

NIVA



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Status report:

Environmental and Socio-Economic Impact of Shrimp Farming in Bangladesh (2nd Phase)

Report from:

The International Conference on Aquaculture in the Third Millennium 20 - 25 February 2000
Bangkok, Thailand



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Abstract

The work plans of the 2nd Phase of the project were prepared and discussed at meetings at Bangladesh Agricultural University (BAU), Mymensingh together with all five collaborating scientists. A seminar, on experience from the ongoing project, were carried out at BAU. Informal meetings were held at The Norwegian Embassy/NORAD and SPARRSO in Dhaka. As a part of objective 1 "water quality monitoring of shrimp farms", an evaluation of chemical methods were accomplished. Students were trained in routine procedures at the laboratory including use of instruments, calibrations, routine analyses and internal quality control. An International Conference on Aquaculture in The Third Millennium were held in Bangkok, Thailand 20- 25 February, 2000, and Bergheim, Braaten and Wahab attended. A short summary of the environmental aspects from the conference is presented together with recommendations from the various sessions. The relevance of the present research projects is briefly discussed in light of the recommendations and findings from the conference. The accepted conference paper on "water quality in extensive and semi-intensive shrimp ponds in Bangladesh" are enclosed.

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1. Akvakultur	1. Aquaculture
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3. Brakkvann	3. Brackish water
4. Miljø	4. Environment

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STATUS REPORT:

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shrimp farming in Bangladesh (2nd Phase)"**

and

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**The International Conference on Aquaculture in
the Third Millennium 20 - 25 February 2000,
Bangkok, Thailand.**

Preface

This is a status report that describes the Norwegian partners' fourth visit to Bangladesh as a part of the Project. A main purpose of the stay was jointly planning of project activities for the next 3 years (Phase II), especially emphasising this year (2000). Secondly, a critical examination of the laboratory routine procedures at BAU was decided in order to improve the reliability of the water quality analysis produced. This activity was successfully performed by Mr. H. Hovind, NIVA.

The program in Bangladesh at BAU, Mymensingh, was mainly arranged by the Project manager, Prof. Dr. M. A. Wahab. The two other collaborating scientists of the Project, Prof. Dr. M. S. Islam, BAU and Dr. M. A. Shahid, SPARRSO attended several meetings and contributed decisively to the planning of the Project activities.

Another part of the project was participation at "The International Conference on Aquaculture in the Third Millennium" held in Bangkok 20 – 25 February. The main objective of the Conference was to envision the state of aquaculture in the new millennium and set agenda for the required action to attain its potential. Project achieved water quality data from Bangladeshi shrimp ponds (1997 – 98) were presented in an accepted paper at the Conference (Book of Abstracts). This paper is enclosed (Ch. 2.4).

We would like to take the opportunity to thank all those who took part, both project involved staff and contributors outside the project.

Oslo, 2000-05-15

Asbjørn Bergheim, RF

Bjørn Braaten, NIVA

M.A. Wahab

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Summary

The work plans of the 2nd Phase of the project were prepared and discussed at meetings at Bangladesh Agricultural University (BAU), Mymensingh together with all five collaborating scientists. A seminar, on experience from the ongoing project, were carried out at BAU. Informal meetings were held at The Norwegian Embassy/NORAD and SPARRSO in Dhaka. As a part of objective 1 “water quality monitoring of shrimp farms”, an evaluation of chemical methods were accomplished. Students were trained in routine procedures at the laboratory including use of instruments, calibrations, routine analyses and internal quality control.

An International Conference on Aquaculture in The Third Millennium were held in Bangkok, Thailand 20 - 25 February, 2000, and Bergheim, Braaten and Wahab attended. A short summary of the environmental aspects from the conference is presented together with recommendations from the various sessions. The relevance of the present research projects is briefly discussed in light of the recommendations and findings from the conference. The accepted conference paper on “water quality in extensive and semi-intensive shrimp ponds in Bangladesh” are enclosed.

1. Project work

1.1 Travel programme

(Mr. Braaten and Mr. Bergheim stayed on holiday 11 – 20 February, Mr. Hovind arrived Dhaka from Norway 26 February)

Date	Time	Description
10.02.00	4 – 5 pm	Departure Stavanger/Oslo (Mr. Braaten, Dr. Bergheim)
11.02.00	00:15 pm	Arrival Bangkok Airport
20.02.00	3:30 pm -	Opening Ceremony “Int. Conf. Aquac. 3rd Millennium”
21 – 25. 02.00	8:45 pm – 6 pm	Participation Conference
27.02.00	10:45 am – 00:15 pm	Departure Bangkok Airport - arrival ZIA Airport, Dhaka
27.02. 00	2 pm – 5 pm	Pick up Mr. Hovind at hotel, Dhaka and travel to Mymensingh (by microbus)
27.02. – 8.03.00		Stay in Mymensingh (Guest House, BAU). Preparation project program year 2000, meetings, seminar
8.03.00	7:30 am – 10 am	Travel Mymensingh – Dhaka (by microbus)
8.03. – 10.03.00		Stay in Dhaka (meetings at Nor. Embassy, SPARRSO)
10.03.00	1:25 pm – 4:40 pm	Departure ZIA Airport, Dhaka – arrival Bangkok Airport (Mr. Hovind heads for Singapore)
10 – 11. 03.00		Stay in Bangkok (spare time)
11.03.00	11:35 pm	Departure Bangkok Airport
12.03.00	10 – 11 am	Arrival Oslo/Stavanger



Figure 1. Project planning at Departement of Fisheries Management, Faculty of Fisheries, BAU. From left to right: Dr. M. S. Islam, Dr. A. M. Wahab, Dr. A. Bergheim and Dr. M. A. Shahid.



Figure 2. Project planning at Departement of Fisheries Management. From left to right: Dr. M. A. Shahid, Mr. B. Braaten, Dr. M. S. Islam and Dr. A. M. Wahab.

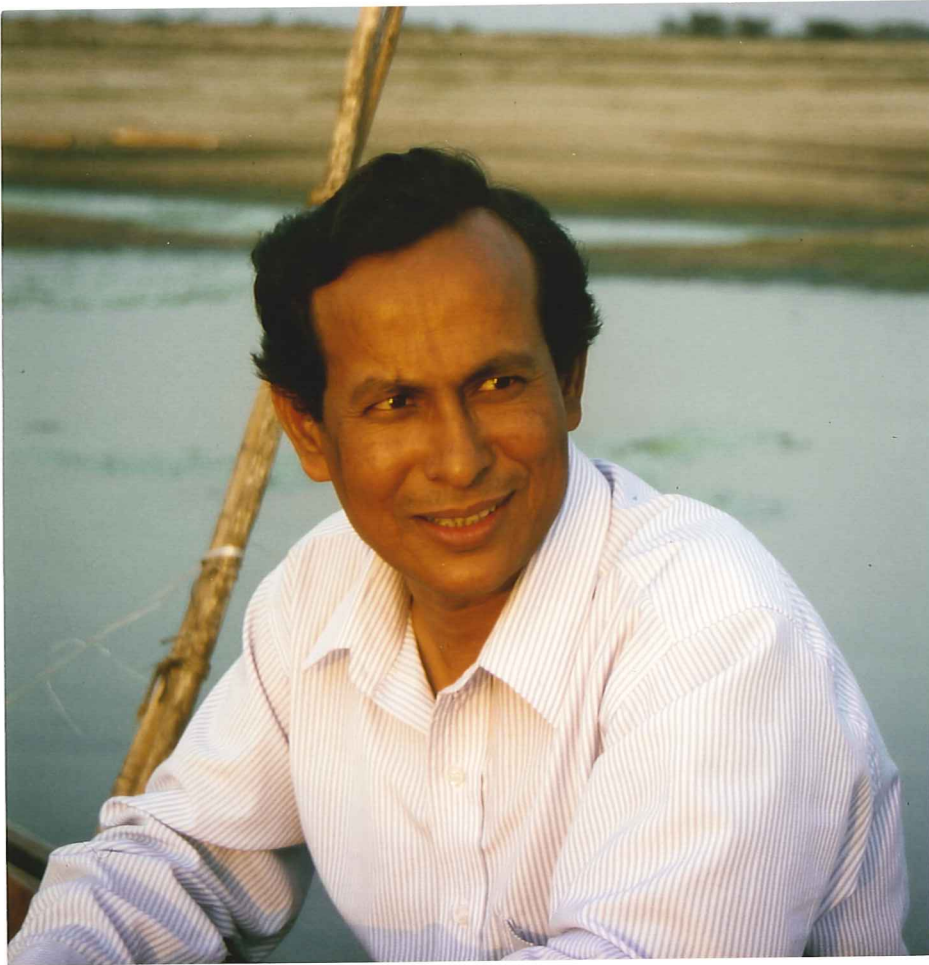


Figure 3. Project leader Dr. A. M.Wahab, Departement of Fisheries Management, Faculty of Fisheries, BAU.

1.2 Workplan of phase II

The work plans of the five Project objectives were prepared and discussed in several meetings held at BAU. All five collaborating scientists attended the meetings. Besides, Mr. H. Hovind at NIVA and the research fellows, Mr. M. S. (“Ronju”) Islam (sampling Cox’s Bazar) and Mr. M. S. (“Shahid”) Islam (sampling Paikgacha), attended meetings discussing Project objectives involving water quality monitoring.

1.2.1 Objective 1 a. Water quality monitoring of the shrimp sites. Recommended sampling procedure

Background

In the 1st project phase (1997-98), sampling of pond inlets – within ponds – pond outlets has been carried out at 3 – 5 farms in Paikgacha and at 1 – 2 farms in Cox’s Bazar. The frequency of the samplings was every 2 – 3 months in 1997 and monthly in 1998. A considerable amount of information about the water quality in extensive shrimp culture is supported. However, a more comprehensive programme needs to be performed (see Justification, Proposal Phase II) based on improved procedures for quality analysis.

Selected sites

- 5 sites in Paikgacha
- 5 sites in Cox’s Bazar

Sampling programme

Water sampling

Sampling sites: Inlet pond – Within pond – Outlet pond

Total sampling period: March 2000 – Feb. 2002

Routine sampling procedure:

- Monthly sampling frequency (rice season: only inlet pond)
 - Inlet: 1 single sample
 - Within pond: 3 single samples (from 3 different spots), 1 mixed sample for analysis
 - Outlet: 1 single sample

(Each sampling: 2 single samples and 1 mixed sample)

Water parameters

The following parameters should be included:

- Temp
- Salinity
- pH
- Dissolved oxygen (DO)
- Total suspended solids (TSS)
- Total nitrogen (TN)
- Total ammonia nitrogen (TAN = $\text{NH}_4\text{-N} + \text{NH}_3\text{-N}$)
- Nitrate nitrogen ($\text{NO}_3\text{-N}$)
- Total phosphorus (TP)

- Phosphate phosphorus (PO₄-P)

Sample treatment

Before going to the sampling site, the equipment for sample treatment and the sample bottles have to be thoroughly prepared. All bottles for nutrient determination (N, P) have to be acid washed to avoid contamination, this also is necessary for the filtering equipment when total ammonia nitrogen, nitrate nitrogen, and phosphate phosphorous are to be determined in filtrated samples. The equipment, and the sample bottles with their screw caps, are soaked in 0.1 mol/l hydrochloric acid overnight, and then rinsed three times with distilled water. The bottles are capped, and the filtering equipment is transported in a closed plastic bag or container.

