REPORT

Norwegian Institute for Water Research

Main Office	Regional Office, Sørlandet	Regional Office, Østlandet	Regional Office, Vestlandet	Akvaplan-NIVA A/S
P.O. Box 173, Kjelsås	Televeien 3	Sandvikaveien 41	Nordnesboder 5	
N-0411 Oslo	N-4879 Grimstad	N-2312 Ottestad	N-5008 Bergen	N-9005 Tromsø
Norway	Norway	Norway	Norway	Norway
Phone (47) 22 18 51 00	Phone (47) 37 29 50 55	Phone (47) 62 57 64 00	Phone (47) 55 30 22 50	Phone (47) 77 68 52 80
Telefax (47) 22 18 52 00	Telefax (47) 37 04 45 13	Telefax (47) 62 57 66 53	Telefax (47) 55 30 22 51	Telefax (47) 77 68 05 09
Internet: www.niva.no				

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Abstract

Bangladesh was visited in the period 25 February - 9 March 2001 to discuss the results from last years field study and to make final plans for 2001. The Gher at Soladana, has been selected as the main study area and details of sampling procedures were determined with the staff at the farm.
A workshop for discussion of the results from 2000 was arranged at the Faculty of Economics & Rural Sociology. The outcome of the scientific studies was presented at meeting at the Royal Norwegian Embassy/NORAD office in Dhaka. A continuation of the project (Phase 3) was discussed briefly at the meeting, and a sketch for an ecotoxicological study was also presented and discussed.
In connection with plans for a possible ecotoxicologial project, visits were made to highly polluted river areas in Dhaka (Buriganga river) and outside Dhaka.
A prelimnary review "Environmental and socio-economic problems of shrimp farming in various countries" has been included as an appendix.

4 keywords, Norwegian	4 keywords, English
1. Akvakultur	1. Aquaculture
2. Reke	2. Shrimp
3. Brakkvann	3. Brackish water
4. Miljø	4. Environment

Project manager	Research manager	Head of research department
Bjørn Braaten		Jens Skei

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STATUS REPORT - MARCH 2001

Environmental and socio-economic impacts of shrimp farming in Bangladesh (2nd Phase)

Preface

This report briefly describes the status quo of the running Project based on a visit in Bangladesh from 25 February to 9 March 2001. Detailed information about the results from last year, 2000, are presented in First Annual Report (Wahab *et al.* 2001). Besides, an up-to-date literature based review of environmental impacts and socio-economic problems of shrimp farming is prepared by Braaten and Bergheim (2001) and attached as Appendix.

The scientific outcome from last year was presented in an arranged Workshop held at BAU. For the first time, studies of socio-economic consequences and denudation of mangrove forests due to the shrimp industry was included as parts of the Project. These topics are highly significant elements of an integrated overview of the positive-negative consequences of the industry.

Parallel analyses of water samples at BAU and NIVA still indicated deviating results from the “true values” (based on median values at ca. 100 laboratories). The analytical accuracy at Lab., BAU has however improved significantly over the last year. In order to obtain reliable effluent loading estimates, sampling of inlet-outlets of a selected Gher in Paikgacha will be carried out this year, based on parallel analyses both at BAU and at NIVA/RF.

A project meeting was held at the Norwegian Embassy/NORAD chaired by Counsellor Erik Berg. Mr. Berg pointed out the Embassy was satisfied with the achieved outcome of the Project and invited the Project team to start assessing how to continue the collaboration between BAU/other Bangladeshi institutions and the involved partners from Norway.

Oslo, 3 August 2001

Bjørn Braaten and Asbjørn Bergheim

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Summary

Bangladesh was visited in the period 25 February - 9 March 2001 to discuss the results from last years field study and to make final plans for 2001. The Gher at Soladana, has been selected as the main study area and details of sampling procedures were determined with the staff at the farm.

A workshop for discussion of the results from 2000 was arranged at the Faculty of Economics & Rural Sociology. The outcome of the scientific studies was presented at meeting at the Royal Norwegian Embassy/NORAD office in Dhaka. A continuation of the project (Phase 3) was discussed briefly at the meeting, and a scetch for an ecotoxicological study was also presented and discussed.

In connection with plans for a possible ecotoxicologial project, visits were made to highly polluted river areas in Dhaka (Buriganga river) and outside Dhaka.

1. Travel programme

The programme in Bangladesh was mainly arranged by Prof. M. A. Wahab.

Date	**Time**	**Activity**
23 February	5 – 7 p.m.	Departure Stavanger/Oslo
24 February	03:05 p.m.	Arrival Bangkok
25 February	10:45 a.m. – 08:00 p.m.	Departure Bangkok – arrival Dhaka airport, then by train to Mymensingh
26 February		Presentation/discussion of "First Annual Report" with Profs. Wahab and Islam (Project team), preparation of the Workshop (to be held on 28 Feb.)
27 February		Discussion of the sampling programme at *Gher* Soladana. Preparation of "Sampling Procedure March – August 2001" (Project team)
28 February	10 a.m. – 01 p.m.	Workshop held in Conference Room, Faculty of Agricultural Economics & Rural Sociology
01 March	10 a.m. – 12 a.m.	1) Discussion of field programme 2001 (socio-economic issues, mangrove studies, water quality issues) at BAU, and 2) Discussion of planned project on study of toxic freshwater algae blooms in the Dhaka region (Prof. S. Kahn, BAU and Senior researcher AA. Molversmyr, RF)
	03:30 – 06:30 p.m.	Travel Mymensingh – Dhaka (stay at Golden Deer Guesthouse)
02 March	00:30 - 05:00 p.m.	Travel Dhaka – Jessore by air, Jessore – Khulna by bus
03 March	08:30 a.m. – 04:30 p.m.	Visit *Gher* Soladana in Paikgacha, emphasising the sampling program (flow estimate, water samples)
04 March	08:30 – 12:00 a.m.	Travel Khulna – Jessore (by microbus), Jessore – Dhaka (by air)
	01:20 p.m.	Research manager S. Sanni, Akvamiljo arrives in Dhaka
05 March	10:30 – 12:00 a.m.	Meeting at the Norwegian Embassy
	02 – 04 p.m.	Visit Lower Dhaka and the estuary of River Buriganga, (relevant site for the planned eco-toxicological study)
06 March		Stay in Dhaka, preparation of Travel Report, planning follow-up of the project (2003 -). Prof. Wahab and Mr. Sanni leave for Mymensingh (08 a.m.)
07 March		Preparation of Travel report, project planning
08 March		Same activity as on the previous day
09 March	01:25 – 04:40 p.m.	Travel Dhaka – Bangkok (by air)
10 March		Stay in Bangkok
11 March	00:40 –10 a.m.	Travel Bankok – Stavanger/Oslo

2. Field visit

2.1 *Gher* Soladana

The *Gher* has been involved in this project since 1998 (Travel Report, 1998); initially sampling at the site was carried out for comparative analysis of parallel water samples (lab, BAU and lab, NIVA, Oslo). Later on, the inlet – outlet water of the *Gher* has been sampled in order to estimate the loading of solids and nutrients from the system. Diurnal sampling was carried out last year during the period March – August (briefly described in Wahab *et al.* 2001; Bergheim, 2001). In a recent standard calibration test at NIVA, still considerable deviations between the analytical values at BAU and NIVA were found (Hovind, 2001). Especially, the analytical results for phosphorus (TP and PO_4-P) seemed to be contaminated (reagents, analytical equipment) at lab, BAU (2 – 10 times the "true values"), while the analyses of nitrogen (TN, NO_3-N) demonstrated less discrepancy (BAU: ± "true values"). At low phosphorus concentrations, the applied analytical method is also somewhat influenced by a relatively high detection level (ca. 60 µg P/L). As a consequence, the project group decided to carry out sampling of the inlet – outlets of the *Gher* over the next production cycle (March – August 2001) combining parallel analyses of nutrients (TP, TN) at lab, BAU and in Norway (labs at NIVA and RF). 100 ml PVC bottles were brought from Norway to be returned for analyses (acid preserved) at the finalised sampling.

At the visit, Mr. Md. Zakir Hossain, Farm Manager at Soladana informed about the existing conditions at the selected *Gher*. The *Gher* is a large pond system with a surface area of 94 ha with one main water inlet point and three different outlet points. In addition, there is a smaller combined inlet/outlet point (Figure 1). Consequently, it seems impossible to sample all inlets-outlets in a representative way. To quantify the water flow at sampling seems especially complicated. The main inlet gate has a size of 128 cm x 80 cm (ca. 1 m^2) and the flow might be roughly estimated at water sampling by measuring the average current velocity through the gate. One main outlet from the *Gher* contains two parallel concrete pipes (diameter 1.5 m), while the two other outlets have lower flow capacity, each with a single pipe of similar diameter (1.5 m). In summary, it was suggested to carry out sampling at the main inlet and the main outlet (Ch. 2.2. Sampling procedure).

The water volume of the *Gher* is routine exchanged during 4 days at full moon every fortnight. Besides, the frequency of inflow-outflow within the 4-day-period is changed from pre-harvest (lasting for 2.5 months/cycle) towards the harvest period. It therefore seems complicated to get a correct review of the water exchange regime. As a solution, Mr. Hossain will detail record the exchange routine throughout the cycle.

Prof. Wahab suggested that the field fellow from BAU should stay permanently in Paikgacha to be able to carry out sampling at the right time points.

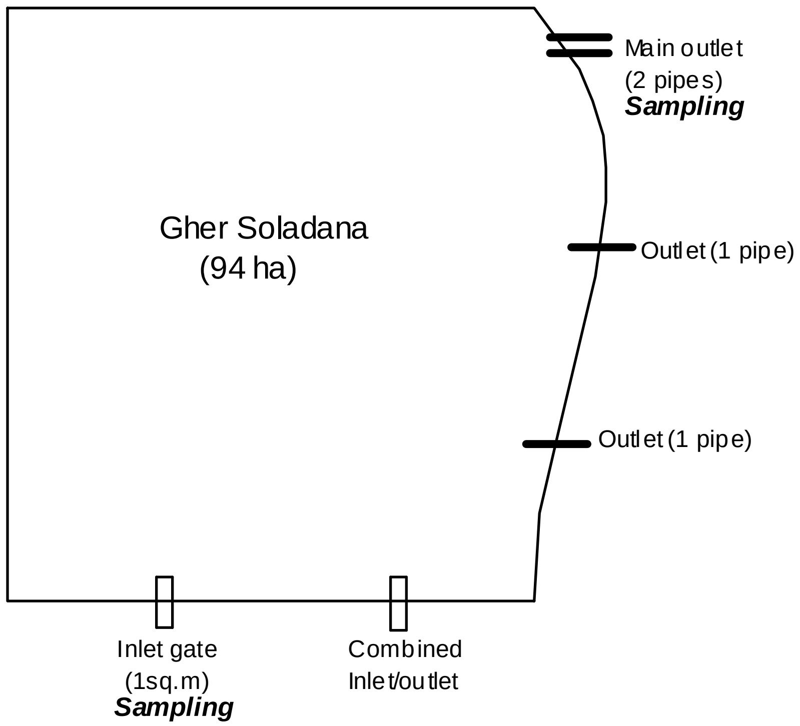

Figure 1. Sketch of *Gher* Soldana in Paikgacha selected for sampling of effluent load during the period March – August 2001 (1st production cycle). The *Gher* has two flow inlets (squared gates) and three outlets (circular pipes of 1.5 m diameter). Sampling points: Main inlet and main outlet.

