The Marine Environmental Condition of the Pakklong Sub-district Coastal Area and their Effect on Coastal Aquaculture

Southeast Asian Fisheries Development Center

TD/RES/77

LBCRM-PD No.17

Department of Fisheries, Thailand

January 2003

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By

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Collaborative project between Southeast Asian Fisheries Development Center and Department of Fisheries, Thailand

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FOREWORD

Under the Fisheries Consultative Group (FCG) mechanism, SEAFDEC/TD and the Department of Fisheries (DOF) has planned and implemented a joint involvement in "Locally Based Coastal Resource Management, Pathew District, Chumporn Province (LBCRM-PD)". This project has the objective of enhancing the people's awareness on the sustainable use of coastal resource management and to develop an effective management framework at the project site.

To lead to the outstanding success of the project activities, the project continues to conduct a baseline survey including the Marine Environmental Condition aspect. This volume is the result of a series of baseline surveys that have been carried out since January 2002. I hope that these survey results will be of great use, not only for Thai coastal fisheries development, but also for other member countries of SEAFDEC-ASEAN.

Panu Tavarutmaneegul
Secretary General

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The Marine Environmental Condition of the Pakklong Sub-district Coastal Area and Their Effect on Coastal Aquaculture

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ABSTRACT

A baseline survey on the marine environmental condition of Pakklong sub-district, Pathew District, Chumporn province was conducted between January and October 2002. Physical,chemical and biological parameter data were collected at twelve stations at monthly intervals in the first half period and at bimonthly intervals in the last period. Weather data were obtained on a daily basis.

The water quality in the study area is suitable for coastal aquaculture, but with special care in the summer season. The physical characteristics of Pathew bay and the properties of the water showed that the bay is at risk from blooms of plankton and the accumulation of wastages. Therefore, limitation of aquaculture area and numbers is necessary to prevent damage from plankton blooms or any other pollution events when the load of aquaculture waste exceeds the carrying capacity of the water.

Key words:

Marine environmental system, Weather data , Pakklong sub-district, coastal aquaculture

1. INTRODUCTION

A baseline survey on the marine environmental condition of Tambol (sub-district) Pakklong, Pathew District, Chumporn Province is an activity under the SEAFDEC/TD-DOF, Thailand collaborative project on coastal resource management, namely The "Locally-based Coastal Resource Management Project, Pathew District" (LBCRM-PD). The purpose of the LBCRM-PD project is to establish a practical framework for locally-based coastal resource management through the encouragement of fishers participation, supported by the creation of alternative job opportunities in coastal fishing communities. Aquaculture is one of the activities that the project plans to encourage the fisherman, however, aquaculture needs good management as it produces soluble inorganic and particulate waste, which can result in organic enrichment of local aquatic environment. To prevent unacceptable changes to the environment, an environmental management framework should be established as a means of regulating development and evaluating potential impacts before permission to develop is granted.

The purpose of this baseline survey is to collect data, which provides reference data against which, changes caused by aquaculture waste and some other human activities can be judged. The baseline survey will also assist in designing an appropriate future-monitoring program. The results of survey can also be taken into account when searching for suitable species for aquaculture in this area.

Study area

Coastline

The survey site is in the southern part of Thailand on the eastern side of Chumporn Province. The coastline of the study area is composed of coral reefs, mangrove areas, a foreshore, rocky shore and sand dunes.

Along the inland and coastland of the study area, there are several human activities including cage culture, mussel culture, small-scale fishing gear operation, shrimp farms, a small fish processing plant, a fishing village and a tourist resort.

Climatic conditions in Chumporn province

Climatic conditions at the site are tropical, with high humidity and monsoon effects. There are two monsoon seasons in a year. The southwest monsoon is from May to October. The northeast monsoon prevails from October to February. These monsoon seasons influence the local category of the season as the rainy and the summer season. The rainy season is from May to December. The southwest monsoon winds carry rain from the Indian Ocean and the northeast monsoon winds carry rain from the South China Sea to Chumporn province. The rainfall is highest in the northeast monsoon season because of low atmospheric pressure and depressions. Water from the mountain in the western part of Chumporn Province flows to the plain area in the eastern part. For this reason the area is prone to flooding.

The summer season is from February to April. During this period, the northeast monsoon has less influence in this area. The temperature gradually increases in February to the highest temperature in April.

2. MATERIALS AND METHODS

The project was planned to observe the physical, chemical and biological water quality parameters of the Pakklong sub-district coastal area. The following parameters were measured during this study: temperature, salinity, dissolved oxygen, pH, chlorophyll-a, nutrient, current direction and speed and a total bacteria count. Each parameter from 12 survey stations (**Fig. 1**) is independent and defines the overall condition of the study area. The survey period was from January to October 2002 and was planned to be conducted once a month during January to April and every two-months after April. The surveys were done onboard Meen Niweth, the research vessel under the Chumporn Marine Fishery Development Center, Department of Fisheries, Thailand.

Because of the variation in climatic conditions, some years the weather in the study area differs from the general pattern. This was also observed in this study.

For this study, the physical parameters including water temperature, salinity, dissolved oxygen and pH were measured at the surface, mid depth and the bottom. The other parameters were determined from the surface water only.