The filters (GF/C glass fibre filters) are spread out on a glass plate and dried at 105 °C for half an hour. After cooling in a desiccator, each filter is weighed and put into a small plastic bag, the weight of the filter is written on the plastic bag.

Temperature, salinity, pH, and dissolved oxygen have to be determined at the sampling site. The filtration for the determination of total ammonia nitrogen, nitrate nitrogen, and phosphate phosphorous has to be done immediately after sampling, and this may be combined with the determination of total suspended solids. A weighed filter is placed in the acid washed filtering equipment, and at least 100 ml of sample is filtered. The filter is folded and put back into the plastic bag, and brought to the laboratory for drying at 105 °C.

The filtrate is poured into an acid washed sample bottle, preserved by addition of 1 ml 4 mol/l sulphuric acid pr. 100 ml of sample. The bottle is immediately tightly capped.

For the determination of total nitrogen and total phosphorous 250 ml sample is transferred to a 250 ml acid washed plastic bottle, preserved by addition of 1 ml 4 mol/l sulphuric acid pr. 100 ml of sample, and tightly capped.

Production data collection

Generally, the same data as emphasised under the “Sampling procedure for effluent loading estimates” should be collected under the water quality monitoring programme:

All relevant pond operational figures influencing the culture system need to be properly recorded. Most importantly, the time of important operations, such as pond preparation, stocking, post stocking management (additional fertilising, liming), water exchange, etc, must be listed in a time table (calendar based system). The following data should be properly collected:

- Pond preparation: esp. applied rates of organic – inorganic fertilisers and lime.
- Stocking rate: Total numbers and individual weight of shrimp fry (PL) introduced.
- Water exchange: Routine water exchange frequency and volume must be detailed noted. The volume of water exchanged should be calculated as accurate as possible (based on tidal fluctuations).
- Other post stocking management: e.g. repeated liming.
- Harvest: Total harvest must be quantified (Nos. of shrimp, average weight).

(A. Bergheim, B. Braaten, H. Hovind, M. A. Wahab).

1.2.2 Objective 1 b. Sampling procedure for effluent loading estimates. Improved procedure year 2000

Background

A former sampling program has been carried out during the period March – October 1998 at 3 Ghers in Paikgacha and at 1 improved extensive pond in Cox's Bazar. A lot of good work was done. However, it became obvious that some of the lab. procedures used were not exact enough to produce reliable water quality analyses. A critical examination of the methods used took place at the Lab, BAU in Feb – March 2000 (Mr. H. Hovind, NIVA). Based on these newly established improved procedures the sampling in 1998 therefore needs to be followed up by another sampling in year 2000. We suggest a somewhat reduced program compared to the 1998- sampling.

Selected sites

- Soladana (st. 1), Paikgacha (extensive culture)
- Chakuria, Cox's Bazar (improved extensive culture)

Sampling programme

Water sampling

Sampling sites: Inlet pond (Gher) and Outlet pond (Gher).

Total sampling period: One production cycle (from stocking till harvest, 100 – 120 days).

Routine sampling procedure:

- Monthly sampling frequency, sampling at full moon (total 3 - 4 samples).
 - 24 hrs/sampling
 - Inlet: 2 – 3 single samples (8 – 12 hrs. intervals), 1 mixed sample for analysis
 - Outlet: 6 single samples (4 hrs. intervals), 6 samples for analysis (no mixed samples)
- (Each sampling: 1 mixed inlet sampling and 6 single outlet samples).

Sampling of pond drainage (at harvest):

- Sampling throughout the drainage phase.
- Inlet: similar to routine sampling (1 mixed sample for analysis).
- Outlet: Mixed samples every 2nd hour based on 10 min sub-sampling (require use of 10L PVC pot with screw cap for mixing).

Normally, the pond drainage represents the peak effluent loading from a pond (especially due to resuspension of settled particles) and it is of crucial importance that this phase is incorporated in the total mass budget throughout the production cycle!

Water parameters

The following parameters should be included:

- Total suspended solids (TSS)
- Total nitrogen (TN)
- Total phosphorus (TP)

Sample treatment

Before going to the sampling site, the bottles for nutrient determinations (N, P) have to be acid washed to avoid contamination. The sample bottles with their screw cap are soaked overnight in 0.1 mol/l hydrochloric acid, and then rinsed three times with distilled water before they are capped.

The filters (GF/C glass fibre filters), for filtration of TSS, are spread out on a glass plate and dried at 105 °C for half an hour. After cooling in a desiccator, each filter is weighed and put into a small plastic bag, the weight of the filter is written on the plastic bag. The weight has to be determined with a balance where the maximum uncertainty is ± 0.1 mg.

A weighed filter is placed in the acid washed filtering equipment, and 500 ml of sample is filtered. The filter is folded and put back into the plastic bag, and brought to the laboratory for drying at 105 °C.

For the determination of total nitrogen and total phosphorous the sample is transferred to a 250 ml acid washed plastic bottle, preserved by addition of 1 ml 4 mol/l sulphuric acid pr. 100 ml of sample, and tightly capped.

Production data collection

All relevant pond operational figures influencing the culture system need to be properly recorded. Most importantly, the time of important operations, such as pond preparation, stocking, post stocking management (additional fertilising, liming), water exchange, etc, must be listed in a time table (calendar based system). The following data should be properly collected:

- Pond preparation: esp. applied rates of organic – inorganic fertilisers and lime.
- Stocking rate: Total numbers of shrimp fry (PL) introduced.
- Water exchange: Routine water exchange frequency and volume must be detailed noted. The volume of water exchanged should be calculated as accurate as possible (based on tidal fluctuations). *Without proper data of the routine water exchange (% pond volume/day or month) and pond drainage flow (e.g. % per hour) the sampling is of no use.*
- Other post stocking management: e.g. repeated liming.
- Harvest: Total harvest must be quantified (Nos. of shrimp, average weight).

(A. Bergheim, B. Braaten, H. Hovind, M. A. Wahab).

1.2.3 Objective 2. To assess the nature and extent of salinisation of shrimp farming on groundwater and wells for drinking water

Brief recommendation

Saltwater intrusion is considered a “giant” environmental impact of shrimp farming causing loss of agriculture crops, freshwater crises and related gastrointestinal diseases, etc. (Rahman *et al.* 1994). However, these impacts are not well documented and this objective therefore should be given priority (see Justification, Project proposal Phase II).

In our opinion, there is a definite need of more detailed planning of the sampling procedure (esp. selection of sites) in the study area (Khulna region) before starting the routine sampling. The selection of sampling spots should be carried out under guidance of a hydrological expert (e.g. from BAU).

Factors as distance to shrimp ponds (Ghers), soil quality, effects of the monsoon, influence by the sensitive buffer zone of freshwater and the saline front (Rahman *et al.* 1994), etc. need to be put into consideration by experts.

There is a close connection between Objective-2 and Objective-3 (Documentation of effects of shrimp farming on the crop diversity). Consequently, these two Objectives should be jointly planned by experts from both fields.

Obviously, this initial phase is of vital importance for the potential outcome of the project. Therefore, a proper planning of the sampling plot pattern must be given priority in year 2000, followed by monitoring of salinity in 2001 – 2002.

(B. Braaten, A. Bergheim, M. A. Wahab).

1.2.4 Objective 3. To document the effects of shrimp farming on the crop diversity and on the overall agricultural production

This Objective will be jointly planned with Objective 2.

1.2.5 Objective 4. Study on denudation of mangrove forest due to shrimp farming using remote sensing and geographical information system

By Dr. M. A. Shahid.

Work plan of the study:

1. Reconnaissance survey:

The whole coastal area of the country will be visited to observe the present situation of shrimp farming and mangrove forest areas.

2. Overview of mangrove forest and shrimp farming areas of the coastal zone:

Data used:

- Landsat MSS of 1975
- Landsat MSS of 1984
- Landsat TM of 1990
- Landsat TM of 1998

Methodology used:

Scanning of Landsat images followed by computer analysis using ERDAS imagine software.

3. Monitoring of mangrove forest denudation due to shrimp farming:

Areas will be selected on the basis of overview of the whole coastal area.

Data used:

- Aerial photograph of 1975
1981
1984

- Landsat TM data of 1990 & 1999
- SPOT data of 1995
- RADARSAT data of 1998
- IRS data of 1998
-

Methodology used:

Scanning of aerial photographs and then computer analysis of scanned data as well as satellite data.

4. Auxilliary/Additional data and Literatures:

- Forest maps
- Maps of coastal afforestation project
- Topo maps
- Available literatures

5. GIS analysis:

PC ARC/INFO GIS system of SPARRSO will be used.

6. Report preparation:

A report will be prepared on the basis of results obtained through the study.

Time schedule:

Name of the item:	Time:
1. Reconnaissance survey	January – May, 2000
2. Overview	June – December, 2000
3. Monitoring of mangrove denudation	January – April, 2001
4. GIS Aanalysis	May – September, 2001
Report writing	October – December, 2001

NB: Ground truthing will be performed as when required within the project period.

1.2.6 Objective 5. Socio-economic consequences of shrimp farming in Bangladesh

By Dr. M. S. Islam.

The specific objectives are:

To document the socioeconomic profile of shrimp farmers and other people involved in shrimp farming activities.

To determine the economic returns of shrimp farming under alternative technologies.

To determine the nature and magnitude of socioeconomic disputes and intersectoral land/water use conflicts in shrimp farming areas and other social problems associated with expansion of shrimp farming.

Methodology

The project is expected to have a life span of 30 months. Field level survey will be conducted for two consecutive years to collect detailed information from the operating farmers and other people associated with shrimp production. Secondary information will be collected from the relevant organisations and agencies. The present status of shrimp farming, constraints to and potentialities of increased production will be determined. Frequent visits will be made to the farming areas and workshops will be organised to discuss the results to field surveys. The socio-economic and institutional problems and constraints will be identified and prioritised for possible actions and solutions.

The primary data will be collected from the Khulna and Cox's Bazar region depending upon the concentration of shrimp farms. From these two regions in total 90 shrimp farmers will be selected for two years to determine the economic returns of shrimp farming. As the shrimps are still produced seasonally with traditional methods and with the alternative of rice and salt production, data will be collected for both shrimps and other crops, if they are produced in the same farming areas. Therefore, other people who are directly and indirectly involved in the shrimp industry who are either benefited or adversely affected, will be selected for this study. Information on shrimp production under different management practises and farm sizes, costs of inputs and revenue received from disposal of shrimps, and problems and constraints in shrimp farming will be collected from shrimp farmers. Information on the nature and magnitude of socioeconomic problems, and of social disputes, will be collected from a cross section of concerned people in the farming areas. However, for all this information, different categories of respondent will be purposively selected and samples will be distributed as shown in Table 1.

The selection of sample shrimp farmers and other respondents will then follow purposive random sampling procedures. Twenty land lessors, ten labourers engaged in shrimp farming and ten shrimp seed collectors will be selected randomly from the Cox's Bazar and Khulna region to know their employment opportunities and income earnings from their present occupation. Government officials, local leaders and other concerned people will be interviewed to investigate the cause of social tension arising in shrimp farming.