2.2 Sampling procedure

Effluent load estimates at a Soladana Gher, March – August 2001 (Analysis at Norwegian laboratories)

Selected *Gher*:

System with separate water inlet and outlet points (preferably only *one* inlet and *one* outlet)

Sampling Period:

One production cycle, March – August 2001 (6 months)

Sampling Frequency:

Every 2nd week (2 samplings/month). *The last sampling MUST cover the final drainage of the Gher!*

Sampling Procedure:

Diurnal sampling (24 hrs.) – Mixed inlet sample, 6 separate outlet samples (4-hour intervals)

Sampling volume (preservation):

100 ml PVC-bottles (100 units brought from Norway), preservation by adding acid (see enclosed preservation procedure)

Sample marking:

Only consecutive numbers on the bottle labels (1, 2, 3, etc.). Further info needed (sampling time and site) must be given in an enclosed record!

Analytical Parameters:

Total Nitrogen (TN), Total Phosphorus (TP)

Total numbers of samples:

84 samples, 168 analysis

Monitoring on spot:

- High tide – low tide levels (cm recorded on a fixed scale placed within the *Gher*) should be conducted at sampling time
- Frequency (date) of every water exchange (open gate) throughout the cycle should be noted!
- Standard measurements of temperature, pH, salinity and dissolved oxygen (one monitoring at night and one at daytime)

Other vital parameters:

- Input of fertilisers (quantity of manure, urea, etc) and lime
- Area of *Gher* (ha), volume and depth at high-low tide
- Nos. of post-larvae (PL) at stocking time
- Mortality rate (any disease problems?)
- Use of chemicals, medicines (antibiotics), etc?
- Harvest: total quantity (kg)

3. Arranged workshop

Venue: Conference Room, Faculty of Agriculture Economics & Rural Sociology
Date: February 28, 2001 **Time:** 10:00 hrs to 13:00 hrs
Programme:
Session 1: Introduction & Overview

Chair: Prof. Dr. Md. Nazrud Islam, Faculty of Fisheries
10:00 Welcome
Project team: M. A. Wahab, Md. S. Islam, Md. A. Shahid, B. Braaten and A. Bergheim
10:10 Overview of environmental and socio-economic impacts of shrimp farming in various countries. B. Braaten (NIVA)
10:30 Questions & Discussion
10:40 Tea break

Session 2: Presentation of the project activities of Year 1 (Jan – Dec 2001)

Chairs: Prof. Dr. Md. Mohsin Ali & Ass. Prof. Dr. Saleha Khan, Faculty of Fisheries
10:50 Environmental impacts: Water quality aspects. M. A. Wahab (BAU)
11:10 Importance of water quality analysis. A. Bergheim (RF)
11:25 Questions & Discussion
11:35 Impacts on mangrove forests. M. A. Shahid (SPARRSO)
11:50 Questions & Discussion
12:00 Socio-economic impacts. M. S. Islam (BAU)
12:20 Questions & Discussion

Session 3: Workshop – how the knowledge and experience gained in the project can be incorporated in the national policy guidelines?

Chair: Research director, Mr. Bjorn Braaten, NIVA
12:30 Workshop discussion
13:00 Lunch & end of Workshop

Participants (Workshop):

Prof. A. Reza, Director, BAURES

Prof. Dr. Md. N. Islam, Faculty of Fisheries

Prof. Dr. Md. S. Haq, “

Prof. Dr. Md. M. Ali, “

Prof. Dr. Md. M. Haque, “

Dr. S. Khan, “

Dr. Md. N. Ahmed, “

Prof. Dr. Md. A. Wahab, Project leader

Prof. Dr. Md. S. Islam, Faculty of Agricultural Economics (Project team)

Mr. Md. A. Karim, “

Mr. Md. M. Alam, “

Ms. Shimla, “

Ms. Pael, “

Ms. Shilpi, “

Ms. H. Akhter (Hena), “

Mr. B. Braaten, NIVA, Oslo (Project team)

Dr. A. Bergheim, RF, Stavanger (Project team)

Dr. Md. A. Shahid, SPARRSO, Dhaka (Project team)

4. Meeting at the Norwegian Embassy

Venue: Meeting Room, Royal Norwegian Embassy, Gulshan, Dhaka
Date: March 5, 2001 **Time:** 10:30 hrs to 12:00 hrs

Participants:

Mr. E. Berg, Deputy Head of Mission, The Embassy (Chairman)

Mr. S. Medby, First Secretary, The Embassy

Prof. Dr. M. A. Wahab, BAU

Prof. Dr. M. S. Islam, BAU

Mr. B. Braaten, NIVA

Dr. A. Bergheim, RF

(Dr. M. A. Shahid at SPARRSO was prevented from attendance)

The main objectives of the meeting were to assess the scientific outcome, significance for the involved institutions, the budget status and the further plans of the Project ("Environmental and Socio-Economic Impact of Shrimp Farming in Bangladesh").

Initially, Mr. Berg emphasised that the Embassy/NORAD was satisfied with the outcome of the Project so far.

The attending members of the Project team were requested to express their opinion of the respective parts of the Project (water quality study, socio-economic issues, and partly the influence on mangrove forests). Prof. Wahab described the on-going collaboration with other shrimp studying projects in Bangladesh.

Mr. Berg indicated three issues of importance for the final outcome of the Project:

1) Assessment of the positive side effects at the Project involved institutions

2) How to inform about the Project in Bangladesh?, and

3) Assessment of the Project outcome in a regional context, especially with regard to the environment

In the following discussion, aspects such as arrangement of nation/local seminars, preparation of plain reports translated to Bengali (e.g. for shrimp farmers), training programs and evaluation of simple guidelines for farmers, etc. were brought up.

Mr. Berg then indicated possible ways to pursue the collaboration with BAU after the completion of the on-going project (year 2003 -). Would a closer co-operation between NIVA/RF and Univ. of Bergen towards BAU be a possible alternative? Is open water fisheries a relevant issue?

After a brief discussion, Mr. Berg concluded that there are obvious possibilities for further Bangladeshi – Norwegian collaboration involving BAU. He requested the members of the project team to come up with plans for further collaboration.

Prof. Wahab also wished to expand the co-operation by involving eco-toxicology (Akvamiljø/RF/NIVA). Mr. Sanni then briefly explained the advantages of up-to-date methods of eco-toxicological testing (bioassays).

Among other factors, the vital importance of the shrimp industry for the Bangladeshi export earnings was emphasised. The export volume represents today about 10% of the total earnings, even though the shrimp producing systems are among the most extensive in the world. A slightly increased production rate, from the present level of 200 – 300 kg/ha/year up to e.g. 400 – 500 kg/ha/year, would therefore contribute significantly to the export income. Most importantly, this expansion should take place in the existing farms without occupying new areas (rice paddies, mangrove forests). Evaluation of procedures to improve the management practise at the running farms is therefore a vital goal in the future.

Generally, Mr. Berg expressed the Embassy's view of reducing the high number of collaborating NGOs and GOs in Bangladesh, at present the Embassy/NORAD deals with more than 30 different institutions making the collaboration over-complex.

The annual project meeting 2001 will be held at BAU in June – July.

5. Other activities

5.1 Visit in Lower Dhaka

The lower parts and the estuary of River Buriganga were examined. The river was heavily polluted from sewage and industrial outlets entering the watercourse without any treatment attempts. A main industrial polluter, the tanning industry, was especially focused. One of the tanneries was also visited. According to Gain & Moral (1998), tannery waste is both poisoning soil and water (especially chromium). The estuary is a relevant study site for the planned eco-toxicological sampling.

After the visit to River Buriganga, the company Tradesworth Ltd, in Dhaka (Managing director Mr. S. M. Husain) was visited. This company distributes HACH products (chemicals, instruments) and is an important supplier for BAU.

5.2 Scrapping of ships

A meeting was held at Golden Deer Guest House with Mr. A. K. Deb of the Fisheries Training & Extension Project (FTEP II), Dept. of Fisheries in Chandpur. Further, Dr. Wahab, Dr. Shahid, Mr. Braaten, Mr. Sanni & Dr. Bergheim attended. Ship decommission is a big industry in Bangladesh (**report from VERITAS**). At present, a project proposal for study of water/soil pollution, eco-toxicological and socio-economic issues are being prepared. The planned project is based on collaboration between Dept. of Fisheries/BAU and NIVA/RF.

5.3 Dinner at the Embassy

The dinner was arranged in Mr. E. Berg's residence on 8 March at 20:00 hrs. In addition to Mr. Berg, Mrs. Skaflestad and Mr. Medby attended from the Embassy, while Prof. Wahab, Dr. Shahid, Mr. Braaten, Mr. Sanni and Dr. Bergheim represented the Project team (Prof. Islam was prevented from attendance).

At this most pleasant event, some vital issues brought up at the meeting at the Embassy (on 5 March) were further discussed.