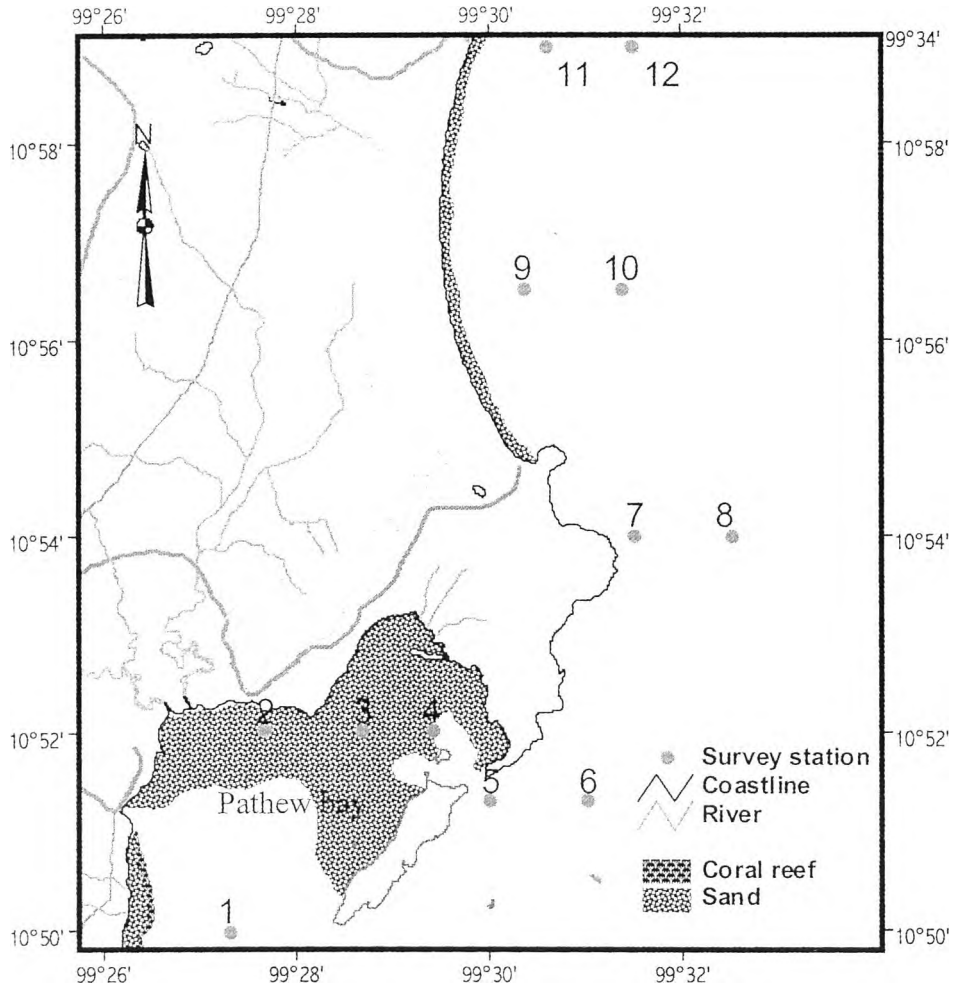

Figure 1 Map of survey stations

Physical parameters

- Water temperature, salinity, dissolved oxygen, pH were measured using YSI 556 MPS multi-sensor at the surface, mid depth and the bottom (see **Fig. 2**)
- Transparency was measured using a Secchi disc.
- Current speed and direction were measured using a model 105 Valepot current meter at 1 meter below the surface for about 10 minutes at each station (**Fig.3**).
- Depths of all stations were measured using a Handy Echo Sounder (see **Fig.4**).
- A total suspended solids (TSS) count was performed at Chumporn Marine Fishery Development Center following the Strickland and Parson, 1972 method.

Figure 2. YSI 556 MPS multi-sensor

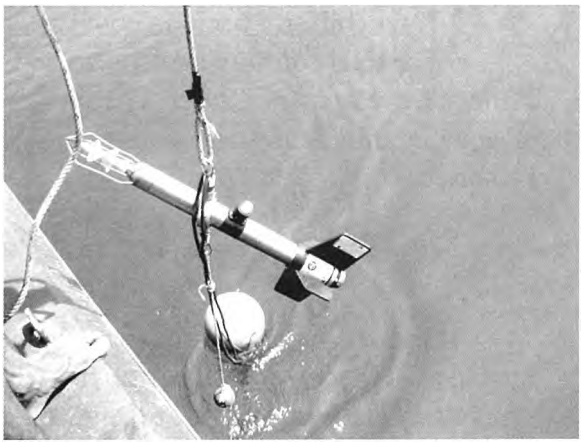

Figure 3. Valepot current meter

Figure 4. Handy echo sounder

Chemical parameters

Nitrate and phosphate measurements were made at the Chumporn Marine Fishery Development Center. Only silicate concentrations were measured at the Laboratory of the Southeast Asian Fisheries Development Center (SEAFDEC), Training Department. Water samples were collected in 1 liter plastic bottles. After collection, the samples were immediately placed on ice. In the laboratory, all water samples were filtered through GFC Whatman filter papers then stored in a freezer until the time of analysis. Samples were analyzed using the standard methods of Strickland and Parson, 1972.

Biological parameters

Chlorophyll-a

Chlorophyll-a measurements were made at the Laboratory of the Southeast Asian Fisheries Development Center, Training Department. The analytical methods used were taken from Parsons et al. (1984). Chlorophyll-a concentration was determined from the GFC Whatman filter paper used for filtering about one liter of water sample. All filter papers were wrapped individually in aluminum foil, placed in small containers with silica gel, and stored in the freezer. During the analytical process, the glass filters were separately immersed in 10 ml of a 90% acetone solution for 24 hours. Each solution was analyzed for chlorophyll-a concentration using a spectrophotometer.

Total coliform bacteria count

The total coliform bacteria count was performed at the Laboratory of the Chumporn Marine Fishery Development Center. The method used followed the manual of monitoring on the quality of aquatic animal and aquaculture areas produced by the Aquaculture Division, Department of Fisheries.

Climatic conditions

Climate data is from the weather observation station at Mueng District, Chumporn Province. The computer unit of the Climatology Division, Thai Meteorological Department, supported data from January to August. Data from September to October was downloaded via the Thai Meteorological Department web site (http://www.tmd.go.th/)

3. RESULTS AND DISCUSSIONS

3.1 Bottom topography

The average depths from all survey periods at each station were plotted and are shown in **Fig.5**. **Table 1** shows the position and the bottom depth. The shallowest is in Ao Pathew area.

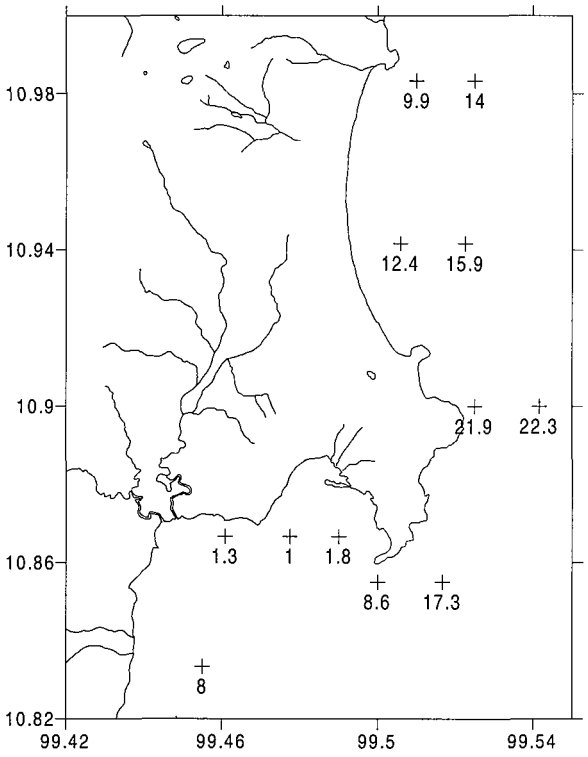

Figure 5 Bottom topography of the survey area

Table1. Position and bottom depth (m) of each station.

St. no.	Latitude (N)	Longitude (E)	Bottom depth (m) , mean ± sd
1	10_50.00	99_27.30	7.96 ± 1.32
2	10_52.00	99_27.65	1.26 ± 0.42
3	10_52.00	99_28.65	1.01 ± 0.40
4	10_52.00	99_29.40	1.78 ± 0.52
5	10_51.30	99_30.00	8.60 ± 1.28
6	10_51.30	99_31.00	17.27 ± 2.21
7	10_54.00	99_31.50	21.92 ± 1.66
8	10_54.00	99_32.80	22.29 ± 2.37
9	10_56.50	99_30.35	12.43 ± 1.16
10	10_56.50	99_31.35	15.93 ± 1.28
11	10_59.00	99_30.60	9.92 ± 1.62
12	10_59.00	99_31.50	14.01 ± 1.21

3.2 Water quality

Physical parameters

Results from the survey in February 2002 show that the physical parameters between the surface, mid-depth and the bottom indicated little difference, which shows that the study area is a well-mixed system. As a result, the physical parameter data collections for mid-depth and bottom water were then discontinued after February 2002 (**Table 2**).

Table 2 Physical data from the surface and mid-depth during the February observations.

