MARINE ENVIRONMENTS AND PHYTOPLANKTON IN THE AREA OF THE LOCALLY BASED COASTAL FISHERIES MANAGEMENT PROJECT: PATHEW DISTRICT, CHUMPHON PROVINCE

Sumana Kajonwattanakul[1] and Chumchoke Singharachai[2]

[1]Marine and Coastal Resources Research Center, The Central Gulf of Thailand, Moo 8, Nathung, Muang, Chumphon 86000, Thailand

[2]Chumphon Marine Fisheries Development Center, Moo 8, Paknam, Muang, Chumphon, 86120, Thailand

ABSTRACT

Investigations on marine environments were carried out at 10 sampling stations in the area of the Locally-Based Coastal Fisheries Management Project, Pathew District, Chumphon Province from 2002 to 2006. The depth of the bottom of the area ranged from 3.4 to 19.3 meters. The environmental variables were measured and the data are as follows: transparency 1.2 - 4.3 meters, mean surface temperature 29.44 ± 0.47°C, salinity 31.08 - 33.53 PSU, pH 7.26 - 8.93 and dissolved oxygen 4.83 - 6.25 mg/l. Nutrients, total suspended solids (TSS) and chlorophyll a were analyzed and the results are: average nitrite 0.010 - 0.290 μg-at N/l, average nitrate 0.121 - 13.570 μg-at N/l, average ammonia 2.153 - 22.294 μg-at N/l, average orthophosphate 0.189 - 0.684 μg-at P/l, average TSS 25.18 - 53.75 mg/l. The biological index used was the average chlorophyll a at 0.116 - 2.201 mg/m^3. Phytoplankton was investigated and 66 genera in 5 divisions were identified. Diatom was the most common. High density of phytoplankton was recorded in June 2004 and September 2005. In June 2004 the dominant species were Ditylum sole from 2.06×10^4 to 1.79×10^5 cells/l while in September 2005 Chaetoceros spp. was more pronounced from 3.45×10^5 to 1.79×10^6 cells/l. As experienced, this density level may cause the red-tide phenomena. Such phenomenon was observed when Noctiluca scintillans which almost entirely makes up the red tide, was dominant at Station 9 in August 2004.

The water quality in the study area is suitable for coastal aquaculture. The physical, chemical and biological indices of Pathew Bay showed that the Bay is at risk from phytoplankton blooms and accumulation of nutrients. Therefore, limitation on aquaculture in terms of area and density of fish stocks should be considered to prevent environmental damage due to plankton blooms and eutrophication when the load of aquaculture waste exceeds the carrying capacity of the Bay.

Key words: Marine environment, Phytoplankton, Locally-Based Coastal Fisheries Management Project: Pathew District, Chumphon Province

I. Introduction

A baseline survey on marine environment and phytoplankton was conducted as an activity of the Locally-based Coastal Fisheries Management Project, Pathew District (LBCRM-PD), a collaborative project between SEAFDEC/TD and Department of Fisheries (DOF). After the reorganization of the government sector in October 2004, Department of Marine and Coastal Resources (DMCR) carried out this activity since November 2004.

The purpose of LBCRM-PD project is to establish a practical framework for locally-based coastal resources management by encouraging fishers' participation, and to support the creation of alternative job opportunities in coastal fishing communities. Aquaculture is one of the alternative activities that the project plans to promote to the fishermen. However, aquaculture needs good farming management as it produces soluble inorganic and particulate wastes, which can result in organic enrichment of the local aquatic environment. In order to prevent unacceptable changes to the environment, an environmental management framework should be established to evaluate the potential impacts before any development permit is granted (Laongmanee *et al.*, 2003). Thus, marine environmental surveys need to be carried out for the duration of the project.

II. Objective

The objective of this survey is to collect data on the marine environment in order to support aquaculture activity and monitor environmental changes, including the abundance of phytoplankton, the primary productivity of food web and the biological index of the rich and abundant marine and coastal resources.

III. Materials and Methods

1. Study area

The project was planned to observe the marine environment variables along the coastal area of LBCRM-PD at 10 sampling stations from 2002 to 2006 (Fig. 1). The surveys were done onboard the R.V. Meen Niweth, a research vessel of the Chumphon Marine Fisheries Development Center of the DOF of Thailand.

2. Methods

The following activities were conducted:

2.1 Depths of all stations were measured using a Handy Echo Sounder.

2.2 Transparency was measured using Secchi disc.

2.3 The physical variables including water temperature, salinity, dissolved oxygen and pH were measured using YSI 556 MPS multi-sensor at the surface.

2.4 From 2005 to 2006, chemical and biological variables were analyzed at the Marine and Coastal Resources Research Center. The water samples were filtered through Whatman GF/C paper, diameter 47 millimeters. Chemical and biological variables including nitrite, nitrate, ammonia, orthophosphate and chlorophyll a were analyzed following the Strickland and Parsons (1972) method. Total suspended solids (TSS) were measured following the Standard Method for Examination of Water and Waste Water (APHA, AWWA and WPCF, 1980).

2.5 From 2004 to 2006, phytoplankton samples were filtered through plankton net, mesh size 22 micron, and preserved by Lugol's solution (Wongrat, 2003). Preserved samples were identified following the Davis (1955), Smith (1977), Fuguyo *et al.* (1990) and Wongrat, 2003. Phytoplankton density were measured by using Sedgewick-Rafter counting cell, volume 1 milliliter, and calculated using the following formula:

Phytoplankton density (cells/l) = (AB/C) X 1000

where, A = number of phytoplankton (cells)

B = volume of preserved samples (milliliters)

C = volume of phytoplankton samples which passed through plankton net (milliliters)