6. Photos

Figure 2 Main water inlet at Soladana shrimp farm

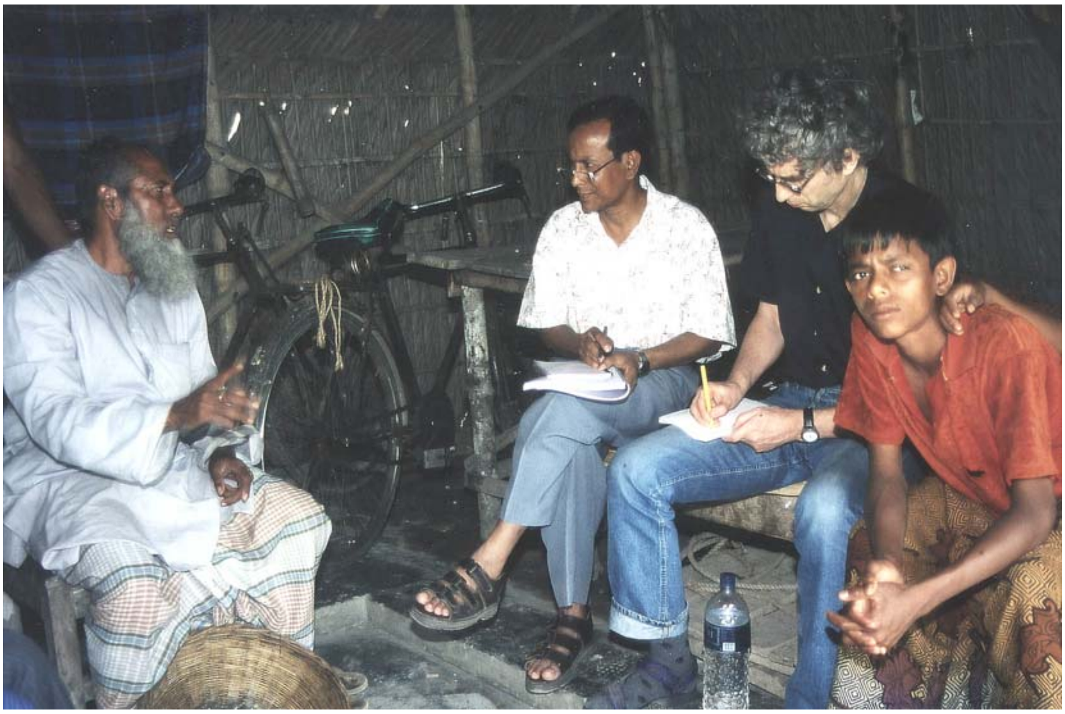

Figure 3 Dr. Wahab and Dr. Bergheim receive information of the management of Soladana shrimp farm, 27 February, 2001-06-21

Figure 4 Employees at the Soladana shrimp farm together with scientist at FRI Mr. M. S. Shahid

Figure 5 Workers at the Soladana shrimp farm, 27 February, 2001

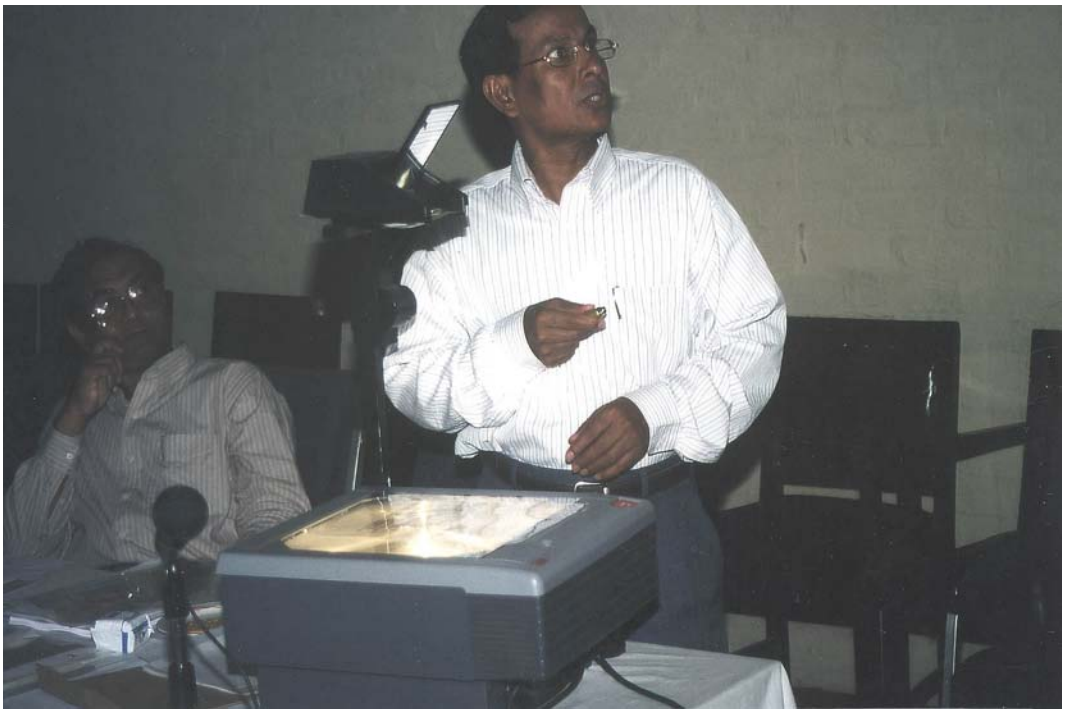

Figure 6 Dr. M. A. Wahab presents his paper at the shrimp environment workshop at the Faculty of Agriculture Economics & Rural Sociology. 28 February, 2001

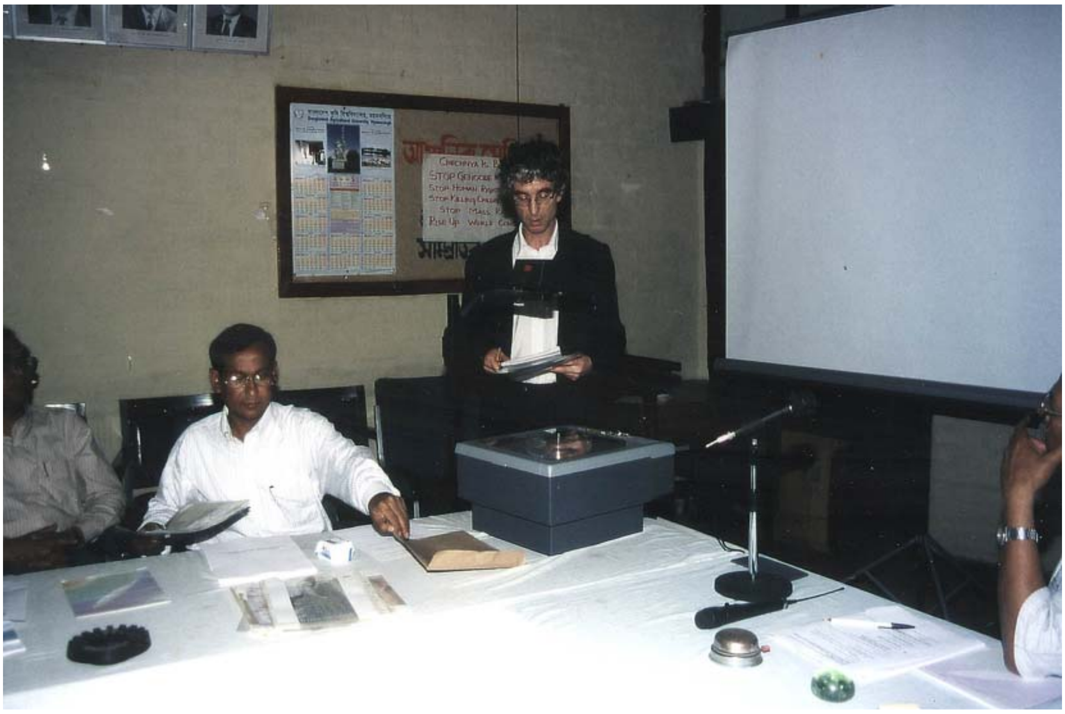

Figure 7 Dr. A. Bergheim presents his paper at the shrimp environment work-shop

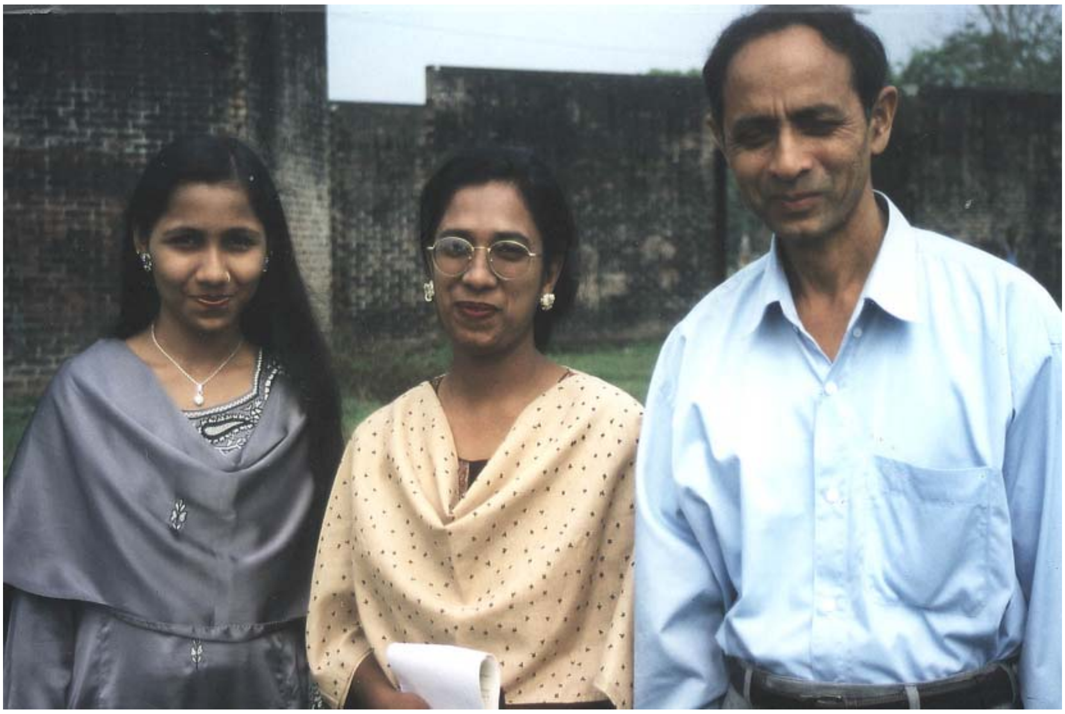

Figure 8 Dr. M. S. Islam with two members of his study team, Ms Shamin Ara Shammi and Ms Romaza Khanum

Figure 9 Dr. M. A. Wahab, Mr. B. Braaten and Dr. M. S. Islam on a boat trip at Bramaputra river, Mymensingh

Figure 10 Storage dam from the outlet of a tannery at Hazaribag, Dhaka

Figure 11 Buriganga river at low water at Hazaribag, Dhaka

7. References

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8. Appendix

Environmental impact and socio-economic problems of shrimp farming in various countries - a prelimnary review.

B. Braaten and A. Bergheim

Contents

Introduction

The aquaculture of penaeid shrimp has grown from an experimental beginning stage to a major industry in less than 30 years. Shrimp farming now takes place on a world-wide basis, provides not only employment of hundred of thousands of skilled and unskilled workers, but also of millions of US dollars in revenue, and high quality food products. The major producing countries are in Asia, where the black tiger shrimp (Penaeus monodon) is the predominant farmed species and in Central America where the western white shrimp (Penaeus vannemei) are grown.

However, the fast growing shrimp industry has also been accompanied by concerns over social, economic and environmental impacts (Flaherty *et al*. 2000, De Silva, 2000). A cost-benefit analyses commissioned by the Indian Supreme Court concluded that shrimp culture caused more economic harm than good, the damage outweighed the benefits by 4 to 1 (Primavera, 1997). The importance of shrimp to Thailand's economy, however has been overshadowed by persistent and intractable social and environmental impacts (Flaherty *et al.* 2000). To date the attention has mainly focused on the loss of mangrove forest, but also on indiscriminate use of antibiotics, degradation of coastal waters, pond abandonment and salinization of water and soil. Concomitant with the growth of the shrimp industry has been the recognition of the ever increasing importance of disease, especially those caused by infectious agents (Lightner and Redman, 1998). Major epizootics have plagued the world's shrimp culture industries, and the historical trends of shrimp production in leading Asian countries (**Figure 1**) show a boom-and bust cycle, related to pollution and diseases (Primavera, 1997).