St. no.	Temperature (C)		Salinity (ppt)		pH		Do (mg/l)	
	Surface	mid-depth	Surface	mid-depth	Surface	mid-depth	Surface	mid-depth
1	28.45	27.78	29.73	30.12	7.93	7.96	6.26	5.96
5	27.75	27.78	30.30	30.79	7.99	7.99	6.02	6.10
6	27.76	27.38	30.73	31.74	8.00	8.14	6.07	6.39
7	27.81	27.13	30.72	31.75	8.14	8.11	6.12	5.41
8	27.69	27.52	30.73	31.69	8.05	8.10	6.14	6.60
9	27.16	26.87	31.97	31.97	8.12	8.07	5.66	5.67
10	27.56	26.85	31.34	31.99	8.08	8.08	5.48	5.52
11	27.75	26.93	31.88	32.00	8.10	8.10	5.56	5.51
12	27.26	26.95	31.69	31.77	8.15	8.11	5.75	5.73

Water Temperature

The mean surface temperature for the Pakklong coastal waters from January to October was approximately 29.39 °C at all sampling sites. The lowest temperature was observed during February ranging from 27.16-29.34 °C. At only two stations in the shallow area, the temperature were higher than 29 °C. The warmest surface water temperature was recorded during April with ranging from 29.9 to 34.82 °C. The extreme difference between the temperature at station 3 (34.82 °C) and the others may be because of the very shallow depth of that station. In general, there was little variation among stations during any particular month (see **Fig. 6a**).

Salinity

Salinity values measured during the study are displayed in **Fig. 6b**. The low saline area was in the area of Ao Pathew during the high rainfall month: January and October with a salinity range of 29.19 to 30.16 ppt. In October, low salinity areas were observed both in the Ao Pathew and at the coast of Bang Boet (st. 9,10,11 and 12). This could be because of the influence of fresh water from a small canal nearby. In the summer period: April, June, July and August the salinity at all stations showed little variation and ranged from 31.35 to 33.54 ppt. Large variations in salinity between each station were observed between February and October.

Dissolved oxygen

The study area has wide-ranging levels of dissolved oxygen from 4.25 to 7.27 mg/l (see **Fig 6c**). These ranges are higher than the minimum limit specified for coastal water quality for aquaculture by the Pollution Control Department, Ministry of Natural Resources and Environment, Thailand. The standard should not be less than 4 mg/l. While a concentration of 5 mg/l DO is recommended for optimum fish health. If the other parameters are considered suitable for the fish, when the DO concentrations drop below 2 mg/l, fish are severely stressed and when concentrations fall below 1 mg/l they begin to die (Francis-Floyd, 1997). These DO concentration values may be a little different for each fish species and size.

The average dissolved oxygen at each station in Ao Pathew (stations 1 to 4) were slightly higher than at other stations. As the study area is an open system, good circulation was observed from the current measurements. Therefore, the concentration of dissolved oxygen is high all through the year. However, for unknown reasons, the dissolved oxygen at stations 4 and 10 in March and station 5 in October indicated extremely low dissolved oxygen concentrations compared to other nearby stations (lower than 4.75 mg/l).

pH

The pH at all stations during the survey period was between 7.93 to 8.67. In general, the pH value shows little variation. Only during June and October the pH pattern showed some variation among the group of stations (see **Fig.6d**).

Transparency

This parameter indicates the amount of light that penetrates the water column. An increased transparency result is more light penetration. It is important for organisms relying on photosynthesis like phytoplankton.

The transparency in this area shows a positive relationship with the bottom depth (**Fig.7**). The lowest transparency areas were in Ao Pathew. Its transparency was high nearly reaching the bottom in dry season (**Fig.8**).

Total suspended solids (TSS)

A measure of total suspended solids not only indicates the ability of light penetration in the water column, it can also indicate heavy storm water runoff and land induced disturbing activity.

Stations in Ao Pathew showed little variation of TSS through the whole survey period (see **Fig. 9**). Outside the bay, the near shore station shows high TSS in the high total rainfall months (April and August). While in the low rainfall months like in February, the TSS near shore and away from shore showed little variation. This suggests that the sediment load from nearby fresh water outflow is the main suspended solid source of Pathew bay throughout the whole year and for outside the ay stations during the rainy season. In the dry season, the other sources would play more important role in the area.

Current speed and direction

Observations of current were made at about 1 meter below the surface for 10 minutes at

each station. The current meter recorded speed and direction every second. The dominant direction and speed data were averaged then plotted as shown in **Fig.10**. The current meter was not available for the January to March survey period thus, current data starts from April 2002.

In general, the current direction was south and southwestward. Strong current speed was observed during June. The average current speed was 0.09 m/s.

Since the current direction and speed were not recorded all the year round, the following information from fisherman can give some idea. They report that in Pathew bay, the current direction was northeastward during the Southwest monsoon season and southwestward during the Northeast monsoon season. Thus, the source of water in Pathew bay comes from both the southern and northern part of the area.

Chemical parameters

Nitrate

Nitrate is a primary plant nutrients. It is essential for phytoplankton. However, above a certain level, nitrate concentration can present a problem.

Nitrate concentration of stations 1 and 12 in June and station 6 in August were in the high range concentration among the stations sampled. The reasons for this are unknown. In general the concentration of nitrate in the study area was low if compared to other areas. For example, the range of nitrate concentration in Pattani bay in 1992 was 0.020-0.117 ppm while in this study it was between 0.0009-0.1006 ppm. As illustrated in **Fig.11a**, there did not appear to be any clear seasonal pattern for nitrate.

Phosphate

Phosphate in seawater comes from several sources including water from runoff, cleaning operations, water treatment plants, sewage disposal plants and the natural decay of plants and animals. Although phosphate is essential for plant growth, too much phosphate often results in excessive growth of aquatic plants and eutrophication of the coastal waters.

Phosphate concentrations seem to have little variation among the stations in the same period, but show large variations between each month. Only in March, phosphate concentrations in Pathew bay were lower by about half of those of the outside stations (see **Fig.11b**).

As phosphate concentration was high in the low total rainfall period (February and March) thus, phosphate load from runoff was not an important source for this area.

Silicate

The source of silicate is usually natural rock thus freshwater contains higher concentrations. Silicate is a major nutrient for diatoms and may become a limiting nutrient during diatom blooms.

Data indicates that silicate varies from month to month more than among each station (Fig.11c). June was considered as the highest silicate concentration month with an average concentration at 36.61 µg/l, while the average value of the other months was 11.28 µg/l.

Biological parameters

Chlorophyll-a

Chlorophyll-a concentration is important for the baseline survey as it indicates an abundance of phytoplankton, which is a food for several marine species. High chlorophyll-a can indicate the presence of an algal bloom.

Highest average chlorophyll-a concentration was observed in August (see **Fig.12**). For comparison, in the intensive shrimp farms in Thailand, the range of chlorophyll-a was between 20-250 mg/m^3. In this area, the range of chlorophyll-a was between 0.068 and 11.102 mg/m^3. It is lower than the average chlorophyll-a concentration in the green mussel culture area of Thailand, which is between 6.5 and 25.18 mg/m^3. Only at stations no. 2 and 9 in March and station no. 5 in October the chlorophyll-a concentrations exceeded 6.5 mg/m^3.