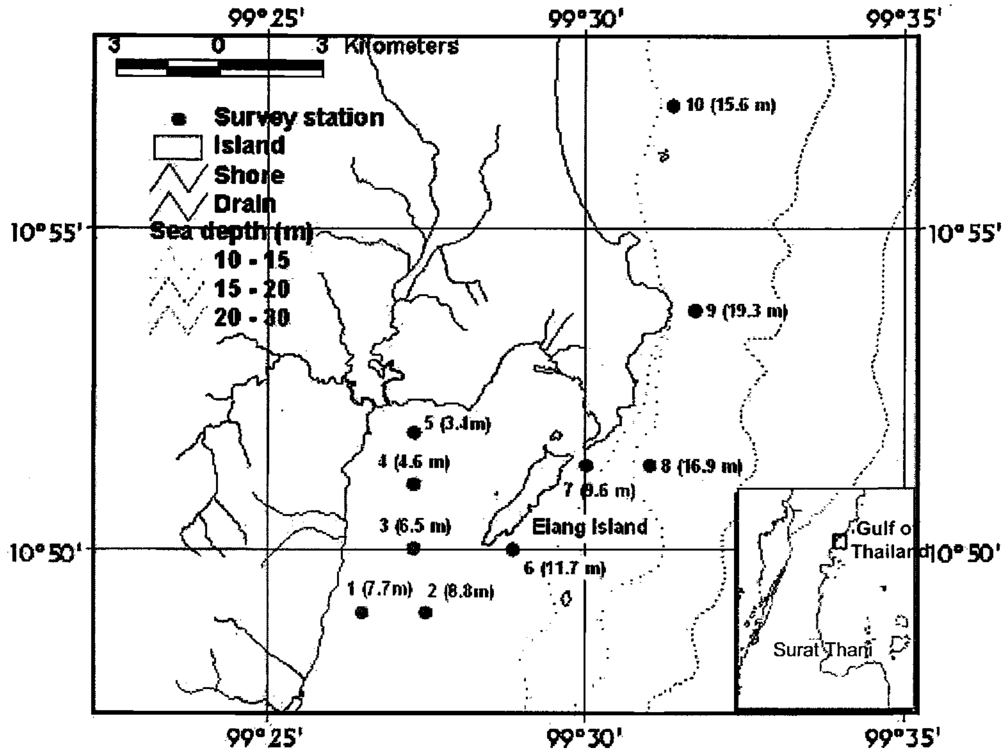

Fig. 1 Map of survey stations and bottom topography

IV. Results

1. Bottom topography

The average depths during the survey period at each station were plotted and are shown in Fig. 1. The shallowest area was located in Ao Pathew.

2. Water quality

2.1 Physical variables

Transparency

This variable indicates the amount of light that penetrates the water column. An increased in transparency results when there is more light penetration. This is important for organisms relying on photosynthesis like the phytoplankton (Laongmanee *et al.*, 2003).

The average transparency in the area shows a significant positive relationship with the bottom depths (r = 0.48, n = 136, P<0.01). The areas with the lowest transparency were in Ao Pathew from 1.2 to 2.0 meters (Fig 2).During the dry season (January to May), transparency was higher than during the wet season (June to December) (Fig 3).