The aim of this review is to present an updated picture of the environmental and socio-economic problems related to shrimp farming in using various farming methods (traditional, extensive, semi-intensive and intensive methods) in different (mostly Asian) countries.

Description of systems and practises

Shrimp hatcheries

Seed supply of the shrimp industry originally relied on captures of wild seed, as it still does in Bangladesh. However wild seed stocks have proven limited and unreliable to support the rapidly expanding industry and consequently shrimp hatcheries have been established in most countries.
The female brood-stocks are still mainly caught in wild by the fishing fleet and placed in special brood stock plants. The sale of wild caught brood-stock in an industry by itself (Forbes, 1992). Ovarian maturation and spawning is also achieved in a laboratory environment, but the offspring have often been of poorer quality (Bray and Lawrence, 1992).

Shrimp hatcheries can be classified into three sizes, small-scale, medium scale and large-scale (Rosenberry, 1995). Small-scale hatcheries (backyard hatcheries) have a low technical input, and low operating costs. They use small tanks, low stocking densities, untreated water and diseases and water quality problems easily knock them out (Shang *et al.* 1998). However, they can easily restart operation after disinfection.
Medium-scale hatcheries use large tanks, low water exchange and encourage algael blooms within the tanks. In Asia, most of the medium-scale hatcheries are based on a design from Japan and are referred to as “eastern hatcheries”. A five-year cash flow analysis revealed that medium scale hatcheries had the highest benefit-cost ratio (Shang *et al.*1998).
Large-scale hatcheries (western hatcheries) require high technology, high cost facilities that produce large quantities of seed in a controlled environment. They have often problems with disease and water quality and had the highest variable and total costs per fry (Shang *et al.* 1998).

Shrimp grow-out systems

Shrimp culture systems can be broadly classified into three types based on major economic and technological differences: extensive, semi-intensive and intensive, although there are many systems in between these main types.

Extensive production systems are either traditional or slightly modified versions of these. They are called low density and low in-put systems, and produce insignificant loading of nutrients or organic matter to the ecosystem. The system relies mainly on natural productivity of the pond, but organic and inorganic fertilisers are occasionally used to promote growth of natural foods. Most labours come from the household of the owner or tenant-operator.

Semi-intensive systems operate with an intermediate level of stocking and other inputs. The biological productivity of the ponds is improved through supplemental feeding, improved culture practice, selective stocking, planned post-harvest and marketing. Farm labours is recruited from the family or the community, and the owner plays an active role in management.

The intensive production is characterised by relatively high densities and high inputs, such as pelletized feed, which increases the nutrient and organic load to the ecosystem. Most investors in intensive systems are urban entrepreneurs or business people, which hire managers and technical staff (Shang et al.1998).

Over 90 % of the farms in major producing Asian countries are classified as extensive or semi-intensive types of operation, except for Thailand where 85 % shrimp farms are intensive. The extensive systems are most important in Bangladesh accounting for at least 90 % of all shrimp farms, followed by Vietnam (80%), India (70 %) and Indonesia (45%). Semi-intensive systems are more popular in China (85%) followed by the Philippines (50%), and Indonesia (45%), while intensive systems are important only in Thailand (**Table 1**).

Land use and farm size

Intensive shrimp culture requires minimal area, compared with other systems, and it is not recommended to build shrimp farms in mangrove areas (Kongkeo, 1997). When shrimp farms are cultured in such areas where water and soil contains high organic loads, **disease problems always occur.** Shrimp farms are recommended in supratidal areas (above the height of the highest tide) which often are rice fields. These areas can be properly treated by complete dry-out and by efficient removal of fouled layer by heavy machines. To prevent conflicts with rice farmers, the ponds must be designed to have proper drainage system without interfering with freshwater channels; and pond embankments should be well compacted to prevent seepage of saline water into rice paddies (Kongkeo, 1997).

Of the intensive farm type, the low-investment farm is recommended, as it can stop their operation for a while, or they can reduce stocking density. In fact, no big farms with high investment and large overheads have been able to survive owing to insufficient care in farm management (Kongkeo 1989). 80 % of intensive farms in Thailand are owned by small-scale operators with 2-3 ponds.

In 1994-1995, a farm performance survey conducted by the Asian Development Bank (ADB)/Network of Aquaculture Centres in Asia-Pacific (NACA) covered a total of 2898 extensive, 1022 semi-intensive, and 870 intensive farms in 13 major Asian producing countries (ADB/NACA, 1996). For consistency in inter-system and inter country comparison, the production cost per kg shrimp is used as a criterion.

The following summary of cost of production is taken from Shang et al. (1998), that based their results from Ling et al. (1996):

For inter-system comparison, the cost of production per kg is highest for the intensive system followed by semi-intensive and extensive system in all of the major producing countries, except for India where the cost of production per kg was highest for the semi-intensive system followed by intensive and extensive systems. Feed and seed are the two most costly items (intensive, semi-intensive), while seed is the most important cost item in the extensive system in Indonesia and the Philippines.

For inter-country comparison, the cost of production per kg for the intensive system was highest in Taiwan (US$ 7.33) followed by the Philippines, India, China, Malaysia, Indonesia, Sri Lanka, and Thailand (US$ 4.26).
For the semi-intensive system, China had the lowest production cost per kg (US$ 2.27) followed by Vietnam (US$ 3.34), Indonesia (US$ 3.78), Philippines (US$ 4.01), Sri Lanka (US$ 4.56), Malaysia (US$ 5.50), India (US$ 5.96) and **Bangladesh (US $ 12.04).** Feed is the most important item and seed is the second.

For the extensive system, again China had the lowest production cost per kg (US$ 1.62), followed by Thailand (US$ 1.74), the Philippines (US$ 2.61), Vietnam (US$ 3.04), Sri Lanka (US$ 3.45, Indonesia (US$ 3.86), **Bangladesh (US $ 4.07)** and India (US$ 4.42). Significant lower use of feed is the important feature of extensive systems as compared with intensive and extensive systems.

The analysis also looked at **profitability** at each culture system by country. For the **intensive** system, Taiwan had the highest profit (US$ 5.13), while China and the Philippines could barely cover their production costs.

For the **semi-intensive system, Bangladesh recorded a net loss of US $ of 6.78 per kg,** while all other countries showed a profit ranging from US $ 0.91 in China to US $ 3.05 in Indonesia.
For **extensive** shrimp culture, Vietnam exhibited a loss of US $ 0.31 per kg, while profit from all other countries ranged from high US $ 4.67 in the Philippines to a low of US $ 1.43 in China**. Bangladesh had a profit per kg of US$ 2.83.**

The study also calculated **efficiency**, and for **extensive** culture, **Vietnam, Cambodia, Bangladesh and Myanmar were found to be highly inefficient** while Thailand was the most efficient. For **semi-intensive** culture, Malaysia, Indonesia, and Sri Lanka were the most efficient while **China and Bangladesh were found to be very inefficient.**

Factors affecting performance and sustainability

From the same study by Shang et al. (1998) many bio-technical factors were identified that affected economic performance and sustainability of the shrimp industry. Many of these factors act directly on the environment and health situation at the farm. Some of the more important one is summarised below:

- Farm performance is generally improved when farms employ separate intake and drainage channels, and where the number of farms discharging shrimp pond effluent into supply channels is small.
- Profit decreases when production pond increases due to difficulties in farm management and disease control.
- Farms with storage ponds with water conditioning, pre-filling and sedimentation ponds prior to effluent discharge reported fewer diseases and environmental problems
- Fallowing the ponds after each harvest usually reduces the cost of drugs (Chemicals and antibiotics) and environmental stress.
- Limiting water exchange to the level needed to maintain the pond environment results in saving in natural pond productivity and chemical/pumping costs.
- Shrimp and milkfish rotation in the Philippines maximised utilisation of natural productivity and minimised organic matter accumulation.
- Utilisation of biological treatment (e.g., use of filter-feeding organisms such as bivalves and seaweeds) in storage and effluent treatment ponds or in the outfall channel can minimise aquaculture pollution.
- Silt removal usually minimises financial loss due to diseases.
- Indices of correlation between shrimp farm and soil type show a lower profitability and higher incidence of diseases for acid-sulphate and sandy types of soil.
- Improving seed quality from hatcheries increases survival and hence profit rates.
- Improving feed formulation and feeding practices reduces feed costs and water pollution.

Impact of unregulated shrimp culture

Collection of wild shrimp fry

From time immortal in Bangladesh, tidal waters have carried post-larvae of shrimps and fin-fishes when trapped in the “gher” (an area impounded by dike) which were allowed to grow for a period of 6 months (Deb, 1998).

In the absence of viable hatchery industry, the shrimp culture in Bangladesh is mostly dependant upon wild source of tiger shrimp for stocking. Along the whole coastline about 75 000 coastal people were engaged, catching annually about 2035 x 10^{6} tiger shrimp fry (BOBP, 1992). The number of fry catches has recently increased to 154 000 (Karim, 1997).

However, for each tiger shrimp fry, about 26 other shrimp, 29 fin-fishes and 70 other zooplankton were simultaneously destroyed in 1994 (Deb, 1998). **Table 2** shows the massive loss of shell-fish and fin-fishes for catching tiger shrimp fry. The collectors or their family members sort out tiger shrimp fry quickly from the catch, and the remainder of the catch is discarded on the shore. This massive loss and destruction of fish- and shell-fish larvae will undoubtedly have a disastrous impact on artisanal and commercial fishery in near future (Deb, 1998). This problem seem to be particular serious in Bangladesh, but the same thing happens in other countries (Vietnam) with few commercial hatcheries.

Shrimp farming in mangrove areas

For experienced aquaculturists and planners the “mangrove issue” is for all intents and purposes closed. However, as new regions take to shrimp and coastal aquaculture, this issue is likely to resurface over and over (De Silva, 2000). The shrimp industry has in particular been blamed as the main cause for destruction of mangroves, but as hard quantitative data gets available the picture changes. In the case of Thailand it has been shown that shrimp farming was responsible for the destruction of 17.5 % or 64 992 ha of mangroves between 1979 and 1986 as opposed to 35.9 % for other uses (Menasveta, 1997). Since 1986, the destruction of mangroves in Thailand has decreased significantly, and almost none of which is due to shrimp farming (FAO, 1999).

The strong critic against aquaculture can easily be understood when we look back a few decades. According to Primavera (1997) culture ponds for shrimp and fish accounted for the destruction of 20-50 % of mangroves worldwide in recent time, in addition to agricultural, industrial and residential development. In the Philippines approximately half of the mangrove loss of 279 000 ha from 1951-1988 resulted from the development of culture ponds. Minh Hai province, with the largest mangrove area in Vietnam, had in 1991 lost 75 % of the original mangrove forest in the district due to population growth, illegal settling, ineffective forest management, and clearing of land to culture shrimp (Sinh, 1994). Reduction in mangrove areas in Equador in 1965-1984 was mainly due to the construction of 21 600 ha of shrimp ponds (Alvarez, Vasconez and Guerro, 1989 cited by Primavera, 1997).

