubbles appearence	hydrophytes availability	plankton availability	Bloom occurence

6. What are the consequences (mortality/poor production?)

7. What can be done to avoid this condition? Will you do it? what do you need to do it?

Salinity (may be able to combine with categorised water exchange regime)
Rate of change is the key issue – eg. does salinity change quickly in your ponds and do you see this as a problem?

8. Do you try to control salinity in your pond – how do you do it and why?

9. Did salinity of the nearby farms remain same as your farm or not? Why?

10. What are the effects of heavy rainfall? If negative, what do you think can be done? will you do it and what do you need to do it

Depth

11. What do you think is the optimal depth of a pond and why?

12. If your pond is not this depth, what are the reasons?

13. Can you change the depth, will you change it and what do you need to change it?

14. What soil condition indicates the best quality of soil?

	colour	Muddy(amount in feet)	Hard bottom condition	Loamy	Silty	Sandy
Good						
Bad						

15. Why good?

16. Why bad?

17. What are the consequences for both good and bad production? (production/ growth)

18. What can be done to get a good condition? Will you do it and what do you need to do it *(avoid responses of simply money – if money, what for and what else)* ?

Stocking

19. What is the best stocking density and why?

<40/dm	40-60/ dm	60-80/dm	80-100/dm	>100/dm

20. What are your main constraints to stocking more in your pond? (prioritise if more than one)

Money problem	Difficult to manage	Disease incidence	other

21. What can be done to get to this condition? will you do it and what do you need to do it *(avoid responses of simply money – if money, what for and what else)* ?

Production

22. How the result is by present culture technique? (mention the production and mortality condition)

Production (kg/bigha)	
Mortality (%)	

23. Generally how long it takes to be a good grade size (grade 20)? What are the causes for less growth performance?

<3 month	3-4 month	4-5 month	5-6 month	>6 month

24. Which culture technique is better for good production, why?

paddy cum shrimp	shrimp	continuous shrimp

25. Do you apply that type of culture technique? If not, why?

Mortalities/disease

26. If mortality occurs then usually at what stage?
27. Have you been forced to harvest earlier than you wanted due to disease:

- ☐ in your pond(s)
- ☐ in neighbouring ponds

28. Where is disease coming from?

supply water	soil	fry	feed	sudden heavy rain	water parameter				others
					temp	salinity	Do	pH	

29. How you become sure?

30. What remedial measure did you take to mitigate disease?

31. What are the major influences affecting the quality of the water and disease incidence in the canals and ponds?

32. How can water quality and disease incidence in supply canals and ponds be improved?

Social/organisation

33. Describe how farmers are organised? (state in relation to supplies, marketing, water management etc.)

34. Is different organisation of any of these better?

35. What is preventing changing to these other types of organisation?

36. What credit arrangements are available to you and used by you?

9.2. Individual mass balance (per hector basis)

Table 9.1. Mass balance of pond exchange water direct from river

			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	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%
	Mortalities	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 9.2. Mass balance of pond exchange water from canal

			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 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%
Fertilizer	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 9.3. Mass balance of pond exchange water through other ponds

			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%
Fertilizer	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%**