Several papers indicate that the concentration of chlorophyll–a is in response to the concentration of dissolved inorganic material (nitrite, nitrate, phosphate or silicate). Gowen et al. (1992) found a linear relationship between phytoplankton chlorophyll and dissolved inorganic nitrate plus nitrite. In this study, the phytoplankton chlorophyll didn't show a relationship with any dissolved inorganic material (**Fig.13**). Therefore, dissolved inorganic materials were not limiting growth of phytoplankton in this area. The other factors like zooplankton grazing was not included in this study.

Total Coliform bacteria

The total Coliform bacteria load in the study area was between 0 to 240 MPN/100ml (**Table 3**). This is below the limit set by the Pollution Control Department, Ministry of Natural Resources and Environment, Thailand, which postulates not more than 1000 MPN/100ml as a standard water quality for coastal aquaculture.

Table 3 Total coliform bacteria (MPN/100ml)

St.no.	January	February	March	April	June	August	October
1	0	0	0	0	0.091	0	0
2	0	0	0	3.6	0	0	0
3	240	0	0	7.3	0	0	0
4	64	93	6.2	0	0	0	0
5	-	240	240	7.3	0	0	0
6	-	23	240	0	0	0	0
7	-	0	0	0	0	0	0
8	-	0	0	11	0	0	0
9	-	23	0	0	0.062	0	0
10	-	23	0	0	0	0	0
11	-	23	-	0	0	0	0
12	-	0	-	3.6	0	3.6	0

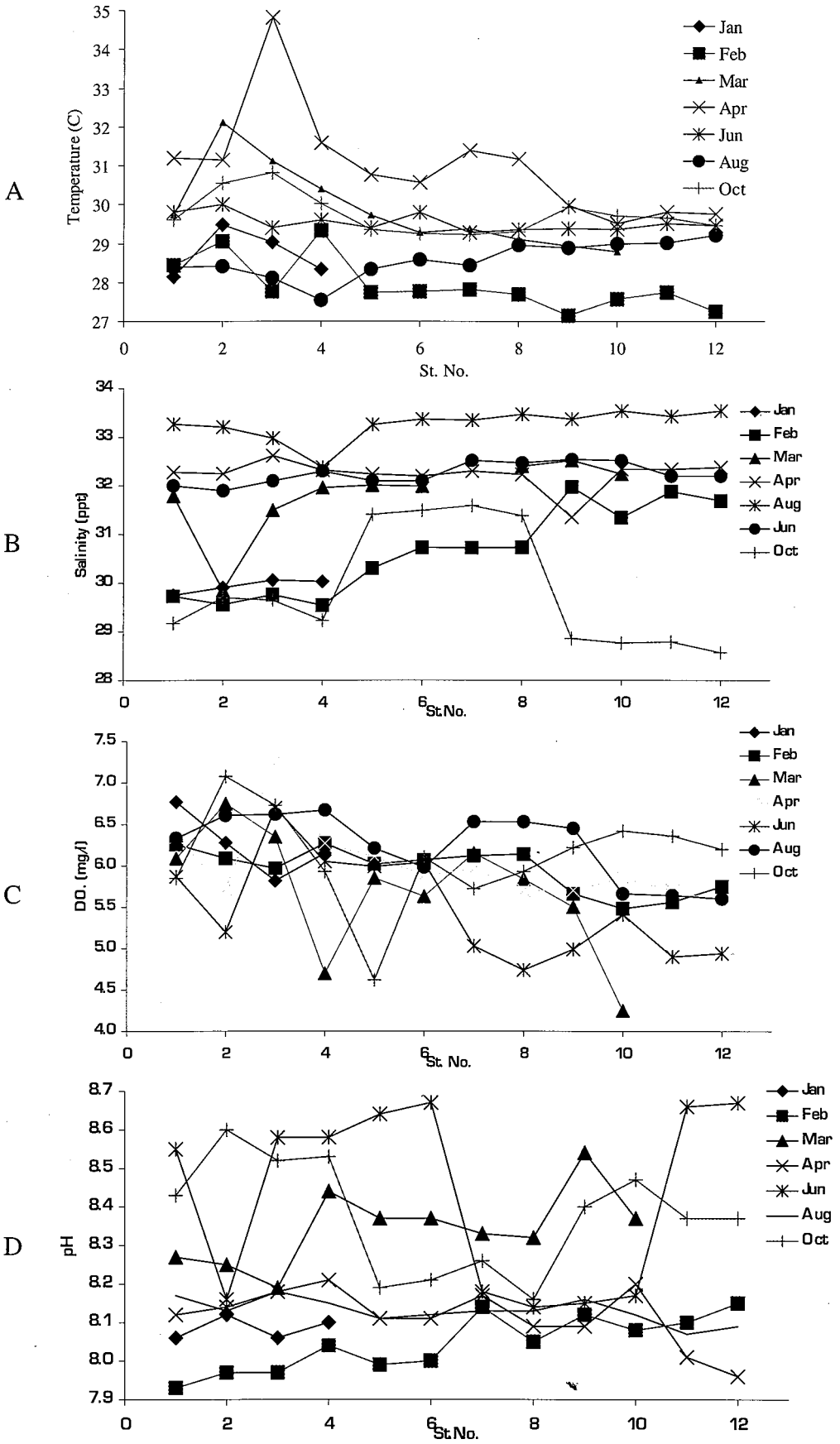

Figure 6a to 6d. Plots of temperature, salinity, dissolved oxygen and pH respectively of all station and all survey periods

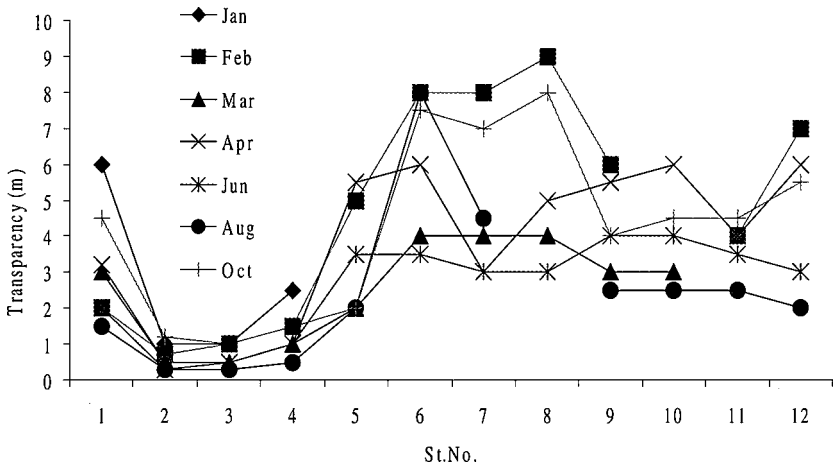

Figure 7 Transparency depth (m) in survey period.