In Chokoria Sundarbans on the South-Eastern Bangladeshi coast, most of the 7500 ha of mangrove forest has been completely removed leaving only 973 ha of shrub forest. The destruction started in 1975 (**Figure 2**) and continued until 1988 (**Figure 3**) (Choudhury et al. 1990). The shrimp growers in this area turned into semi-intensive and even intensive culture, but today, most of the shrimp culture in the area has been closed off due to problems with diseases and natural disasters (typhoons, floods etc). The environment has completely changed, and this area is now open and will be very much susceptible to the cyclones and storm surges that are regular phenomena in the coastal area. A cyclone caused thousands of death and enormous property damage in 1991 after the installation of shrimp farms (Choudhury et al. 1994). Cyclones and floods, also destroyed the shrimp farms in 1997 (Wahab et al. 1997).

This wide scale expansion of shrimp culture into mangroves has transformed a multifunctional ecosystem that generates a diversity of resources and services into private ponds that produces only on resource (Bailey, 1988) and degraded the environment at the same time.

Mangroves have contributed significantly to the well-being of coastal communities for centuries through products used for fuel, construction, fishing, agriculture, forage for livestock, paper, medicines, textile and leather and food items – mainly fish, crustaceans and molluscs (Primavera, 1997 and others). A positive correlation between mangrove area and shrimp/fish catches has been documented for the Philippines, Malaysia, Indonesia, and Australia (Primavera, 1995, and references therein), and is reflected in the parallel decline in Philippine mangrove and municipal fisheries.

The knowledge about the importance of mangrove forests today, makes it likely that such areas will be avoided in the future when new areas are selected for shrimp culture. It is also important to be aware of the fact that mangrove areas are not suited for shrimp culture, and disease problems will always occur, at least in intensive systems (Kongkeo, 1997).

One way of protecting the mangroves, have been the development of shrimp-mangrove integrated farming systems, and such a study was tested in Vietnam (Binh et al. 1997). A total of 161 shrimp-mangrove farms on the east and west coasts of Ngoc Hien district were surveyed. An economic analysis, based solely on the economic return from the shrimp culture showed that the farming system with a mangrove coverage of 30-50% of the pond area gave the highest annual economic returns. The results demonstrate a better economic return to farmers who maintain mangroves in their farming systems.

Salinity intrusion

The introduction of marine and brackish-water shrimp farming near shore and inland has created ecological and social problems by changing the quality of agricultural land, natural vegetation, poultry and life stock production and daily life in the area. Water use in shrimp culture affects the surrounding environment through extraction of ground water and discharge of pond water. Heavy water use may draw water from freshwater aquifer and reduce supply of domestic and agricultural water, aside from causing seawater contamination, especially of depleted aquifers (Primavera, 1997).

Communities adjacent to shrimp farms in Bangladesh, Sri Lanka, Indonesia and the Philippines experienced salinization or complete drying up of shallow wells for domestic water supply, and browning of previously green orchards and rice lands (Yap, 1990 and others cited by Primavera, 1997). According to Rahman et al. (1994) unplanned shrimp farming, very often forced into villages, has salinizised homestead gardens and caused depletion of vegetable and fruit trees. Deb (1998) informs that in the south-western part of Bangladesh, the salt intrusion has caused a giant problem because of loss in crop production, fresh water crisis and related gastrointestinal diseases, loss in fodder etc. However, it is difficult to find documentation based on scientific studies and reports to confirm these serious problems.

The encroachment of shrimp farming into freshwater environments, and the potential impact on rice cropping, has been a concern in Thailand since the first boom in pond development occurred during the late 1980s (Thailand Development Support Committee, 1990 cited by Flaherty et al. 2000). Low salinity shrimp farming introduces the potential for salt accumulation to a much larger area, and the most recent estimate of total land subject to direct salinization impact, as a result of inland shrimp farming, is 22 455 ha (Department of Fisheries, 1998, cited by Flaherty et al, 2000). The significance and extent of indirect soil salinization effects is, however difficult to access, but were estimated to 1.8 tonnes per crop. Recent studies by Thai Department of Land Development suggest that seepage or effluent disposal can increase soil salinity up to 50 meters or more from the edge of inland shrimp ponds.

Impacts of wastes and effluents

The two significant components of the pond environment are the pond water and sediments, which interact continuously to influence the culture environment (Funge-Smith and Briggs, 1998). Pond sediments can be further divided into the pond soil component (the pond bottom and walls) and the accumulated sediment component (the sludge that accumulate on the pond bottom during culture) (Briggs and Funge-Smith, 1994). Pond management activities are a third external factor which influence the culture environment. Management activities include feeding, use of aerators, water exchange and liming (**Figure 4,** Funge-Smith and Briggs, 1998).

The amount of waste discharged from a shrimp farm will depend upon the type of farm (extensive, semi-intensive, intensive), but also of the management practise. The original intensive shrimp farm in Thailand involved high stocking rates, high feeding rates and high rates of water exchange and accumulated sediment were removed between cycles. Applied feed accounted for 78 % of the input N to the ponds, erosion of pond soil added 16 % to the system. The sinks for the system were sediments (24%), harvested shrimp (18%) and discharged water 27 %, and 30 % of N were unaccounted for, but probably lost to atmosphere as ammonia. The principal source of phosphorous in this system was applied feed (51 %) and the 26 % shortfall in input was estimated to be eroded pond bottom. Effluent water constituted 10 % loss in the budget and 84 % of P was trapped in the sediment that was removed (Funge-Smith and Briggs, 1998).

Common problems in open water exchange systems include phytoplankton crashes, deteriorated pond bottoms and bacterial diseases. Due to deterioration of estuarine and coastal water bodies, many shrimp culture areas no longer have required the clean seawater and has reduced water exchange. One reason is that water exchange has probably triggered disease outbreaks, and there is now substantial evidence that the viral disease “yellowhead” is transmitted in water and that white spot disease is introduced via crustacean intermediates during water exchange (Funge-Smith and Briggs, 1998). These things have given rise to “closed” and “semi-closed” culture systems in Thailand. Low water systems as these are complete sinks for nutrients and thus there are no outlets for wastes during production except for discharge at harvest- (**Table 3 and Figure 5**). Recently low salinity farms have increased in number dramatically due to establishment of closed system culture technique, and they are situated inland much further from the coast than once thought feasible. The rapid development of low salinity culture in freshwater areas that are predominately used for paddy rice cultivation, however now represent a major land and water management challenge (Flaherty et al. 2000). The Thai Government banned inland farming in response to concerns about salinization of soil and irrigation water (Boyd, 2001). However, considerable controversy over the ban still remains, and the Thai Government is now attempting to find a way to address the concern and still allow inland shrimp farming.

Fluxes and mass balances of nutrients in semi-intensive shrimp farms have been developed in Mexico (Paez-Osuna et al.1997, 1998) and Honduras (Teichert-Coddington et al. 2000). Shrimp farms in Latin America typically have low stocking rates and are managed without aeration. In the study from Honduras water exchange resulted in a net discharge of organic matter and the majority of net nitrogen and phosphorous loss from ponds were derived from feed. For each kg of shrimp yield 16.6 g of N and 2.3 g of P were discharged as net loss to the environment. In the Honduras study, inorganic fertilisation had a notable effect on effluent concentrations of soluble N and P. Shrimp farms should minimise the use of fertilisers unless site specific studies demonstrate that fertilisation increases yield.

In the intensive open ponds in Thailand 21 g N and 0.7 g P were discharged with water exchange per kg of shrimp produced (Briggs and Funge-Smith, 1994). 10 fold more water per kg of shrimp production was exchanged in Honduras than in Thailand, to combat projected episodes of low DO, because ponds are not equipped with aerators. Hopkins et al. (1993) demonstrated that a 10-fold decrease in water exchange from 25 % to 2.5 % per day in ponds stocked with 44 shrimp/m^2 resulted in a twofold decrease in nitrogen discharge by water exchange.

The Mexican study (Paez-Osuna et al.1997) estimated environmental loss of N and P to 28.3 g and 4.6 g respectively, per kg shrimp produced.

Unfortunately, no data are available on nutrient concentration in shrimp ponds or effluent water in Bangladesh (Deb, 1998), although the present research project at Mymensingh (Wahab et al. 2000) will supply new figures. From Vietnam there has recently been presented carbon and nitrogen budgets in shrimp ponds of extensive mixed shrimp – mangrove forestry farms in the Mekong delta (Alongi et al. 2000). The latter study showed that tidal exchange was the major pathway for inputs and outputs of carbon and nitrogen. No fertiliser or artificial feeds were added. On average, nutrient outputs were greater than inputs. This imbalance partly explains why shrimp yields are declining in these ponds.

A comparison of P and N load from fish and shrimp farming is presented in **table 4.** (Paez-Osuna et al. 1999). Although the different conditions on climate, management and species involved in the distinct studies, there are comparative levels in nutrient loads, particularly for N. These load values indicate that the environmental impact of aquaculture, independent of the culture system, is of the same magnitude.

Use of chemicals

Diseases in shrimp always have an environmental component, and chemical treatment is seldom if ever effective on their own (Chanratchakool et al. 1998). Some chemicals can seriously damage the plankton bloom in the pond, or may be harmful if released from the pond. Unfortunately there is very little information available regarding the safe and effective use of chemicals in shrimp ponds. As a result, there are only a few chemicals which can be recommended for use in shrimp pond culture (Chanratchakool et al. 1998).

Treatment for external fouling is usually associated with deterioration in the pond bottom or the water quality. The most commonly used component for this purpose is formalin (37 to 40 % formaldehyde).

A number of chemicals have been recommended for reducing the load of harmful bacteria in the pond. Most of the recommended substances are broad spectrum disinfectants including quaternary ammonium compounds e.g. benzalkonium chloride, buffered iodophores e.g. povidine iodine and calcium hypochlorite. They have affect on bacteria as well as on plankton. Lime can also be considered as a pond disinfectant.

The use of antibiotic substances is the cause of much controversy, and there is no doubt that these compounds are widely abused in shrimp farming at present (Chanratchakool et al, 1998).

After mechanical pond treatment, various common chemicals including lime, tea seed cake and fertiliser, are generally applied in intensive shrimp farming in Indonesia, Philippines, Taiwan and Thailand (Kongkeo, 1997). Although the fouled layer of the bottom has been commonly removed, Thai farmers still prefer to apply more lime than is usual in other countries.

The new low salinity inland shrimp farming in Thailand also face severe unique disease and pollutant risks due to their location amongst rice paddies. Rice farmers use a variety of pesticides and insecticides to protect their crop. Crustaceans as shrimp are much more related to insects than most other cultured marine species and are particularly vulnerable to pesticides through their life cycle and numerous cases have been reported of shrimp crop losses (Flaherty et al. 2000).