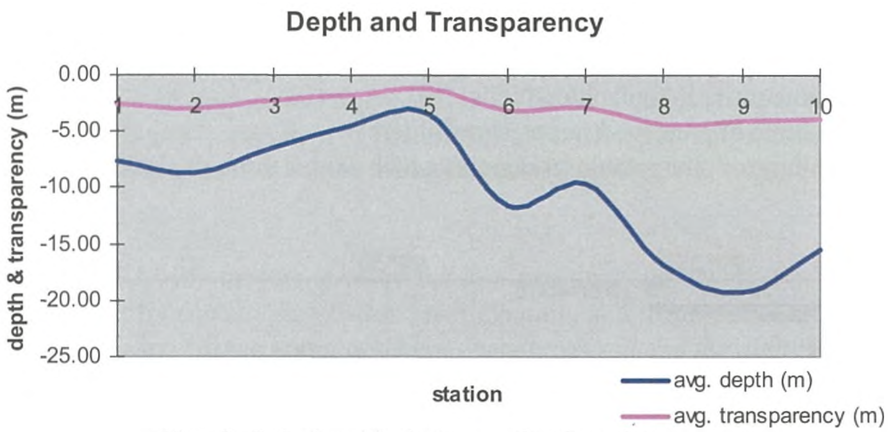

Fig. 2 Relationship between depth and transparency

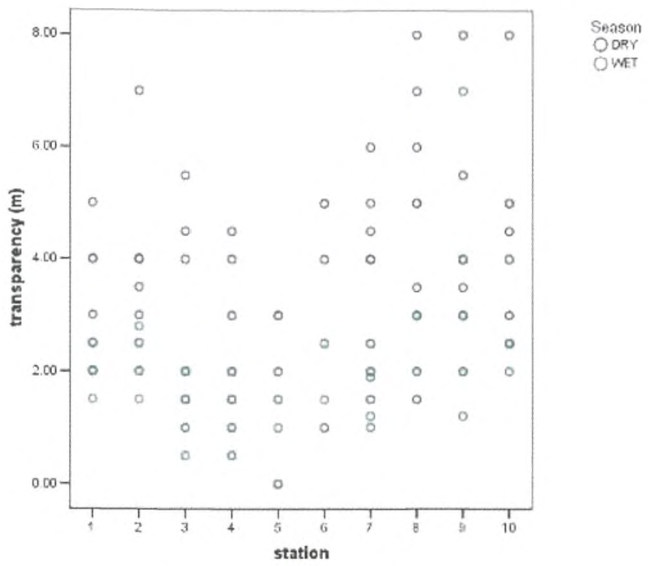

Fig. 3 Transparency in dry and wet

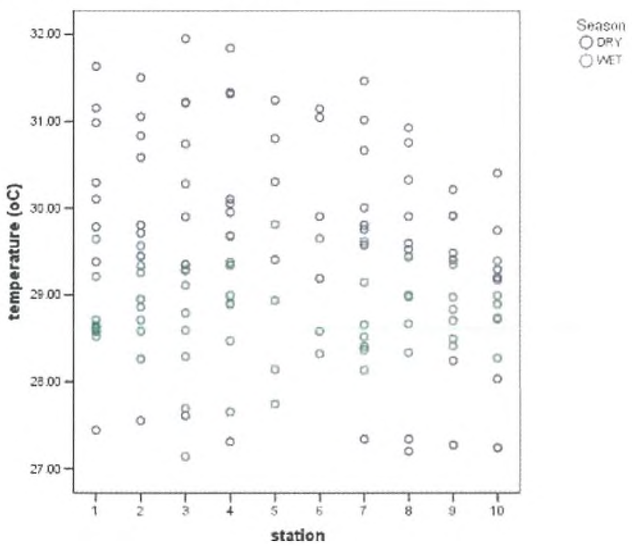

Fig. 4 Water temperature in dry and wet seasons

Water temperature

The mean surface temperature in all stations of the LBCRM-PD coastal area was 29.44 ± 0.47°C. Lowest temperatures were observed in February and August, 28.83 ± 0.22°C and 28.83 ± 1.21°C, respectively. The warmest surface temperature was recorded in April at 30.15 ± 1.55°C. Water temperature shows a significant relationship with the seasons ($r = 0.42$, $n = 136$, $P<0.01$). The temperature during the wet season is lower than during the dry season (Fig. 4).

Salinity

The salinity ranged from 31.08 to 33.53 PSU. In general, the salinity value shows little variation in each station. The salinity in wet season was higher than in the dry season (Fig 5), significant at $r = 0.54$, $n = 136$, $P<0.01$.

pH

The pH at all stations during the survey period ranged from 7.26 to 8.93. The pH values did show any difference between the dry and wet seasons (Fig 6).

Dissolved oxygen

During the survey period, dissolved oxygen ranged from 4.83 to 6.25 mg/l. The dissolved oxygen values showed a significant negative relationship with the surface temperature ($r = -0.26$, $n = 136$, $P<0.01$). This means that oxygen can be more dissolved at lower temperatures. The dissolved oxygen values did not show any difference between the seasons (Fig 7).

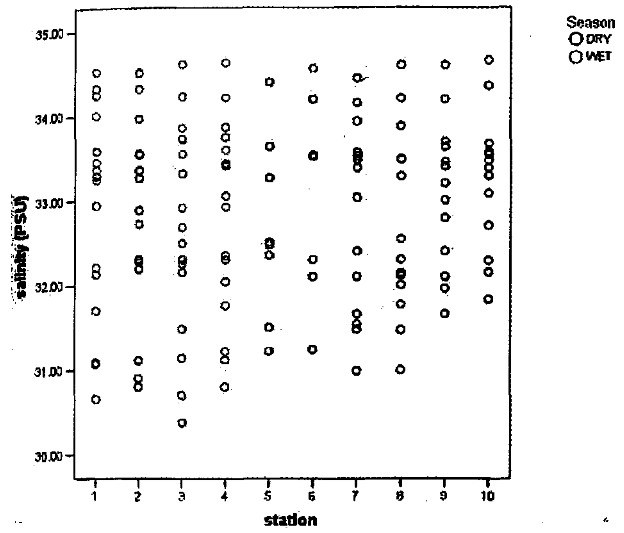

Fig. 5 Salinity in dry and wet seasons

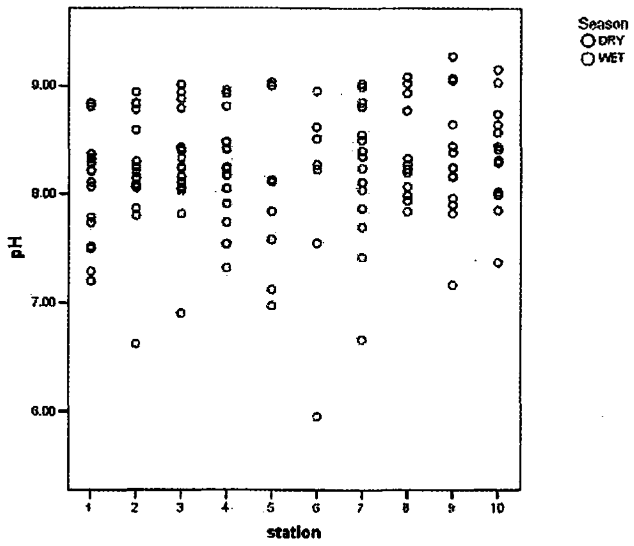

Fig. 6 pH in dry and wet seasons

Total suspended solids (TSS)
A measure of the TSS not only indicates the ability of light penetration in the water column but it can also indicate heavy storm, water runoff and land induced disturbing activity (Laongmanee *et al.*, 2003).

The TSS data showed a significant relationship with the seasons and depth ($r = 0.30$, $P<0.01$ and $r = -0.26$, $P<0.05$, respectively, $n = 74$). This means that in the wet season TSS value was higher than in dry season, and in shallow areas the value was high. The station in the area of Ao Pathew showed a TSS value higher than 110.00 mg/l in December 2005 (Fig 8).

