PRELIMINARY RESULTS ON THE

LARGE PELAGIC FISHERIES RESOURCES

SURVEY IN THE ANDAMAN SEA

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

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RESOURCES SURVEY IN THE ANDAMAN SEA

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SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
TRAINING DEPARTMENT

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Preface

In response to the ASEAN-SEAFDEC Resolution on Sustainable Fisheries for Food Security for the ASEAN Region, SEAFDEC/TD has formulated a project proposal for harvesting of under-utilized resources since 2003. The main objective is to investigate the potential of under-exploited fisheries resources and promote their exploitation in a precautionary manner based upon analysis of the best available scientific information. Regarding this, TD had conducted the large pelagic fisheries resources survey in the Andaman Sea, in collaboration with the Department of Fisheries Thailand, Myanmar and Indonesia from 14-26 November 2004 using MV SEAFDEC, one month before Tsunami occurred in the outside of Andaman Sea.

The preliminary results on the large pelagic fisheries resources survey in the Andaman Sea is one of the technical outcome that point out various scope of research works such as large pelagic resources, fishery oceanography, primary production, fishery biology and nutrients. The outcomes of this study are considered to help a better understanding of the existence and distribution of large commercial pelagic species in the Andaman Sea.

On behalf of SEAFDEC, I should like to express my deepest appreciation to the Department of Fisheries Thailand, Myanmar and Indonesia that have collaborated with SEAFDEC on the joint survey. Hopefully, the publication will provide useful information and could contribute to the management and development of fishery sectors in the region.

Dr. Siri Ekmaharaj
Secretary-General and
The Chief of Training Department of SEAFDEC

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The Publication of This Book is Prepared By Mr. Songphon Chindakhan

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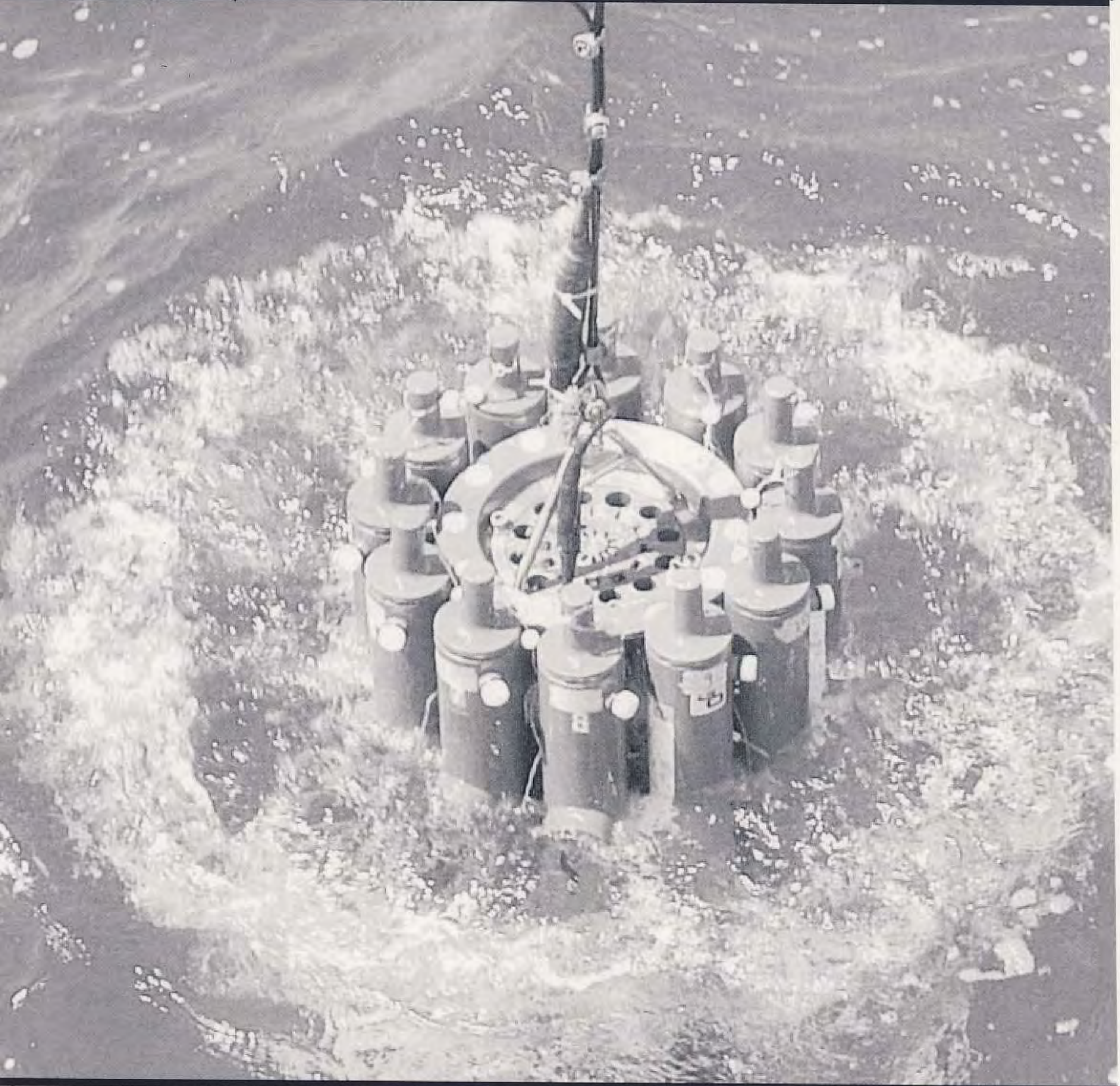

PRELIMINARY RESULTS ON

THE LARGE PELAGIC FISHERIES

RESOURCES SURVEY IN THE ANDAMAN SEA

PELAGIC FISHERIES RESOURCES SURVEY IN THE ANDAMAN SEA

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INTRODUCTION

Considering that many fisheries resources in the Southeast Asian Region are currently heavily exploited, increased production from these fisheries can only be derived from greater utilization of existing catches. However an increasing human population and associated demand for fish and fishery products means there is a need to increase fisheries production even further. This may be achieved by developing new fisheries and increasing production from currently under-exploited fisheries.

In the regional context, under-exploited resources are defined as those that are known to exist but are currently not harvested to full potential because of practical, operational or economic impediments. According to the FAO, moderately exploited or under-exploited fish resources exist in both the Eastern Indian Ocean and the Western Central Pacific regions (FAO statistical areas). These stocks are thought to be mainly pelagic species like tunas, scads, mackerel and squid. However, there is little scientific knowledge supporting their full extent and status.

To support plan and action of sustainable fisheries for food security and to assist investigation of under-exploited resources in the region, therefore the ASEAN-SEAFDEC program on Harvesting of under-Exploited Resource has been developed. Andaman Sea is assumed as one of the areas where fisheries resources are under-exploited status. The Andaman sea coastline is covered by 4 SEAFDEC member countries namely Indonesia, Malaysia, Thailand and Myanmar. To date, there is little knowledge on the ecosystem based on fisheries management in the Andaman Sea. Investigation for the ecosystem and fisheries resources in the Andaman Sea therefore is essential for those concerned countries. For this reason, SEAFDEC Training Department proposes to conduct the joint research survey on large pelagic fisheries resources in the Andaman Sea where the depth of waters is deeper than 700 m. Large pelagic fishes and oceanic squid are the main target species while fish and squid larvae and oceanographic data will also be collected and analyzed.

TABLE1. List of researchers and observers

No.		NAME
1	SEAFDEC/TD	Mrs. Penchan Laongmanee
2		Mr. Pratakphol Prajakjitt
3		Mr. Sayan Promjinda
4		Ms. Sukanya Obromwan
5		Ms. Umaporn Paovana
6		Ms. Aleisa Lamanna
7		Ms. Supranee Limpuangkaev
8		Mr. Noppol Arunrat
9	Indonesia	Mr. Agustinus Anung Widodo
10		Suwarso
11	Malaysia	Mr. Richard Rumpet
12	Myanmar	Myint Soe
13		Htun Thein
14		Aung Win Sein
15	Thailand	Mr. Chitjaroon Tantivala
16		Ms. Sopana Boonyapiwat
17		Lt.JG Pisanu Siripitrakool
18	Thailand	Ms. Sampan Panjarat
19	Thailand	Mr. Santi Poungcharean
20		Mr. Rittirong Prommas

OSITION	E-MAIL ADDRESS	CONTACT ADDRESS
shing ground researcher shing gear researcher ssistance researcher ssistance researcher udio Visual/trainee EAFDEC-TD Canadian Intern rainee rainee	penchan@seafdec.org pratakphol@seafdec.org sayan@seafdec.org sukanya@seafdec.org umaporn@seafdec.org alamanna@dal.ca a_real_14@hotmail.com njunnoi@chaiyo.com	Southeast Asian Fisheries Development Center, Suksawat road, Phrasamutchedi, Samut Prakan, 10290, Thailand Tel: 662-4256141 Fax: 662-4256110-11
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Biologist	poomanz@hotmail.com	Department of Fishery biology, Faculty of Fisheries, Kasetsart University, Chatuchak, Bangkok, 10900 THAILAND Tel: 662-5795575-6
Marine Bio-tech researcher	Aom_marine@yahoo.com	Department of Marine science, Faculty of Fisheries, Kasetsart University, Chatuchak, Bangkok, 10900 THAILAND Tel: 662-5797610

OBJECTIVES

1) To investigate the potential of large pelagic fisheries resources such as tuna, billfishs, oceanic squid and etc, in the Andaman Sea by using pelagic long line and squid jigging gears in related to oceanographic information;

2) To collect the biological and oceanographic information in the Andaman Sea to serve as SEAFDEC database on fisheries oceanography;

SCOPE OF WORK:

The scope of works of this joint research survey was as follows;

❁ **FISHING OPERATION**: Fish samplings to investigate abundance and distribution of pelagic fish will be conducted using Pelagic long-line and Automatic squid jigging gears (Figure 1).

❁ **FISHERY OCEANOGRAPHY**: Water temperature, salinity, pH, dissolved oxygen, fluorescence, light intensity, current, water transparency, sea color, etc. will be collected. A total of 13 stations are planned.

❁ **PRIMARY PRODUCTION**: Distribution, abundance and composition of phytoplankton, sub-thermo cline chlorophyll maxima will be collected and analyzed. Survey stations are the same as fishery oceanographic survey stations.

❁ **FISHERY BIOLOGY**: Distribution, abundance and composition of priority species from fishing operation and from larvae samplings will be analyzed.

❁ **NUTRIENTS**: Water samples from different standard depths will be collected for nutrients analysis (nitrite, nitrate, silicate and phosphate). Survey stations are the same as fishery oceanographic survey stations.

PARTICIPANTS / RESEARCHERS

List of researchers and observers were as in Table 1:

RESEARCH VESSEL

MV.SEAFDEC will be employed for this joint research survey (see enclosed document).

SURVEY AREA

Survey area, the Andaman Sea is located in the EEZ of Indonesia, Myanmar and Thailand (see Figure 2).

Latitude	06_30'- 13_00'N
Longitude	095_30'- 097_00'E

EXPECTED OUTPUT

This preliminary catch result in relation with oceanographic data will provide basic knowledge/information on potential pelagic fisheries resources particular on tuna, oceanic squid and other new fisheries resources in the Andaman Sea. This best available scientific information will be useful for managing the fisheries resources and promoting their exploitation in a precautionary manner in the SEAFDEC member countries.

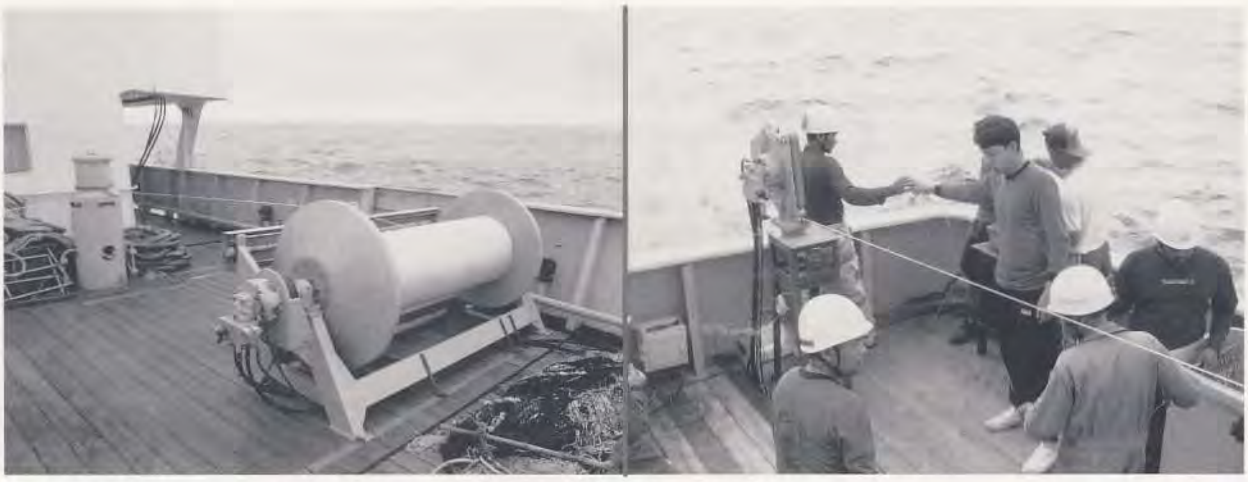


FIGURE 1a. Pelagic Long-Line Gear.