In Sri Lanka all farmers use lime during pond preparation and liming is continued during the culture cycle (semi-intensive farms). Urea and superphosphate were the only ferilisers used prior to stocking (Corea et al. 1998). Other commonly used chemicals were tea seed cake (saponin) and rotenone. They are used to kill the fish in the prawn ponds. The present practise of using tea seed cake to destroy fish in prawn ponds is locally recommended, but the water may be harmful if released afterwards (Corea et al. 1998). According to Indian authors, these chemicals only loose their toxicity after 24 to 48 hours.

In the course of pond management, a lot of chemicals are used in Bangladesh, e.g. piscicides and molluscides (tea seed cake, rotenone, tobacco dust, thiodan, lime and fertilisers, antibiotics (oxytetracycline, streptomycine, tetracycline, etc.), disinfectants and many other known and unknown chemicals (Deb 1998). In Bangladesh, the problem in getting information is that the owners of farms maintain secrecy in the use of chemicals.

The overuse of chemicals and the difficulties in treating shrimp diseases were also factors that contributed to the decline of shrimp production in Taiwan (from 100 000 mt/yr in 1987 to less than 10 000 mt/yr in 1988 (Lin, 1989).

The problem of diseases

Almost from the beginning of the shrimp culture industry, disease was recognised as a biological treat. Most diseases in shrimp are a combination of poor environmental conditions, resulting in either damage to the shrimp, or reduction in its capacity to fight disease. The basic treatment and preventive measure against diseases is therefore to maintain good water quality and pond bottom conditions. In this connection the main problem is how to avoid spreading of diseases to the surroundings.

The vast majority of shrimp farms still rely on wild post-larvae (PL) or hatchery reared PL which are produced from nauplii of wild-caught spawners. Wild spawners are often used in maturation facilities to produce nauplii. These wild shrimps can easily be carriers of bacterial and vital diseases. Reports from South-east Asia indicate that a strategy of exclusion of the virus from the ponds is an effective way of managing around the virus. The essential step is to stock the ponds with virus-free PLs (Persyn, 1999). The pond water is sterilised or treated with insecticide to exclude carrier organisms. Water is not exchanged for fear of contaminating the shrimp with virus. Most if not all P.mondon PLs in Asia are produced from wild spawners or from maturation of wild spawners. The problems in Bangladesh, which are totally dependant upon PL caught in the rivers, are a high susceptibility of contamination by diseases when the ponds are stocked with wild seed.

Another problem is the import of wild fry from other countries. According to Deb (1998) entrepreneurs imported 800 millions fry from Thailand and India through special cargo services in 1995. However, there are evidences that shrimp pathogens have been widely disseminated through introduction and transfer of shrimp. Moving shrimp between countries or between district areas within a country should be avoided wherever possible. Moving stocks of shrimp not only carries the risk of introducing disease to farms, but may also have an adverse effects on the local population of wild shrimp (Chanratchakool et al. 1998).

If there is disease in an area, viral diseases can be prevented by following guidelines presented by Kongkeo (1997). One of the most important steps is disinfection of the pond bottom and eliminate virus carriers. The incoming water should be filtered and treated with formalin or sodium hyphochloride and pond system should use a recycled or closed system. A difficult but highly important step is to select non-infested postlarva for stocking, on that assumption that this is possible.

Socio-economic implications

Modern shrimp farming has socio-economic costs aside from the ecological consequences that has been discussed above. The aquaculture sector witnessed some major calamities in different nations, mostly in respect of shrimp culture ventures, when viral disease outbreaks, abetted by poor management practices, went out of control to a certain degree. The spread and intensification of shrimp farming is also thought to have brought about land subsidence (from excess use of ground water) and salinization of freshwaters in some regions (De Silva, 2000). Barraclough and Finger-Stich (1996) point out that these social and environmental problems are only the latest incidents in the broader processes associated with the expansion of other mono-cultures (e.g. banana, cotton, coffee, and sugar) that have generated social exclusion and environmental degradation (Primavera, 1997). Hence, intensive shrimp farming repeats the pattern of unsustainable growth described for many other industries (Folke and Kautsky, 1992).

All across Asia, residential, agricultural and forestlands are being converted into shrimp farms. Even burial grounds, pastures, areas for drying nets and other common land have not been spared by the shrimp fever (Primavera, 1997). In many cases, this has involved a direct buying out by big companies of small-scale landowners. Often saltwater contamination by adjacent shrimp ponds makes agricultural land barren (as described above), and the only option of poor farmers with no capital for aquaculture is to sell their land.

Water conflicts

Fresh water of good quality is a shortage many places and it is not surprising that low salinity farms (in Thailand) has evolved within traditional rice growing areas. Although very limited information is available on existing water use, a typical inland intensive farm can be expected to require 66 000 m^3 of water per ha of pond area per year (Flaherty et al. 2000). This figure is far greater than most domestic or industrial water uses and is substantially higher than the annual water requirement of rice paddy. A large number of inland farmers have tapped into existing rice irrigation structures by constructing small canals to their pond/farm inlet structures, and this can affect the overall performance of irrigation systems. A ban on use of groundwater pumping for aquaculture purposes has been imposed in many areas in Thailand, and water use conflicts could easily appear. The salinization of aquifers and fresh water wells is another hot topic in many areas that easily create serious conflicts.

Insight into the husbandry and water management practices of inland shrimp farmers are drawn from a survey of 86 operators in Chachoengsao Province conducted during 1997 and 1998 (Flaherty et al. 2000). The majority of inland farmers surveyed, used stocking density well above recommended levels which increases the risk of disease outbreaks, and they paid little attention to their waste disposal practises. This could lead to a repetition of the devastating cycle of self-pollution, disease outbreaks and crop failures that decimated many coastal shrimp farms in Thailand.

Water is usually not included as a cost item, except for pumping costs. However, as the quantity and quality of water declines and deteriorates in the future, the cost of suitable water would become an important cost item (Shang et al. 1998).

Food problems

Most cultured shrimp is destined for luxury export market, and the fast development of the industry is driven by economic realities. A shrimp crop in Thailand earns up to 30 times the profit in rice farming, but almost all of it is exported (Primavera, 1997). The shrimp culture is not helping in malnutrition – most of the coastal people do not have the buying capacity of the costly shrimp (Deb, 1998) but they have an income and can buy other food items.

Decreasing rice production from around 40 000 tonnes in 1976 to only 36 tonnes in 1986 in Satkhira in Bangladesh, can be traced to salinization and loss of soil fertility as saltwater canals from shrimp ponds cut across paddy fields (Shiva 1995 cited by Primavera, 1997). Shrimp mono-culture has led to the decline of traditional *pokali* fields in India and Bangladesh, where alternating rice and shrimp/fish harvest have been sustainable (Baird and Quarto, 1994 cited by Primavera, 1997).

Deb (1998) states that shrimp culture has originated vulnerabilities among the poor in coastal areas of Bangladesh. In Khulna, common grazing grounds have been converted to shrimp ponds and owners do not allow cattle to pass over the dikes thus restricting the grazing areas. It has been shown from 1986-1989, total production of cows and buffalos have declined by 47 % and yield by 25 % and mortality of chicken in high areas where salinity is very high. Production of poultry declined by 36 % in shrimp culture areas of Khulna and raising ducks have been difficult. Fruit trees like coconut, mango and beetle-nut have been significantly reduced in both Khulna and Cox's Bazar area. The coastal paddy farmers have fallen victim in the hand of shrimp farm owners and there are growing conflicts which ended in violent clash in 1998.

Ownership and distribution of natural resources

The allocation of resources for shrimp farming and the distribution of benefits depend upon the social context and institutional framework (Barraclough and Finger-Stich, 1996). Where land and other resources are under the control of a small elite, most of the shrimp production is concentrated in a few large entrepreneurs as in India and Bangladesh. On the other hand, most shrimp farms in Thailand are operated by small and medium sized farmers (Kongkeo, 1995 cited by Primavera,1997) where land is widely distributed. This is also the case in Vietnam, where land and other natural resources belong to the state (Sinh, 1994).

The aquaculture sector is characterised by a wide range of practises. At one level extreme are the rural, subsistence level, at the other extreme are highly capital intensive as some forms of shrimp culture. It is expected that there will be a shift in the rural aquaculture sector towards more intensification, a strategy that will be driven by the need to make more efficient use of natural resources (area, water etc). Equally the extent of industrial aquaculture will increase significantly. However intermediate practise will most likely continue to dominate (De Silva, 2000).

Ongoing socio-economic studies in Bangladesh (Islam and Wahab, 2000), has shown that expansion of shrimp farming played significant role to develop roads and communication, market system and to improve overall economic condition in the study areas. The studies also showed benefits gained from coastal aquaculture operation (shrimp farming) are higher than any other agricultural activities compared to land productivity.

Methods to reduce environmental problems

Almost all shrimp farming are performed in earth ponds of various size and intensity. In each country there is a variety of technology and experience and the dominating technology depends upon a number of factors as: governmental planning of aquaculture activity, access to capital, level of learning, infrastructure and access to necessary modern feed and veterinary service. In Thailand, the world leader in shrimp farming, the intensive culture are now moving away from open systems with high rates of water exchange. The increasing amount of diseases have been associated with water exchange and this has given rise to closed and "semi"-closed culture systems. Low water systems are complete sinks for nutrients, and there is no release of nutrients during the production phase except for discharge at harvest. This is still a critical phase.
Another development is the increase in low salinity culture systems in the inland. By transporting hypersaline water (brine) inland, shrimp farmers can be established almost anywhere an adequate source of freshwater can be found. These farms now represent a major land- and water management challenge. What about future use of water, and will the increased use of saline water affect the rice production, agriculture and animal husbandry production?

When intensive farming is practised, the life span of ponds do not exceed 5 – 10 years because of attendant problems of self-pollution and diseases (Primavera, 1997). This "rape and run" practise is unacceptable, and the ponds should be rehabilitated. On option is to follow rotational cropping of shrimp and fish culture or a poly-culture or both. This depends on the suitability of the area as suggested by Deb (1998) that describes the system in detail.

Bangladesh have also tried out semi-intensive shrimp production in large scale in the Cox's Bazar region, which in earlier days was mangrove area (Chokoria Sunderban). After a total destruction of the mangrove forest in the period 1975-1988, a number of farms came in operation. However, the economic analyses (Shang et al. 1998) has shown a profitability with net loss of US $ 6.78 per kg shrimp produced. The area has been attacked by "White spot disease" during 1994-96 and in 1991 a cyclone caused thousand of death and enormous property damage. In 1998 the area was hit again by floods and cyclones which almost destroyed all the shrimp farms in the Cox's Bazar area.

The extensive culture system has a low production, and seems to operate without serious disease problems. It is a relative simple technology, with low output of nutrients to the environment However the method it is evaluated as highly inefficient.