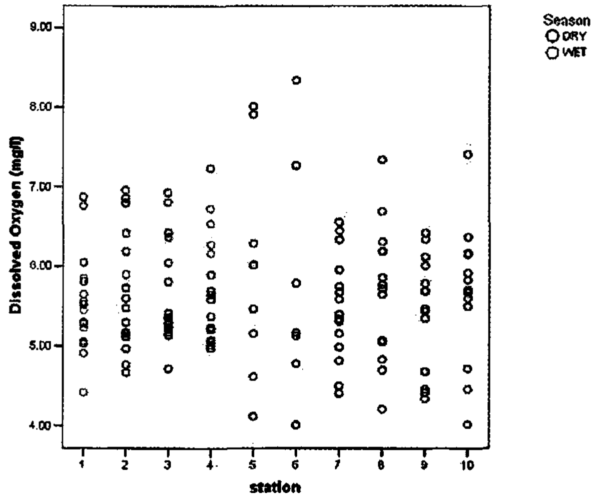

Fig. 7 Dissolved oxygen in dry and wet seasons

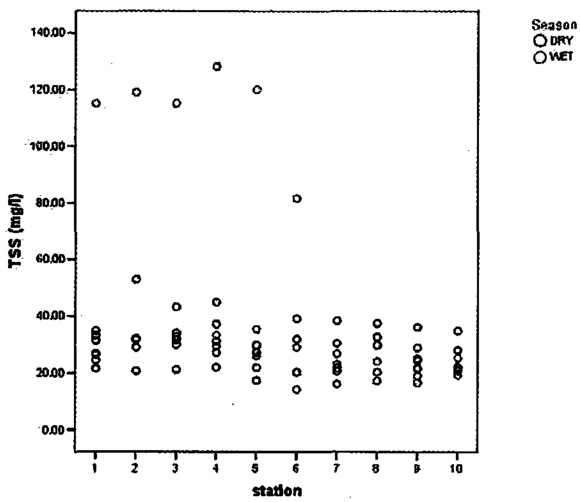

Fig. 8 TSS in dry and wet seasons

2.2 Biological variables

Chlorophyll a
Chlorophyll a is biological indicator for abundance of phytoplankton, food of some marine organisms. High chlorophyll a can indicate abundance of marine and coastal resources and the presence of phytoplankton bloom.

The area's average chlorophyll a ranged from 0.116 to 2.201 mg/m^3. The concentration of chlorophyll a did not show any difference between seasons (Fig 9). A significant relationship between chlorophyll a with nitrate and ammonia ($r = 0.39$ and 0.29, respectively, $n = 74$, $P<0.01$) was however observed.

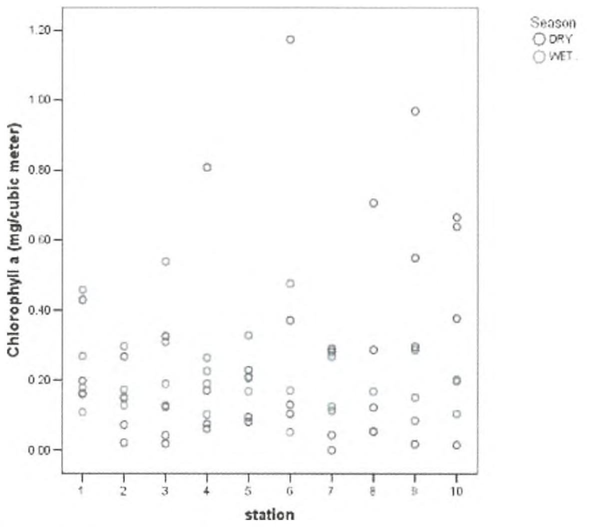

Fig. 9 Chlorophyll a in dry and wet seasons

2.3 Chemicals variables

Chemical variables in this study are nutrients, including nitrite, nitrate, ammonia and orthophosphate. These are essential for phytoplankton growth.

Nitrite

The average concentration of nitrite ranged from 0.010 to 0.290 µg-at N/l. Nitrite concentration showed significant relationship between the seasons ($r = 0.28$, $n = 74$, $P<0.01$), with the concentration higher during the wet seasons than in the dry season. The concentration of nitrite in each station in 2005 was lower than in 2006 (Fig 10).

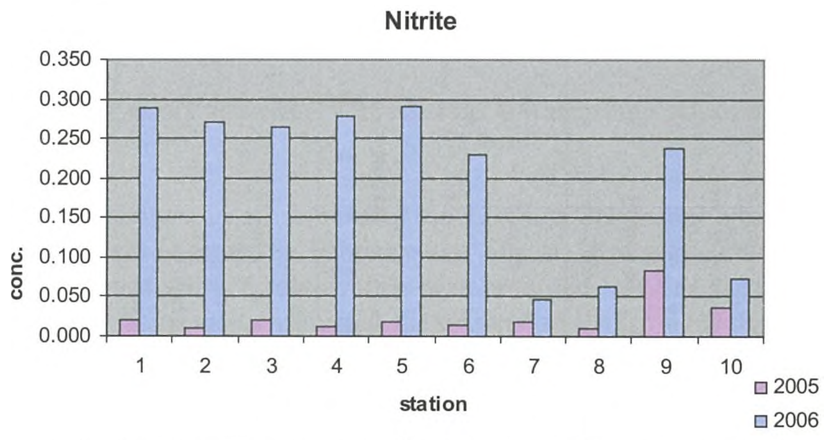

Fig. 10 Nitrite concentration in each station in 2005 and 2006

Nitrate

The average nitrate concentration ranged from 0.121 to 13.570 µg-at N/l. Nitrate concentration showed a significant relationship with pH ($r = 0.28$, $n = 74$, $P<0.05$). The concentration of nitrate in each station in 2005 was lower than in 2006, except in station 4 (Fig 10).

Ammonia

The average concentration of ammonia ranged from 2.153 to 22.294 µg-at N/l. The ammonia concentration showed a significant relationship with pH ($r = 0.30$, $n = 74$, $P<0.01$). The concentration of ammonia in each station in 2005 was lower than in 2006 (Fig 12).