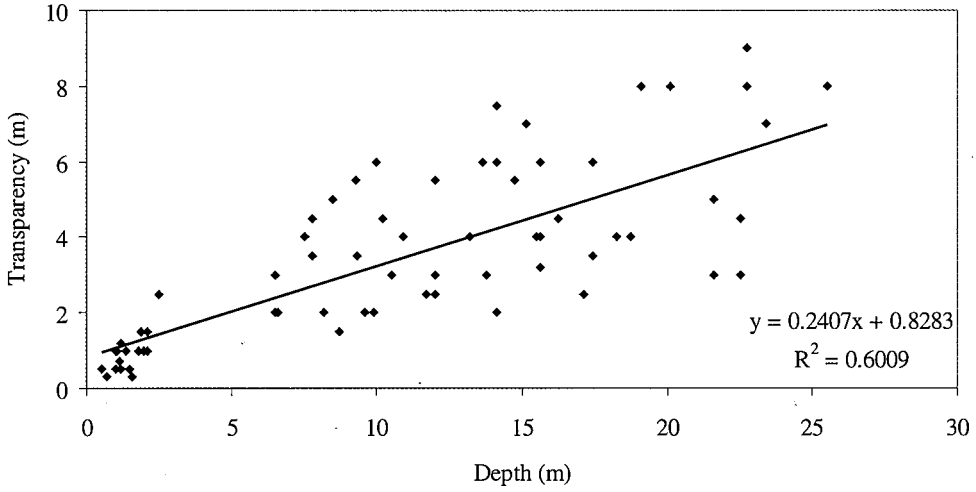

Figure 8 Relationship between transparency depth (m) and bottom depth (m)

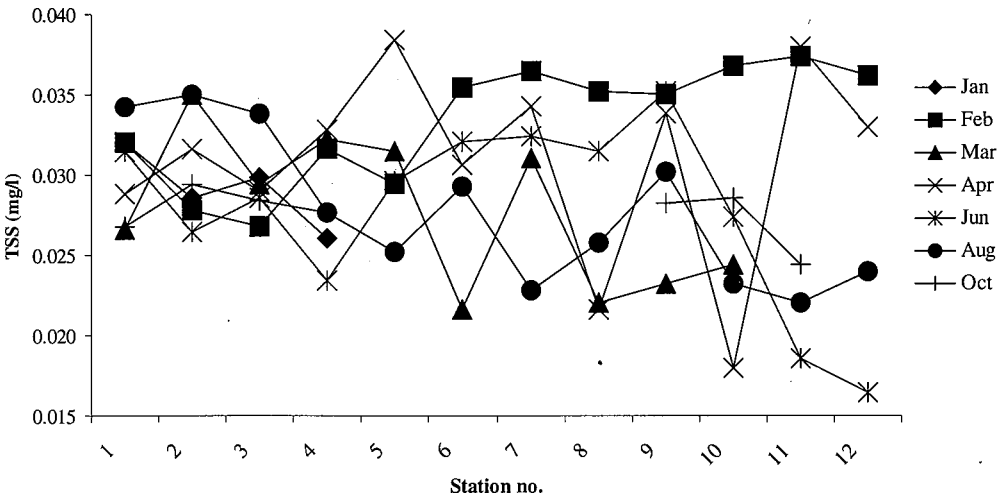

Figure 9 TSS (mg/l) from survey station.