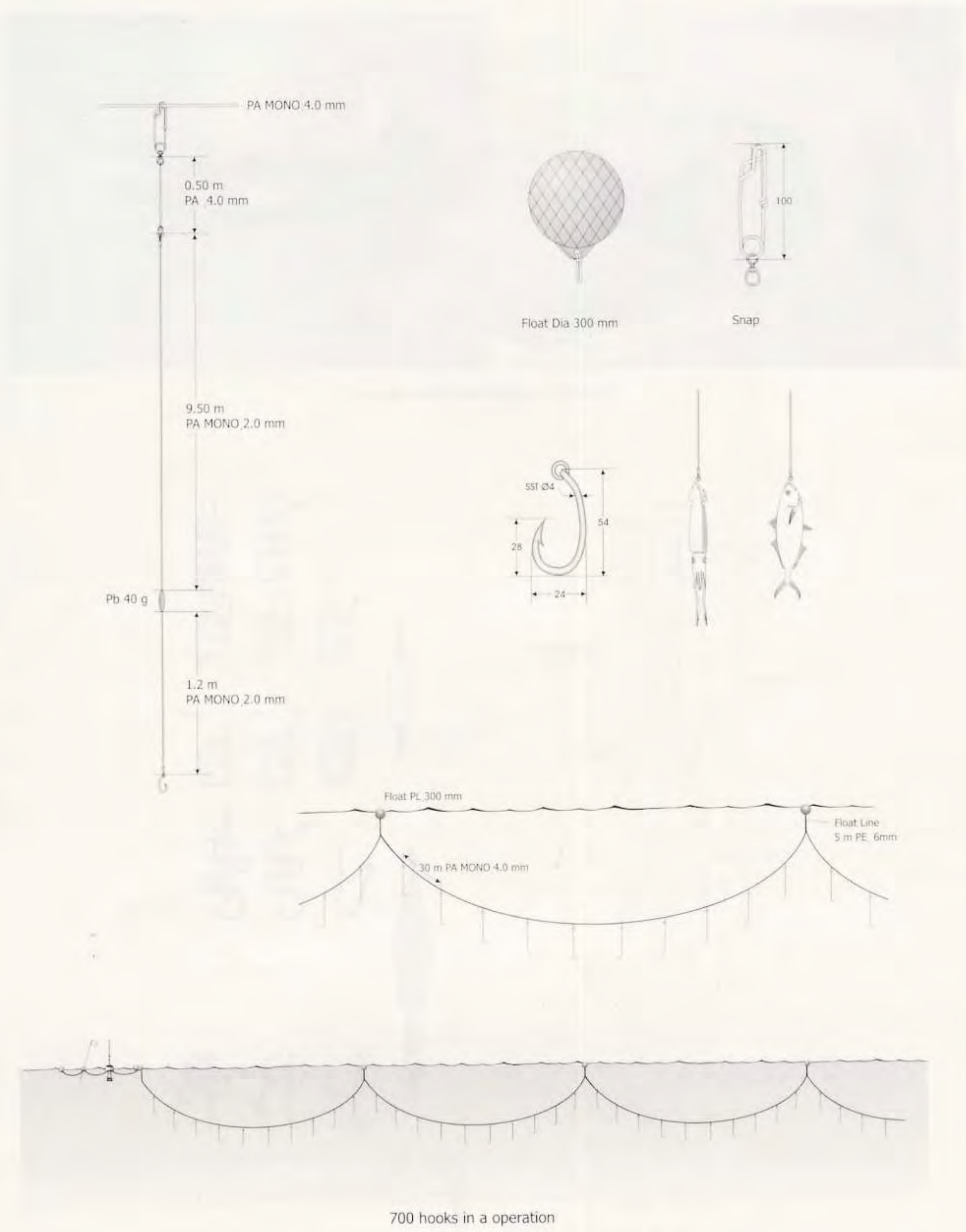


FIGURE 1b. Fishing Gear Construction for Tuna Longline Fishing Trial

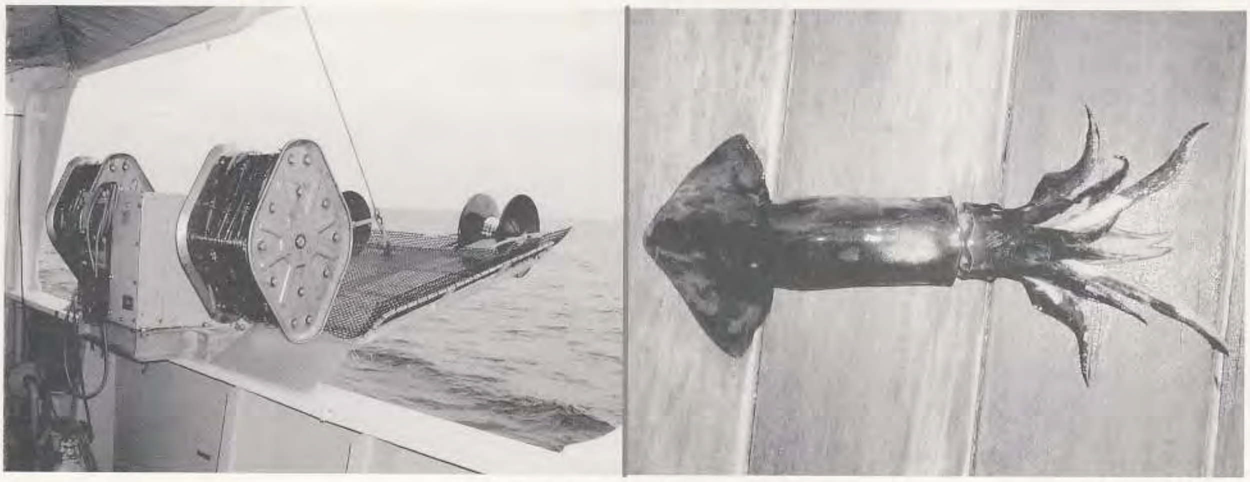


FIGURE 1c. Automatic Squid Jigging

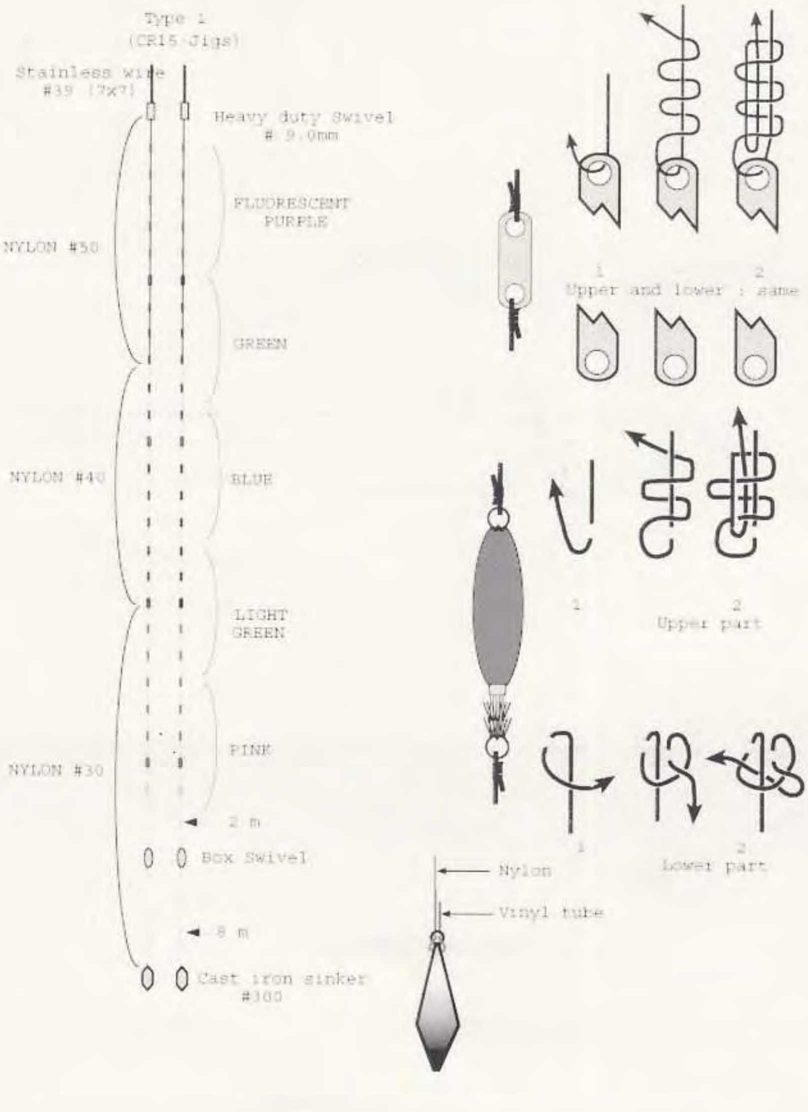
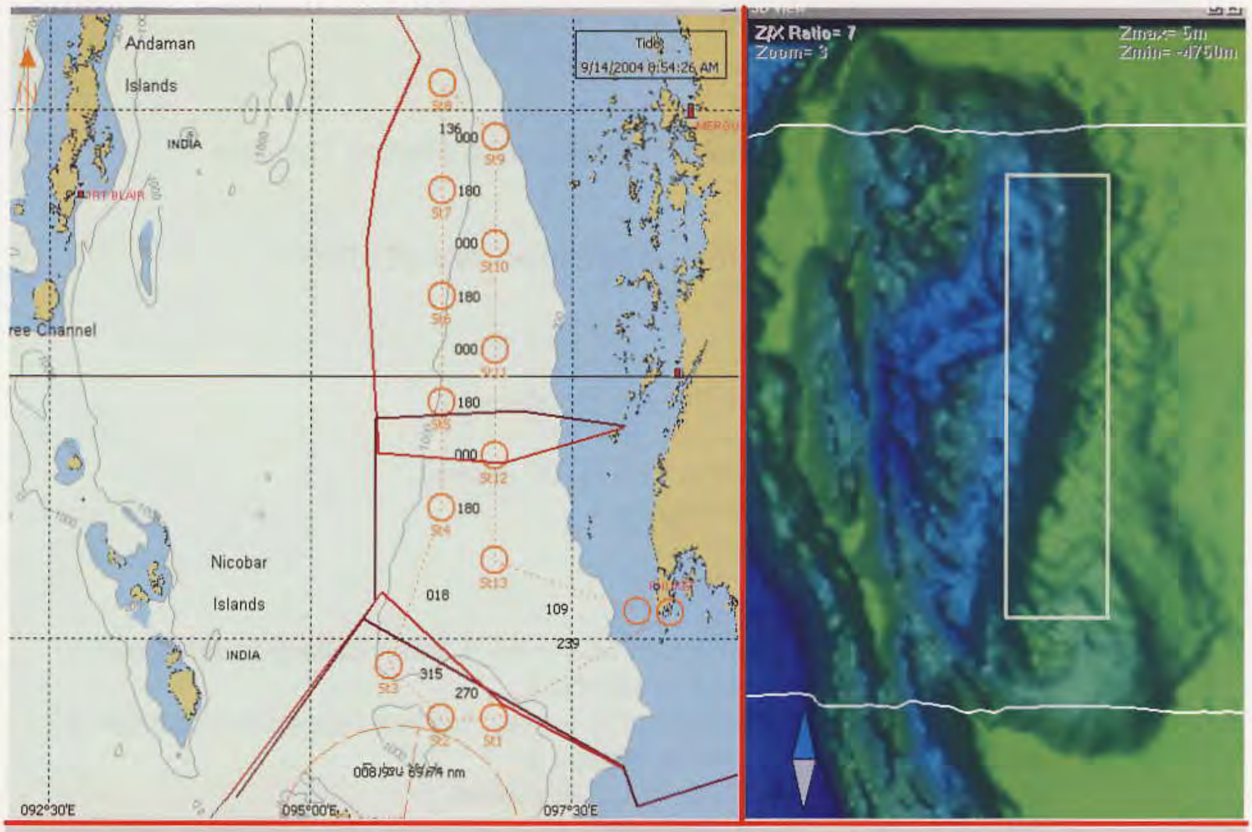


FIGURE 1b. Fishing Gear Construction for Automatic Squid Jigging Trial



Name : Route001

Comment :

Waypoints

N°	Name	Position	Route	Range	Remains	Total Range	Max
1		07°45'844 N - 098°26'882 E			893.5 nm	0.0000 m	
2	St1	06°45'000 N - 096°45'000 E	239.0°	118.0 nm	775.6 nm	118.0 nm	1000.
3	St2	06°45'000 N - 096°15'000 E	270.0°	29.79 nm	745.8 nm	147.8 nm	1000.
4	St3	07°15'000 N - 095°45'000 E	315.2°	42.27 nm	703.5 nm	190.0 nm	1000.
5	St4	08°45'000 N - 096°15'000 E	018.3°	94.78 nm	608.7 nm	284.8 nm	1000.
6	St5	09°45'000 N - 096°15'000 E	000.0°	60.00 nm	548.7 nm	344.8 nm	1000.
7	St6	10°45'000 N - 096°15'000 E	000.0°	60.00 nm	488.7 nm	404.8 nm	1000.
8	St7	11°45'000 N - 096°15'000 E	000.0°	60.00 nm	428.7 nm	464.8 nm	1000.
9	St8	12°45'000 N - 096°15'000 E	000.0°	60.00 nm	368.7 nm	524.8 nm	1000.
10	St9	12°15'000 N - 096°45'000 E	135.7°	41.93 nm	326.8 nm	566.7 nm	1000.
11	St10	11°15'000 N - 096°45'000 E	180.0°	60.00 nm	266.8 nm	626.7 nm	1000.
12	St11	10°15'000 N - 096°45'000 E	180.0°	60.00 nm	206.8 nm	686.7 nm	1000.
13	St12	09°15'000 N - 096°45'000 E	180.0°	60.00 nm	146.8 nm	746.7 nm	1000.
14	St13	08°15'000 N - 096°45'000 E	180.0°	60.00 nm	86.80 nm	806.7 nm	1000.
15		07°46'031 N - 098°07'625 E	109.5°	86.80 nm	0.0000 m	893.5 nm	1000.

FIGURE 2. Survey Map and Position of Survey Stations

Survey Plan / Schedule

14 Nov. (Sunday)
0800-1800 hrs. : All participants arrived at Phuket/ Thailand

15 Nov. (Monday)
1000 hrs. : All participants embark MV SEAFDEC
1300 hrs. : Orientation

16 Nov. (Tuesday)
0800 hrs. : Leave Phuket for station 1
1700 hrs. : Arrive station 1
1800 hrs. : Shooting PLL 1(700 hooks)
2030 -2400 hrs. : Squid Jigging 1

17 Nov. (Wednesday)
0530 hrs. : Hauling PLL 1
0800 hrs. : Oceanographic survey, Larvae collection at station 1
1000 hrs. : proceed to station 2
1230 hrs. : Oceanographic survey, Larvae collection at station 2
1430 hrs. : Proceed to station 3
1700 hrs. : Shooting PLL 2 at station 3
2000-2400 hrs. : Squid Jigging2

18 Nov. (Thursday)
0530 hrs. : Hauling PLL 2
0800 hrs. : Oceanographic survey, Larvae collection at station 3
1000 hrs. : proceed to station 4
1730 hrs. : Shooting PLL 3 at station 4
2000-2400 hrs. : Squid Jigging 3

19 Nov. (Friday)
0530 hrs. : Hauling PLL 3
0800 hrs. : Oceanographic survey, Larvae collection at station 4
1000 hrs. : proceed to station 5
1500 hrs. : Oceanographic survey, Larvae collection at station 5
1730 hrs. : Shooting PLL 4 at station 5
2000-2400 hrs. : Squid jigging 4

20 Nov. (Saturday)
0600 hrs. : Hauling PLL 4
0900 hrs. : proceed to station 6
1400 hrs. : Oceanographic survey, Larvae collection at station 6
1700 hrs. : Shooting PLL 5 at station 6
2000-2400 hrs. : Squid Jigging 5

Survey Plan / Schedule

21 Nov. (Sunday)

0600 hrs.	: Hauling PLL 5
0900 hrs.	: proceed to station 7
1400 hrs.	: Oceanographic survey, Larvae collection at station 7
1700 hrs.	: Shooting PLL 6 at station 7
2000-2400 hrs.	: Squid Jigging 6

22 Nov. (Monday)

0600 hrs.	: Hauling PLL 6
0900 hrs.	: proceed to station 8
1400 hrs.	: Oceanographic survey, Larvae collection at station 8
1700 hrs.	: Shooting PLL7 at station 8
2000-2400 hrs.	: Squid Jigging 7

23 Nov. (Tuesday)

0600 hrs.	: Hauling PLL 7
0900 hrs.	: proceed to station 9
1230 hrs.	: Oceanographic survey, Larvae collection at station 9
1430 hrs.	: Proceed to station 10
1930 hrs.	: Oceanographic survey, Larvae collection at station 10
2130 hrs.	: Proceed to station 11

24 Nov. (Wednesday)

0230 hrs.	: Oceanographic survey, Larvae collection at station 11
0430 hrs.	: Proceed to station 12
0930 hrs.	: Oceanographic survey, Larvae collection at station 12
1130 hrs.	: Proceed to station 13
1630 hrs.	: Oceanographic survey, Larvae collection at station 13
1830 hrs.	: proceed to Phuket

25 Nov. (Thursday)

0800 hrs.	: Arrive Phuket
1000 hrs.	: All participants disembark MV SEAFDEC, stay at Hotel
1800 hrs.	: Farewell party

26 Nov. (Friday)

0700-1800 hrs.	: All participants leave Phuket/ Thailand

OCEANOGRAPHIC CONDITION DURING THE PELAGIC FISHERIES RESOURCES SURVEY IN THE ANDAMAN SEA

Penchan Laongmanee[1], Sukanya Obromwan [1], Noppol Arunrat[2] and Supranee Limpuangkaew[2]

1 Southeast Asian Fisheries Development Center, Phrasamutchedi, Samut Prakan, Thailand [1]

2.School of engineering and Resources Management, Walailak University, Nakornsithammarat, Thailand[2]

ABSTRACT

Thirteen oceanographic stations were surveyed for a better understanding of the distribution and abundance of resources during the Fisheries Resources Survey in the Andaman Sea. The general features of oceanographic condition were similar in the whole study area except at the surface layer where the northern part was influenced by low salinity surface water. This is from the Irrawaddy delta and the Arakan coast, while the southern part was influenced by a strong flow from the Sumatra strait. It induces a well-mixed layer to a deeper depth. The thermocline layer in this area is between 30 and 211 meters depth at a temperature interval of about 12.88 – 30.21°C. Low dissolved oxygen concentrations that were observed in the thermocline layer is the main parameter limiting the vertical distribution of pelagic resources like tunas in the area. The habitat of tunas in the study area is shallower than in the eastern Indian Ocean.

INTRODUCTION

This study is a part of the Pelagic Fisheries Resources Survey in the Andaman Sea under the ASEAN-SEAFDEC Program: "Harvesting of Under-Exploited Resources." The study area is along the continental shelf of the Andaman sea, comprising of the waters of three countries namely; Myanmar, Thailand and Indonesia. The oceanographic condition survey was conducted to gain a better understanding of the distribution and abundance of the resource. Since the area covers water of three country and their boundary, a few studies on both resources and oceanographic condition had been done in the area.