One of the most serious environmental problems is the massive destruction of shellfish and fin-fish larvae in the collection of PL larvae for stocking the ponds. In the long run it absolutely necessary to build a number of hatcheries that can support the industry with PL- larvae and avoid the massive collection of wild fry. Besides of being a threat to local fisheries, the use of wild PL-larvae will always increase the risk of introducing diseases to the farm.

The cutting of mangroves for building of shrimp farms seems to have ended in most countries, but the mangrove areas need to be surveyed continuously. Experience from Ecuador revealed that corruption is a major cause behind the mangrove destruction associated with shrimp culture development (Meltzoff and LiPuma, 1986) and official laws, decrees and regulations are often ignored. Recent results also show that mangrove areas are not suited for shrimp culture and disease problems will always occur, at least in intensive systems. If mangrove areas still need to be used, mangrove coverage of 30 – 50 % seems to give the highest economic return.

The salinization problems in connection to inland farming of marine shrimps, represent a major management challenge and need to be taken seriously. It can be conducted without causing adverse effects if the provisions for good management practice, as suggested by Boyd, 2001, are followed. But these guidelines are not easy to follow in Bangladesh without changing to-days practice completely.

In a longer perspective it is natural that the extensive systems gradually gets more effective and ends up as form of semi-intensive systems. However, before Bangladesh can introduce a more efficient technology, they need to improve a lot of things. First of all they need to carry out a better planning of their aquaculture activities and build up an infrastructure that can serve the industry. Shang et al. (1998) summarised a number of factors that affects performance and sustainability of shrimp farms. The farm performance is generally improved when the size is reduced and when farms employ seperate inake and drainage channels. Many extensive farms in Bangladesh are very large and have a combined inlet and outlet. The use of storage ponds with water conditioning, pre-filling and sedimentation ponds prior to effluent discharge gives fewer diseases and environmental problems.

As a part of a better planning, the government should develop a Code of Conduct for shrimp farming like Thailand (Tookwinas et al. 2000). A similar action has been initiated in India by the Aquaculture Authority of India (AAI). The AAI has framed guidelines to grant licences to shrimp farms adopting improved technology.

Disease has emerged as a major constraint to the sustainable growth of shrimp. Many diseases are linked to environmental deterioration and stress associated with farm intensification. It is a number of valuable guidelines how to avoid diseases that cover the introduction of PL-larvae, intake and exchange of water, use of mangrove areas, self-pollution and other factors that has been discussed above. It is important to realise that **disease prevention is more important than treatment.** The solution to the problem must deal with site selection, design and sustainable farm management.

The use of chemicals in Asian countries is almost without control and regulation. Many countries have no control or barely knowledge of which products that is used and even less information of the actual quantum used. These matters need to be regulated by the respective governments, because products for export could be banned for international markets if chemicals are detected.

It is a growing importance of international agreement that involve food (and fish) safety aspect. About 40 % of all fish products is traded internationally, which means that there is a search for common criteria that allows the issue of clear compliance rules (Josupeit and Lem, 2000). Most of the shrimp from Asia is exported. All matters related to safety, quality, trade and marketing rely on the ability to identify and trace the product. Tracability of food is an enormous problem to be solved, but will be a key factor in the future. Shrimp farmers should be aware of the problem and put pressure on the goverment to start to solve these problems.

Conclusions

Aquaculture has an increasing role to play in the next decade and beyond. Although shrimp production never had the intention to be a large producer of food to the hungry world, shrimp is one of the dominant luxury export products from Asia to the west which give millions of US$ in revenue to poor countries. Benefits gained from coastal aquaculture operation are many places higher than any other agricultural activities compared to land productivity.

It is vital for the future of the shrimp industry to prove that shrimp farming will develop as a sector that perturbs the environment minimally. Until now the industry have been in focus for having a negative influence on the environment and to create a number of social and economic conflicts.

As we have seen from the summary, parts of the critic have been true, and most countries need to give higher priority to develop a clear national policy for aquaculture development to be implemented, based on financial, socio-economic and environmental sustainability. Shrimp culture is an important part of national economy of Bangladesh, however without a planned development, the shrimp industry will have serious problems to survive. In the long run – only efficient producers will survive.

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Figures and tables

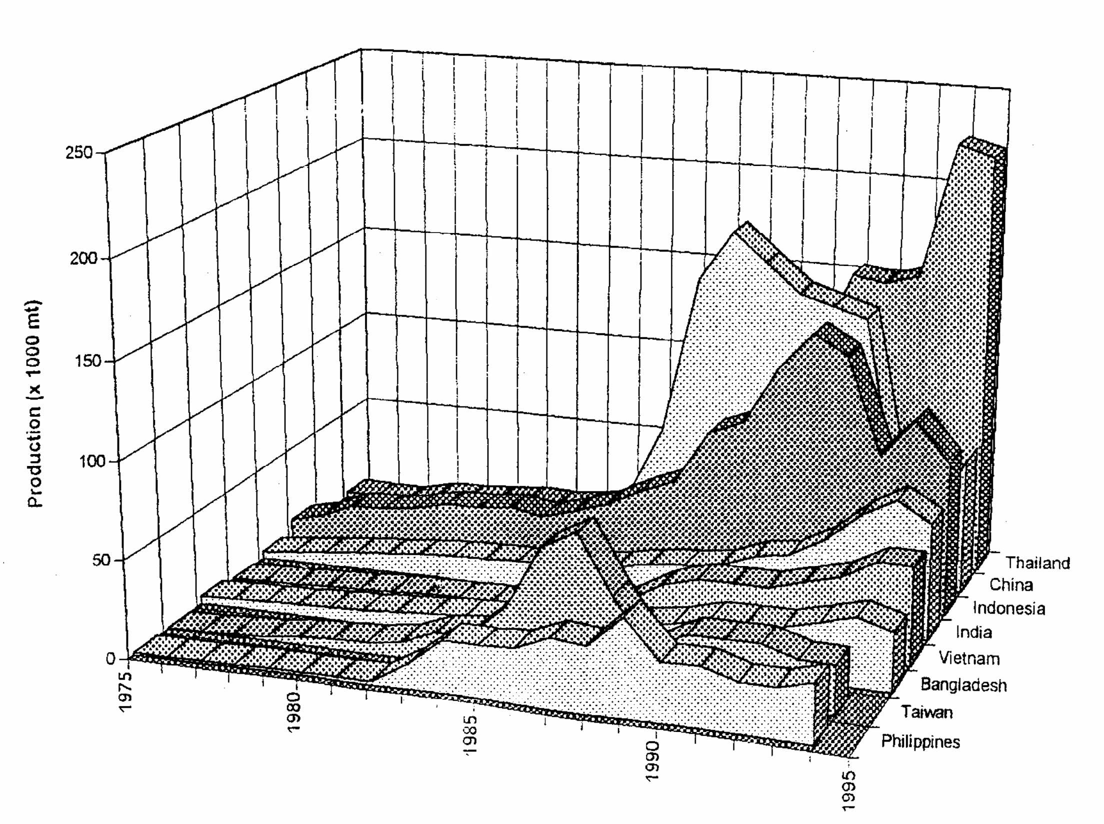

Figure 1 Production (thousand tonnes) of cultured shrimp in leading Asian countries (Primavera, 1997 cited from Rosenberry 1989-95 and Ferdouse, 1990).

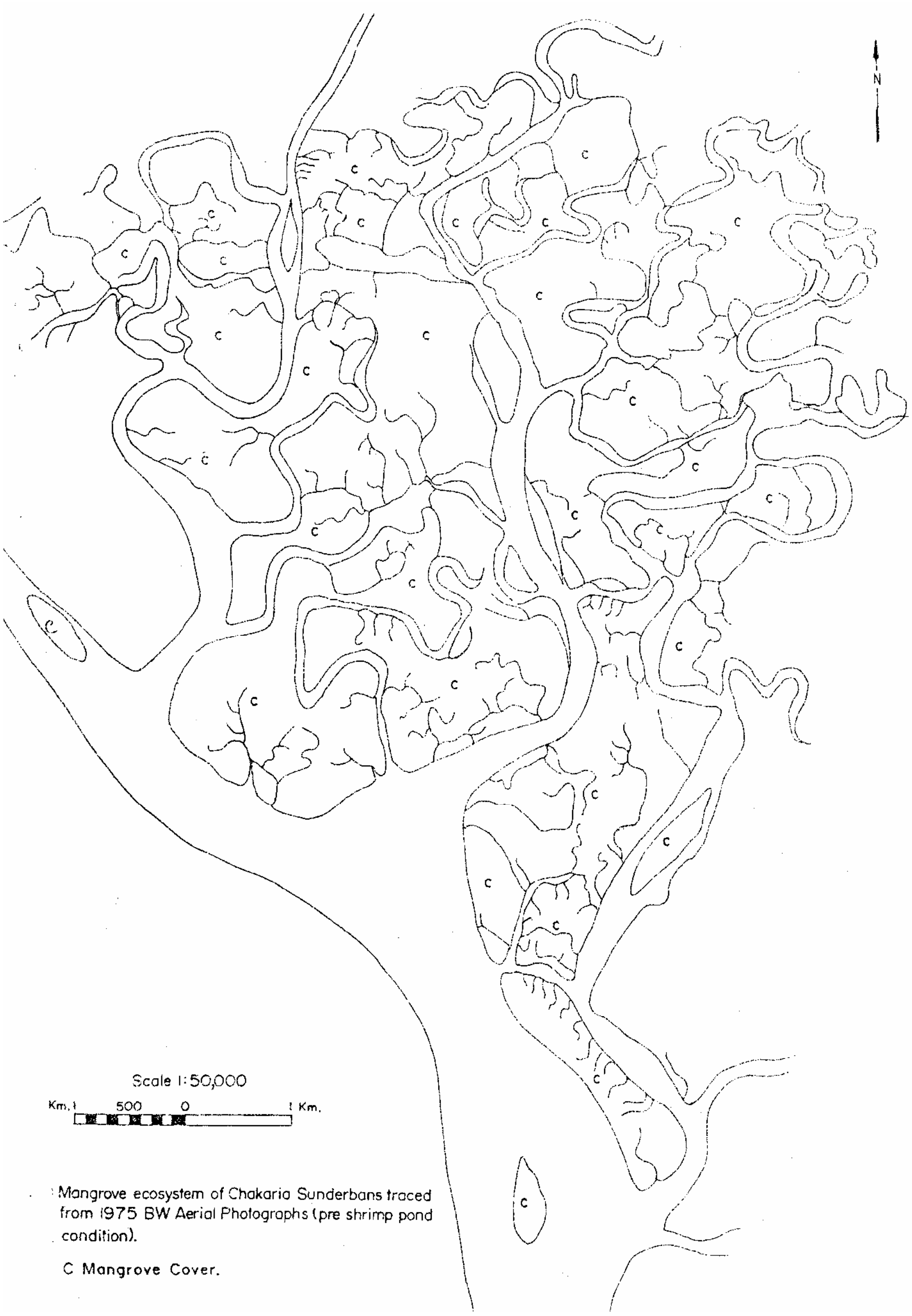

Figure 2 Mangrove system of Chokoria Sunderban traced from 1975 BW Aerial Photograph at pre shrimp –pond condition. (Choudhury, Quadir and Islam, 1990).