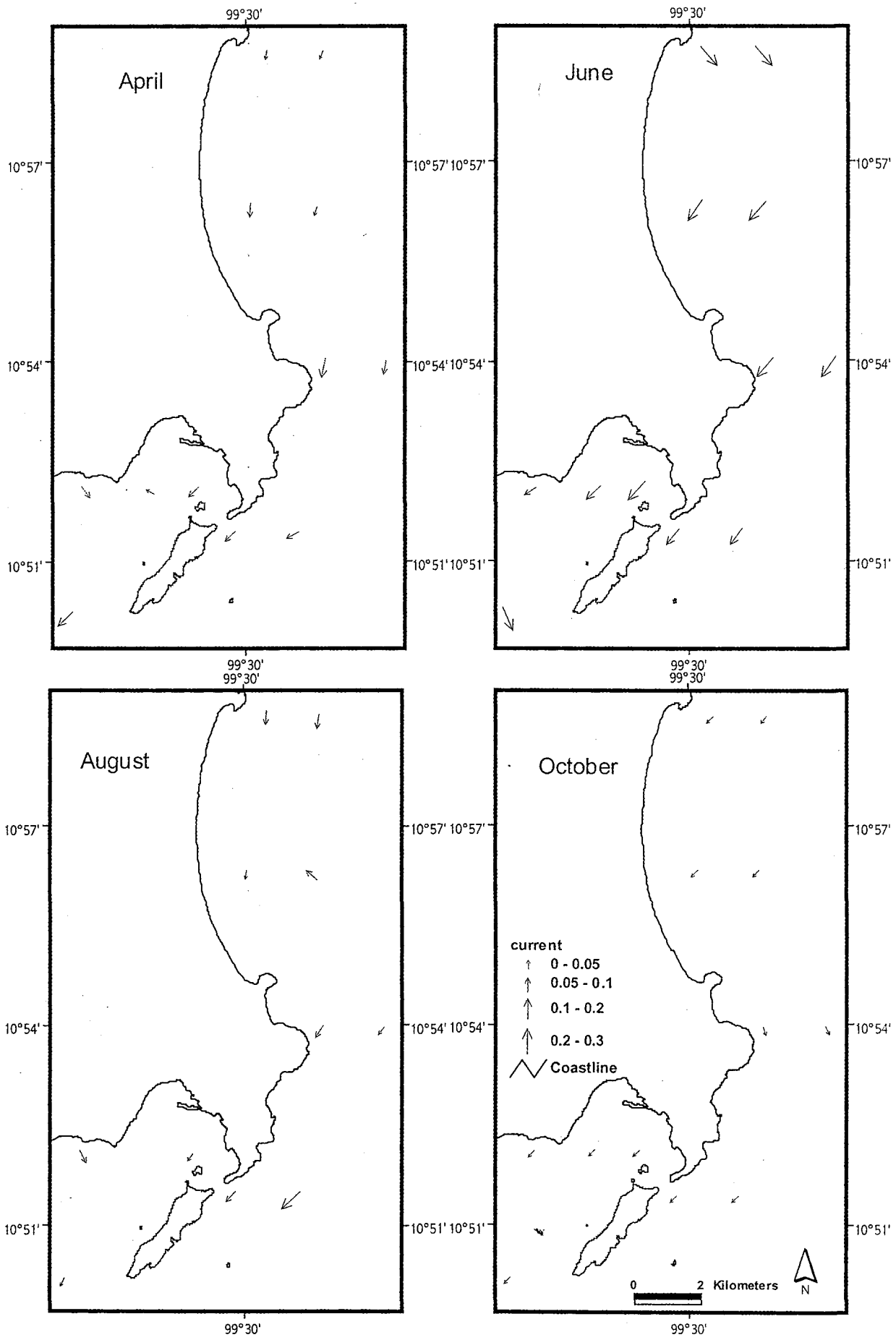

Figure.10 Current speed and direction during the survey period

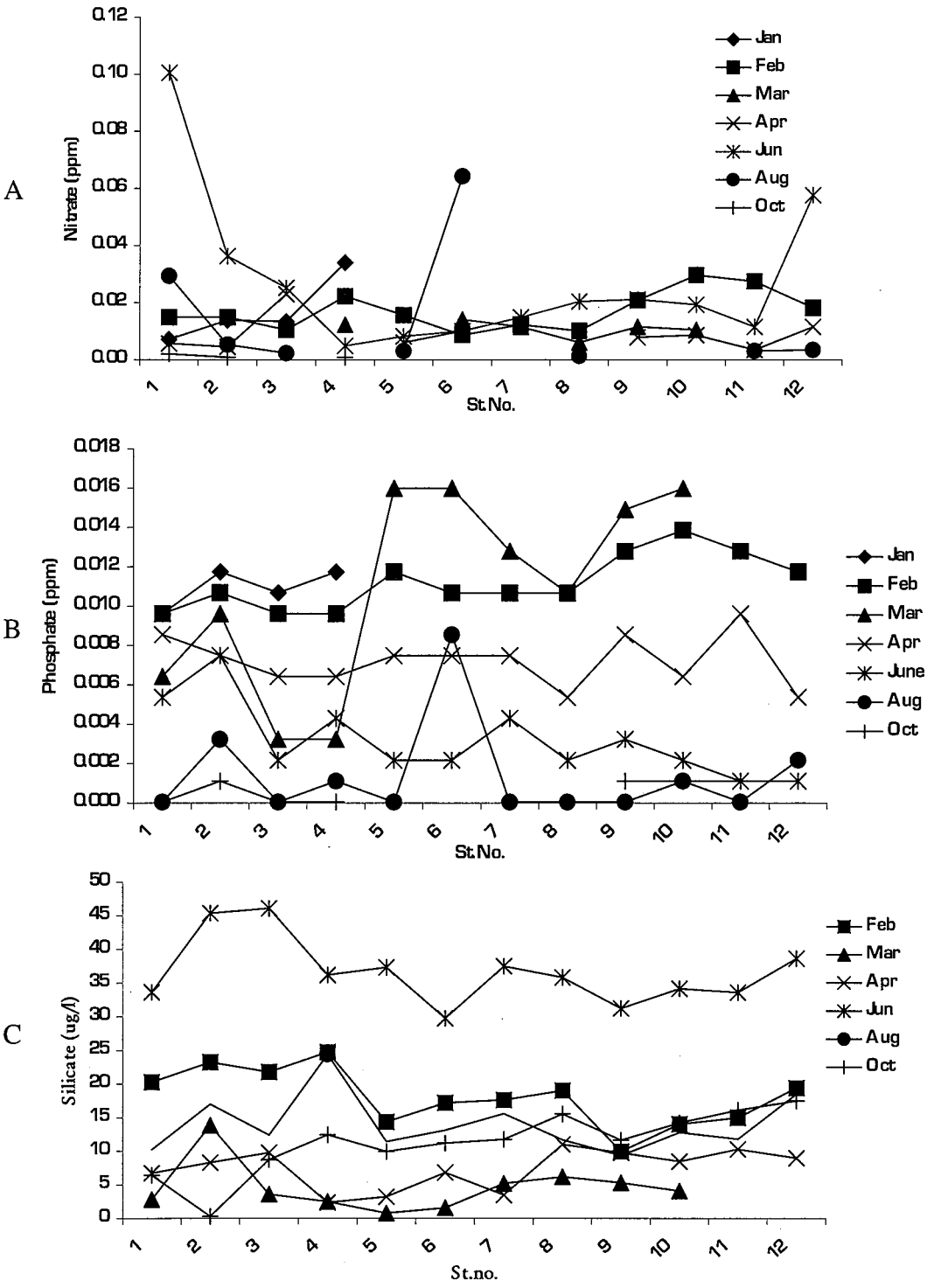

Figure 11a to 11c. Plot of the concentration of nitrate, phosphate in ppm and silicate in ug/l.

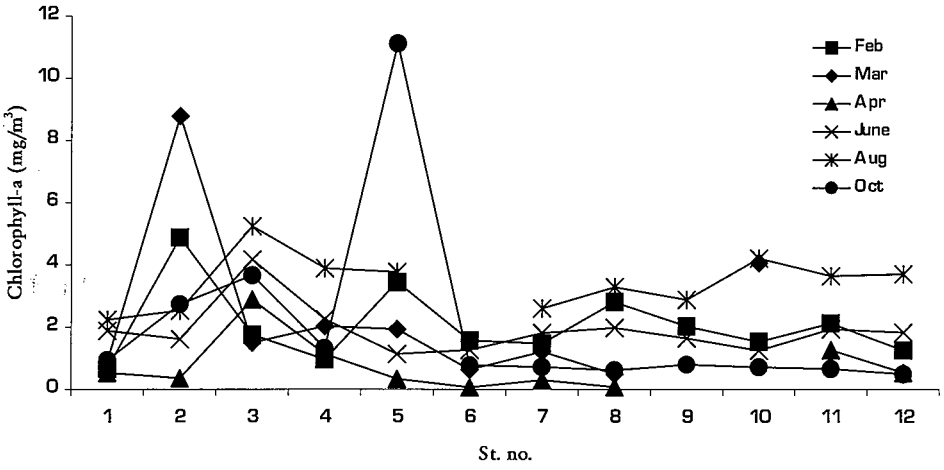

Figure.12 Concentration of chlorophyll-a (mg/m^3)

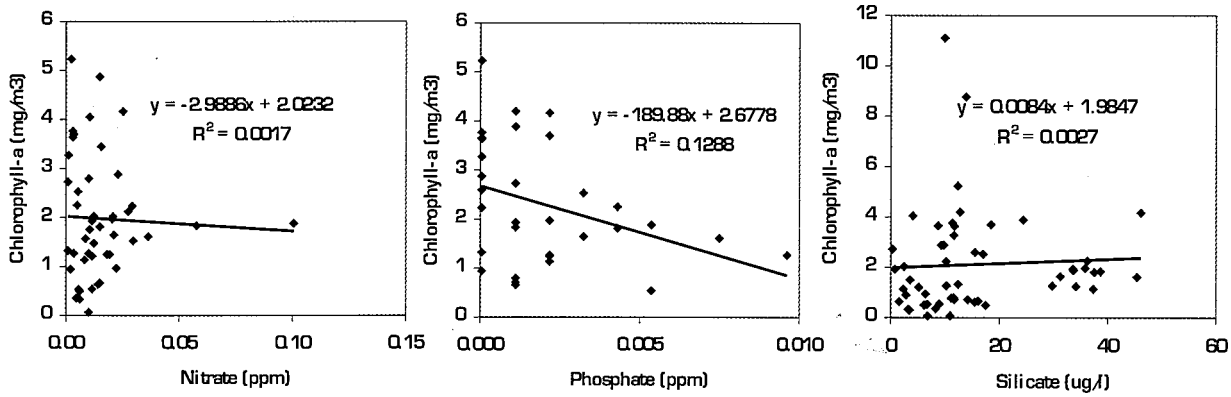

Figure 13 Plot between nutrient and chlorophyll-a (mg/m^3).

3.3 Air temperature and rainfall

Air temperature and rainfall was also included in the baseline surveys as they directly influence water temperature, salinity and other water quality parameters. Moreover, fishermen can observe these for themselves.

Thai Meteorological Department provided the climatic data for the year 2002 for this study. From **Fig.14**, the highest temperature was in April with a temperature range from 24.3 to 34.1 °C, while the lowest temperature was in January with temperatures ranging from 21.7 to 30.6 °C. High rainfall was observed in May, August and September (see **Fig.15**). The minimum rainfall level was in February.