After the 26th December 2004 South Asian Tsunami and earthquake disaster, researchers started to look into the effects of destructive waves in this area. However due to the lack of studies in the area, the assessment of the tsunami effect will be difficult to quantify. The survey period of this study is just a few days before the tragedy, thus the results could be used as information for the effect of the Tsunami for the oceanographic condition of the area.

MATERIALS AND METHODS

MV. SEAFDEC left Phuket port to carry out the Pelagic Fisheries Resources Survey in the Andaman Sea during 16th – 25th November 2004. There were 13 oceanographic stations (***Fig. 1.***): 3 stations in Indonesia (st. 1- 3), 4 stations in Thailand (st. 4, 5, 12 and 13) and 5 stations in Myanmar (st 6-10).

The CTD was the main oceanographic equipment for collecting the physical characteristics of temperature and salinity from the surface to a maximum depth at about 900m. It was equipped with twelve 2.5 liters Niskin water samplers. The samples were taken from standard depth for pH measurement and dissolved oxygen determination, which were done immediately after sampling. The pH was measured using the Fisher Accumet 1002 pH meter. Dissolved oxygen was determined by the Whinkle titration procedure.

The thermocline in this paper is a seasonal thermocline which is classified by slope of temperature that decreases rapidly with increasing depth by more than 0.05 °c. The seasonal thermocline is more relevant to pelagic resources than the permanent thermocline which is in the deeper layer. For a better understanding of the oceanographic conditions of the Andaman Sea in a larger area, the 8 day mapped 4 km file of MODIS (Moderate Resolution Imaging Spectroradiometer) Aqua Level 3 from http://oceancolor.Gsfc.nasa.gov/PRODUCTS was used. These color images were further processed and analyzed for the distribution of sea surface temperature and chlorophyll-a using SeaWiFS data Analysis System (SeaDAS). The AVISO absolute geostrophic current was acquired from AVISO Live Access server (data available at http://las.aviso.oceanobs.com/las/servlets/data)

Oceanographic data analyses was done using Ocean Data View software (Schlitzer, 2005)

RESULTS AND DISCUSSIONS

Oceanographic Condition

The temperature, salinity, dissolved oxygen and pH profiles of the survey area are shown in Fig. 2. The thermocline layer in this area was between 30 and 211 meter depth at the temperature interval of 12.88 – 30.21 °c. The deep upper limit of thermocline was observed at stations no. 1,2, 4 and 13 (more than 50 m) where low surface temperatures were also observed. Rapid changes of salinity, dissolved oxygen and pH with increasing depth were also observed at the thermocline layer. At a greater depth, salinity and pH were nearly stable, while dissolved oxygen exhibited a small increase with increasing of depth. The pH of the bottom layer of station no. 1 showed a different pattern from the others for unknown reasons.

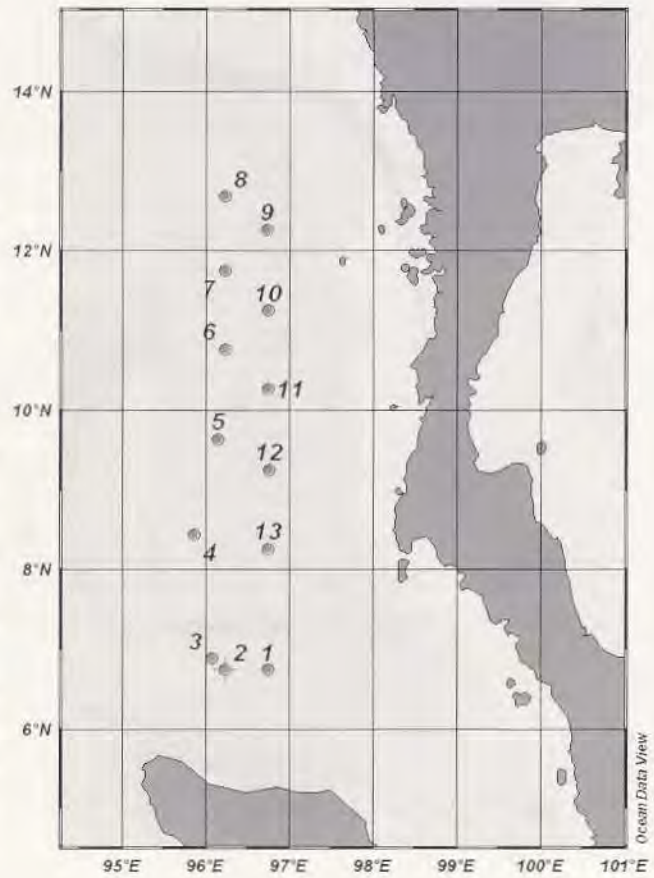


FIGURE 1. Oceanographic station in the study

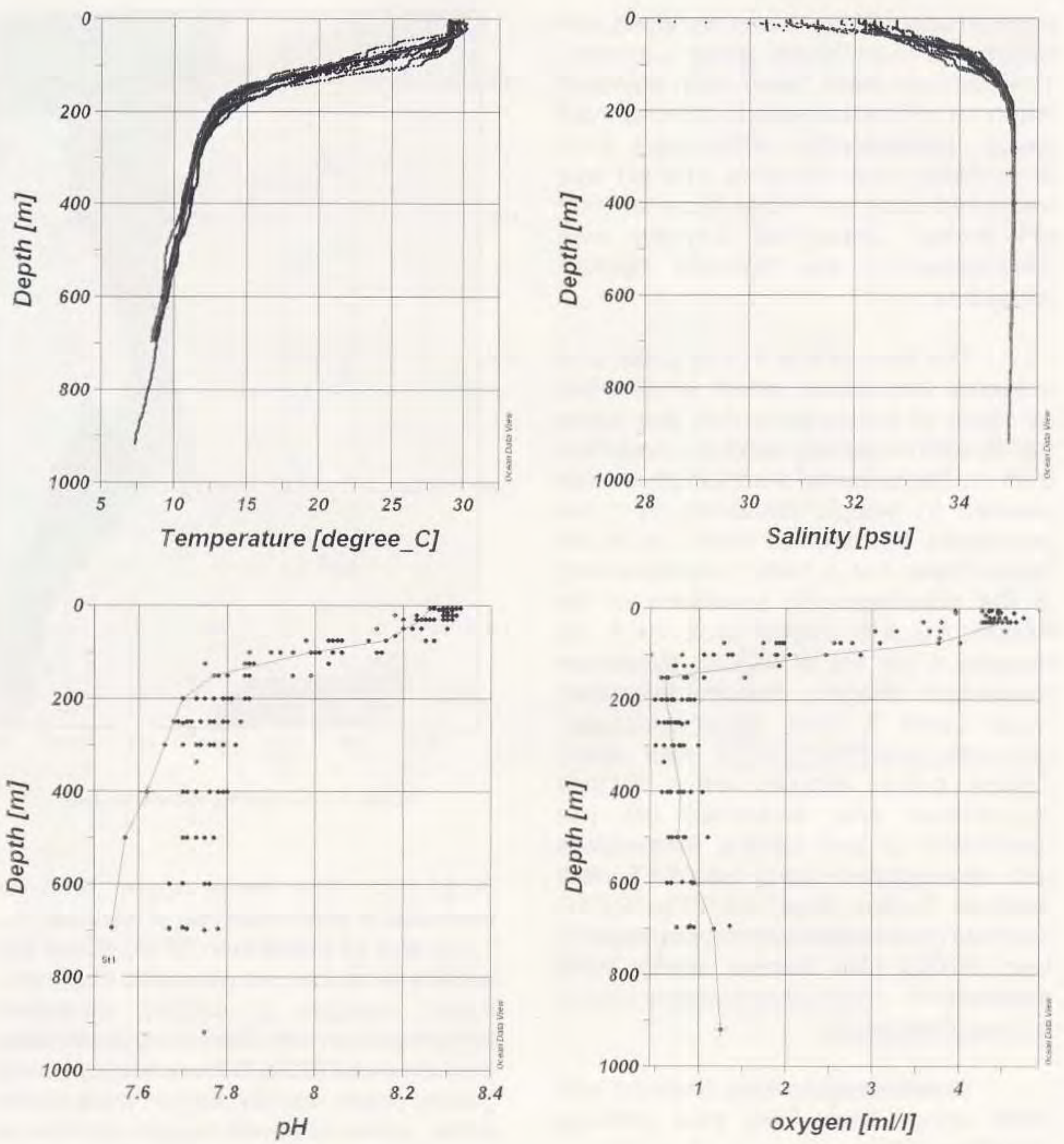


FIGURE 2. Profiles of temperature (°C), salinity (psu), dissolved oxygen (ml/l) and pH from all 13 stations.

Sea surface temperatures of the study area were between 29 - 30 °c. while the Southern part of the survey area had lower temperatures (Fig. 3). MODIS Aqua sea surface temperatures from 16^{th} – 23^{rd} November 2004 also confirmed the study result (Fig. 7). Low salinity was observed at the surface of the northern part where temperature was also high. The pH at the surface of the whole area was similar and was within the range of 8.26 -8.33. Surface dissolved oxygen was within the range of 3.95 -4.93 ml/l (Fig. 3).

Figures 4 and 5 show a similarity of the vertical oceanographic feature in the study area, except at the surface mixing layer (surface to about 50 m). The low sea surface temperature of the southern part can be explained by section B that the well mixed layers of these stations are deeper than the others. Low temperature, high salinity, low pH and high oxygen content were observed as the surface water was mixed with deeper water. These mentioned phenomenon could be affected from the strong current in this area, which flows from the Sumatra Strait. Figure 6 shows geostrophic current from the AVISO Live Access Server on 17th November 2004.

The high temperature and low salinity observed at the northern part influences only the surface layer of the area (from surface to about 50 meters; sections A and B). The water may originate from the surface waters of the Delta and Arakan coast of Myanmar, which are extensively mixed with fresh water from runoff of the Irrawaddy and Salween rivers although there was no observation data to confirm this assumption. But the eight day composite mapped during 16th –23rd November 2004 of MODIS Aqua sea surface temperature and chlorophyll – a (Fig. 7) shows that from Latitude 14°30'N to the northern part of the study area have a similar pattern. The distribution of low salinity surface water from mouth of the Irrawaddy and Salween to the northern part of survey area was also observed during surveys of the Marine Fish Resources of Burma, September – November 1979 with R/V DR. Fridtj of Nanses (Fig. 8).

Oceanographic conditions and fishing grounds

The bigeye tuna is more tolerant of lower temperatures and lower dissolved oxygen concentrations than the other tunas. The adults inhabits the thermocline where temperatures descend to almost 10°C, providing dissolved oxygen concentration of more than 1 ml/l (**http://www.edaff.gov.au/nfpd/atlas/37441011.cfm**).

Assuming that the 10 °C sea water temperature and 1 ml/l of dissolved oxygen is the lower limit for tunas, thus dissolved oxygen is the real limiting factor to the vertical distribution of tunas in this area. The 1 ml/l dissolved oxygen contour lines were observed at about 150 meters depth while the 10 °C contour lines were at about 500 meters depth.

Figure 9 shows typical profiles of oxygen in the Indian Ocean: dissolved oxygen is higher than 1 ml/l in the whole water column from the surface to the maximum observed depth. Therefore tunas in the study area inhabit the shallower waters compared to tunas in the Indian Ocean.

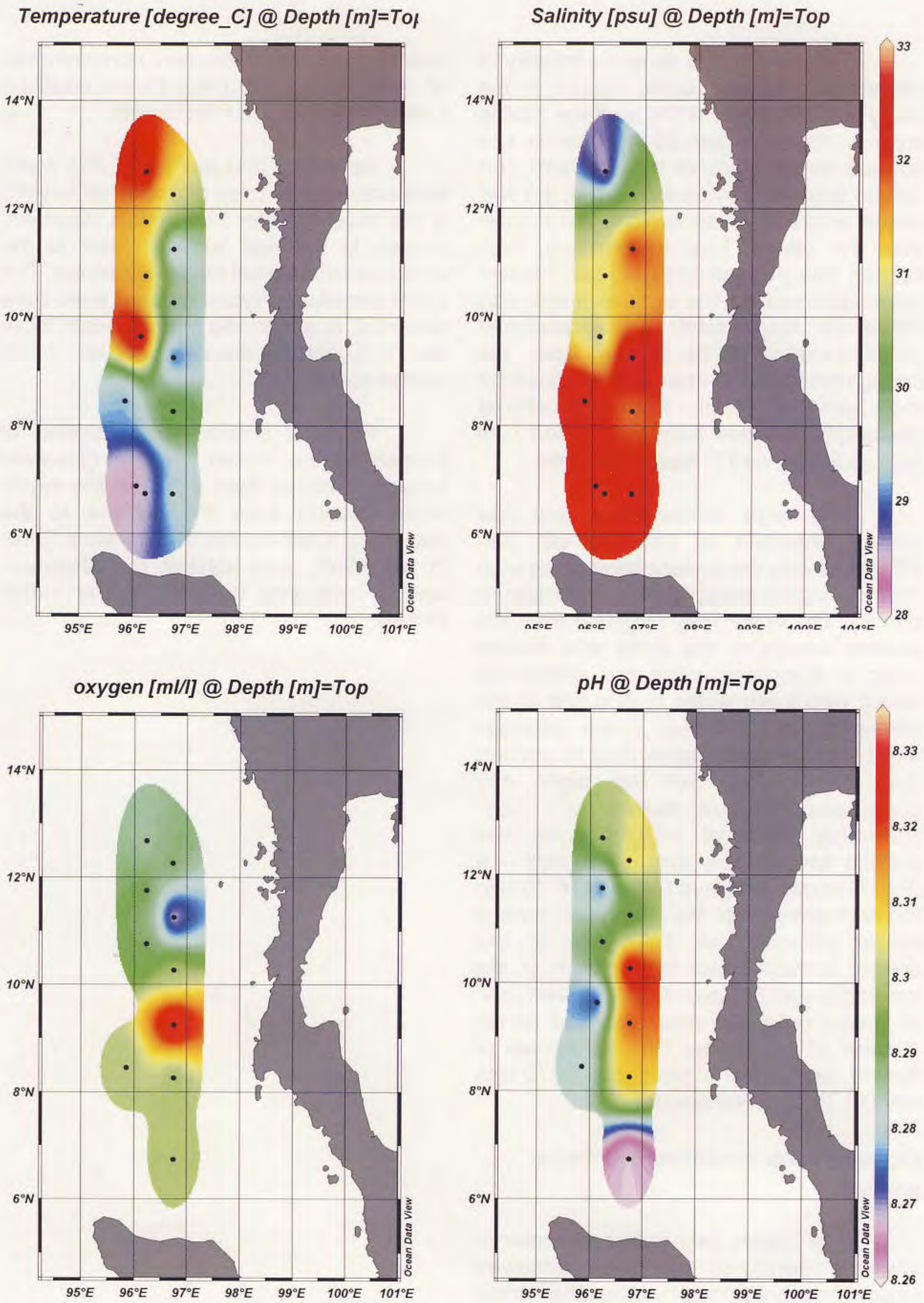


FIGURE 3. Horizontal distribution of surface temperature (°C), salinity (psu), dissolved oxygen (ml/l) and pH (at about 5 meters depth)