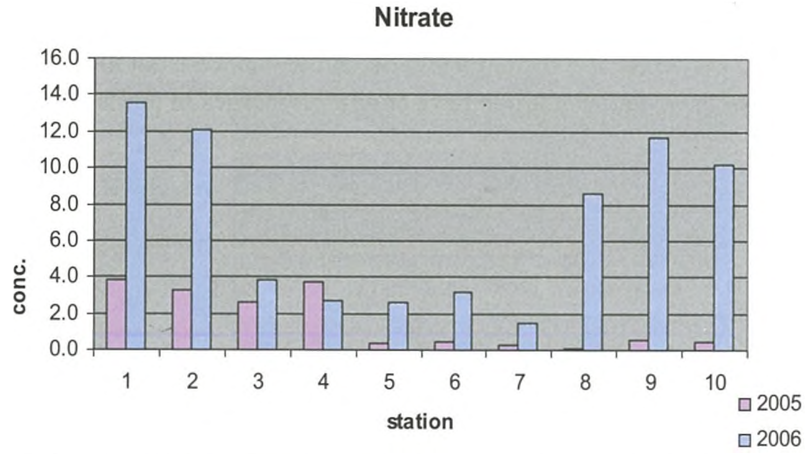

Fig. 11 Nitrate concentration in each station in 2005 and 2006

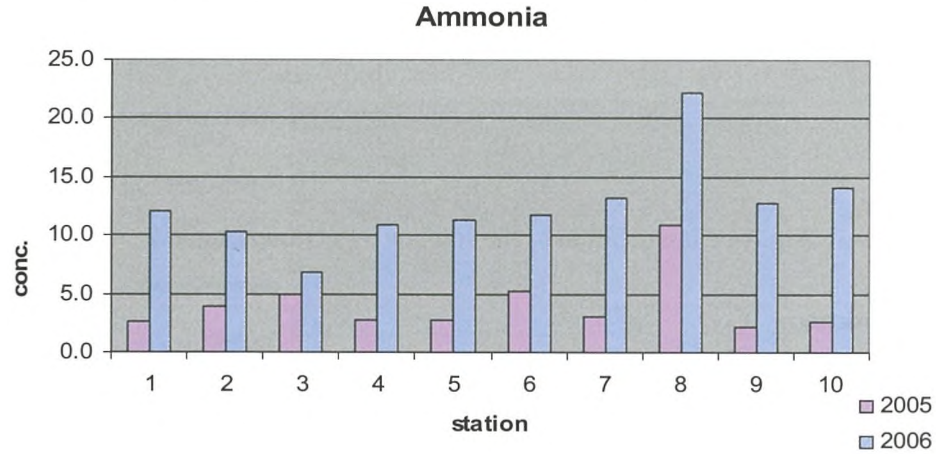

Fig. 12 Ammonia concentration in each station in 2005 and 2006

<u>Orthophosphate</u>

The average concentration of orthophosphate ranged from 0.189 to 0.684 g-at P/l. The orthophosphate concentration showed a significant relationship with ammonia ($r = 0.47$, $n = 74$, $P<0.01$). The concentration of orthophosphate in station 8 was very high, compared with those in other stations in 2006 (Fig 13).

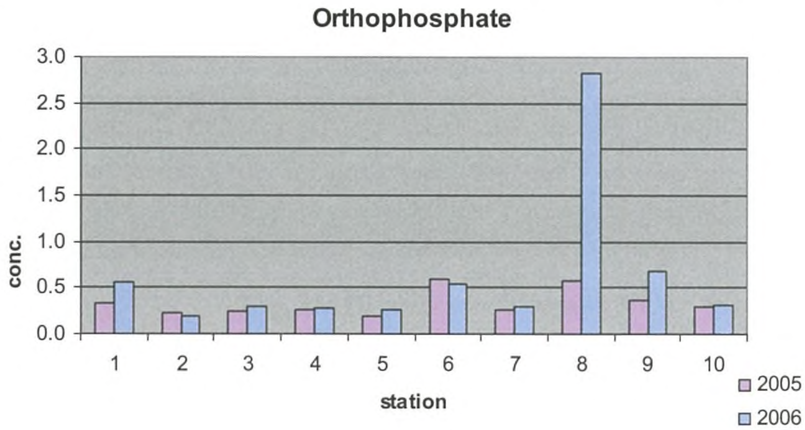

Fig. 13 Orthophosphate concentration in each station in 2005 and 2006

From the data on TSS, nutrients and chlorophyll a in 2004 until 2006, the stations were classified into 2 groups (Fig 14). Stations 1 to 5, located in Ao Pathew comprised the first group. The second group includes stations 6, 7 and 10, where the bottom depth of all stations were not more than 15 meters. The data indicate that the stations under each group have similar properties in terms of water quality.

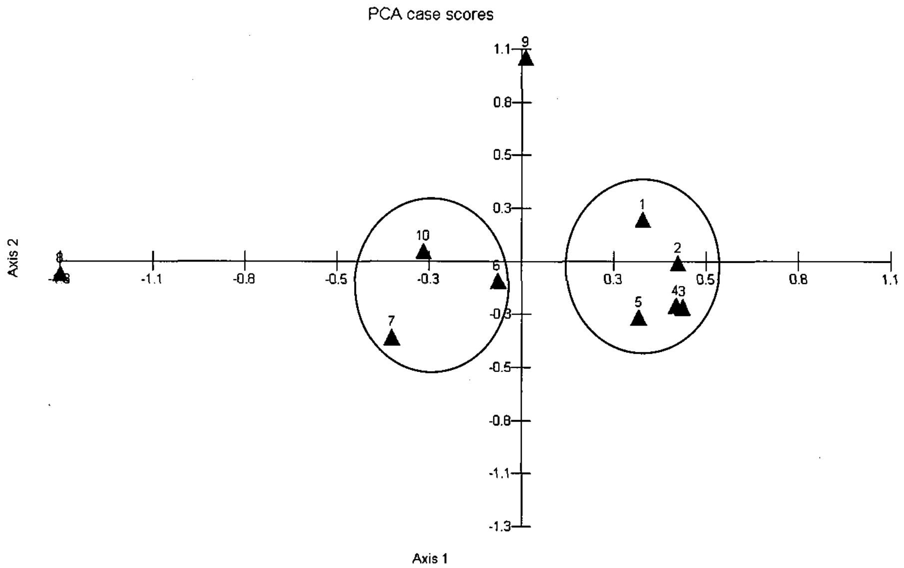

Fig. 14 Classification of the stations into Groups 1 and 2

3. Phytoplankton

Phytoplankton were investigated and 66 genera in 5 divisions were identified: (1) diatoms: 43 genera such as *Chaetoceros*, *Bacteriastrum*, *Pleurosigma*, *Nitzschia* and *Rhizosolenia* etc.; (2) dinoflagellates: 14 genera such as *Alexandrium*, *Dinophysis*, *Noctiluca*, *Ceratium* and *Protoperidinium* etc.; (3) blue green algae: 4 genera such as *Oscillatoria* and *Anabaena* etc.; (4) green algae: 3 genera such as *Closterium*, *Scenedesmus* and *Spirulina*; and (5) brown algae: 2 genera such as *Dictyocha* and *Dinobryon*. Diatom was the most common. The number of phytoplankton showed a significant relationship with the season ($r = 0.23$, $n = 74$, $P<0.05$). Phytoplankton was abundant in the wet season. The density of phytoplankton in 5 divisions is shown in Fig 15.