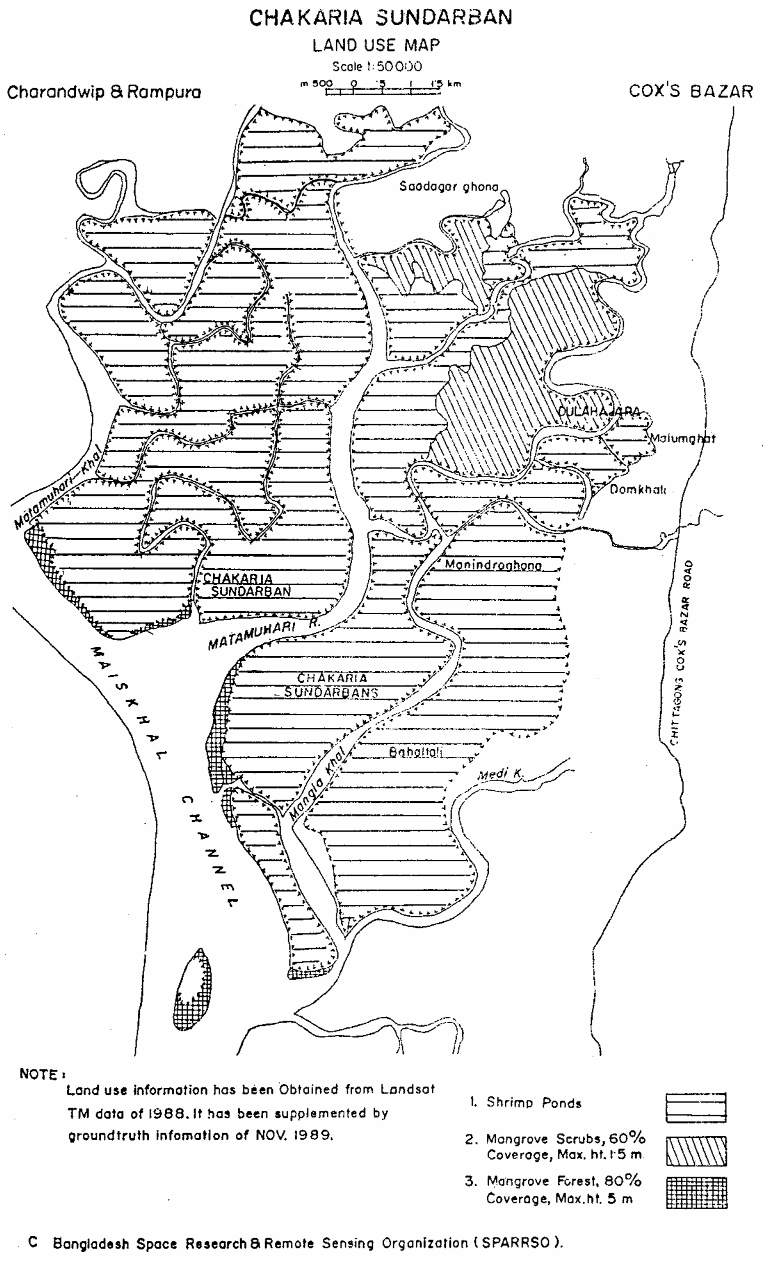

Figure 3 Mangrove system of Chokoria Sunderban obtained from Landsat TM data of 1988, and supplemented by groundtruth information of Nov. 1989. (Choudhury, Quadir and Islam, 1990).

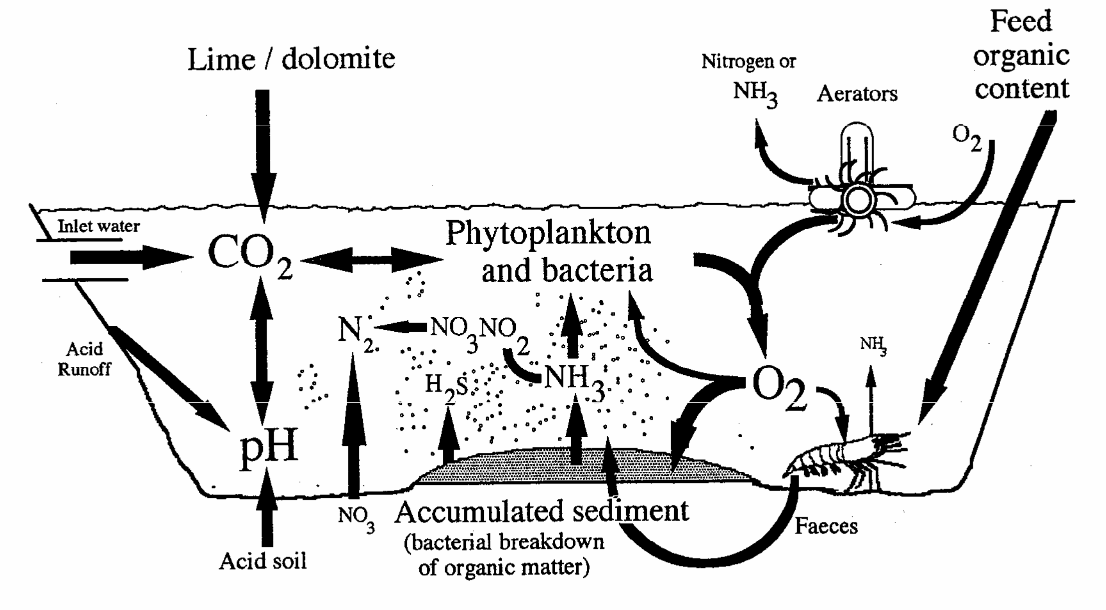

Figure 4 Water quality interactions and management activities in intensive shrimp ponds. (Funge-Smith and Briggs, 1998).

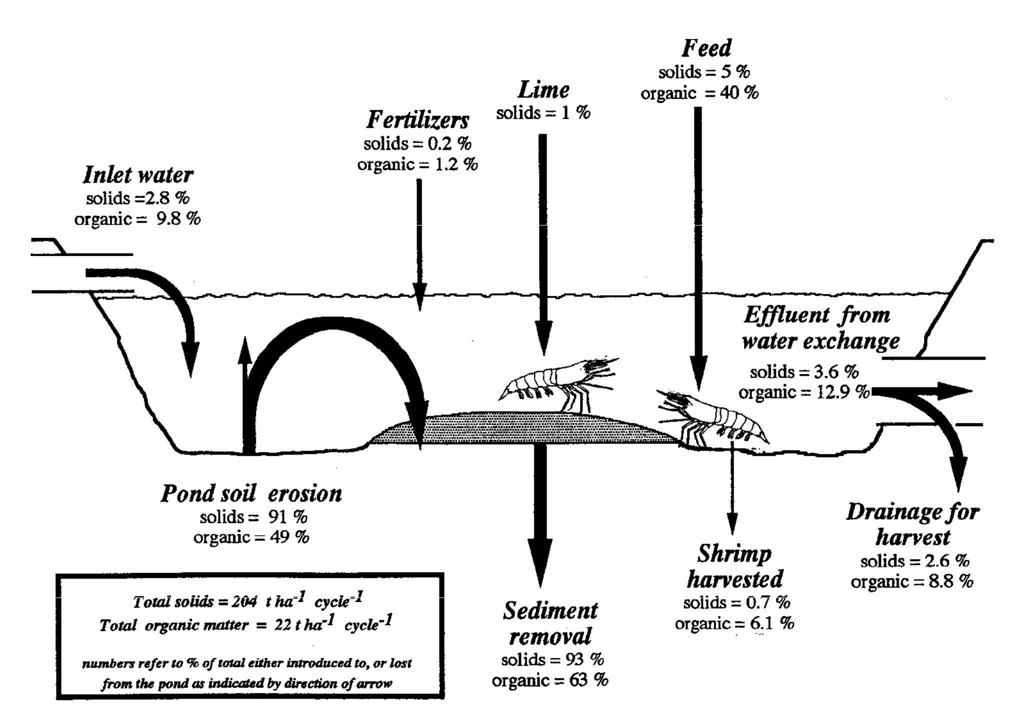

Figure 5 Total and organic solids budgets for intensive Thai shrimp ponds. (Funge-Smith and Briggs, 1998 (based on unpublished data)).

Table 1 Level of intensity of shrimp farms in 1995 (Rosenberry 1995 cited by Shang et al. 1998)

	Extensive (%)	Semi-intensive (%)	Intensive (%)
China	10	85	5
Bangladesh	90	10	0
India	70	25	5
Indonesia	45	45	10
Philippines[a]	35	50	15
Thailand	5	10	85
Vietnam	80	15	5

Table 2 Massive loss of shell-fish and fin-fishes for catching tiger shrimp fry (Deb, 1998).

	Year	*P. monodon*	Other shrimps	Fin-fish	Others	Total
Percentage	1990	1.20	21.50	30.79	46.50	100
composition	1994	0.79	20.09	22.90	56.21	100
For 1 fry of	1990	—	18.65	26.57	39.81	85.03
P. monodon	1994	—	25.82	29.36	70.43	125.61
Catch/net/hr	1990	58.20	1081.71	1541.03	2310.79	4991.73
(individuals)	1994	30.83	844.99	955.66	2147.85	3979.33
Catch/net/day	1990	349.23	6490.26	9246.18	13 864.77	29 950.4
(indivs.)	1994	184.98	5069.94	5733.96	12 887.10	23 875.9
S-E coast/yr	1990	1092.33	18 539.45	26 392.17	40 443.47	86 467.4
($\times 10^6$)	1994	748.38	18 336.54	20 954.79	53 192.14	93 231.8
All coast/yr ($\times 10^6$)	1992	2035.00	—	—	—	176 927

Table 3 Nutrient loading as a result of water exchange activities (Funge-Smith, 1996 cited by Funge-Smith and Briggs, 1998).

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

Table 4 P and N load from fish and shrimp farming, expressed in load per ton produced. (This work refers to Paez Osuna et al. 1999).

P and N load from fish and shrimp farming, expressed in load per ton produced

Culture system	Load kg ton^{-1} produced		Reference
	P	N	
Cage-fish in freshwater	23	100	Penczac *et al.* (1982)
Land-based fish farms	16	68	Solbe (1982)
Cage-fish in marine waters	20	90	Enell (1987)
Cage-fish in marine waters	9.5	78	Ackefors and Enell (1990)
Intensive shrimp (*P. monodon*) ponds	42	104	Briggs and Funge-Smith (1994)
Semi-intensive shrimp (*P. vannamei*) ponds	14	50	Páez-Osuna *et al.* (1997)
Semi-intensive/extensive shrimp (*P. vannamei*) ponds	16	58	This work