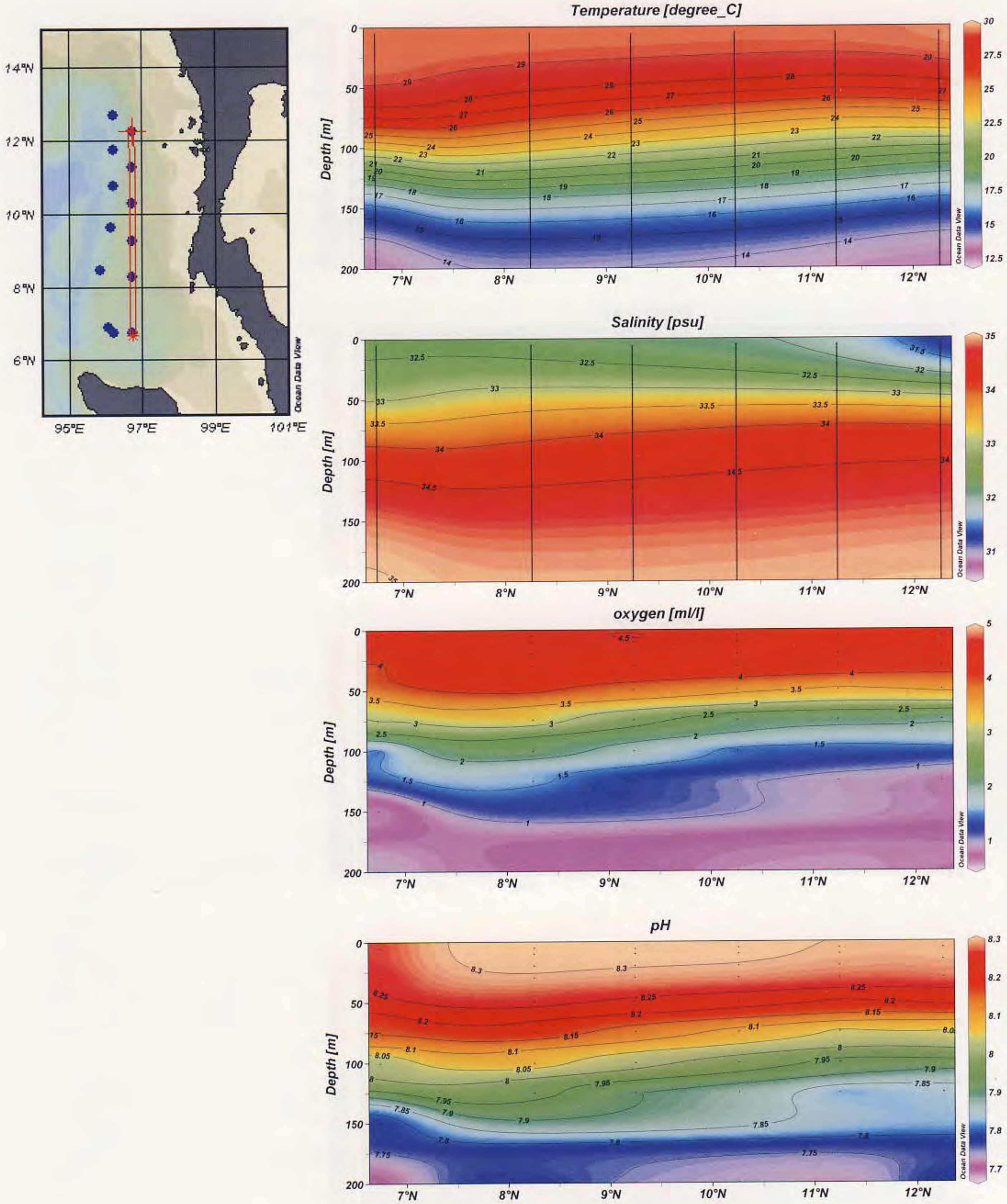


FIGURE 4. Section A from surface to 200 m: temperature (°C), salinity (psu), dissolved oxygen (ml/l) and pH

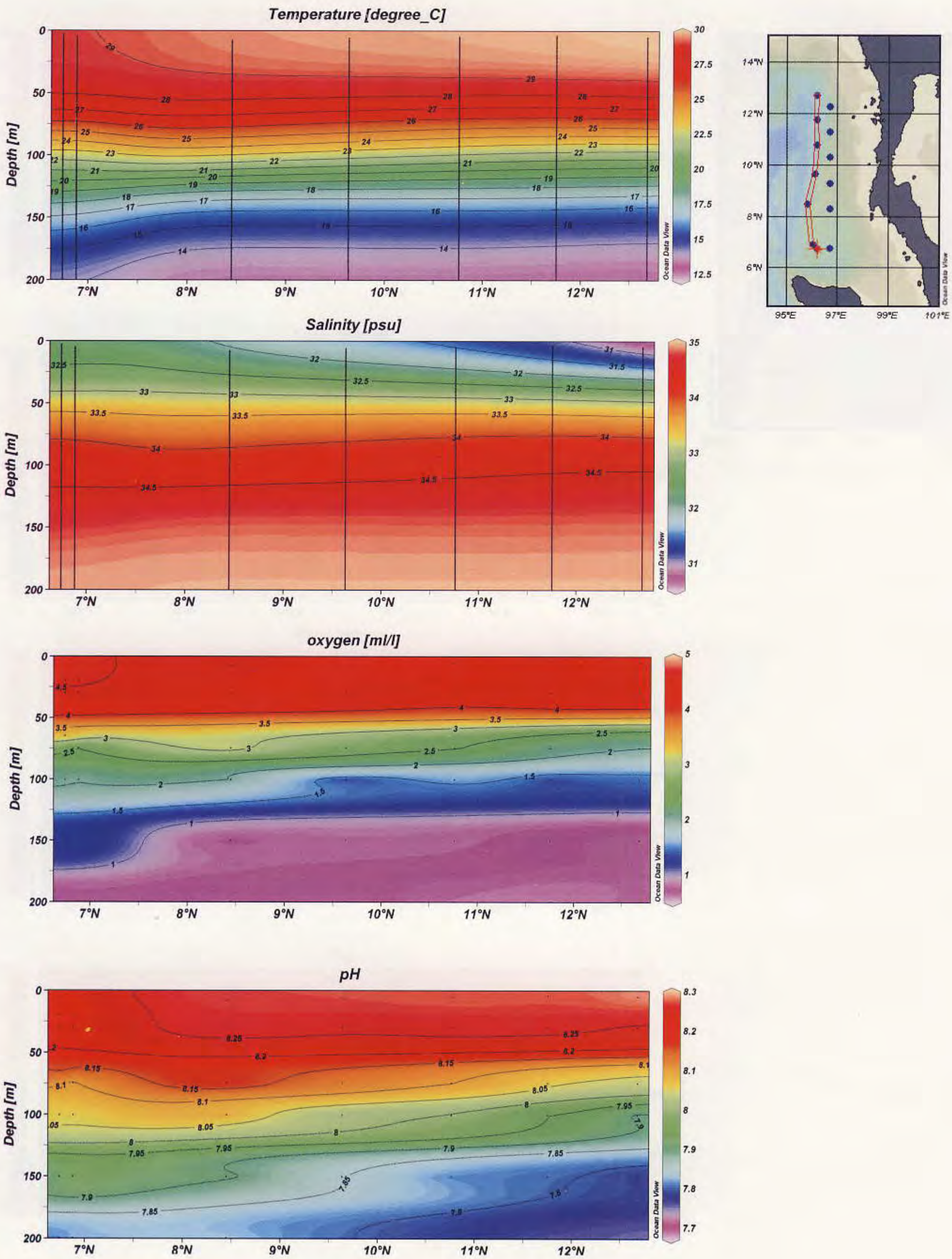


FIGURE 5. Section B from surface to 200 m: temperature (°C), salinity (psu), dissolved oxygen (ml/l) and pH

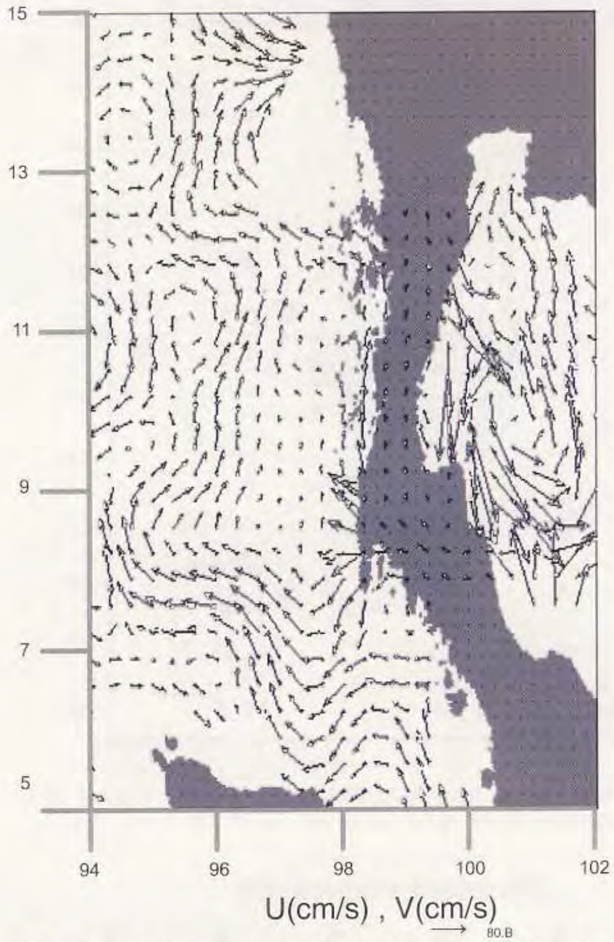


FIGURE 6. Absolute geostrophic current on 17th November 2004, acquired from the AVISO Live Access server

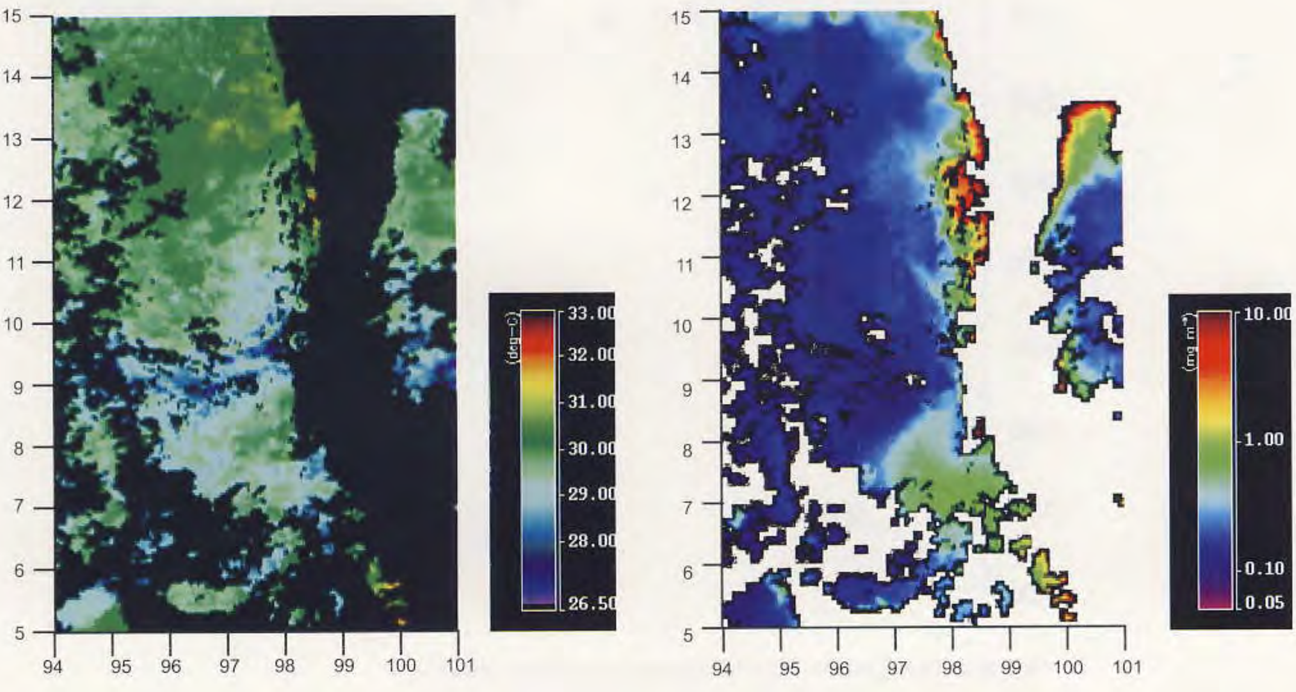


FIGURE 7. Eight day composite (16th –23rd November 2004) of the MODIS aqua sea surface temperature °C and Chlorophyll-a (mg/m^3)

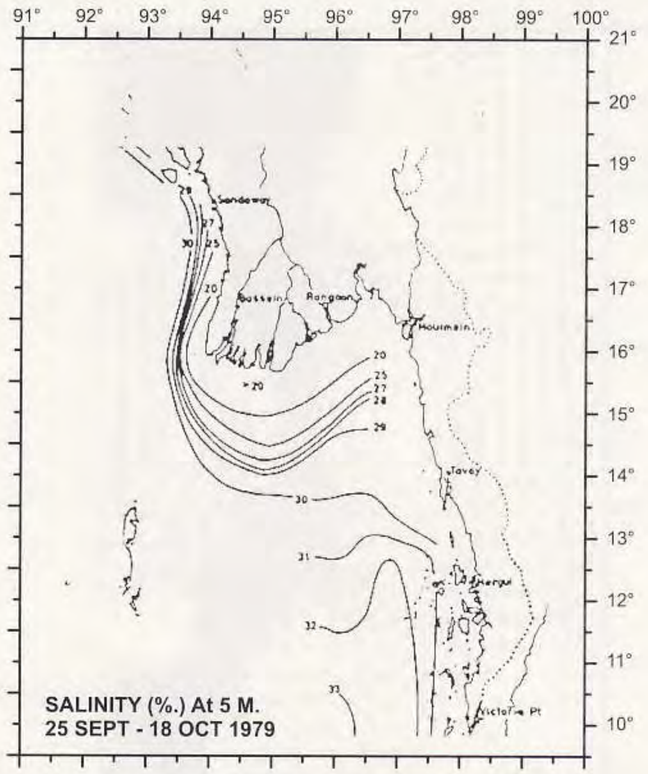


FIGURE 8. Salinity at 5 meters depth during 25th September – 18th October 1979
(Fig. copy from Report of the Survey with the R/V DR. Fridtjof Nansen)

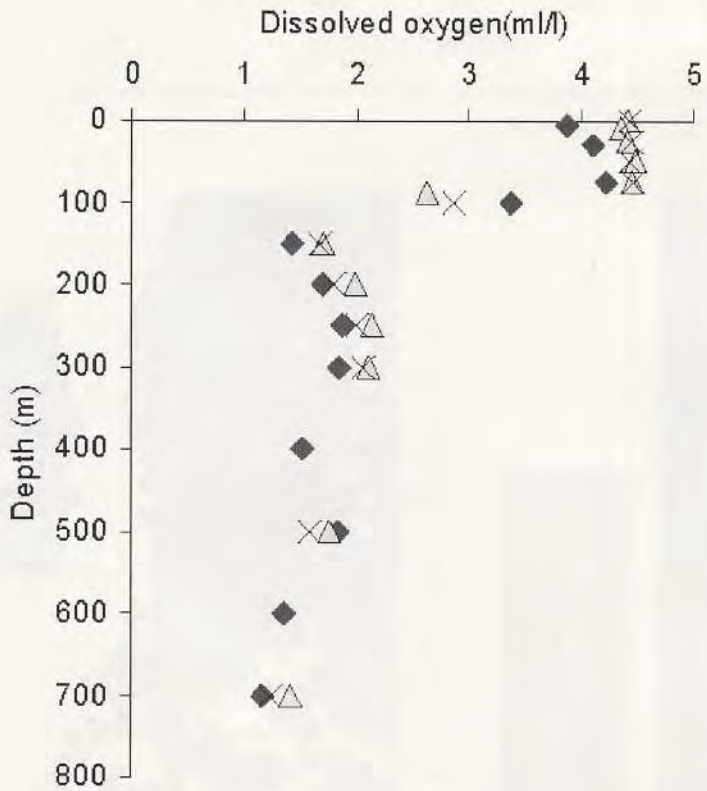


FIGURE 9. Typical profile of dissolved oxygen in the Eastern Indian Ocean

CONCLUSIONS

The general features of oceanographic conditions in the whole study area are similar except at the surface layer where the northern part is influenced by low salinity surface water from the Delta and the Arakan coast. This water is extensively mixed with runoff from the Irrawaddy and Salween rivers. A well-mixed layer of the water in the southern part of survey area is deeper. Low temperature, high salinity, low pH and high dissolved oxygen were observed. The strong flow from the Sumatra strait induces this deep well-mixed layer.

As low dissolved oxygen concentrations are observed in the thermocline, this will limit the vertical distribution of tunas in the area. The habitat of tunas in the study area is shallower than that in the eastern Indian Ocean.

ACKNOWLEDGEMENT

We thank all MV.SEAFDEC crew for their corporation and hard work during the survey.