High density of phytoplankton was recorded in 2004 and 2005. In June 2004, the dominant species were *Ditylum sole* (Fig 16), blooming in the Ao Pathew area at stations 1 to 5 from 9.67 x 10^4 to 1.79 x 10^5 cells/l. Highest density was at station 3. While in August 2004, the dominant species were the *Chaetoceros* spp. (Fig 17) at stations 3 to 5 with from 1.25 x 10^5 to 1.44 x 10^5 cells/l. The highest density was at station 3. The dominant species in 2005 recorded in September was *Chaetoceros* spp. from 1.60 x 10^5 to 1.79 x 10^6 cells/l. There was also *Chaetoceros* spp bloom at station 5, 7 and 8, where the highest density was at station 5.

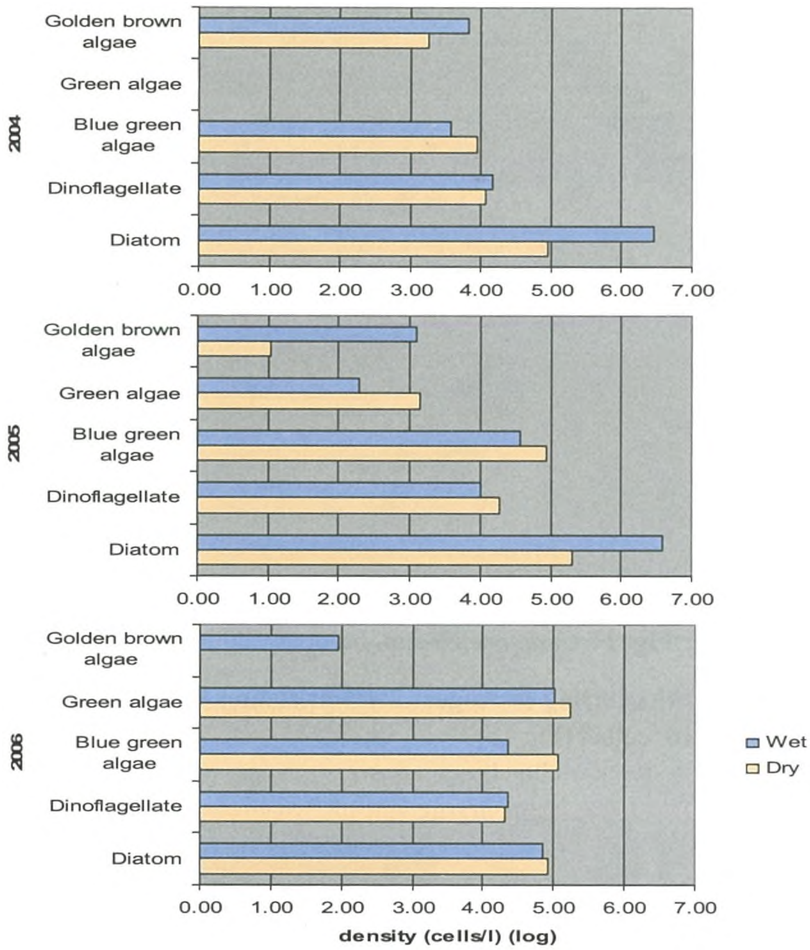

Fig. 15 The density of 5 divisions of phytoplankton

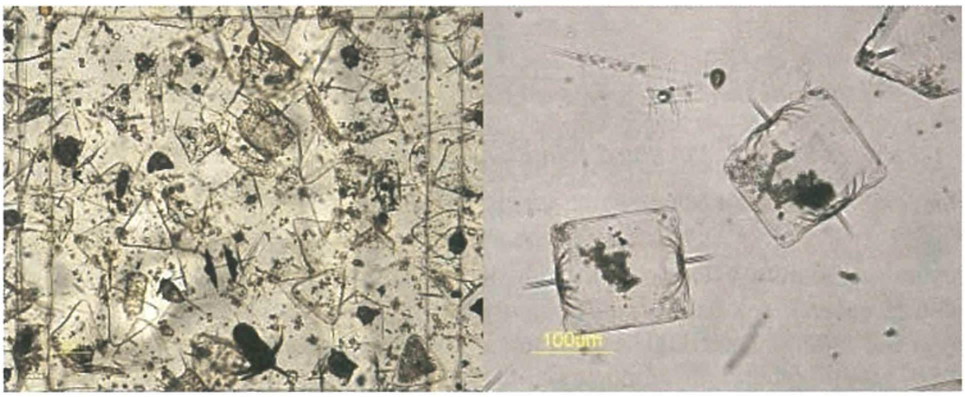

Fig. 16 *Ditylum sole* bloom in 2004

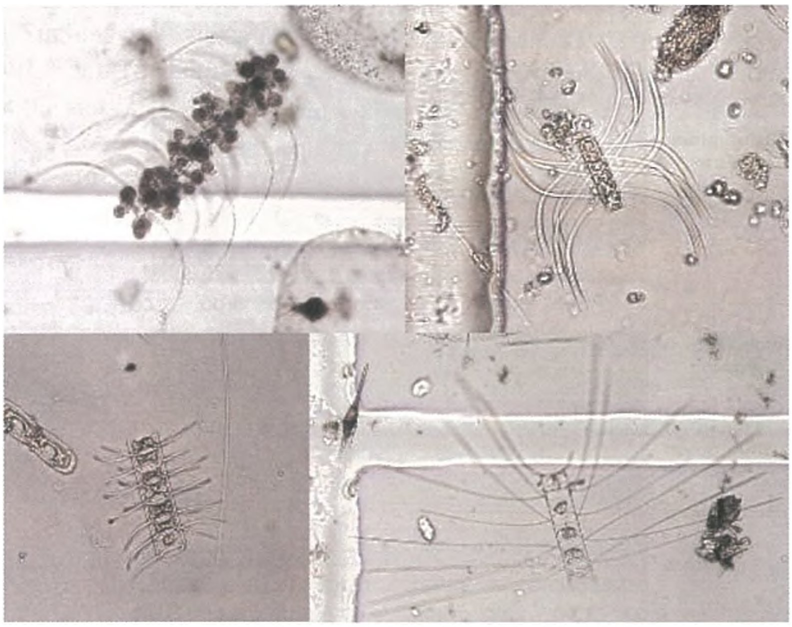

Fig. 17 *Chaetoceros* spp. bloom in 2004

A red tide phenomenon was occurring in August 2004 at station 9. This was caused by *Noctiluca scintillans* bloom at 5.77 x 10^3 cells/l (Fig 18).

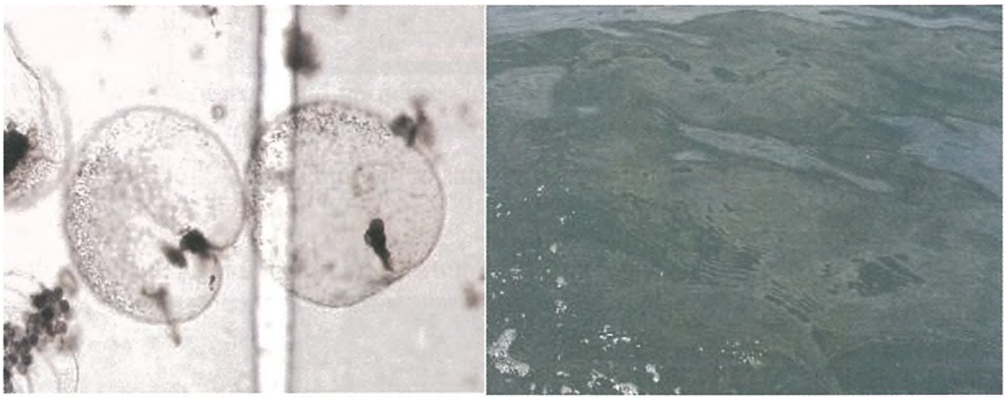

Fig. 18 *Noctiluca scintillans* bloom causing red tide

V. Conclusions And Discussions

There are several aquaculture activities in the study area composed of cage culture: grouper (*Epinephelus tauvina* and *E. bleekeri*), sea bass (*Lates calcarifer*), green mussel (*Perna viridis*) culture (Fig 19) (Arnupapboon and Laongmanee, 2003).