Collection of data will be completed by two years. All sample respondents will be equally distributed for two years.

In most cases, tabular method of analysis will be used to determine the costs, returns and profitability of farm enterprises, and to assess and forecast the social tension. However, specific analytical technique will depend upon the requirement of the objective.

Table 1. Sampling and distribution of sample respondents (Objective5).

Alternative technologies	Sample respondents					
	Shrimp farmers		Land lessors (rice/salt farmers) lease out land to shrimp farmers		Labours engaged in shrimp farming	Shrimp seed collectors
	Khulna region	Cox's Bazar region	Khulna region	Cox's Bazar region		
a. Alternative shrimp rice farming	30	-				
b. Year round only shrimp culture	10	10				
c. Only agricultural crop year round in the vicinity of shrimp culture	10	10				
d. Alternative shrimp – salt farming	-	20				
Total	50	40	10	10	10	10

Collection of data will be completed by two years. All sample respondents will be equally distributed for two years.

In most cases, tabular method of analysis will be used to determine the costs, returns and profitability of farm enterprises, and to assess and forecast the social tension. However, specific analytical technique will depend upon the requirement of the objective.

1.3 Evaluation of chemical analytical methods

By Haavard Hovind, NIVA.

Introduction

The chemical laboratory at the Department of Fisheries Management, Faculty of Fisheries at Bangladesh Agricultural University (BAU) has no permanent staff. All analyses are performed by students under the guidance of the professors at the faculty. Technical assistants with no chemical education may also be of help to carry out the analyses. Part of the equipment used in the project has been given to the institute by foreign donors, obtained in other projects, or bought specifically to this NORAD project. Under these circumstances we can not expect the laboratory to function as a fully professional routine analytical laboratory.

In 1998 a set of samples were taken for parallel analysis between the laboratories at the Department of Fisheries Management, Bangladesh, and Norwegian institute for water research (NIVA), Norway. The sampling was performed during the visit of Mr. Braaten and Mr. Bergheim to Bangladesh, and the samples were split into two equal sets of subsamples, the laboratories received one set each. The results of the parallel analyses are presented in Table 2.

Table 2. Results of the parallel analyses in 1998. N – results from NIVA, Norway, B – results from Mymensingh, Bangladesh. F – filtrated sample, U – unfiltrated sample.

Sample No	TOT-P µg/l		PO4-P µg/l		TOT-N µg/l		NH4-N µg/l		NO3-N µg/l		TOC mg/l	
	N	B	N	B	N	B	N	B	N	B	N	B
1 U	40	1850			520	1120					3.0	
1 F			17	1750			16	610	305	1700	3.4	
2 U	27	1230			450	560					3.6	
2 F			< 1	670			-	1120	109	1800	4.8	
3 U	43	980			725	1120					7.6	
3 F			1	430			12	450	6	1800	6.0	
4 U	48	590			1240	1120					13.5	
4 F			< 1	130			22	1500	5	2100	10.2	
5 U	50	810			1240	560					14.9	
5 F			3	160			26	2750	1	2300	12.4	

Table 2 demonstrates that the comparability between the laboratories was very poor. Therefore, it was of uttermost importance to find an explanation for these differences, and decide what necessary actions must be performed to improve the comparability. As the methods used by the NIVA laboratory are controlled independently by the participation in several international intercomparisons every year, it was decided that the methods used by the laboratory in Mymensingh had to be evaluated during the visit to the laboratory in 2000.

Evaluation of methods

Phosphate

The routine method for the determination of phosphate at the laboratory was used. To make a first check of the routine procedures used at the laboratory, and the instrument used, a series of calibration solutions were prepared by the students.

The volumetric flasks used for the preparation of the solutions were washed with tap water which was added a detergent where no specification of the content of phosphate was given, and finally rinsed with tap water. There was no information available about the concentration of phosphorous compounds in the tap water. Therefore, the students were told to rinse the volumetric flasks with distilled water several times to reduce possible phosphorous contamination.

To prepare a stock solution, 1000 mg/l PO₄-P, 0.4393 g KH₂PO₄ should be weighed and dissolved in 100 ml distilled water. To minimize the weighing error, a balance with measuring uncertainty of ± 0.0001 g has to be used. Unfortunately, the two balances of this kind at the laboratory were out of order. The only available balance had an uncertainty of ± 0.01 g, which is too much when 0.4 g shall be weighed. Therefore, the weighed amount of the compound was increased to reduce the weighing error, thus 4.44 g was weighed and dissolved in 1000 ml distilled water. The weighing error is reduced from approximately 2.5 % to 0.25 % by increasing the weighed amount from 0.44 to 4.44 g.

For the dilution process graduated pipettes were used instead of full pipettes which are more convenient for pipetting constant volumes. The suction apparatus used for pipetting was applied in

such a way that the solution was blown out of the pipette. The correct manner is to empty the pipette by gravity only, and use 5 – 10 seconds extra to let the solution flow down the inner walls of the pipette. The tip of the pipette shall be in touch of the inner wall of the volumetric flask all the time when the solution is running out of the pipette. When blowing out the pipette, an error up to nearly 5 % may be introduced to the calibration solutions. The students were also instructed to rinse the pipette with the solution to be taken out, and empty it into the sink, **not** back into the solution from where it was taken. The latter action may easily introduce contamination errors.

The instrument, Hach DR 2000, was used according to the manual of the producer. The only “calibration” of the instrument was to zero it with the blank solution according to the procedure described in the manual of the instrument producer, no other calibration solutions were used! Consequently, there is no control proving that the instrument are calculating the correct concentration.

After the addition of the sample and the reagent to the measurement cell, a rubber stopper was used to close the cell, and the cell was shaken to dissolve the reagent. This rubber stopper was not rinsed between each sample, and will therefore contaminate the next sample! This effect is especially pronounced when a sample with low concentration is following a sample with high concentration.

The concentrations calculated for the calibration solutions, and the results determined with Hach DR 2000, are given in Table 3.

Table 3. Results for calibration solutions determined with the Hach DR 2000 according to the routine procedures at the laboratory.

Concentration calculated, mg/l P	Reading on Hach DR 2000 mg/l P
0.05	0.15
0.10	0.34
0.20	0.62
0.50	1.00
1.00	1.90
2.00	> 2.75 *

* 2.75 is the highest reading on the instrument

A repeatability test was performed with the 0.05 mg/l PO₄-P solution, the results are given in Table 4. The two last results were measured when the rubber stopper was omitted!

Table 4. The first repeatability test.

Number	Reading on Hach DR 2000 mg/l P
1	< 0 *
2	0.23
3	0.07
4	0.09

* negative reading

An arbitrarily chosen natural sample was also measured, but without any addition of colour developing reagents. The result was 0.60 mg/l PO₄-P, which is caused by the particulate matter in the light path only, and not by the phosphorous of the sample! This demonstrates clearly the importance of the absence of particulate matter in the light path when photometric methods are used.

These results demonstrates that contamination of the laboratory equipment is a serious and dominating problem in the routine analytical work. To avoid this problem in the future, all equipment must be acid washed before use: volumetric flasks and their stoppers, pipettes, sample bottles, filters, filtration equipment etc. During the following tests all the equipment was rinsed with hydrochloric acid, and thereafter several times with distilled water.

New calibration solutions were prepared using the acid rinsed equipment. Because the Hach DR 2000 proved not to be sensitive enough for the determination of phosphate at very low concentrations, it was also prepared reagents necessary for the use of Milton Roy Spectronic 1001 Plus spectrophotometer. The reagents were prepared according to Stirling (1985). A separate standard operation procedure was prepared, describing the method for the determination of low concentrations of phosphate with the spectrophotometer. The results using the Milton Roy spectrophotometer, and the corresponding readings using Hach DR 200, are presented in Table 5.

Table 5. Results with solutions prepared after acid washing of the volumetric equipment.

Calculated conc., mg/l P	Absorbance, Milton Roy	Hach reading, mg/l P
0.05	0.036	0.07
0.10	0.070	0.20
0.20	0.117	0.39
0.50	0.324	0.99
1.00	0.625	2.00
2.00	1.060	> 2.75

The calibration graph is approximately linear to about 1.00 mg/l PO₄-P, and then curved downwards at higher concentrations. To use the upper part of the calibration range, it is necessary to include several more calibration solutions with concentrations between 1.00 and 2.00 mg/l PO₄-P. Alternatively the samples may be diluted to less than 1.00 mg/l PO₄-P.

A repeatability test was performed using the solution where the concentration was 0.02 mg/l PO₄-P, with both instruments. The results are presented in Table 6.

Table 6. Repeatability test for phosphate determination with Milton Roy and Hach DR 2000.

No.	Absorbance Milton Roy	Hach reading, mg/l P
1	0.030	0.10
2	0.030	0.08
3	0.027	0.07
4	0.031	0.09
5	0.031	0.09
6	0.031	0.08
Mean value	0.030	0.085
Standard deviation	0.0016	0.010

Defining the detection limit as 3 times the standard deviation, these results lead to an absorbance value of 0.005 with the Milton Roy spectrophotometer, corresponding to a detection limit of 0.008 mg/l PO₄-P. With some more training and experience using the Milton Roy spectrophotometer, it is possible to lower the detection limit somewhat. Applying a 5 cm (or 10 cm) cuvette instead of 1 cm as used here, it is possible to reduce the detection limit to 1 µg/l or lower, if necessary.

Similar calculations for the Hach instrument leads to a detection limit of 0.030 mg/l PO₄-P. This instrument is not sensitive enough for the determination of the low concentrations of phosphate found in many of the samples from shrimp farming. The Hach instrument may be used for determination of higher concentrations, however, it is necessary to recalibrate the instrument to give correct concentrations. The adjustment of the instrument in these tests gave systematically too high readings. Alternatively, the readings may be recorded as arbitrary scale readings, and used for the construction of a calibration graph.

Total phosphorus

The total phosphorous concentration in water samples has been determined at the soil laboratory so far. It was now decided that this determination should preferably be determined at the laboratories of the Department of Fisheries in Mymensingh, and a method described by Stirling (1985) was tested for this purpose.

A digestion solution was prepared by dissolving 6.00 g potassium peroxodisulfate in water, some heating was necessary to dissolve all of the chemical. Then 10 ml 1.8 mol/l sulfuric acid was added, and the solution diluted to 100 ml with distilled water. Three calibration solutions were prepared: 0.05, 0.50 and 1.00 mg/l PO₄-P. These solutions were measured with the Milton Roy spectrophotometer both before and after digestion, to check for possible contamination during the digestion process.

The autoclave was filled with tap water up to the bottom of the the inner container of the autoclave. Because the laboratory did not have digestion flasks with screw caps, 100 ml conical flasks were used for the digestion. 25 ml of sample and 5 ml of oxidation solution was added to the conical flasks which were numbered, the flasks closed with aluminium foil to reduce the risk of contamination, and autoclaved at 120 °C for 30 minutes. The solutions were cooled to room temperature and analysed as phosphate with the method tested above. Direct reading of the calibration solutions without digestion gave the following absorbances:

0.05 mg/l PO ₄ -P	0.031
0.50	0.301
1.00	0.588

The calibration graph is linear in this concentration range.