REFERENCES

Australian Fisheries Resources. 1993 .Bureau of Rural Sciences and the Fisheries Research and Development Corporation. Available from www.edaff.gov.au/nfpd/atlas/37441011.cfm

Report of survey with the R/V DR. Fridtjof Nansen on Marine Fish Resources of Burma, September – November 1979 and March – April 1980 Edited by T. Stremme, O. Nakken, Sann Aung and G., Satersdal. 90 p.

Schlitzer, R., Ocean Data View, http://www.awi-bremerhaven.de/GEO/ODV, 2005.

SPATIAL DISTRIBUTION OF NUTRIENT IN THE ANDAMAN SEA

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ABSTRACT

The spatial distribution of nutrient (nitrite, nitrate, silicate and phosphate) in the Andaman Sea were determined between 17th 24th November,2004. During the Joint Research Survey on Pelagic Fisheries Resources in the Andaman Sea within the EEZs of Indonesia, Myanmar and Thailand by MV SEAFDEC. Water samples from thirteen stations were analyzed by The Integral Futura Continuous Flow Automated Analysis of Seawater Nutrients. The average of nitrate, silicate and phosphate at surface layer (5 m.) were 7.31 µM, 5.38 µM and 0.49 µM, respectively and at the bottom layer (depending on each station) were 31.01 µM, 59.56 µM and 1.78 µM, respectively. The results indicated that the concentrations of nitrate, silicate and phosphate increase with depth. Thus, the concentration of nitrite in seawater is usually low and is non-detectable at some stations. At the surface layer, chlorophyll maximum layer (75 m) and sub-chlorophyll maximum layer (100 m) of each nutrient shown the upper latitude stations have higher nutrient concentrations than stations located in the southern part. At level 250 m. nutrient concentration have tended to be constant at both upper and southern stations.

Key words: Nutrient, Andaman Sea, Spatial distribution

INTRODUCTION

Traditionally, many of the essential nutrient elements are present in sea water in very low concentrations, but these are required by living organisms. Nutrients such as inorganic nitrogen (nitrite and nitrate), silicate and phosphate are essential for growth of phytoplankton and other algae which form the base of the ocean food chain. Phytoplankton are primary producer in the sea. Through photosynthesis, they produce food for zooplankton, which are then consumed by organisms higher up in the food chain. When phytoplankton, zooplankton or higher organisms are dead, marine bacteria decompose them. This returns the particle form of nutrients to a dissolved form that phytoplankton can use more easily.

The objective of this present study was to measure nutrient level (nitrite, nitrate, silicate and phosphate) for nutrient distribution in the Andaman Sea. Based upon the Joint Research Survey by MV SEAFDEC on Pelagic Fisheries Resources in the Andaman Sea within the EEZ of Indonesia, Myanmar and Thailand from 17th 24th November 2004.

MATERIALS AND METHODS

Study Location

The study location is in the Andaman Sea within the EEZs of Indonesia, Myanmar and Thailand. A total of 13 station were set during the cruise, from latitude 06°N to 12° N and longitude 95°E to 96°E (***Fig.1***). The sampling sites are listed in Table1.

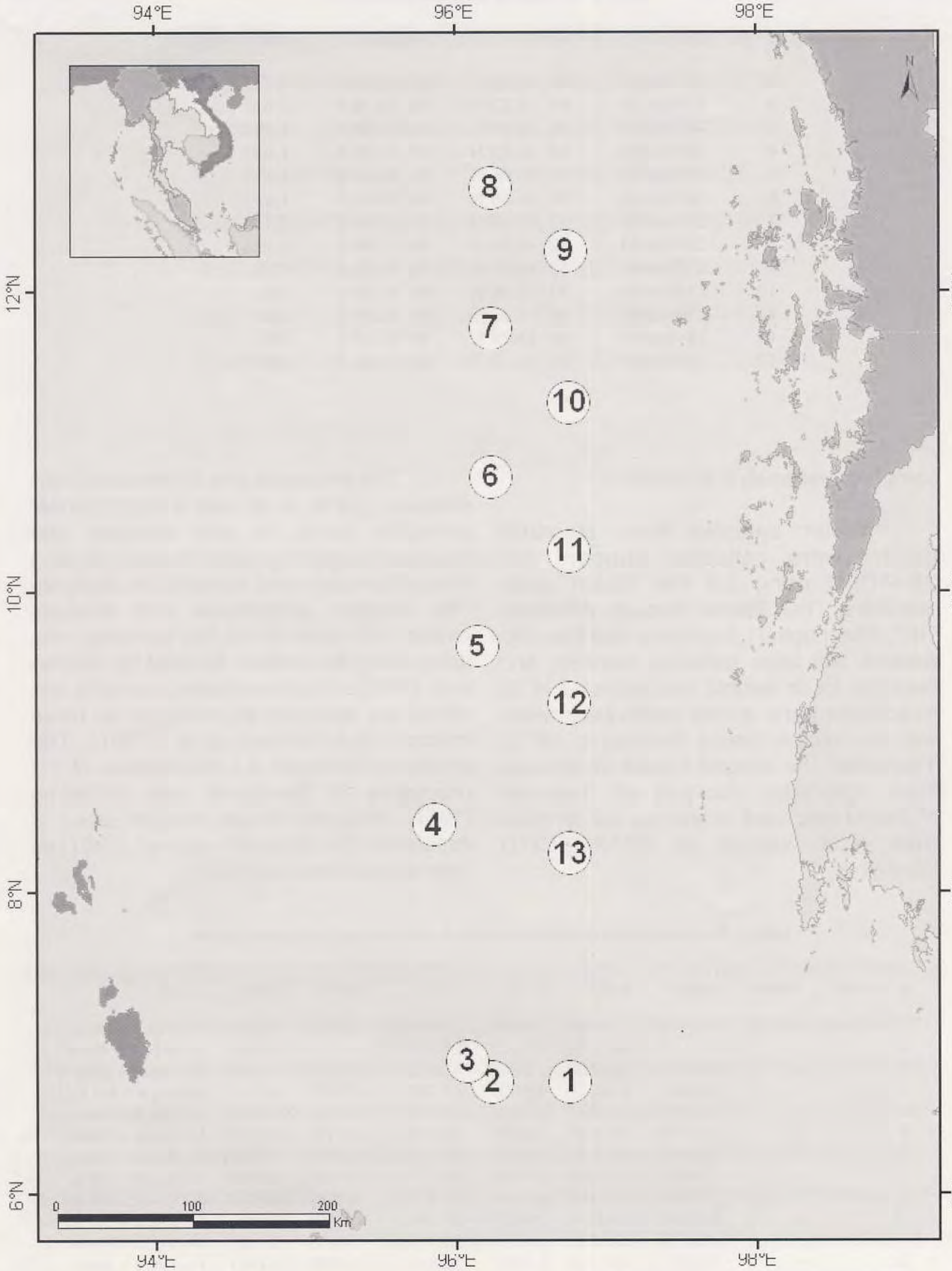

FIGURE 1. : Map of the Andaman Sea showing the location of sampling sites.

TABLE 1: The sampling site in the Andaman Sea.

St. No.	Date	Latitude	Longitude	Bottom Depth (m)
1	17-Nov-04	06_44.39 N	96_44.94 E	1,153
2	17-Nov-04	06_44.52 N	96_13.78 E	1,037
3	18-Nov-04	06_52.84 N	96_03.99 E	1,294
4	19-Nov-04	08_26.89 N	95_51.20 E	1,001
5	19-Nov-04	09_38.06 N	96_08.26 E	1,116
6	20-Nov-04	10_45.60 N	96_13.90 E	1,615
7	21-Nov-04	11_45.15 N	96_13.98 E	2,150
8	22-Nov-04	12_40.84 N	96_13.99 E	1,136
9	23-Nov-04	12_15.65 N	96_44.00 E	726
10	23-Nov-04	11_15.06 N	96_45.08 E	346
11	24-Nov-04	10_15.95 N	96_44.99 E	370
12	24-Nov-04	09_14.99 N	96_45.25 E	385
13	24-Nov-04	08_15.39 N	96_45.06 E	500

Sampling And Analytical Methods

Water samples from standard depths were collected onboard MV SEAFDEC using 2.5 liter Niskin water samplers. Then filtered through Whatman GF/C filter paper (1.2 μm pore size filters) to remove any large particles, plankton and bacteria. Each sample was collected in 60 ml polypropylene bottles, which were rinsed with the sample before freezing at -20°C. Thereafter The Integral Futura Continuous Flow Automated Analysis of Seawater Nutrients was used to analyze the samples from each station at SEAFDEC/TD laboratory.

The procedure of a Continuous Flow Analyzer (CFA) is to use a multichannel peristaltic pump to mix samples and chemical reagents in a continuously flowing stream for automated colorimetric analysis. The reagent preparation and analysis method of nutrients in the samples was done using the method detailed by Gordon et al. (1993) in that the nitrate plus nitrite and nitrate are analyzed according to the basic method of Armstrong et al. (1967). The phosphate analysis is a modification of the procedure of Bernhardt and Wilhelms (1967). And the silicate method used is essentially that of Armstrong et al. (1967) as adapted by Atlas et al.(1971)

TABLE 2: The concentration of determined nutrients at the surface(S) and bottom layer(B).

St	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Remark
1	0.0318	0.1132	6.1563	31.6183	8.4480	95.1184	0.0426	2.5888	S = 5 m., B = 700 m.
2	-	-	-	34.1226	-	110.1812	-	2.6656	S =20 m., B = 700 m.
3	-	-	9.4523	32.2783	9.2682	93.8723	0.1278	2.6141	S = 5 m., B = 600 m.
4	-	-	5.0363	35.8228	4.0418	87.7678	0.0005	2.6323	S = 5m., B = 925 m.
5	-	-	12.1483	36.1046	4.5926	74.9182	0.1087	2.5398	S = 5 m., B = 700 m.
6	-	-	11.5560	29.3801	3.5562	58.2093	0.1156	2.0119	S = 5 m., B = 700 m.
7	-	-	3.5864	32.0371	5.0070	60.3897	1.0367	1.7952	S = 5 m., B = 700 m.
8	-	-	7.5610	31.5990	6.7744	66.7776	2.0323	0.8110	S = 5 m., B = 700 m.
9	-	-	7.2390	25.2460	6.6244	32.8675	0.9860	0.8110	S = 5 m., B = 500 m.
10	-	-	5.0566	29.2306	2.4877	37.9442	0.8502	2.0266	S = 5 m., B = 250 m.
11	-	-	4.5270	30.9893	6.6241	38.4550	0.1633	0.2664	S = 5 m., B = 250 m.
12	-	-	8.5247	30.1062	3.9600	36.8661	0.2098	0.2943	S = 5 m., B = 250 m.
13	-	-	6.8413	24.5945	3.2155	31.4809	0.2238	2.0950	S = 5 m., B = 400 m.

RESULTS

The concentration of determined nutrients of the survey cruises at the surface (5 m from surface) and bottom layer (depending on sea bottom depth of each station) of sampling stations are presented in Table 2.

Several samples from this table show that the bottom samples have a higher concentration than surface samples. Except for phosphate concentrations at the bottom layer in station 8 and 9 have lower concentrations than the surface samples. Thus, the concentration of nitrite in seawater usually is low until becoming non-detectable at some stations.

Nitrite and nitrate concentrations always have the same relations. Nitrite is the intermediate oxidation state between ammonium and nitrate, and as such it can appear as a transient in both the oxidation of ammonium and the reduction of nitrate. (Spencer, 1975) Though it can be considered that some part of the nitrite was been oxidized into nitrate and made non-detectable the nitrite concentration at almost all of the stations.

Results for nitrate concentrations at the surface and bottom layers are shown in Table 2. The nitrate values ranged between 3.59-12.15 µM with a mean of 7.31 µM at the surface level and ranged between 24.59 -36.10 µM with a mean of 31.01 µM at the bottom layer. A minimum value 0.09 µM was found in station 4 at 75 m. and maximum value 36.10 µM was found in station 5 at 700 m. (bottom layer). Variation of nitrate concentrations for each station is presented in Fig. 7-8. All the result show that the concentrations at the bottom layer is always higher than the surface layer. From the surface to 200 m. nitrate concentrations increase with depth. However, nitrate concentration at 200 m and below has tended to constant at all the stations, and

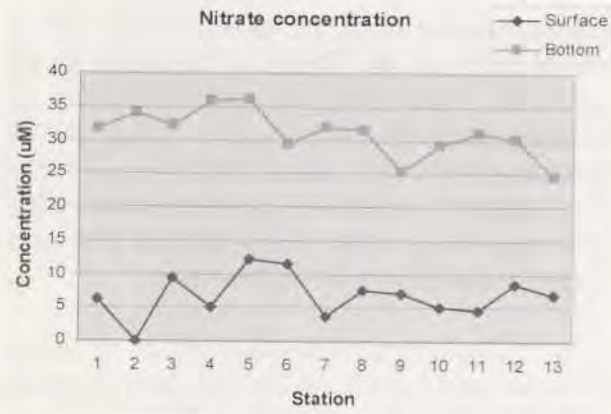

FIGURE 2: Concentration of nitrate at both surface and bottom layers.

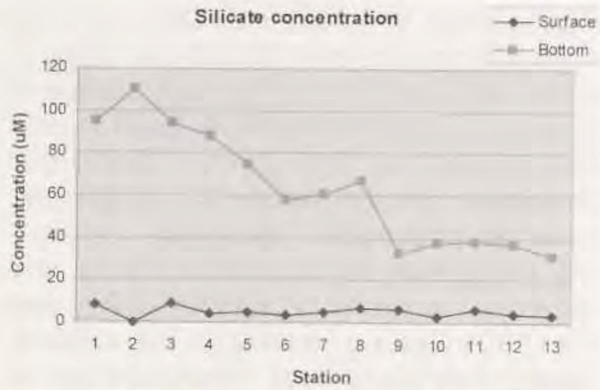

FIGURE 3: Concentration of silicate at both surface and bottom layers.

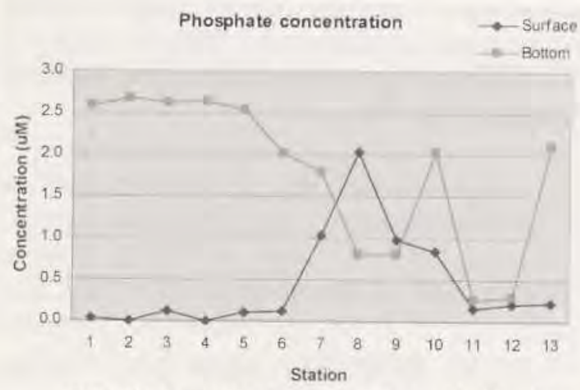

FIGURE 4: Concentration of phosphate at both surface and bottom layers.

ranged between 24.68-32.69 µM with a mean of 29.68 µM.

The silicate concentration was also extremly low at the surface water. Silicate concentration at the sea surface ranged from 2.49-9.27 µM with a mean of 5.38 µM. While silicate concentration at the bottom layers ranged from 31.48-95.12 µM with a mean of 59.56 µM (Table 2) The result for all stations show that the concentration of silicate increase with depth. (Fig. 9-10) Bottom layer (700 m.) of station no. 2 have the highest silicate concentration with 110.18 µM and the lowest at 1.69 µM was found in station no.10 at level 20 m.

The phosphate values at the surface level ranged from 0.04-2.03 µM with a mean of 0.49 µM and ranged from 0.27-2.67 µM with a mean of 1.78 µM at the bottom layer. Station no. 4 had the lowest phosphate concentration at 0.0005 µM (Table 2), while highest concentration 2.93 µM was found in station no. 9 at 125 m. (Fig. 11) Variation of phosphate concentrations for each station are shown in Fig. 11-12. Generally phosphate concentrations for nitrate and the concentrations of phosphate increase with depth from the surface to 200 m. and are fairly constant or slightly decreased after 200 m. was passed at all the stations. Except that phosphate concentrations at stations no.8 and 9, show that phosphate values have decreased after 200 m. was passed so phosphate concentrations at the bottom layer in station 8 (700 m.) and 9 (500 m.) have higher levels than the surface samples.(Fig. 11).