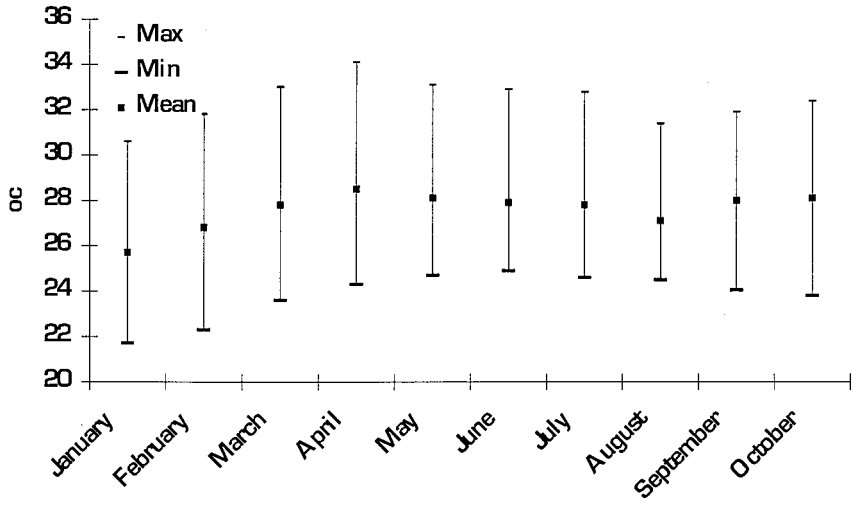

Figure.14 Plot of air temperature (°c) during the survey period

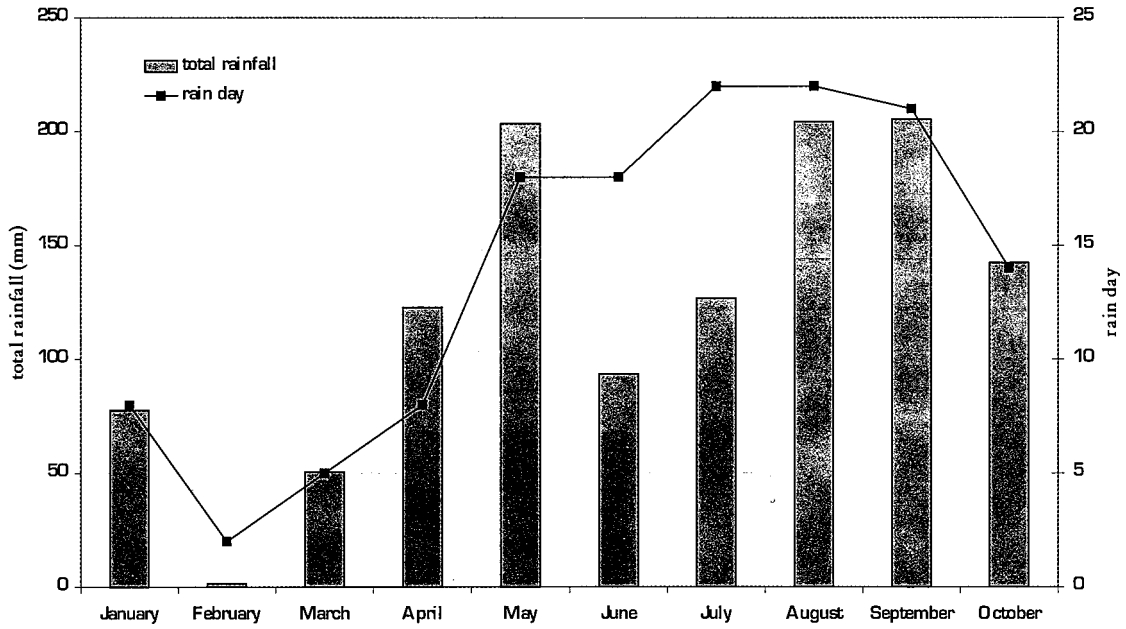

Figure 15. Plot of total rainfall and rain day during the survey period

3.4 Implications of baseline data to aquaculture in the area

There are several aquaculture activities in the study area composed of cage culture (see **Fig.16a and 16b**), mussel culture (see **Fig.17**), shrimp farms, etc. Almost all of the aquaculture activity at sea in the study area was in Pathew bay. This is because of strong winds and currents during the peaks of each monsoon season.

From the mapping survey on February 2002 (Laongmanee and Arnuparpboon,2002), there were 15 cage cultures operating in Pathew bay. Grouper (*Epinephelus tauvina* and *E. bleekeri*) and giant seaperch (*Lates calcarifer*) being the cultured species.

There were only four green mussel (*Perna viridis*) culture activities during February 2002. They used bamboo poles for the settlement of spat. Some of them take advantage of the bamboo poles to act as a fence for fish cage areas and as poles for green mussel.

In the Pakklong sub-district, there were 31 intensive shrimp farms and there were some extensive shrimp farms in the mangrove areas, which cannot be included in the survey of the number of farms. The fishermen blame the rapid expansion of intensive shrimp farms during the last four years as the reason for the poor water quality in Pathew Bay, causing a decreasing catch and a reduction of the mangrove areas.

In this study, the monitoring of the quality of the outflow water from shrimp farm was not included. Further studies should consider this factor as it is one of the sources of high nutrient and the other chemical concentrations.

As coastal aquaculture is one of the activities that the LBCRM-PD project plans to use as a tool in fisheries management, therefore the kind and species suitable for this area in term of optimum in hydrographic parameters should be investigated. Although, some fishermen have already started aquaculture in the area the information for deciding the cultured species is determined only by the market. The species cultured in almost all Thailand's coastal area are grouper (*Epinephelus tauvina* and *E. bleekeri*), giant seaperch (*Lates calcarifer*), green mussel (*Perna viridis*) and blood cockle (*Anadara granosa*). The optimum parameters for each species will be compared with the marine environmental baseline data. **Table 4** shows suitable conditions for each species.

Table 4 Range of parameters suitable for each species

Parameter	Grouper	Giant seaperch	Green mussel	Blood cockle
Temperature (°C)	26-33 (5)	<33 (4)	24-33.5 (2)	21-33 (3)
Salinity (ppt)	20-32 (1)	both fresh and	13-32 (1)	13-32 (1)
		saline water		
Dissolved oxygen (mg/l)	5 (1)	5 (1)	3.8-8 (2)	3.8-8 (2)
pH	6.2-8.5 (1)	6.2-8.5 (1)	6.8-9.3 (2)	6.8-9.3 (2)
Transparency (m)	-	-	0.1-1.5 (2)	0.2-1.8 (2)
Chlorophyll (mg/l)	-	-	6.5-25.1 (2)	6.5-25.1 (2)

Remarks: (1) Tookwinas, 1985
(2) Tookwinas *et.al*, 1985
(3) Junkyamphin, 1996
(4) Department of Pollution Control, 2002
(5) Ruangpanit and Boonlippatanon, 1993

Because of the strong winds and currents in this area during the monsoon season, only inside Pathew bay are conditions suitable for aquaculture. Thus, only the data from stations 1 to 4 will be considered for determining suitable species for culturing.