Three calibration solutions, a blank solution, two intercomparison solutions from NIVA, and three natural samples collected from the fish ponds outside the institute were autoclaved and then the phosphate content was determined. The results are given in Table 7.

Table 7. Determination of total phosphorous with Milton Roy spectrophotometer. Column B is the absorbance when the blank value is subtracted and the absorbance is corrected for the dilution factor. Column C gives the results calculated from the digested calibration solutions.

No.	Sample	Absorbance	B	C
1	Blank	0.019	-	-
2	0.05 mg/l PO ₄ -P	0.047	0.0346	0.056
3	0.50 mg/l PO ₄ -P	0.263	0.293	0.485
4	1.00 mg/l PO ₄ -P	0.522	0.604	1.000
5	G NIVA	0.028	0.011	0.018
6	H NIVA	0.028	< 0.005	< 0.005
7	Pond 3	0.010	0.276	0.456
8	Pond 4	0.249	0.0828	0.137
9	Pond 6	0.088	0.084	0.139

Both samples G and H is less than 0.005 mg/l PO₄-P, therefore the result for sample G is too high. This may be caused by the fact that we did not use digestion flasks which could be closed with screw caps, and contamination may be a serious problem. This supposition is also supported by the high blank value observed. The method tested here is applicable for the water samples to be analysed in the NORAD project, however, it is strongly recommended to use digestion flasks with screw caps to reduce the contamination problem.

Nitrate

The routine method used by the laboratory was based on a Hach method applicable for the concentration range 1 – 30 mg/l NO₃-N. As most of the routine samples to be determined at the laboratory have nitrate concentrations far below this range (see the results of the parallel analyses), the method was completely unusable for the purpose. A Hach method for the concentration range 0.10 – 0.400 mg/l NO₃-N is available. However, the necessary reagents were not available in the laboratory, and therefore the method could not be tested during the visit to Mymensingh. Thus, this method has to be tested by the students as soon as the necessary reagents have been purchased.

An alternative is to use the spectrophotometric method on the Milton Roy instrument, applying a cadmium column for the reduction of nitrate to nitrite. However, such a column is rather difficult to stabilize, especially when the column is not used very often. Application of a peristaltic pump would reduce the problem, but this apparatus was not available during the visit. The detection limit of such a method is normally less than 5 µg/l NO₃-N, and may even be improved by using a longer measurement cuvette (5 or 10 cm).

It is recommended to give a priority to test the Hach method, as this method is the simplest one to handle.

Ammonium

The Hach DR 2000 instrument was used for the concentration range 0.03 – 2.5 mg/l NH₄-N at a wavelength of 425 nm, using Nessler reagents. This method is probably sensitive enough for the samples of the NORAD project, alternatively the indophenol blue method may be used on the Milton Roy spectrophotometer.

An ammonium stock solution containing 1000 mg/l $\text{NH}_4\text{-N}$ was prepared by dissolution of 3.82 g ammonium chloride in 1000 ml distilled water. A set of calibration solutions were prepared: 0.05, 0.20, 0.50, 1.00, and 2.00 mg/l $\text{NH}_4\text{-N}$ by diluting 0.5, 2, 5, 10, and 20 ml, respectively, of the stock solution to 100 ml in volumetric flasks. 25 ml sample solution is added 1 ml Rochelle salt solution (potassium sodium tartrate) and 1 ml Rochelle salt solution (mercury diiodide and sodium iodide in sodium hydroxide), and mixed again. The addition of reagents were done with drop counters, which proved to give a rather unprecise volume of reagent. If the reagent volume prove to be critical, it is recommended in the future to use 1 ml full pipettes, which give a precise volume of the reagent solutions added.

The reaction time is 1 minute, and the reading on the instrument has to be performed within 5 minutes. This indicates that the reaction time may be critical for the precision of the method, and should be controlled during routine analytical work. As contamination is known to be a serious problem when determining ammonium at very low concentrations, the calibration solutions were prepared in two series, the second one after acid washing of the volumetric flasks. The results are given in Table 8.

Table 8. The results from the test of the ammonium method.

Calculated concentration, $\text{NH}_4\text{-N}$	Recorded value, mg/l $\text{NH}_4\text{-N}$ series I	Recorded value, mg/l $\text{NH}_4\text{-N}$ series II
0.05	0.15	0.04
0.20	0.08	0.27
0.50	0.42	0.62
1.00	0.96	
2.00	2.15	

These results indicate that there are problems with the precision of the method, this includes possible contamination, the effect of volume added, and the reaction time. These factors must therefore be controlled during routine analyses. The students should do some testing on the effect of these critical factors, to improve the method.

A repeatability test was performed using a solution containing 0.20 mg/l $\text{NH}_4\text{-N}$. The results are presented in Table 9.

Table 9. Repeatability test for ammonium.

No.	Recorded value, mg/l $\text{NH}_4\text{-N}$
1	0.27
2	0.25
3	0.27
4	0.26
5	0.27
6	0.30

The mean value is 0.27 mg/l $\text{NH}_4\text{-N}$, however, it has to be pointed out that this test solution was prepared using a volumetric flask which was not acid washed, that may explain the high mean value. The standard deviation is 0.0167 $\text{NH}_4\text{-N}$, and using the rule that the detection limit of the method is 3 times the standard deviation, leads to a detection limit of 0.05 mg/l $\text{NH}_4\text{-N}$, which is higher than expected. It is of the uttermost importance to control the contamination problem to obtain a sufficiently low detection limit. To illustrate this, we may look at the effect of the last recording. If the

last measurement was 0.25 instead of 0.30, the mean value and the standard deviation would have been 0.26 and 0.0098 mg/l NH₄-N, respectively. The corresponding detection limit would have been reduced to 0.03 mg/l NH₄-N! With some training and experience with the method it should be possible to obtain a detection limit of about 0.02 mg/l NH₄-N.

The alternative is to use the Milton Roy spectrophotometer, applying the indophenol blue method which is more sensitive. If a 5 cm cuvette is used, it should be possible to obtain a detection limit of 1 – 2 µg/l NH₄-N. Of course it is absolutely necessary to control the contamination problem. This method was not tested during the visit because one of the reagents was not available at the laboratory.

Total nitrogen

Until now the determination of total nitrogen has been done by the soil laboratory, and they used the Kjeldahl method, which do not include the nitrogen compounds in the valency state V, for instance nitrate. A digestion method based on the use of acid peroxodisulfate solution, which transfers organic nitrogen into ammonium ions might be a possible alternative. Therefore, a test was performed with such a method. A series of calibration solutions containing 0.05, 1.00, 1.50, 2.00, and 2.50 mg/l NH₄-N was prepared, and analysed directly and after digestion in autoclave. To test the digestion effect a series of solutions containing varying concentrations of EDTA was also prepared, 1.0, 1.5, 2.0, and 2.5 mg/l NH₄-N.

The oxidation solution was prepared by dissolving 6.00 g potassiumperoxodisulfate in approximately 80 ml distilled water, some heating was necessary to dissolve all solid material, and then 10 ml 1.8 mol/l sulfuric acid was added before dilution to 100 ml. For the digestion process 25 ml of sample solution was added to 100 ml conical flasks, and then 5 ml oxidation solution. The flasks were finally covered with aluminium foil. One blank, four ammonium calibration solutions, and four EDTA solutions were autoclaved at 120 °C for two hours (in addition to two hours waiting time in the range 90 - 120 °C, because of disappearing electricity). The solutions were cooled to room temperature and analysed as ammonium with Hach DR 2000 using the Nessler method. The observed values are presented in Table 10.

Table 10. Results from the total nitrogen test.

Calculated concentration, TOT-N	Measured directly, mg/l TOT-N	Digested solution, mg/l TOT-N
Blank	0.66	0.19
0.50 mg/l NH ₄ -N	1.28	-
1.00	1.88	0.64
1.50	2.41	1.07
2.00	2.75	1.61
2.50		1.69
1.00 mg/l EDTA-N		0.35
1.50		0.62
2.00		0.72
2.50		1.00

The results clearly indicate that the method is not working properly under the conditions used here, and has to be improved before acceptable results are obtained. Probably the alkaline oxidation, which is ending in the acidic region at the end of the oxidation process, is more effective as digestion

method. In this latter method the nitrogen will be determined as nitrate, which may be done using the Hach instrument. In this case a method with intermedial sensitivity, probably, has to be used. By this method both ammonium, nitrate and nitrite are included together with the organic bound nitrogen. The results produced by such a method is not directly comparable with the results produced with the Kjeldahl method, which determine nitrogen in the valency state III only.

Total suspended matter

This method was not tested because no balance with sufficient accuracy and precision was available at the laboratory, however, the routine method was discussed with the students at the laboratory. Whatman GF/C glass fiber filters are used for the determination of suspended matter. However, it proved to be no routine for acid washing of the filters if the filtrate should be used for determination of phosphate, nitrate or ammonium. For the determination of accurate values in the low concentration range, it is necessary to determine the weight of each filter after washing and drying. This is not allways done today.

It was observed that the glass sinter and the vacuum flask was not washed properly. For the determination of total suspended matter only, this is not critical. However, if the equipment shall be used for the filtration of samples to determine the dissolved fraction of nutrients, it is necessary to acid wash all parts of the equipment before used in the field, and the sinter and the vacuum flask must be rinsed with distilled water between each sample. The tubing used between the vacuum pump and the vacuum flask proved to be made of a soft material, thus the tube was quite flat when the vacuum increased. This is not effective, and it is recommended to use an armed tubing, which can withstand the vacuum without being flattened.

Internal quality control

The laboratory did not use any kind of quality control of the routine determinations, neither using control samples, certified reference materials, nor participating in interlaboratory comparisons. Today this is mandatory for all accredited laboratories around the world. Therefore, the students were lectured about the principles and practical routines for internal quality control at analytical laboratories: the principles for using control charts, and how to start the process of establishing control charts for routine use.

It was underlined that at least one control sample with concentration representative for the routine samples analysed at the laboratory, shall be included in every series of samples, and analysed every time the determination is performed. The control result shall be plotted immediately in the control chart to demonstrate that the analysis is under control. If the control result is outside the action limits of the control chart, the analyse must be stopped and immediate remedial actions have to be performed to locate and correct the error, before the analytical work may be continued.

Conclusions and recommendations

Internal quality control using control charts must be established for all analytical methods. One or two control samples with concentrations representative for the routine samples analysed in the NORAD project should be included every time samples are analysed. The control samples may be prepared synthetically at the laboratory, or natural samples analysed together with intercomparison samples may be used.

For the determination of phosphate a more sensitive method must be used, because most samples in this project have very low phosphate concentrations. A method using the Milton Roy spectrophotometer are recommended instead of the less sensitive Hach method used so far. It is also recommended to use a 5 or 10 cm cuvette to increase the sensitivity of the method.

The laboratory should establish a method for the determination of total phosphorous, using digestion with peroxodisulfate in autoclave at 120 °C. It is strongly recommended to purchase digestion flasks with screw caps for this purpose, to reduce the contamination risk. When such a method is established there is no need for sending the total phosphorous samples to the soil laboratory.