Generally, the water quality of the study area is suitable for coastal aquaculture. All variables were consistent with the standards for aquaculture and coral reef conservation (Pollution Control Department, 2006). In the Ao Pathew area, especially in the shallow area and the station along the coastline which is influenced by water runoff and human activities, TSS will be higher than in other stations. Transparency also decreased following the TSS in that area. The same result was also gathered by the study of Laongmanee and Singharachai (2004). Temperatures in some stations in the shallow area were higher than 29□C. Thus, the farmers should be aware of possible temperature shock in fish cage culture. Salinity in wet season was higher than in dry season. The total rainfall in 2003 and 2004 were higher in the wet season than in the dry season (Laongmanee *et al.*, 2003) and (Kajonwattanakul and Nokkate, 2005). This shows that water runoff and rainfall did not have any influence on the salinity in the study area. But salinity in this area was affected by the open sea.

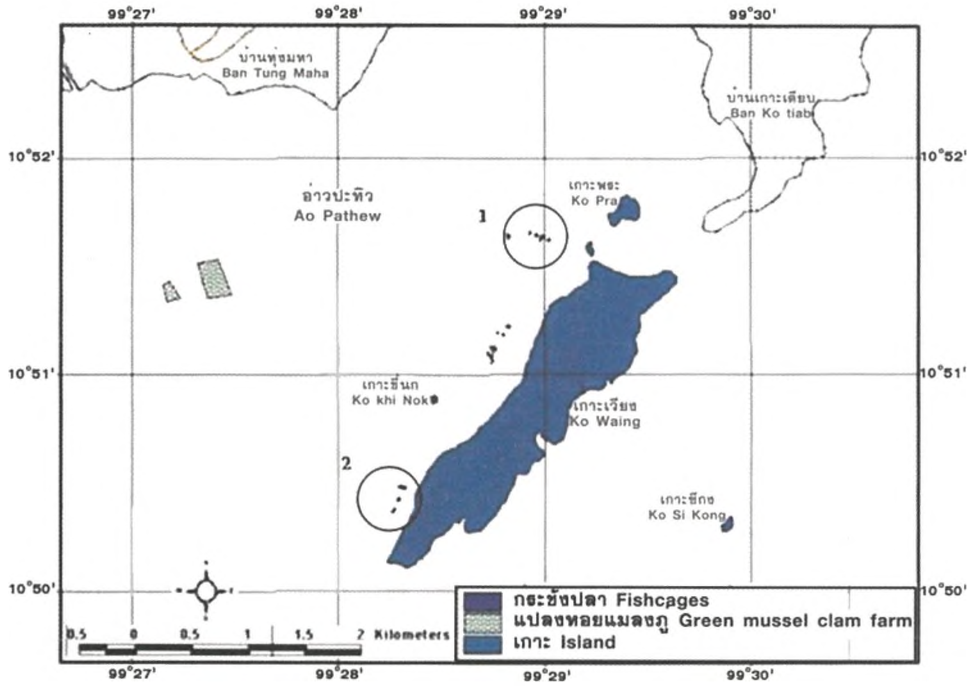

Fig. 19 Aquaculture activities near the LBCRM-PD) area

Laongmanee *et al.*, 2003 studied the water current speed and direction in this area. They found out that the current direction was southwestward. Strong current speed was observed during June at an average current speed of 0.09 m/s. Since the current direction and speed were not recorded all year, information from the fishermen were gathered and this indicated that in Ao Pathew, the current direction was northeastward during the southwest monsoon and southwestward during the northeast monsoon. Thus, the source of water in Ao Pathew comes from both the southern and northern parts of the sea.