Nutrient are not distributed only in the vertical direction, but also horizontally. (Fig. 13-15) In the surface layer, concentration of nitrate at stations that are near shore (st. 9-13) are lower than stations that are far away from shore (st. 5,6)(Fig. 13-A). The highest nitrate concentration of 12.1483 µM was found at station no. 5. While at level 75 m (chlorophyll maximum or sub-thermocline layer) concentrations of nitrate at stations that are near shore (st. 9-12) are higher than stations that are far away from shore. The upper latitude stations (st. 7,8,9) also have higher nitrate values than stations that are located in the southern part (Fig. 13-B). Maximum nitrate concentrations were found at station no.10 with 11.69 µM. At level 100 m. (sub-chlorophyll maximum) the upper latitude stations also had higher nitrate values than the southern part (st. 1-4,13) (Fig. 13-C). Station no.5 had the highest nitrate concentrations at 21.35 µM. But at level 250 m. the concentration of nitrate had tended to constant at all stations with a mean of 28.52 µM. (Fig. 13-D)

The distribution of silicate concentrations at the surface layer tended to be constant at all stations with a mean of 5.38 µM (Fig. 14-A). Stations that are located in the southern part (st 1-3) have a little higher silicate concentration than other stations, a maximum silicate concentration 12.59 µM was found at station no. 2. At level 75 m.(Fig. 14-B), concentration of silicate both at upper latitude stations and southern part increase from the surface layer with a mean of 12.65 µM, while at the middle part (st. 4,5,12,13) are slightly increased with a mean of 7.16 µM. For level 100 m silicate concentration at all station have tended to be constant with a mean of 19.81 µM. (Fig. 14-C) Station no.5 had the highest silicate concentration of 27.57 µM and station no. 13 had the lowest silicate value at 10.07 µM. While at level 250 m. station no.1,2 and 3 had higher silicate values than at upper latitude stations (Fig. 14-D), in which silicate concentration had a mean of 36.21 µM. In this layer, station no.3 had the maximum silicate concentration, which was 61.97 µM.

The horizontal distribution of phosphate concentration are presented in Fig. 15, are show that high concentrations of phosphate are distributed from the upper latitude stations (st. 7,8,9,10) to low at stations that are located in the southern part. At upper latitude stations at the surface layer (Fig. 15-A) had phosphate concentrations with a mean of 1.23 µM, while stations in the southern part had a mean of 0.12 µM. The chlorophyll maximum layer (75 m) (Fig. 15-B) and sub-chlorophyll maximum layer (100 m) (Fig. 15-C), at upper latitude stations also had higher phosphate values than the southern part, which means that phosphate at the upper stations was 2.34 μM (75 m) and 2.46 μM (100 m) while at stations in the southern part a mean of 0.43 μM (75 m) and 1.01 μM (100m), respectively was noted. At level 250 m. (Fig. 15-D) concentrations of phosphate had tended to constant at all stations with a mean of 2.14 μM.

CONCLUSIONS

The result of this study shows that the distribution of each of the nutrients (nitrate, silicate and phosphate) uniformly increased with depth at all stations. Higher nitrate, silicate and phosphate concentrations were found in deeper water than in the surface water. The nutrient values were almost constant or slightly decreased after 200 m was passed at all the stations. Furthermore, horizontal distribution in the surface layer, chlorophyll maximum layer (75 m) and sub-chlorophyll maximum layer (100 m) of each nutrient shows that the upper latitude stations had higher nutrient concentration than stations that are located in the southern part. And at level 250 m. nutrient concentration tended to be constant at both upper and southern stations. Thus concentrations of nitrite in most water samples unable to be determined, it was estimated that some part of the nitrite had been oxidized into nitrate and made non-detectable nitrite concentrations in almost all stations.

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REFERENCES

Armstrong, F.A.J., C.R. Stearns, and J.D.H. Strickland. 1967. The measurement of upwelling and subsequent biological processes by means of the Technicon AutoAnalyzer_and associated equipment. *Deep-Sea Res.* 14(3): 381-389.

Atlas, E. L., S.W. Hager, L.I. Gordon and P.K. Park. 1971. A practical manual for use of the Technicon_AutoAnalyzer_in seawater nutrient analysesa; revised. Technical Report 215. Oregon State University, Dept of Oceanography, Ref.No. 71-22. 48 pp.

Bernhardt, H. And A. Wilhelms. 1967. The continuous determination of low level iron, soluble phosphate and total phosphate with the AutoAnalyzer. Technicon Symp., 1967, Vol.I, p.386.

Gordon, Louis I., Joe C. Jennings, Jr., Andrew A. Ross and James M. Krest. 1993. A Suggested Protocol for Continuous Flow Automated Analysis of Seawater Nutrients (Phosphate, Nitrate, Nitrite and Silicic Acid) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study. College of Oceanic and Atmospheric Sciences. Oregon State University. 55 pp.

Measures, Chris. 2001. Chemical Distributions : the roles of biology and physics. University of Hawaii, Dept of Oceanography. 9 pp.

Spencer, C.P. 1975. The Micronutrient Elements. *In* " Chemical Oceanography" (J.P. Riley and G. Skirrow, eds.), Vol II, pp. 245-300. Academic Press, London.

SUB-THERMOCLINE CHLOROPHYLL MAXIMA IN THE ANDAMAN SEA

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ABSTRACT

The research was carried out on the M.V. SEAFDEC cruise in the Andaman sea covering 13 stations between 16th-25th November 2004. Chlorophyll a and b were measured by HPLC analysis at the surface, thermocline, sub-thermocline and sub-chlorophyll maximum levels. The concentration of chlorophyll a and b were found as a maximum in the sub-thermocline level at a depth of 50-80 m. The spatial distribution of chlorophyll a and b were highest at Station 1. HPLC chromatograms showed some relationships with phytoplankton composition identified under the microscope. The more complex spectra were found in the chlorophyll maximum layer as the more diverse species of phytoplankton. The dominating class of phytoplankton were diatoms that showed the highest peak of fucoxanthin and related pigments. The peak of chlorophyll b was supposed to belong to nano-plankton, which cannot be identified under the microscope.

INTRODUCTION

In the marine environment phyto plankton plays a most important role as the base of the marine food web and is the primary food and energy source for the animal populations. Chlorophyll is the principal pigment which phytoplankton use in a photosynthetic process for converting nutrients into plant material. Chlorophyll has long been recognized as a unique indicator of oceanic biomass and productivity. The abundance of primary productivity is able to monitor the fishery production [Jeffrey and Mantura (1997)].

During the period of vertical stratification , a deep chlorophyll maximum is frequently observed below the thermocline and subthermocline chlorophyll maximum (SCM) is recorded [Varela et al., (1992)]. SCM is a phenomenon, which occurred in the tropics, subtropics and temperate seas [Ichikawa (1990); Musikasang (1999); Lokman et al. (1988)]. Steele (1964) reported that SCM affects phytoplankton communities as reflecting the light intensity, on the other hand, Anderson (1969) reported a SCM made up of actively growing cells of phytoplankton.

Chlorophyll is a photopigment that most people use as a quantitative indicator for phytoplankton studies, but there are many other pigments in phytoplankton that can help fingerprint different algal groups. Chlorophyll a (CHLa) and β-carotene are present in all groups of phytoplankton while some pigments are the characteristics of the phytoplankton classes. Fucoxanthin, peridinin, zeaxanthin and CHLb have been used as biomarkers for diatoms, dinoflagelllates, blue green algae and green algae, respectively [Jeffrey and Vesk (1997)]. Thus, pigment measurement allows us to rapidly identify and quantify different phytoplankton classes in a mixed water sample without tedious microscopy work. In recent years, the pigment analysis by HPLC has been used for chemotaxo nomics of phytoplankton in natural waters [(Obayashi et al. (2001); Li et al. (2002);

Gibb et al. (2001)], microphytobenthos communities [Brotas and Plante-Cuny (2003)] and also for investigating phytoplankton dynamics during red tide [(Wong and Wong, 2003)]. Pigment analysis by the HPLC method is useful as markers for phytoplankton taxonomy defined as ecological or physiological markers of phytoplankton population. Gibb et al., (2001) showed a potential of pigment data as biomarkers in the biogeochemical cycles.

In this study, the concentrations of CHLa and CHLb in phytoplankton taken from seawater at 4 levels were determined by using HPLC. This method can separate CHLa and CHLb from any interfering chlorophyll degradation products and the determination of CHLa and CHLb are reliable. This study is focused on the distribution of CHLa and CHLb in horizontal and vertical profiles to define their distribution and the chlorophyll maximum depth. The chlorophyll concentration reflects the primary productivity and was used as the basis for predicting the fishery resources in the Andaman sea. We also tried to evaluate the phytoplankton compositions, which usually require an experienced specialist and considerable time by application from HPLC pigment chromatogram.

MATERIALS AND METHODS

The present study was conducted during the survey cruise of M.V. SEAFDEC in the Andaman Sea between 16th-25th November 2004. The samples were collected from 13 sampling stations between 06°45N,096°15E and 12°45N,096°45E covering the Andaman waters of the southern part of Thailand and the southern part of Myanmar (Fig 1).

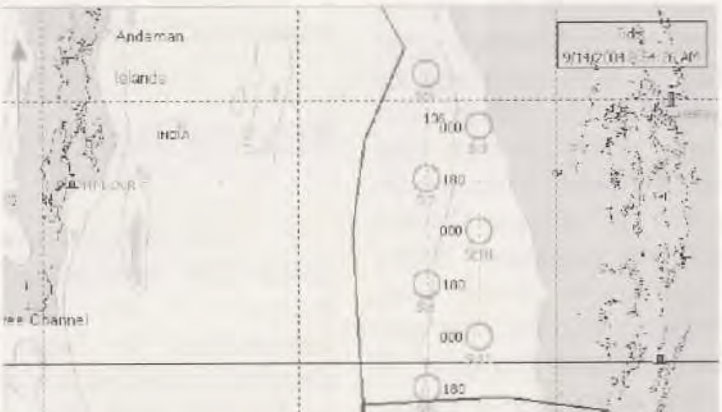

FIGURE 1 Sampling stations in the Andaman sea

Sample Collection

Water samples were taken at 4 levels: surface (2 m), thermocline, chlorophyll maximum (sub-thermocline) and sub-chlorophyll maximum (Table 1). The thermocline level was determined by temperature profile, which was derived from ICTD. The chlorophyll maximum depth was collected below the thermocline layer. (about 25-50 m.) The 10-15 L of seawater of were collected by Vandorn water sampler and prefiltered through a 300 μm mesh-size plankton net to remove zooplankton. Then the samples were immediately filtered through GF/F filters of 47 mm diameter under reducing vacuum. The filtered samples were kept frozen for extraction. Since chlorophyll were labile compounds, all procedure were done under dim light.

Sample Extraction

Shipboard extraction of the filtered samples was performed immediately after filtration. The extraction was achieved by the method of Furuya et al. (1998). The filters were cut into small pieces and extracted with 4 ml of Dimethylformamide and ground with a glass-teflon homogenizer. Then the extracted filters were kept in the refrigerator for 30 min. They were centrifuged for 6 min at 3,000 rpm and the supernatants were filtered through 0.2 μm PTFE filters. The extracted pigments were kept in amber vials and stored in the freezer at -20°C for further separation by HPLC.

HPLC Analysis

The extracted samples were separated for CHLa and CHLb by HPLC. The HPLC system was run by Thermoseparation equipment (a binary gradient pump, UV detector (440nm), autosampler and vacuum degasser) and the separated column a 5 μm HiCHROM S5ODS (4.6x250mm). The solvent programs of step-isocratic elution were applied from Mantoura et al. (1997) as solvent A (MeOH: 0.5 M Ammonium Acetate; 80:20) and solvent B (MeOH: Acetone; 90:10). In the first 3 minutes, solvent A was pumped into the system then step changed to solvent B for 15 minutes and 5 minutes later with solvent A. The flow rate was controlled at 1 ml/min and sample injection volume was 100 μl. CHLa and CHLb were identified by comparing their retention time with standard pigment (CHLa and CHLb: Fluka) the other peaks were compared with published pigment spectra [Jeffrey and Mantoura (1997)].

Phytoplankton identification

The water sample of 40 L taken by Van dorn sampler was filtered through a 20 μm mesh phytoplankton net. The filtered phytoplankton was preserved in 4% formalin. Phytoplankton was transferred to a Sedgwick-Rafter counting slide for enumeration under the microscope.

RESULTS AND DISCUSSIONS

The concentrations of CHLa and CHLb that collected at 4 levels from 13 stations in the Andaman Sea were summarized in Table 1. The vertical distribution of CHLa and CHLb were shown in Fig. 2 and this revealed that the chlorophyll maximum layer appeared at sub- thermocline layers at a depth of 50-80 m which is defined as sub-thermocline chlorophyll maximum depth (SCM). Deetae and Wisespongpand (2001) also reported that CHLa and CHLb in Vietnamese waters reached their maximum value in the chlorophyll maximum level, which is observed mostly in the sub-thermocline layer. The SCM in Sarawak waters was observed at 60 m by Lokman et al. (1988) and CHLa concentration ranged from 0.006-0.257 mg m^{-3} , which is close to the

TABLE 1. Concentrations of chlorophyll a and b (mg m^{-3}) at various depths.

Station	Surface		Thermocline		Chlorophyll maximum		Sub-chlorophyll maximum	
	CHLa	CHLb	CHLa	CHLb	CHLa	CHLb	CHLa	CHLb
1	0.05	0.01	0.18	0.05	0.28	0.12	0.08	0.04
2	0.04	0.00	0.09	0.01	0.20	0.07	0.08	0.05
3	0.06	0.01	0.16	0.03	0.10	0.07	0.02	0.03
4	0.06	0.01	0.09	0.01	0.08	0.04	0.01	0.00
5	0.05	0.01	0.12	0.02	0.08	0.05	0.02	0.01
6	0.11	0.02	0.07	0.01	0.21	0.07	0.02	0.01
7	0.06	0.01	0.08	0.01	0.18	0.04	0.06	0.03
8	0.05	0.01	0.13	0.03	0.12	0.05	0.01	0.01
9	0.03	0.02	0.05	0.02	0.11	0.05	0.02	0.01
10	0.08	0.02	0.11	0.03	0.18	0.07	0.03	0.02
11	0.06	0.01	0.10	0.02	0.19	0.07	0.04	0.02
12	0.07	0.02	0.07	0.02	0.08	0.04	0.03	0.02
13	0.07	0.01	0.09	0.02	0.20	0.07	0.07	0.04

TABLE 2. Bottom depth and sampling depths (m) of chlorophyll samples.