The Hach method used so far for the determination of nitrate is definitely not sensitive enough for the samples included in this project, the detection limit being about 1 mg/l NO₃-N. As a more suitable alternative it is recommended to apply the Hach method especially made for low nitrate concentrations, 0 - 400 µg/l NO₃-N. If a more sensitive method is necessary, the spectrophotometric method using the Milton Roy instrument may be used, where it is possible to use a cuvette with longer light path.

The Hach method used for the determination of ammonium is probably sensitive enough, under the presupposition that the contamination problem is brought under control. If a more sensitive method is required, it is recommended to use the indophenol blue method applying the Milton Roy spectrophotometer.

The method tested for the determination of total nitrogen was not good enough, and NIVA will provide you with another method based on digestion with peroxodisulfate in autoclave. The method has to be tested thoroughly by the students before it is established as a routine method. Digestion flasks with screw cap is recommended to reduce the contamination risk during the digestion step.

For the determination of total suspended matter it is an absolute requirement to use a balance with uncertainty not greater than ± 0.0001 g. Each filter has to be dried at 105 °C, cooled to room temperature, and weighed before use.

The contamination problem proved to be very serious at the laboratory, and must be brought under control. Acid washing of **all** laboratory equipment and sample containers used for the determination of nutrients is mandatory.

We suggest that, as a control of the routine methods used in the NORAD project, a set of parallel samples are taken every second month. Five or six samples are taken and being split into two sets, where one set is analysed at the Department of Fisheries Management, and the other set is sent to NIVA. This will give a continuous control of the analytical data during the project period.

It is strongly recommended that the laboratory in the future employ an analytical chemist in a permanent position. This person will be responsible for the analytical methods used at the laboratory, the maintenance of the instruments and the general laboratory equipment, and the daily following-up of the quality control routines. He should also advise / teach the students about the working routines and the methods used by the laboratory, and preferably also the sampling methods and the field analyses. This is especially important because the students using the methods are not especially trained in analytical chemistry, and in most cases several years have elapsed since they learned chemistry. In addition to this fact, today there is an additional problem at the laboratory: the day a skilled person is leaving the laboratory, he is bringing the knowledge about the analytical methods with him. A permanently employed analyst will secure the continuity at the laboratory. It is understandable that such a recommendation is not easy to meet, because it involves a decision about giving high priority to such an employment at the institute.

In the meantime NIVA will provide the laboratory with advices about analytical matters, for instance with written detailed analytical procedures for the most important methods and working routines. It is recommended that the students are preparing a draft for the procedure they wish to describe, and we can check this and provide advices based on our knowledge about the method in our laboratory.

We also invite the students and employees at the Department of Fisheries Management to contact us about any problems they think we may help to solve.

References

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Figure 4. Preparing of water analysis at the chemical laboratory by students. Mr. M. S. "Shahid" Islam (in front) and Mr. M. S. "Ronju" Islam (behind).



Figure 5. NIVA chemist Mr. Haavard Hovind are introducing quality assurance in chemical analysis at the laboratory to students. From left to right "Shahid", "Ronju", M.M. "Titu" Rahman. and Håvard Hovind.



Figure 6. Asbjørn Bergheim and Bjørn Braaten go through the sampling procedures together with the students.

1.4 Seminars and meetings

1.4.1 Arranged seminar

Seminar on “Environmental impacts of shrimp farming in Bangladesh” was held 7 March at 11am in the Seminar Room, Faculty of Fisheries. Professor Abidur Reza, BAURES chaired the Seminar. About 20 people (project involved staff, teachers and post graduate students of the Faculty) attended the seminar.

The following prepared talks were presented (20 – 30 min each):

Mr. H. Hovind, NIVA: Assessment of the water quality analysis procedures used at the Faculty of Fisheries and recommended improved procedures.

Prof. M. A. Wahab, BAU: 1) A general introduction reviewing the significance of the Bangladeshi shrimp industry, and 2) “Water quality in extensive and semi-intensive shrimp ponds in Bangladesh” (Paper for the Conf. Aquac. 3rd Mill., Bangkok).

Dr. A. Bergheim, RF: “Waste production trends in intensive cold-water fish farming” (Paper for the Conf. Aquac. 3rd Mill., Bangkok).

Mr. B. Braaten, NIVA: Presentation of photos of 1) Project involved shrimp culture in Bangladesh, and 2) Culture systems for cold-water fish farming.

After a short discussion, the Chairman closed the Seminar (at 1pm).

1.4.2 Meeting at The Norwegian Embassy/NORAD

This meeting was held at The Norwegian Embassy in Dhaka, 8 March, 11:30am – 1pm. The following persons attended the meeting:

- Mr. S. Medby, The Embassy/NORAD
- Mrs. N. Mahbub, The Embassy/NORAD
- Prof. M. A. Wahab, BAU
- Dr. M. S. Islam, BAU
- Dr. M. A. Shahid, SPARRSO
- Mr. B. Braaten, NIVA
- Mr. H. Hovind, NIVA
- Dr. A. Bergheim, RF

Initially, Prof. Wahab described the existing Project situation especially emphasising the formal date of project start-up, 1 Jan. 2000.

The Annual Meeting between NORAD and BAURES will be held at BAURES (Mymensingh) 29 June at 10am. The NIVA and RF representatives are prevented from participation.

Mr. Braaten and Dr. Bergheim informed about the work plans of Objective 1, and Mr. Hovind succeeded with a presentation of the ongoing efforts to improve the water quality analysis at BAU (parallel analysis will be carried out at BAU and NIVA every second month).

Objectives 2 & 3: As formerly informed, these two coinciding objectives need more proper planning this year and the field collection will be initiated in year 2001.

Drs. Shahid and Islam presented the plans for Objectives 4 and 5, respectively.

Finally, a short meeting was arranged between Mr. Medby and the Norwegian counterparts. The potential effect of the Project was assessed.

1.4.3 Other meetings

Visit at SPARRSO

Invited by Dr. M. A. Shahid the Norwegian representatives visited SPARRSO in Dhaka on 8 March (1pm – 2:30pm). Initially, Dr. A. M. Choudhury, Chairman at SPARRSO, gave a brief review of the activities at the institute using space technology. The introduction was followed by demonstrations of how the technology is applied in different fields, such as agriculture, water resources, forestry, geology, fisheries, oceanography, meteorology, environment, climate changes, natural calamities, etc.

Mapping of the mangrove ecosystems using LANDSAT digital data and aerial photographs – a vital part of the Project (Phase II) – was emphasised. The procedure used was convincingly demonstrated in a former study of Chokoria Sunderbans with special emphasis on shrimp ponds.

Visit by Mr. Deb

Mr. A. K. Deb, Senior trainer at FTEP-2, Chandpur, arrived for a meeting in Golden Deer Guest House, Dhaka on 8 March at 8pm. Mr. Deb is a senior researcher in the field of shrimp farming and he briefly described his former socio-economic studies with Dr. Islam, BAU. His comprehensive review: *Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh* (Ocean & Coastal Mngm, 41:63-88) is a very useful contribution to the debate of the consequences of the industry.

Both parts expressed their interest of future co-operation. Mr. Deb planned to contact Drs. Wahab and Islam in near future.

2. The International Conference on Aquaculture in the Third Millennium, 20 - 25 February 2000, Bangkok, Thailand

2.1 Summary from the Conference report

As a part of the project, it was decided to attend this Conference (Dr. Wahab, Mr. Braaten and Dr. Bergheim). Two scientific papers titled “Water quality in extensive and semi-intensive shrimp ponds in Bangladesh”, and “Waste production trends in intensive cold-water fish farming”) were prepared and submitted the Conference committee. The accepted manuscripts will be reviewed before publishing. The conference was a follow-up of the FAO Technical Conference on Aquaculture in Kyoto, Japan in 1976. The intention of the conference was to take stock of elements relevant to the future of the aquaculture sector and to recommend action plans to be implemented by identified public sector. It sums up the present status of aquaculture world-wide and present and discuss **possible problems, challenges and opportunities in the new third millennium.**

The intention of this summary is twofold; firstly present important trends and future challenges for the aquaculture industry, and secondly assess the relevance of the present research project (**environmental and socio-economic impacts of shrimp farming in Bangladesh**) in relation to the recommended guidelines.

The conference consisted of 5 Sessions and Session 1 (Global and regional overview of aquaculture developments and trends) was quite relevant for this project.

2.1.1 Asian aquaculture: Review of the trends, issues and prospects (Kongkeo, 2000)

Diversity

The Asian region dominates global aquaculture production, and is characterised by a great diversity of cultured species, technologies and farming systems. Asia’s contribution to the total world aquaculture includes 82 % of molluscs, 84 % of crustaceans, 89 % of finfish and almost all the aquatic plants produced.

A number of threats to sustainable growth have emerged as the aquaculture sector has developed, and disease is one of the most significant constraints. Recent estimates from regional surveys in 1994-95 suggest that the annual losses from disease and environmentally related problems, (carp and shrimp farming systems alone) are about \$ 300 million a year. Losses have increased with expansion and intensification. However, disease related losses in small scale and extensive systems also have significant social and economic impact.

A negative public perception of aquaculture due to the environmental and social concerns associated with some activities has also constrained this sector and this pressure is likely to increase. This has been particular evident in shrimp culture (De Silva, 2000): “It is not uncommon, often in developing nations, for lobby groups with vested interests, to use environmental issues to mask underlying social and political issues. Shrimp farming has created great social problems both in Bangladesh and India, which is still unsolved, and Indian Supreme Court has endorsed a moratorium on shrimp culture. In the new millennium, there is a lesson to be learnt from the above experience, and governments need to be alert with regard to choosing the appropriate strategy that minimises the tinkering of the social fabric”.

Interaction with the environment

Environmental issues have become an increasing concern for several reasons. One is the increasing resource pressure in some coastal and inland areas. More attention is being paid to the impact of aquaculture on the environment and on the social issues surrounding aquaculture.

Technology advances

The three commodities that have received intense research and development in Asia over the past two decades are carps, shrimp and tilapia. **However much remains to be done in marine shrimp particularly in terms of closing life cycles.**

Shift in strategies

Two major influences on the way in which the sector is viewed in national development context are the shift in emphasis from technical and economic to social objectives of aquaculture development that include livelihood development and food security, and the links between sustainable aquaculture practises and trade.

Constraints

The nature of constraints has shifted more from the technological to the social, economic and environmental.

2.1.2 A global perspective of a quaculture in the new millennium (De Silva, 2000)

Introduction

It is expected that in the new millennium, the basic paradigm changes will be from an increased production, at almost any cost, in the past, to a sustainable increase in production with **minimal environmental perturbations.**

Overall production

Prior to 1984 the aquaculture sector was rather small. However with the gradual development of the sector and the simultaneous reduction in the growth of capture fisheries globally, aquaculture production in the world was in 1997, 36 million tonnes and 28 million tonnes excluding aquatic plants. The global production has shown a steady increase since 1984, and in percentage terms this increase is 244.7 % and/or 17.5 % per annum. In the new millennium it is important at least to sustain the present rate of growth, and any increase above this would be a bonus to the worlds food supplies. All growth however, needs to be achieved with minimal environmental perturbations.