Grouper

Grouper is the most attractive species for culture, because of its high market value. In general, water quality in Pathew bay is good enough for grouper cage culture. However, in the summer season, special care is needed as seen in the high water temperatures at station no.3 in April and the low dissolved oxygen in station no. 4 in March, which are outside of the optimum range for grouper.

Giant seaperch

The optimum water quality values for giant seaperch are wider than for grouper, especially in salinity. The recommendation is similar to grouper in that the water quality in Pathew bay is suitable for giant seaperch culture with great care in the summer season.

Molluscs (Green mussel and Blood cockle)

Optimum environmental condition for both green mussel and blood cockle are similar. Their requirements are fitted to the water qualities in Pathew bay with special care in the summer season. The concentration of chlorophyll-a is rather lower than the optimum requirement, therefore the growth rate of molluscs in this area may be lower than in the other culture areas. Mollusc culture was cited by Tookwinas and Youngvanisset, 1998 as a tool for coastal zone management. It is the most suitable for small-scale fishermen for several reasons including:

- Can be practiced by traditional and semi-traditional methods.
- Doesn't have costs for feeding
- Seed is available naturally
- High demand in the local market

In the study area, mullusc culture is also one choice of management tool. It can remove phytoplankton, which can be higher than natural because of high nutrients from the feces and residues of feed from cage culture and shrimp farms.

Figure 16a Cage culture in Pathew bay

Figure 16b Cage culture in Pathew bay

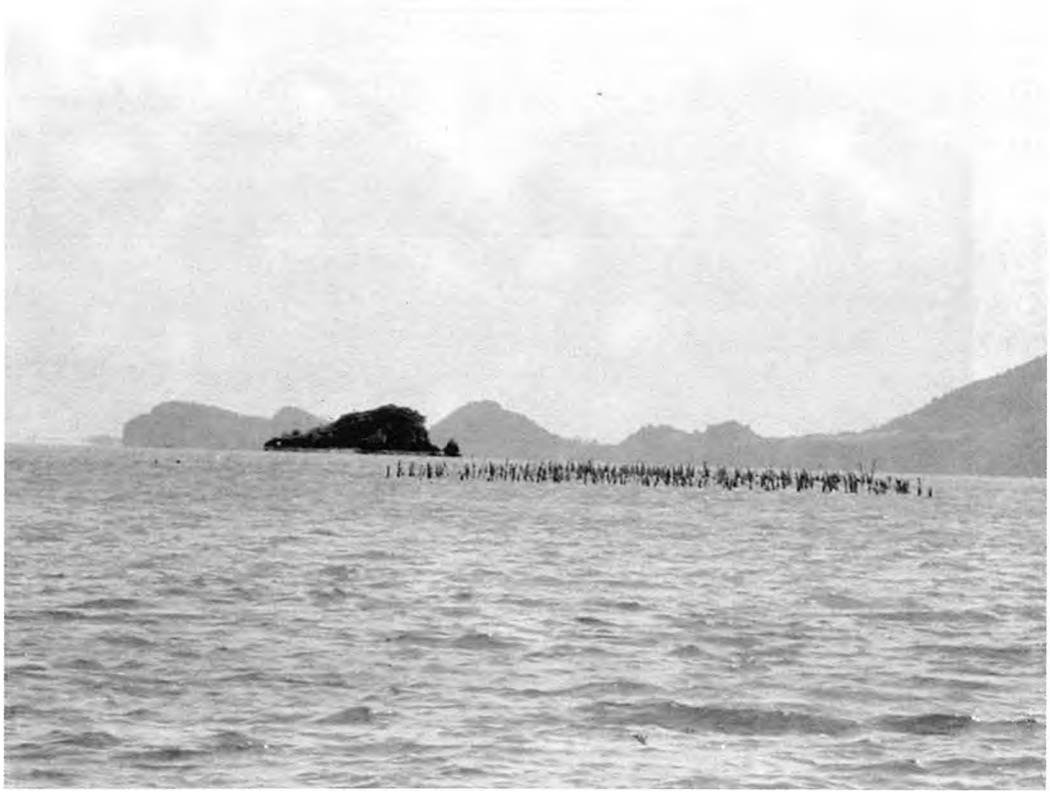

Figure 17 Green mussel culture in Pathew bay

3.5 Suggestions for a future monitoring program

1. Frequency of surveying

For calculating a flushing time of the bay, tidal current was assumed as only one current type that influences Pathew bay. An estimated flushing time of the bay can be calculated from the high water volume and the tidal volume (GESAMP, 1996). The high water area of Pathew bay is 4.75 km2. The average depth of water in the bay is 4.2 m (the average depth of stations nos.1 to 5) The average tidal amplitude is 1.2 m.

Therefore the high water volume = high water area x average depth
$= 4.75 \times 10^6 . \times 4.2$
$= 19.95 \times 10^6$

Tidal volume = high water area x tidal amplitude
$= 4.75 \times 10^6 \times 1.2$

It would take about 3.5 tides to replace the water of the bay. Pathew bay is a diurnal tidal area. Therefore, the bay is flushed every three and a half-days.

The growth pattern of tropical phytoplankton is very rapid with a daily average generation time estimated at 6.5 hours (Sheldon, 1984). Therefore the three and a half-days flushing time is long enough for the phytoplankton life cycle. The nutrient enrichment in Pathew bay can occur. Because, phytoplankton cannot remain in the bay to utilize the nutrient and can accumulate their biomass in the bay. However, data of nutrient and chlorophyll-a concentration from the baseline survey shows that the concentration of these parameters in Pathew bay is still lower than the other culture areas. This means that the effect of nutrient released from the farms is low.

Dissolved oxygen and temperature were out of the optimum range in summer. Therefore, in summer a monitoring survey is needed every month, while in the other seasons a two-monthly interval would be sufficient.

2. Number of stations

The most necessary area for monitoring is in the Pathew bay, while outside the bay is needed as a source of water and as a reference station.

Information from current direction and current speed shows that, the source of water in Pathew bay comes from both the southern and northern parts of the area. Therefore, observation stations in the southern part of the area should be increased.

The number of stations in the northern part of the bay can be decreased as shown in the statistical analysis of variance for all survey parameters of stations 5 to 12 in that they do not show significant differences ($P<0.05$).

3. To monitor the water quality of the aquaculture area, a log book system recorded by the fisherman for all aquaculture activities is needed. Information in the log book like the number of fish, size of fish, amount of food fed, any irregular fish behavior can help to analyze not only water quality but also fish disease.

4. The methodology for measuring current direction and current speed should be improved. As the data from current speed and direction doesn't give any clear picture for the current system in

the area. The twenty-four current speed and direction observations at some stations could give better information.

4. CONCLUSIONS

Generally, the water quality of the study area is suitable for coastal aquaculture. However in the summer season the shallow area in Pathew bay could have a high temperature problem. If considering the water quality, economic species in Thailand aquaculture like grouper (*Epinephelus tauvina* and *E. bleekeri*), giant seaperch (*Lates calcarifer*), green mussel (*Perna viridis*) and blood cockle (*Anadara granosa*) can be cultured in this area.

The long flushing time and slow current speed in the Pathew bay allows the accumulation of nutrient, organic material, drugs used in aquaculture, etc. Therefore, limitation of aquaculture area and numbers is needed to prevent any damages from plankton blooms or pollution when the load of aquaculture waste is over the carrying capacity of the water.

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