Station	Bottom Depth	Surface	Thermocline	Chlorophyll maximumb	Sub- Chlorophyll maximum
1	1153	2	50	75	100
2	1037	2	40	75	100
3	1294	2	40	75	100
4	1001	2	50	80	100
5	1116	2	40	75	100
6	1615	2	40	75	100
7	2150	2	30	50	100
8	1136	2	30	50	100
9	726	2	30	50	100
10	346	2	30	50	100
11	371	2	30	50	100
12	385	2	30	50	100
13	500	2	50	75	100

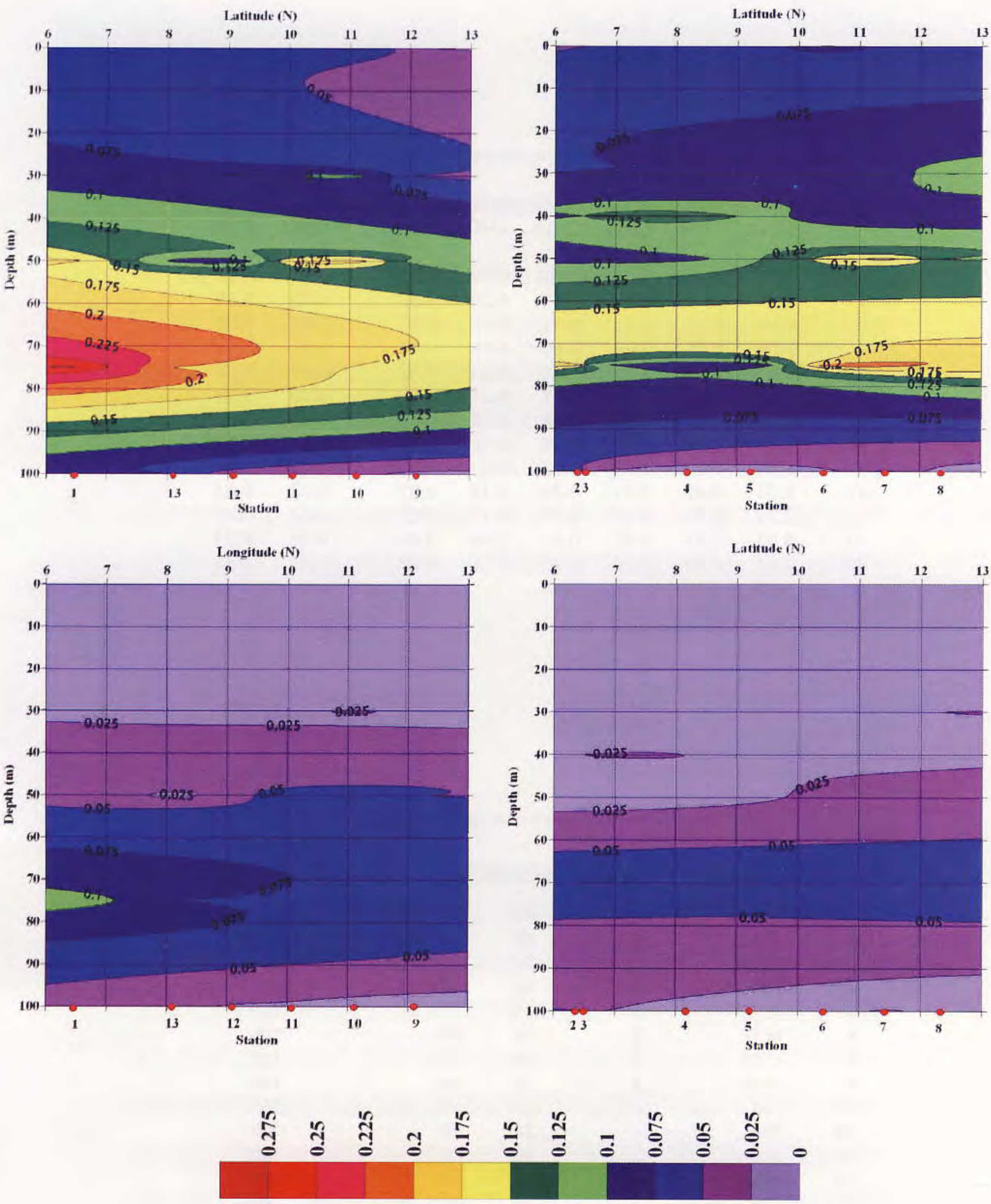

FIGURE 2. Vertical distribution of chlorophyll a and b (mg m^{-3}) at various sampling levels

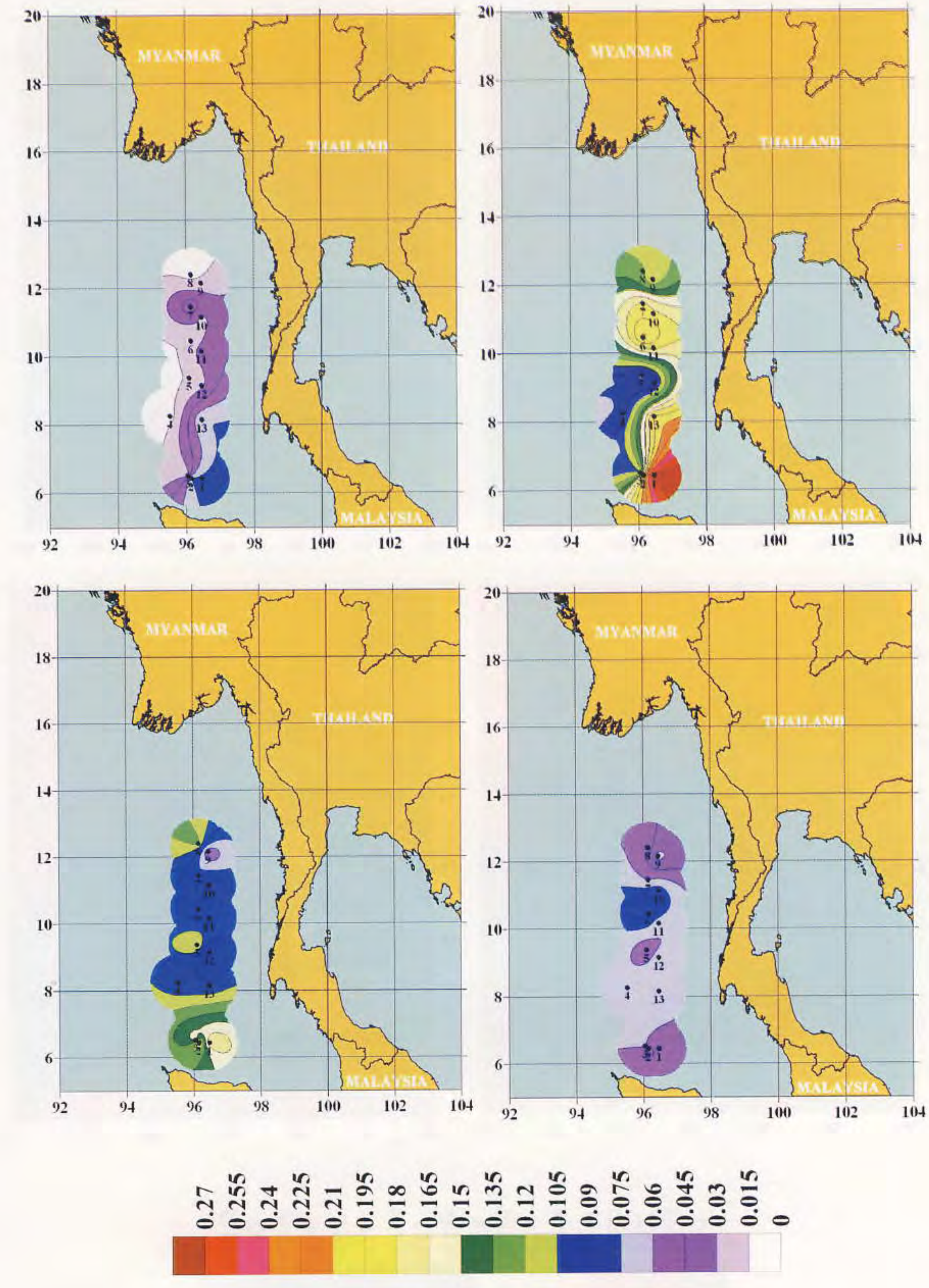

FIGURE 3. Concentration of chlorophyll a (mg m^{-3}) at various sampling levels

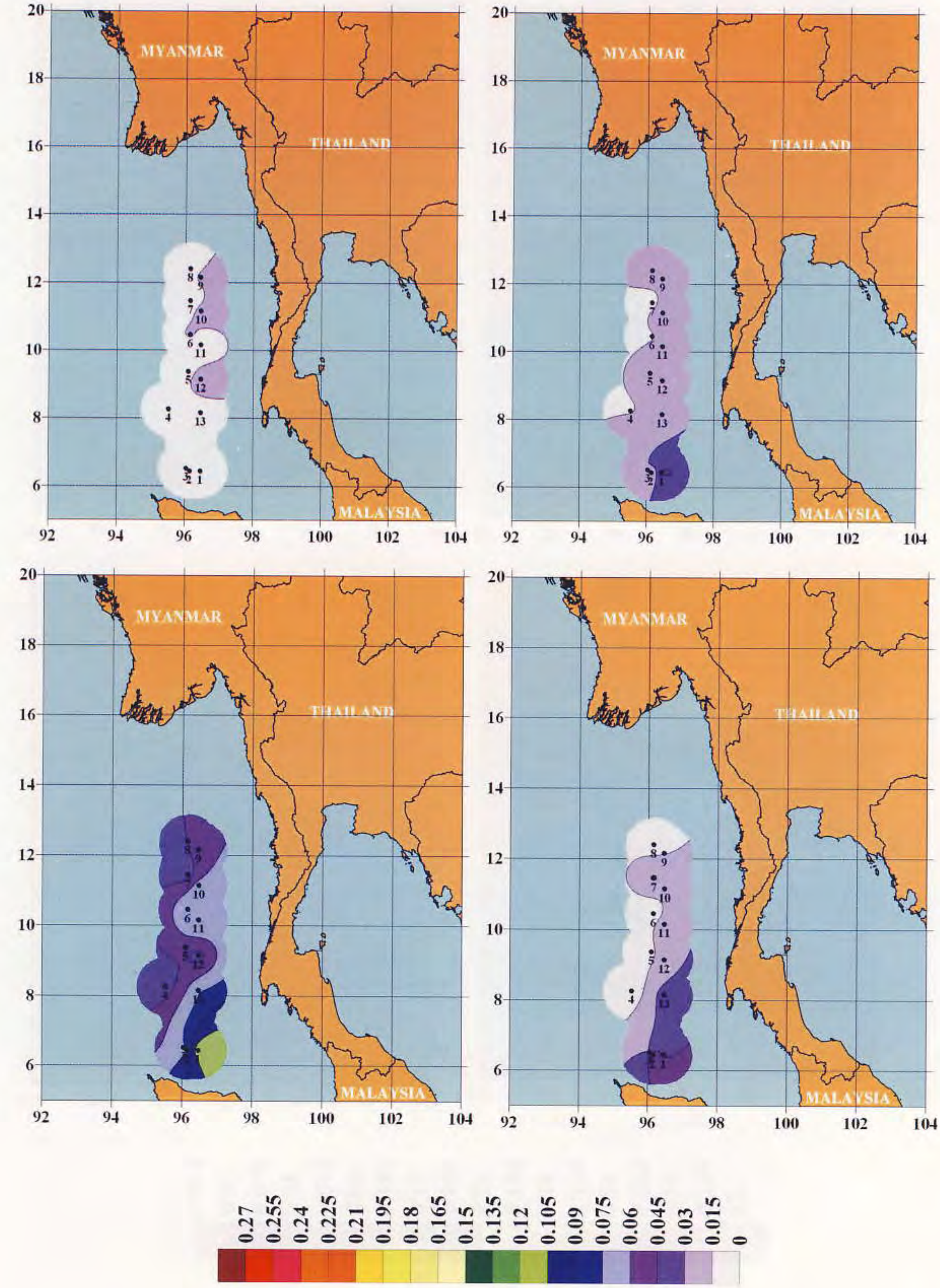

FIGURE 4. Concentration of chlorophyll b (mg m^{-3}) at various sampling levels

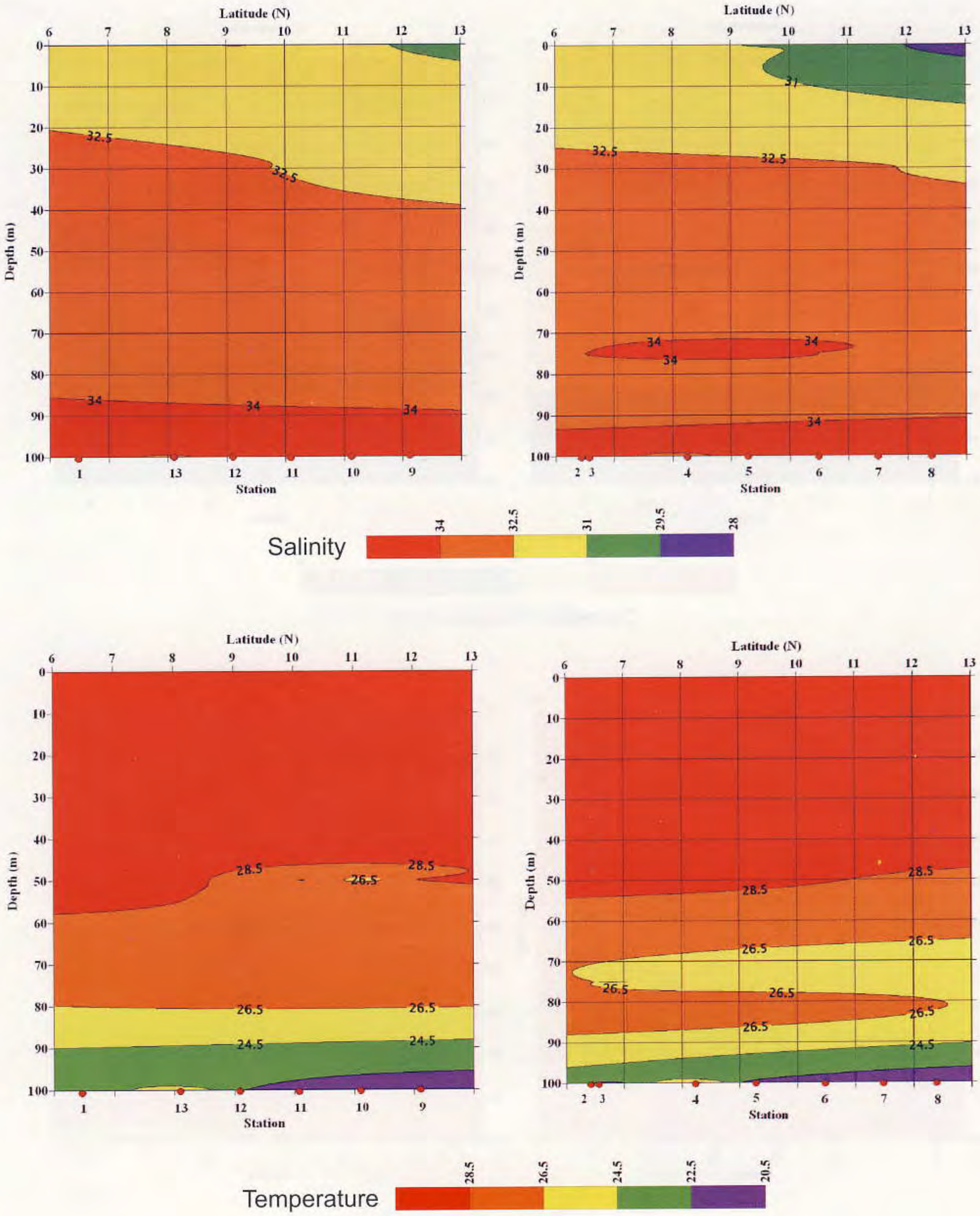

FIGURE 5. Vertical distribution of Salinity (PSU) and Temperature (°C)