The main upsurge in the sector can be summarised as resulting from a transformation of aquaculture **from “art” form to a “science”**. The change has brought many advances ranging from a reduction on the dependence on wild caught seed for a great majority of species cultured. Currently, the life cycles of almost all major cultured species, except perhaps in the case of anguillid fishes, have been closed, at least technically. On the other hand, in respect of some such as **the Penaeid shrimps, the life cycle has been closed technically, but not commercially**, i.e. the sector, by and large, depends on wild caught broodstock, as well as wild caught post-larvae in some other countries (Primavera, 1998). **This is the situation for Bangladesh.**

Important changes were evident over the period 1984-1997. In 1984 the ten species that were produced in highest quantity included six finfish, three aquatic plants, and one mollusc. By 1997 however five finfish, three molluscan and two aquatic species were among the top ten. All species listed **feed lower in the food chain**. The list does not include a single species whose culture is dependant upon the provision of an artificial feed. It is highly unlikely that carnivorous species, or species high on the trophic ladder, will make the list.

The aquaculture sector has witnessed **large scale industrial aquaculture** being developed over the last two decades or so. The development of salmonid and shrimp culture in South America, **salmonid culture in Norway**, marine fish culture in the Mediterranean region and the development of channel catfish industry in the United States are some examples.

Asia continues to dominate the aquaculture production totally as well as that of all the major commodities. By 1997, nine Asian nations/territories were among the top ten producers, with China the biggest. By 1997 Thailand and Vietnam had emerged as major aquaculture nations.

Aquaculture is very diverse and finfish is the major commodity cultured; more than 125 species globally. However, the number of species that are produced in excess of 100 000 metric tonnes per annum are less than 20, of which 11 are cyprinids. Except for salmonids, Asia leads in all other groups.

Compared to finfish production, the cultured crustacean production is relatively small, but has continued to grow, until about 1993, when the shrimp production levelled off. A concurrent growth of crab culture, mainly a fattening process has occurred, in Asia. Crustacean culture is almost completely dominated by shrimp culture, contributing nearly 80 % to the total. **The tiger prawn, *Penaeus monodon* contributes more than 50 %**. Shrimp culture is essentially confined to Asia and S. America.

The new millennium

It is expected that the new millennium will pose new challenges to most primary industries including aquaculture, and some challenges will be consequent to the perceptions that have been generated. These perceptions are indirectly linked to the fact that there is an increasing global call to minimise environmental perturbations and the need to strive towards sustainable development. According to Kutty (1997) **the long term sustainability of the aquaculture sector will depend on environmental viability rather than economic viability**.

In the past environmental issues were of limited concern. We are now aware that this was a gross misperception; aquaculture uses primary resources and has to compete with other prospective users and is not always environmentally friendly. The sector in the new millennium will develop and thrive, and be sustained only if it can ensure environmental integrity (De Silva, 2000).

Sorgeloos (2000) gave summary based on a keynote presentation in the Plenary Session of the World Aquaculture '99, where he received inputs from more than 60 colleagues from all over the world. Many agreed that the production cannot increase at the same pace simply because of limitations of suitable water resources. Sorgeloos also pointed out the importance that further development of the industry must take a holistic approach to culture technologies, socio-economics, natural resources and environment so that sustainability can be achieved.

Environmental aspects

Effluent quality

The direct influence of aquaculture on the environment is through its effect on effluent discharge. In the case of organisms such as **shrimp**, which are not recognised to be efficient feeders, the wastage is greater than fish (only 25 % of food nitrogen in salmonids result in production).

The shrimp sector has experienced major calamities in different nations, mostly in connection to viral disease outbreaks, abetted by poor management practises. The spread and intensification of shrimp farming is also thought to have brought about land subsidence (from excess use of ground water) and salination of freshwaters in some regions. This has created large conflicts between agriculture and inland aquaculture. The overall sustainable development of the sector requires that water quality is protected.

Environmental deterioration has been erroneously attributed to aquaculture, particularly in respect of excessive discharge of nitrogen and phosphorous in aquaculture effluent. Lobbyists rarely appreciate the progress through the development of high energy diets that have been responsible for significant reductions in discharge of N and P. This trend will have to be increasingly pursued with regard to intensive culture of finfish **and crustaceans** in the ensuing decade, and indeed **may be considered as a priority area of research in the sector in the new millennium**. With regard to the coastal and marine environment, one has come to realise that these ecosystems must be managed as a whole and that we need to model these systems for nutrient carrying capacities (Sorgeloos, 1999).

Mangrove destruction

The mangrove issue is likely to resurface over and over as new regions take to shrimp and coastal aquaculture. In this context it is relevant that the **available scientific information on the purported association between aquaculture and mangrove destruction be dealt with utilising as much quantitative information as possible**.

Hard quantitative data are only beginning to be available and the general belief that shrimp farming was almost solely responsible for mangrove destruction is being increasingly and successfully challenged.

Targets and qualitative changes

Sorgeloos (1999) suggested that aquaculture is at the cross-roads and predicted it will come of age in this millennium, and that for it to happen, the sector will require more responsible researchers and more integrated research and development approaches than at present.

The aquaculture sector is involved in a very diverse array of food organisms and a wide range of practices. At one extreme is the rural subsistence level, low input practise etc (Bangladesh). At the other extreme is the large scale industrial practises, which tend to be highly capital intensive, high primary resource etc. 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 economic use of natural resources.

Challenges and opportunities

In a nutshell the global strategies may be two fold:

- To increase aquaculture production, significantly, so that it continues to have an impact on food security, employment generation and social equity, and
- For all development to be sustainable and environmentally sound.

Technical

It is relevant to highlight the main technical needs and advances required to meet the production targets under a milieu of sustainability. Foremost among these are genetic improvement of major cultured aquatic species, feed development which should encompass both a decreasing dependence on fish meal as a major protein source in feeds, and a lowering of nitrogen and phosphorous in effluent, and improvement in health management of cultured organisms. **However, researchers often might not realise that, depending on specific circumstances, social and economic factors may be more important than technological factors (Sorgeloos, 1999).**

Disease is now clearly recognised as one of the most significant constraints to aquaculture production and trade. It affects both economic and socio-economic development in many countries of the world. **Within the shrimp culture sector, disease is considered as the single most important factor limiting today's production.** Although environmental factors, such as poor water quality resulting from effluent and waste mismanagement, have been implicated in major disease outbreaks, the underlying cause(s) of epizootics are usually more complex and difficult to pinpoint. Experience in trying to control aquatic diseases outbreaks demonstrates the importance of taking all components of the production system into account. This includes a need for broader "ecosystem management" approaches, actively preventing environmental deterioration as well as introduction of pathogens through live introductions and transfers – the "Systems Management Approach" (SMA) to aquatic animal health.

Protocols for safe transboundary movement of aquatic animals and animal products form a first line of defence against inadvertent introduction or transfer of infectious pathogens or diseases. **The use of wild caught shrimp seed in Bangladesh is a continuous source of contamination with a variety of pathogens to the Ghers.**

Inter-regional co-operation

In the new millennium it will be imperative that networking is extended further, and should be inter-regional co-operation and networking with a view to facilitating transfer and exchange of technology and information, education and training and dissemination of relevant knowledge to all.

Governmental role

Governmental role will undoubtedly be the most variable element in the aquaculture development equation. Governmental role has to go beyond mere "policing" and in the new millennium governments have to work hand in hand with practitioners than in the past, and make investments in partnership to solve common problems.

Education, training and extension

In Asia farmer level training and education is fairly satisfactory (the execution of training is facilitated by regional bodies as NACA). In the new millennium practitioners will need to have a more holistic approach. According to De Silva et al. (2000) the emphasis on training has been much less than desired over the past decade. **Often training with donor funded projects tend to be primarily in the form of short workshops and or study tours. It is suggested that in the new millennium there will be need for much more attention on long- term capacity building among practitioners.**

In the new millennium researchers with different expertise will have to work in tandem and not in watertight compartments. The issues on education, training and extension are closely linked to capacity building.

Concluding comments

A major issue facing the globe remains feeding of the hungry. The world has gone through a decline in agricultural production, from an annual rate of 3 % (1960) to about 1.6 % in 1986-95. The outlook for future until 2010 is an annual growth of 1.8%. No further increase to aquatic food supply from capture fisheries and the envisaged marginal increase in agriculture production, aquaculture may have an increasing role to play in the next decade and beyond. If aquaculture is to become the mainstay in the supply of aquatic food supply in the next millennium, further developments in aquaculture must be environmentally sustainable, particularly large scale commercial practices.

2.2 The relevance of the project "Environmental and socio-economic impacts of shrimp farming in Bangladesh

The millennium conference has focused strongly of the importance of the development of a sustainable aquaculture production with minimal environmental perturbations. A negative public perception of aquaculture, due to environmental and social concern has developed, and mainly due to problems with shrimp farming. The long term sustainable development will depend more on environmental viability than economical.

The release of nitrogen and phosphorous in the effluent may be considered as a priority area of research in the new millennium. Within the shrimp sector disease is considered as the single most important factor limiting today's production. The use of wild caught seed (as it is practised in Bangladesh) is a continuous source of contamination with a variety of pathogens.

Available quantitative scientific information on the association between aquaculture and mangrove destruction is strongly needed.

The aquaculture industry has changed from an "art" to "science". These changes demands that the new millennium researchers will have to work in tandem and both researchers and practitioners will need to have a more "holistic" approach. Environmental problems will also include socio-economic aspects, and social and economic factors may be more important than technological factors. The issues of education, training and extension are closely related to capacity building, and there will be need for much more attention on long-term capacity building among practitioners.

The present research project includes many highly important and relevant topics and should therefore be very useful for both the protection of the environment, the shrimp culture industry of Bangladesh and capacity building at the university of Mymensingh.

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2.3 Recommendations from the conference (draft)

(From "Fish Farming International" March 2000)

The Bangkok Declaration

industry template for the third millennium?

More than 600 top-level delegates from around 70 countries gathered in Bangkok, Thailand, last month for the Conference on Aquaculture in the Third Millennium. Representing the greatest concentration of top-level aquaculturists since Kyoto in 1976, they spent a week trying to thrash out a declaration that would have as big an impact as Kyoto. As the only international trade journal present, FFI publishes this draft declaration for our readers. Although only a draft, the final version is expected to change little.

We, the participants to the Conference on Aquaculture in the Third Millennium, Bangkok 2000, recognise that:

During the past three decades, aquaculture has become the fastest growing food-producing sector and is an increasingly important contributor to national development, the global food supply and food security.

Aquaculture consists of a broad spectrum of systems, practices and species, operating through a continuum, ranging from simple backyard household ponds to large-scale, industrial systems.

There is now a decreasing availability of natural fish and aquatic resources from inland and marine waters.

A great proportion of production comes from developing countries, where aquaculture will continue to contribute to food security, poverty alleviation, income generation, employment and trade.

There has been a significant increase in commercial and industrial aquaculture, both in developed and developing countries that has contributed to export income and trade.

Globally, aquaculture is at varying stages of development and will require different strategies for growth.

The potential of aquaculture to contribute to food production has not been realised across all continents.

Aquaculture complements other food production systems and integrated aquaculture can add value to the current use of on-farm resources.

Aquaculture can be an entry point for improving livelihoods, planning natural resource use and contributing to environmental enhancement.

Responsible aquaculture practitioners are legitimate users of resources.

Education and research will continue to make a significant contribution to the growth of aquaculture.