Nutrient concentrations did not indicate the eutrophication in the area. But limiting the area for aquaculture and the density of fish stocks should be considered. Tookwinas *et al.* (2003) estimated the carrying capacity of marine finfish cage culture at Pathew Bay, considering the oxygen consumption of fish and oxygen supply in the area. They established that for cage culture in group 2 with 450 fishes: size 250-450 g/fish, the dissolved oxygen outflow during low tide is lower than the standard dissolved oxygen for aquaculture (4 mg/l). Sea bass and grouper were cultured at higher carrying capacity of 67.1% or 302 (450-148) fishes and 73.1% or 329 (450-121) fishes, respectively. For the cage culture in group 1 with 950 fishes: size 250-1000 g/fish), sea bass was cultured at lower carrying capacity around 33.45% or 217 (867-650) fishes, while grouper was cultured at higher carrying capacity of around 28.0% or 84 (300-213) fishes. This means that farmers can stock sea bass by about 33.4% more but need to decrease the number of groupers by around 28%.

Phytoplankton was abundant in wet season but did not show a significant relationship with chlorophyll a and nutrients. Several studies have indicated that phytoplankton can directly uptake inorganic nitrogen such as nitrite and nitrate (Libes, 1992 and Department of Marine and Coastal Resources, 2005) and the concentration of chlorophyll a is attributed to the concentration of dissolved inorganic materials (nitrite, nitrate, ammonia and orthophosphate). In this study however, the concentration of chlorophyll a showed a significant relationship with nitrate and ammonia.

Phytoplankton bloom and red tide phenomena were recorded 4 times throughout the period of this study. The Marine and Coastal Resources Research Center (2006) recorded the red tide phenomena from 2004 to 2006. It occurred 8 times along the Chumphon coastline. This phenomenon is caused mostly by *Noctiluca scintillans*, but only once did the mixed bloom of *N. scintillans* and *Ceratium furca* happened. When red tide phenomena occur, dissolved oxygen decreases due to photosynthesis by the phytoplankton, and as dissolved oxygen collapse, it uses microorganism as a decomposer. Although red tide did not occur in the project site, but since most phytoplankton blooms happened in Ao Pathew area, cage culture farmers should keep a close watch when the red tide phenomenon is occurring.

VI. Acknowledgement

This study would not have been possible without the help and support of many colleagues. We especially acknowledge the staff of RV. Meen Niveth and those who participated in the survey including Saowaluk Suwanlaong, Jeamsak Sukwisuth and the excellent technicians of the Marine and Coastal Research Center of the Central Gulf of Thailand. We would like to thank Mr. Wannakiat Thubthimsang who kindly commented on this paper.

VII. References

APHA, AWWA and WPCF. 1980. Standard Method for the Examination of Water and Wastewater. 15th edition. American Public Health Publisher, New York. 1134 pp.

Arnupapboon, Sakchai and Wirote Laongmanee. 2003. Overview of Fishing Activities in the Pakklong Sub-district Coastal Area. Pathew District, Chumphon Province. TD/RES/73 LBCRM-PD No. 15, Southeast Asian Fisheries Development Center and Department of Fisheries. 36 pp.

Davis, C. C. 1955. The Marine and Fresh-Water Plankton. Michigan State University Press. 562 pp.

Department of Marine and Coastal Resources. 2005. Ecosystem of Bangpakong Estuaries. Chulalongkorn University Press, Bangkok. 189 pp.

Fukuyo, Y., H. Takano, M. Chihara and K. Matsuoka. 1990. Red Tide Organisms in Japan – An Illustrated Taxonomic Guide. Uchida Rokakoho Publishing Co., Ltd., Tokyo. 407 pp.

Kajonwattanakul, S. and N. Nokkate. 2005. Sea Water Quality and Phytoplankton in Locally-Based Coastal Fisheries Management Project: Pathew District, Chumphon Province. Technical paper no. 10/2005. Phuket Marine Biological Center, Department of Marine and Coastal Resources. 19 pp.

Laongmanee, P., S. Kajonwattanakul and C. Singharachai. 2003. The Marine Environmental Condition of Pakklong Sub-district Coastal Area and Their Effect on Coastal Aquaculture. TD/RES/77 LBCRM-PD No. 17, Southeast Asian Fisheries Development Center and Department of Fisheries. 22 pp.

Laongmanee, P. and C. Singharachai. 2004. The Marine Environmental and Carrying Capacity of Aquculture Area. **In:** Seminar of Locally-Based Coastal Fisheries Management Project. TD/RP/68 LBCRM-PD No. 40, Southeast Asian Fisheries Development Center and Department of Fisheries. p. 47-58.

Libes, S. M. 1992. An Introduction to Marine Biogeochemistry. John Wiley & Sons, Inc., Singapore. 734 pp.

Marine and coastal resources research center, The Central Gulf of Thailand. 2006. Red Tide Phenomena in The Central Gulf of Thailand. 11 pp.

Pollution Control Department. 2006. Marine Water Quality Standard. PC 02-176. 7 pp.

Smith, D. L. 1977. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Kendall/Hunt Publishing Company. 161 pp.

Strickland, J. D. H. and T. R. Parsons. 1972. A Practical Handbook of Sea Water Analysis. 2nd edition. Fisheries Research Board of Canada, Ottawa. 310 pp.

Tookwinas, S., Songsangjinda, P., Kajonwattanakul, S. and Singharachai, C. 2003. Carrying Capacity Estimation of Marine Finfish Cage Culture at Patue Bay, Chumphon Province, Southern Thailand. 10 pp. (Unpuplished paper)

Wongrat, L. 2003. Phytoplankton. 2nd edition. Kasetsart University Press, Bangkok. 851 pp.