Some poorly planned and managed aquaculture operations have resulted in negative impacts on coastal eco-systems and communities.

Continued growth will occur through the investment of the private and public sectors.

Effective national institutional arrangements and capacity, policy, planning and regulatory frameworks in aquaculture are essential to support development.

Improving co-operation among stakeholders at national, regional and inter-regional levels will be a pivotal element in further development.

The potential of aquaculture to contribute to human development and social empowerment is not yet fully realised. The sector requires fresh, dynamic and responsible strategies to realise its goals, and the participants declare that:

Aquaculture should continue to be developed towards its full potential, making a net contribution to global food availability, household food security, economic growth, trade and improved living standards.

The practice of aquaculture should be pursued as an integral component of development, contributing towards sustainable livelihoods for poor sectors of the community, promoting human development and enhancing social well-being.

Aquaculture policies and regulations should encourage farming and management practices that are environmentally responsible and socially acceptable.

National aquaculture development processes should be transparent and take place within the framework of relevant national, regional and international agreements, treaties and conventions.

In pursuing development, governments, private sector, and other stakeholders should co-operate to promote responsible aquaculture.

Strengthened regional and inter-regional co-operation should increase the efficiency and effectiveness of aquaculture development efforts.

All parties formulating improved policies and implementing practices for aquaculture should consider and where appropriate build on the FAO Code of Conduct for Responsible Fisheries.

Strategy for development

The Bangkok Declaration is based on major strategy elements from the conference session recommendations. The detailed recommendations from the sessions are documented separately.

A Strategy for Aquaculture Development Beyond 2000 was developed along with the Declaration, covering many areas, from education and training, through investment and marketing, to applying innovations.

On implementation, the Conference has seven main points:

- Encouraging governments, private sector and other organisations to implement the strategy.
- Primary responsibilities for development and implementation rest with governments and private sector.
- Co-operative mechanisms among countries provide an excellent opportunity to support development. The application of technical co-operation among developing countries deserves special support.
- Conference recommends the development of an effective programme of regional and inter-regional co-operation.
- The Conference recommends to make effective use and build on existing mechanisms and seek to promote synergy and cooperation between existing regional and inter-regional organisations. Where these do not exist, the opportunities to build such mechanisms, and to promote sharing of experiences, is recommended.
- The Conference notes that there are considerable opportunities for co-operation including government, non-government organisations, farmers' bodies, regional/international groups, and donors/lending agencies.
- Aquaculture has become considerably more diverse since Kyoto. This provides considerable opportunity for productive co-operation. The Conference recommends that the opportunities for co-operation should be utilised effectively.

In general, countries "are encouraged to incorporate in their strategies for aquaculture development the key elements identified during the Conference". These key elements are as follows (**not full text**).

Investing in people through education and training: Further investment is essential to build the skills of all people involved in the sector. Skills development can be made more cost-effective and responsive to needs.

Investing in R&D: There is a need to increase investment in aquaculture research, while making efficient use of resources and building the capacity of institutions to be more responsive to development requirements through such mechanisms as: collaborative multi-disciplinary research; stakeholder participation; improving linkages; collaborative funding; efficient communication; regional/inter-regional cooperation; and a continued effort to build skills.

Improving information flow and communication: For the efficient management of the sector improved information flows at national, regional and inter-regional levels is required.

Such an approach will avoid duplication of effort and save costs, encourage consistency in areas such as education and training, policy-making, planning and the application of rules and procedures.

Improving environmental sustainability: There is a need to further develop environmentally sound technologies and resource-efficient farming systems, and integrate farms into coastal areas and inland watersheds.

Managing aquatic animal health: Disease has become a primary constraint to aquaculture growth, and is now impacting both economic and socio-economic development, and rural livelihoods in many countries of the world. Addressing aquatic animal health issues with both pro-active and reactive programs has therefore, become an urgent requirement for sustaining growth of aquaculture.

The need to harmonise approaches, strongly argue for effective co-operation at all levels of management to make the most effective use of resources.

Improving Nutrition: For maximising production, the nutritional requirements of cultured species have to be satisfied. Feed development will need to give increase emphasis on efficient use of resources. Further work will be required to minimise discharge of waste nutrients.

Fishmeal reduction in diets will also be important to reduce the costs of feeds and because of social and environmental concerns. The nutrient dynamics of semi-intensive culture practices need to be better understood.

Supporting strong regional and inter-regional cooperation: Over the years regional and inter-regional cooperation have brought considerable benefits to aquaculture development.

In an era of globalisation, further strengthening of this cooperation at all levels will ensure increased benefits for sectoral development and sustainability.

Integrating aquaculture into rural development: With the goal of increasing the impact of aquaculture on rural development, strategies are required to integrate aquaculture into such programmes in inland and coastal areas.

Investing in aquaculture development: Future investment in aquaculture should be made with long-term strategies in mind to ensure sustainability. Among the recommendations were moves to give initial financial encouragement, developing mechanisms to promote environmentally and socially responsible aquaculture, and establishing credit schemes.

Also, to make efficient use of international donor resources, a program approach to multi-sectoral development should be applied under which donors can more effectively cooperate and collaborate with each other.

Ultimately, this should occur within comprehensive frameworks. There is thus a need for donors to adopt more cohesive approaches and procedures.

Strengthening institutional support: One of the key issues for the growth of aquaculture will be the ability of countries and organisations to strengthen their institutional capacity to establish and implement policy and regulatory frameworks that are both transparent and enforceable.

Incentives, especially economic incentives deserve to be given more attention in the planning and management of aquaculture development, Institutional capacity should be made more effective and strengthened.

Improving enhancements and culture-based fisheries: Enhancements include culture-based fisheries or habitat modifications in common pool aquatic resources, which require minimal food and energy inputs.

These practices therefore provide important opportunities for resource poor sections of the population to benefit from relevant aquaculture technologies and permit efficient of under utilized, new or degraded resources. Culture-based fisheries in particular have considerable potential for increased fish supplies and generating income in rural areas.

Applying genetics and biotechnology to aquaculture:

Genetics and biotechnology have important roles to play in increasing productivity and sustainability in aquaculture through higher survival, increased turnover rate, better use of resources, reduced production costs and environmental protection.

This could require resources but the benefits in both the short and long term may justify this effort. There are many elements and practices of genetics and biotechnology that may be considered for aquaculture.

Aquaculture has not benefited as much as terrestrial animal husbandry has from the adoption of best practices such as selective breeding and stock improvement programmes.

Improving food quality and safety: As consumer awareness increases, aquaculture producers and processors will need to improve the quality of products and enhance product safety and nutritional value. The incentives for this will be potentially higher prices, lower insurance rates and increased consumer demand.

Promoting market development and trade: A focus on market development and trade will add value and increase returns for aquaculture products. This will require developing marketing and promotional strategies and understanding consumer requirements and changing market demands.

These goals can be achieved through liberalisation of trade, developing market-driven commercial aquaculture, assisting producers, processors and manufacturers in identifying markets, providing data for, and investing in IT-based market information systems that are easily accessed by producers and processors, researching changing consumption, taking special care to address consumer concerns (eeg. GMOs) and ensuring transparency in "chain traceability".

Applying innovations in aquaculture: The technologies for sustainable aquaculture development should provide a varied and adaptable "tool kit", from which people can select and design the system which most effectively meets their needs and best fits the opportunities and constraints of the local environment.

The delivery of such techniques requires efficient communication networks, reliable data on the merits and drawbacks of the various approaches, and help the decision making process through which people design their production.

As we move into the next two decades, water and land for aquaculture will become critical issues. New opportunities for aquaculture development will also emerge through improvements in science and technology for aquaculture systems.

2.4 Water quality in extensive and semi-intensive shrimp ponds in Bangladesh (Paper for the Conference)

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ABSTRACT

In a current Bangladeshi - Norwegian project, water sampling has been conducted in some brackish water shrimp ponds stocked with *Penaeus monodon* in Bangladesh since 1997. The overall objective of the project is to ensure that shrimp farming develops in a sustainable way that utilises natural resources with minimum harmful ecological effects.

The sampling program included five extensive - improved extensive farms in the Khulna region, *Ghers* with an annual production of 100 - 500 kg ha⁻¹, and four improved extensive farms and one semi-intensive farm (3,000 - 5,000 kg ha⁻¹ year⁻¹) in the Cox's Bazar region. In addition to water sampling, data of input of manure, fertiliser and feed; shrimp stocking density, mortality and production; and water exchange rate data were collected.

Outbreaks of the so-called 'White spot disease' have severely damaged the shrimp industry in Bangladesh. Disease outbreaks often occur when there is stress-inducing deterioration of the water quality. In most cases, the examined water parameters were not indicating stress conditions. The combination of low salinity (< 10 ppt), an increased mid-afternoon pH (> 8.5), and a resulting unionised ammonia level of 0.5 - 1.0 mg L⁻¹, measured in extensive *Ghers* in Mid-Summer, is however considered sub-optimal conditions for growth of penaeids. In both regions, excessive rainfall reduces the pond salinity down to 1 - 6 ppt in July / August, normally coinciding with the end of the second production cycle.

Generally, the water quality throughout the growth cycle seemed to improve with increasing stocking density and water exchange rate.

Introduction

In recent years, diseases have been a regular occurrence in the shrimp farms in both traditional culture systems in the SouthWest and in semi-intensive culture systems in the SouthEast Bangladesh. Disease outbreaks like mass mortality for unidentified reasons in the wet season, gill parasites, black spot disease, etc were not detrimental for the industry until the outbreak of a new disease, White Spot Disease (WSD) or "China Virus" (e. g. identified by Wang *et al.* (1997), in 1994. WSD accounted about 90 % losses in the SE and about 40 % in the SW situated farms of Bangladesh since the initial outbreak (Wahab, 1997). In a country review, shrimp disease was reported to be a major concern on 13 % of extensive farms and a very high 74 % of semi-intensive farms (Choudhury, 1997). Water quality problems, such as low salinity, fluctuating temperature and high turbidity, were reported on 23 % of extensive farms and on 39 % of semi-intensive farms.

Management of the shrimp pond environment is considered to be a vital factor for disease prevention (Chanratchakool *et al.* 1998). High mortality caused by virulent shrimp pathogens is often precipitated by transient conditions of stress, such as sudden changes in pH and low dissolved oxygen concentration (Flegel, 1996). Environmental stressors such as ammonia may enhance the severity of

WSD in culture shrimp (Wang *et al.* 1997). In Bangladesh, there is a growing evidence that environmental impacts related to shrimp culture play a significant role in outbreaks of diseases affecting shrimp ponds (DoF, 1994).

This paper deals with water quality measurements performed at brackish water shrimp farms covering a range of culture systems, from traditional extensive systems in the Khulna region (SW Bangladesh) to semi-intensive systems in the Cox's Bazar region (SE Bangladesh).

Materials and Methods

Shrimp farms

All involved farms in the Khulna region were traditional extensive systems:

Ghers (ponds): 40 – 100 ha size, Water exchange tidal based (rate: 0 – 10 %/day), Stocking rate: 1 – 2 PL/m², Cumulative mortality: 40 – 50 %/cycle (WSD outbreak: 85 – 90 % mortality), Production: 200 – 300 kg/ha/year (2 cycles/year), No artificial feeding, Fertiliser: 1,000 – 3,000 kg cow dung/ha/cycle + 100 kg inorganic (N, P)/ha/cycle, Lime: 500 – 1,000 kg CaO/ha/cycle.

Improved extensive farms, both in the Khulna region and Cox's Bazar:

Introduction of Nursery pond practice within the Gher, Stocking rate grow-out ponds: 2 – 4 PL/m², Cumulative mortality: 40 – 50 %/cycle (WSD outbreak frequency reduced), Production: 300 – 500 kg/ha/year (2 cycles/year). Other practice (water exchange, fertiliser input) as described for traditional systems.

Semi-intensive farms in Cox's Bazar (Beximco Fisheries Ltd.):

Pond size: 1 – 2 ha, Recirculation of water: inlet from sea (tidal based) – reservoir (sedimentation, lime addition) – feeder canal – shrimp pond – discharge canal – reservoir – etc., Pumping/aeration, Stocking rate: 15 – 20 PL/m², Cumulative mortality: 30 – 50 %/cycle, Production: 3,000 – 5,000 kg/ha/year (2 cycles/year), Artificial feeding.

Sampling and analytical procedure

Manual sampling of pond inlets, within ponds and pond outlets was carried out every second week at five extensive farms (*Ghers*) in the Khulna region in 1997. The planned sampling at farms in Cox's Bazar failed in 1997 due to a cyclone in April followed by a severe flooding episode in July. In 1998, within pond sampling was confined to five farms in Cox's Bazar. Sample collection and on-site measurements (1997-98) were carried out in daylight, between 10 am and 2 pm. In order to study diurnal fluctuations, sampling was performed every 4th hour a day at one farm in Cox's Bazar in May - June 1999.

Temperature, salinity (Refractometer, mod. 4200/REV A/05-95, Conductivity meter), pH (pH Meter, mod. EC 10 portable pH meter, Hach) and dissolved oxygen (D.O. Meter, mod. DO 175, Hach) were measured on the spot. After acid preservation water samples were brought to Water Quality and Pond Dynamics Laboratory., Bangladesh Agricultural University, Mymensingh for measurement of total ammonia nitrogen (TAN = NH₄-N + NH₃-N) using (Stirling, 1985). Un-ionised ammonia (NH₃) was calculated from measurements of TAN, pH, temperature and salinity (Fivelstad, 1988).

Results and Discussion

Water quality measurements from extensive culture systems (*Ghers*) in Khulna and improved extensive culture systems in Cox's Bazar are shown in Table 1. The results obtained from the second production cycle (July – September) within the large extensive *Ghers* indicate a relatively high concentration of total ammonia (TAN) and, in spite of sampling solely in daylight, a strongly fluctuating pH level. Comprising all extensive system sites, un-ionised ammonia (NH₃) peak concentrations of 0.29 – 0.86 mg N/L were found. In improved extensive culture systems, no sub-critical ammonia (NH₃) concentrations were detected at midday.

Diurnal differences in temperature ranged 6 – 8 °C, pH ranged 0.9 – 1.2 units, dissolved oxygen ranged c. 2 mg/L, while un-ionised ammonia and nitrite concentrations were consistently low in semi-intensive ponds in Cox's Bazar (Table 2). The lowest early morning dissolved oxygen levels were 5.5 mg/L and the highest pH peaks in the afternoon 8.4.

In most cases, the observed variation of water quality was within the acceptable range for *P. monodon* culture (Table 3). The salinity level during the second production cycle (July – September) decreased however gradually to 1 – 2 ppt in the Khulna based *Ghers*, far below the recommended lower limit. However, freshwater will stunt the shrimp only after 100 days of culture period (Kongkeo, 1997). The viability of *P. monodon* in low-saline water was indicated in a recent report (Saha *et al.* 1999): when salinity decreased after 60 days of culture (> 5 ppt) to freshwater level (0.16 ppt) the growth rate and the feed utilisation of the shrimp stock was still satisfactory in semi-intensive pond. Neither in Khulna nor in Cox's Bazar, daily salinity fluctuations exceeding 5 ppt seem likely.

Table 1. Within pond water quality range at brackish water shrimp farms in two Bangladeshi regions, in the Khulna region and in Cox's Bazar 1997-98. Biweekly routine sampling.

Khulna region, July - Sept. 1997:

Site	Production system	Temp., °C	pH	Salinity, ppt	DO, mg/L	TAN, mg/L	NH ₃ -N, mg/L
Soldana	Extensive	29.5 - 32.7	6.5 - 8.3	1.2 - 8.9	4.5 - 4.7	1.7 - 2.5	0.01 - 0.41
Horikhali, Station 1	Extensive	29.3 - 30.0	7.1 - 8.3	1.6 - 9.8	3.8 - 5.0	1.1 - 2.3	0.01 - 0.33
Horikhali, Station 2	Extensive	29.7 - 32.4	6.2 - 8.9	1.3 - 11.2	3.3 - 4.9	1.4 - 2.1	0.00 - 0.86
Sorlgram	Extensive	27.0 - 30.6	7.7 - 8.3	1.1 - 6.8	4.5 - 5.4	0.5 - 2.1	0.02 - 0.29
Melek-purikati	Extensive	29.7 - 32.5	7.7 - 8.7	2.6 - 8.5	4.5 - 4.8	1.9 - 2.6	0.07 - 0.58

Cox's Bazar, April - Oct. 1998:

Site	Production system	Temp., °C	pH	Salinity, ppt	DO, mg/L	TAN, mg/L	NH ₃ -N, mg/L
Chakhuria Station 1	Improved extensive	27.1 - 31.1	6.2 - 7.7	5 - 26	5.4 - 6.7	0.5 - 1.1	0.00 - 0.02
Chakhuria Station 2	Improved extensive	27.1 - 32.2	6.8 - 7.9	5 - 24	6.2 - 6.9	0.4 - 1.0	0.00 - 0.04
Chakhuria Station 3	Improved extensive	27.0 - 32.0	6.6 - 7.3	5 - 25	6.6 - 7.3	0.4 - 1.1	0.00 - 0.07

Table 2. Diurnal water quality fluctuations in Beximco Fisheries Ltd, Cox's Bazar May – June 1999. Production system: Semi - intensive:

Time	Sampling site	Temp., °C	pH	DO, mg/L	NO ₂ -N, mg/L	TAN, mg/L	NH ₃ -N, mg/L
15 – 16 May	Inlet	24.0 - 32.0	7.1 – 7.9	4.7 – 6.8	< 0.012	0.13 – 0.24	< 0.01
	Pond	25.0 - 32.5	7.2 – 8.4	5.7 – 8.0	< 0.011	0.08 – 0.25	< 0.01
	Outlet*	31.5 - 32.0	7.6 ± 0.0	6.3 – 6.7	< 0.006	0.11 – 0.15	< 0.01
09 – 10 June	Inlet	28.0 - 36.0	7.4 – 8.3	5.2 – 8.4	< 0.013	0.11 – 0.19	< 0.01
	Pond	29.0 – 35.0	7.3 – 8.4	5.5 – 7.8	< 0.014	0.01 – 0.21	< 0.01
	Outlet*	33.5 - 34.0	8.1 – 8.4	5.5 – 7.3	< 0.010	0.13 – 0.19	< 0.01

*: outlet sampling, afternoon 1 – 4 hrs

Un-ionised ammonia is highly toxic to *P. monodon* but the toxicity decreases with increasing age: for example, the 24-d LC₅₀ increases from 0.54 to 4.7 mg NH₃-N/L as the shrimp progresses from nauplii to postlarvae (Chin & Chen, 1987). In grow-out ponds, the risk of acute mortality due to ammonia toxicity is normally low. Sub-lethal levels of ammonia, e. g. estimated as 0.21 mg NH₃-N/L at which growth is reduced 5 % over 3 weeks in juvenile *P. monodon* (Allan *et al.* 1990), seem more liable to occur. Obviously, the ammonia concentrations measured in *Ghers* in the Khulna area in July – August 1997 (0.09 – 0.86 mg NH₃-N/L) were fluctuating in the “sub-lethal” range. Besides, these measurements only represent biweekly sampling at noon. The main source of inorganic nitrogen in the *Ghers* seemed to be the inlet water (TAN concentrations: 0.2 – 2.3 mg/L), while the input of fertiliser and manure enhanced the concentrations only shortly after application.

Neither early morning dissolved oxygen levels nor pH peaks in the afternoon showed signs of sub-critical conditions in semi-intensive culture (Table 2). In Indonesian *tambaks*, early morning dissolved oxygen concentrations between 3 and 5 mg/L were considered favourable to growth without causing stress in *P. monodon* (Hariati *et al.* 1996). According to Hall & van Hamm (1998), dissolved oxygen concentrations need to be maintained “above 4 mg/L during the grow-out period if repeated bouts of metabolic stress to the prawns are to be avoided” (juvenile *P. monodon*).

Table 3. Recommended water parameters for successful culture of *P. monodon* (Chanratchakool *et al.* 1998). Acceptable range (Corea *et al.* 1998).

Water parameter	Successful production		Acceptable range
	Optimum level	Comments	
pH	7.5 - 8.3	Daily fluctuations < 0.5 units	6.8 – 8.7
Salinity	10 - 30 ppt	Daily fluctuations < 5 ppt	10 – 25 ppt
Dissolved oxygen	5 - 6 ppm	Not less than 4 ppm	> 3.5 ppm
Alkalinity	> 80 ppm (as CaCO ₃)	Dependent on pH fluctuations	-
Secchi disc transparency	30 - 50 cm		-
H ₂ S	< 0.03 ppm	More toxic at low pH	-
Un-ionised ammonia (NH ₃)	< 0.1 ppm	More toxic at high pH and temperature	< 1 ppm TAN (NH ₄ ⁺ + NH ₃)

-: no figures.

Except for occasionally sub-critical un-ionised ammonia concentrations within the traditional culture systems (*Ghers*), no obvious signs of stress-inducing water quality parameters were found. The observed ammonia concentrations at pH > 8.5 may be a potential environmental stressor contributing to disease outbreak. In an experimental infection trial, addition of 2 ppm total ammonia (TAN) lead to 40 % mortality among *P. monodon* caused by White Spot Disease (Wang *et al.* 1997). However, no epidemic WSD caused mortality was reported at the traditional farms in 1997 (40 – 50 % losses/cycle). The study-involved semi-intensive farm in Cox's Bazar (Beximco Fisheries Ltd.) which was hit by WSD in 1998 and was only able to harvest 25 % of the biomass. In the following year (Table 2), the water quality ranges at this farm were within acceptable reference values.

In conclusion, the water quality in the extensive culture systems in Khulna, the improved extensive systems and semi-intensive ponds in Cox's Bazar are usually within acceptable ranges for shrimp farming. However, sub-lethal levels of ammonia can be present and create stressing conditions in the extensive culture systems. In the Khulna area, low salinity could also create unfavourable environmental conditions. Outbreak of WSD, Yellow Head Disease and similar viruses often occur in dams with poor environmental conditions. All the dams are stocked with wild seed, and it is known that WSD most commonly enters with infected post larvae. The present situation, with few hatcheries, an extensive use of wild seed and periods of unfavourable environmental conditions makes it likely that new outbreaks of WSD or other viral diseases will appear.

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