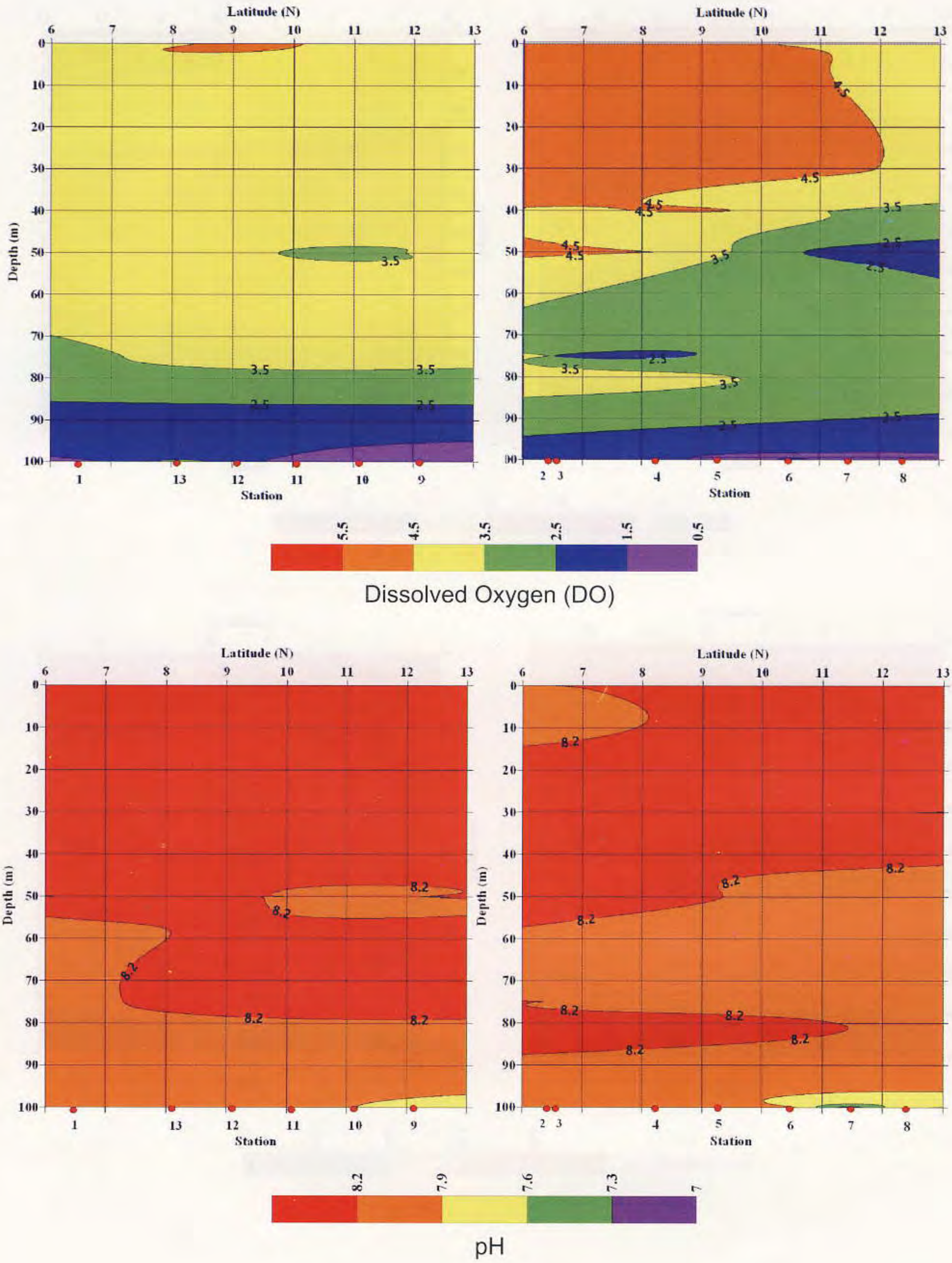

FIGURE 6. Vertical distribution of DO (mg/L) and pH

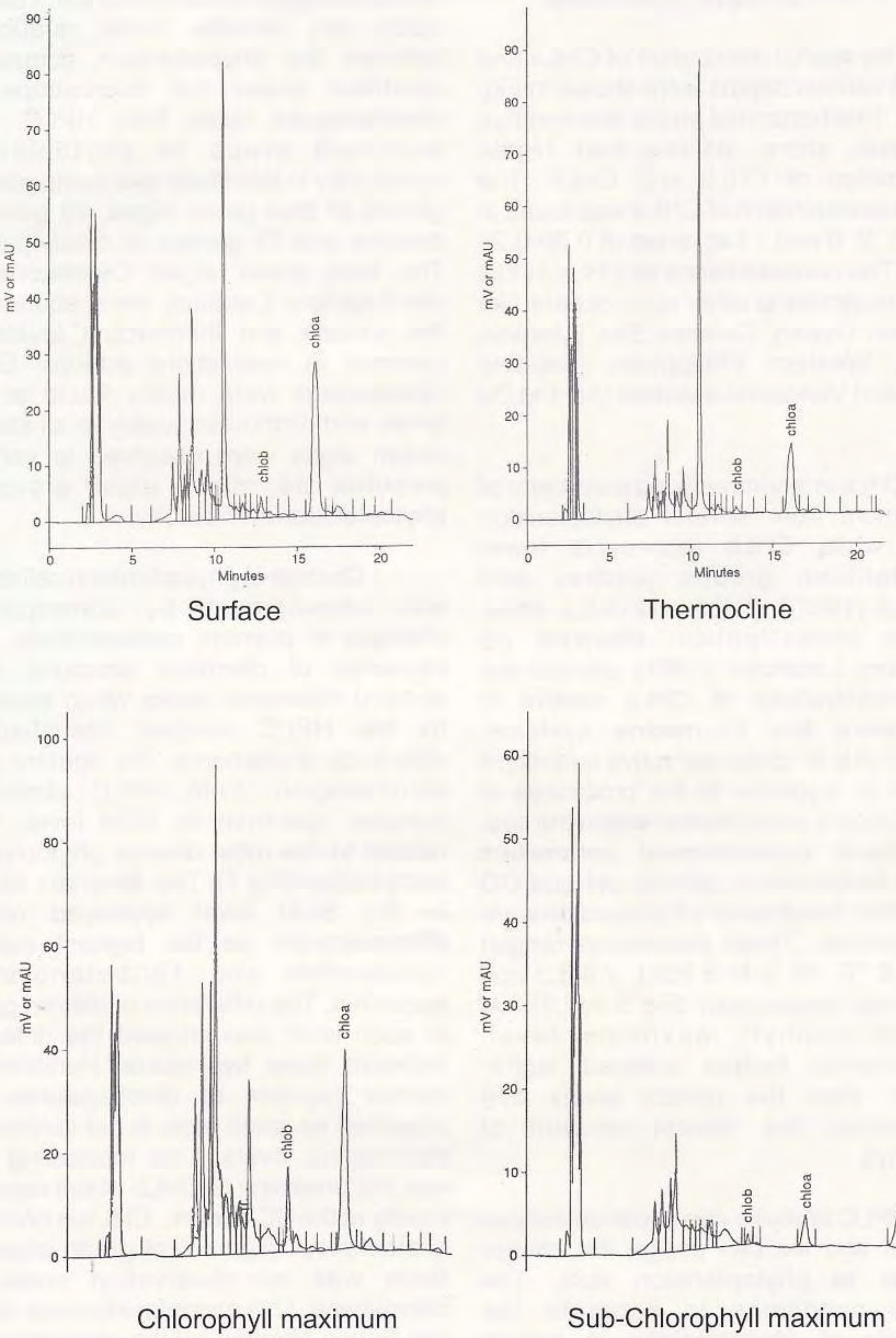

FIGURE 7. HPLC Chromatogram at various depths

range of 0.08- 0.28 mg m^{-3} in our study.

The spatial distribution of CHLa and CHLb at various depths were shown in Fig. 3 and 4. This horizontal profile showed that most near shore stations had higher concentration of CHLa and CHLb. The highest concentration of CHLa was found at station 1, 2, 6 and 13 at range of 0.20-0.28 mg m^{-3}. The concentrations of CHLa in this area were similar to other open oceans like the Indian Ocean, Celebes Sea [Marumo (1972)], Western Philippines [Bajarias (2000)] and Vietnamese waters [An and Du (2001)].

CHLa is a summarizing parameter of the pigment from several phytoplankton groups while CHLb represents fewer phytoplankton groups [Jeffrey and Mantoura (1997)]. CHLa and CHLb under present investigation showed no correlation. Lorenzen (1981) pointed out that concentrations of CHLa relative to CHLb were low in marine systems. Chlorophyll is a nonconservative quantity; it changes in response to the processes of production and consumption within the sea. Some basic environmental parameters such as temperature, salinity, pH and DO which affect the chlorophyll production were also examined. These parameters ranged 20.5-30.0 °C, 28.2-34.6 PSU, 7.8-8.3 and 0.4-5.5 mg/l respectively (Fig 5 and 6). At sub- chlorophyll maximum level, environmental factors showed higher variation than the others levels that represented the lowest amount of chlorophyll.

HPLC analysis can separate various pigments and we can assign the marker pigments to phytoplankton taxa. The suitable conditions to separate the complexity of phytoplankton in natural waters need high performance equipment like the binary gradient pump, photodiode array detector and many specified pigments as reference standards. In this study we used HPLC to separate the pigments which focused only on CHLa and CHLb. Thus, our study can provide some relationship between the phytoplankton composition identified under the microscope and chromatogram taken from HPLC. The dominant group of phytoplankton community in this study was composed of 1 genera of blue green algae, 29 genera of diatoms and 15 genera of dinoflagellates. The blue green algae Oscillatoria and dinoflagellate Ceratium were abundant at the surface and thermocline levels and common in near shore stations. Diatom Chaetoceros were mostly found at SCM levels and distributed widely in all stations. Green algae were observed in very low amounts as minor algal groups of phytoplankton in this study.

Change in phytoplankton cell density was accompanied by corresponding changes in pigment concentration. The character of chemical structure, which showed difference peaks when separated by the HPLC method, identified the difference of pigments. The spectra of the chromatogram from HPLC showed a complex spectrum in SCM level, which related to the most diverse phytoplankton composition (Fig 7). The dominant diatoms in the SCM level appeared on the chromatogram as the highest peak of fucoxanthin and 19/-butanoyloxyfu coxanthin. The difference of diatom genera in each level also showed the difference between those two peaks. Peridinin, the marker pigment of dinoflagellates was observed as small peak in the surface and thermocline levels. One interesting peak was the presence of CHLb which appeared mostly at the SCM level. CHLb is one of the characteristic pigment of green algae but there was no observation under the microscope. This nanoplankton was usually lost during filtration by the plankton net or destroyed by preservation reagent. Nanoplankton is found in large concentrations in the sea and is likely to account for a significant component of primary production in the ocean [Partensky et al. (1993)]. So, HPLC has more advantages for nanoplankton investigation. We observed more peaks of chlorophyll degradation pigment (phaeopytin) in sub-chlorophyll maximum level. The peak of Zeaxanthin which is the characteristic of blue green algae was not shown under this HPLC condition. By the advanced HPLC system with more accurate separation, pigment analysis can be used as valuable chemotaxonomic markers of phytoplankton.

REFERENCES

An, N. T. and H.T. Du. : Studies on Phytoplankton Pigments : Chlorophyll, Total Carotenoids and Degradation Products in Vietnamese Waters. Proceedings of the 4 th. technical seminar on marine fishery resources survey in the South China Sea (area IV) : Vietnamese Waters. Special paper No. SEC/SP/44. Southeast Asian Fisheries Development Center, Bangkok. 233-247 pp. (2001).

Anderson G. C. : Subsurface Chlorophyll Maximum in the Northeast Pacific Ocean. *Limnology and Oceanography*, 14, 386-391 (1969).

Bajarias F. F. : Phytoplankton in the surface layers of the South China Sea, Area III: Western Philippines. in Proceeding of the third technical seminar on marine fishery resources survey in the South China Sea, Area III: Western Philippines. 220-234 (2000).

Brotas, V. and M. Plante-Cuny. : The use of HPLC pigment analysis to study microphytobenthos communities. *Acta Oecologia*, 24, S109-S115 (2003).

Deetae, S. and P. Wisespongpand. : Sub-thermocline chlorophyll maxima in the South China Sea (Area IV) : Vietnamese Waters. Proceedings of the 4 th. technical seminar on marine fishery resources survey in the South China Sea (area IV) : Vietnamese Waters. Special paper No. SEC/SP/44. Southeast Asian Fisheries Development Center, Bangkok. 251-264 pp. (2001).

Furuya K., .M. Hayashi and Y.Yabushita : HPLC Determination of Phytoplankton Pigments Using N, N-Dimethylformamide. *J.Oceanogr.*, 54, 199-202 (1998).

Gibb, S.W., D.G. Cummings, X. Irigoien, R.G. Barlow, R. Fauzi and C. Mantoura. : Phytoplankton pigment chemotaxonomy of the northeastern Atlantic. *Deep-Sea Research II*, 48, 795-823 (2001).

Ichikawa T. : Particulate organic carbon and chlorophyll in the South China Sea off Sabah. *FPSS. UPM. OCC.*, 9, 81-85 (1990).

Jeffrey S. W. and M. Vesk : Introduction to marine phytoplankton and their pigment signatures, in "Phytoplankton Pigments in Oceanography" (ed. by S.W. Jeffrey, R.F.C. Mantoura and S.W. Wright), UNESCO, Paris, 1997, pp. 37-84.

Jeffrey S. W. and R. F. C. Mantoura : Development of pigment methods for oceanography : SCOR - Supported Working Groups, in "Phytoplankton Pigments in Oceanography" (ed. by S.W. Jeffrey, R.F.C. Mantoura and S.W. Wright), UNESCO, Paris, 1997, pp. 19-36.

Li, H.P., G.C. Gong and T.M. Hsiung. Phytoplankton pigment analysis by HPLC and its application in algal community investigations. *Bot. Bull. Acad. Sin.* 43, 283-290 (2002).

Lokman B. S., K. B. B. Kaironi and M.N.B. Saadon : Chlorophyll "a" content off the Sarawak Waters of the South China Sea. *FPSS. U.P.M. OCC.*, 8, 87-90 (1988).

Lorenzen C. J. : Chlorophyll b in the eastern North Pacific Ocean. *Deep-Sea Research*, 28, 1049-1056 (1981).

Mantoura, R.F.C., R.G. Barlow and E.J.H. Head : Simple isocratic HPLC methods for chlorophylls and their degradation products, in "Phytoplankton Pigments in Oceanography" (ed. by S.W. Jeffrey, R.F.C. Mantoura and S.W. Wright), UNESCO, Paris, 1997, pp. 307-326.

Marumo R. : Phytoplankton in the Sea Area of the Southeast Asia. in "Proc. of the Third CSK Symposium" Bangkok, Thailand (1972).

Musikasung W., M.S.B Yosoff and S. B. A. Rasak : Primary Production Determination in the South China Sea, Area I : Gulf of Thailand and East Coast of Peninsular Malaysia. in "Proceedings of the first technical seminar on marine fishery resources survey in the South China Sea Area I. Gulf of Thailand and East Coast of Peninsular Malaysia 24-26 November 1997". Bangkok, Thailand, pp. 135-146 (1999).

Obayashi, Y., E. Tanoue, K. Suzuki, N. Handa, Y. Nojiri and C.S. Wong. : Spatial and temporal variability of phytoplankton community structure in the northern North Pacific as determined by phytoplankton pigments. *Deep-Sea research I*, 48, 439-469 (2001).

Partensky, F., N. Hoepner, W.K.W. Li, O. Ulloa and D. Vaulot. : Photo-acclimation of *Prochlorococcus sp.* (Prochlorophyto) strains isolated from the North Atlantic and the Mediterranean Sea. *Plant Physiology*, 101, 285-296 (1993)

Steele J.H. 1964. A study of production in the Gulf of Mexico. *J. Mar.Res.* 22, 211-222.

Varela R. A., A. Cruzado, J. Tintore and E. Garcia-Ladona : Modeling the deep-chlorophyll maximum. A Coupled physical-biological approach. J. *Mar. Res.*, 50, 441-463 (1992).

Wong C.K. and C.K. Wong. : HPLC pigment analysis of marine phytoplankton during a red tide occurrence in Tolo Harbor, Hong Kong. *Chemosphere*, 52, 1633-1640 (2003).

PHYTOPLANKTON SAMPLING ACTIVITIES

COMPOSITION, ABUNDANCE AND DISTRIBUTION OF PHYTOPLANKTON IN THE ANDAMAN SEA

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A Phytoplankton investigation was conducted in the Andaman Sea within the EEZs of Indonesia, Myanmar and Thailand between 17th–24th Nov. 2004. The samples were collected by Van Dorn water sampler at the surface, the starting depth of the thermocline and 20-35 m below the thermocline. Thirty liters of water samples were filtered through a 20 μm mesh phytoplankton net and preserved in 1-2 % formalin. The samples were identified and cell counted. A filament count was made for bluegreen algae. The results revealed that phytoplankton densities were highest in Myanmar's waters. The highest density was 8,658 cells/L found at 50 m depth (20 m below the thermocline) of the northernmost station of the study area. Sixty-nine genera and 164 species were identified. *Oscillatoria erythraea* distributed predominantly in the surface layer of the whole study area. The other dominant species, which occurred below the surface layer were *Chaetoceros affinis, C. pseudodichaeta, Fragilariopsis doliolus, Leptocylindrus mediterraneus* and *Thalassionema frauenfeldii*. Toxic species were found with low cell densities.

Keywords: Phytoplankton, Andaman Sea

INTRODUCTION

Phytoplankton is well known as a producer of the primary food supply of the sea. It plays a vital role in marine ecosystems. The Andaman Sea is of paramount importance for bordering countries' fisheries. The information of phytoplankton in this area is very scanty. Taylor (1976) reported dinoflagellate species and their distribution in the Indian Ocean including the Andaman Sea. Boonyapiwat (1987) studied phytoplankton in the Andaman Sea, the area from Langkawi Island through the coastal waters of Ranong Province in May 1985. Rines *et al*., (2000) noted new species of *Chaetoceros* obtained near Phuket Island.

This study is a part of a project on "Large Pelagic Fisheries Resources in the Andaman Sea." The investigation of phytoplankton in the Andaman Sea within the EEZs of Indonesia, Myanmar and Thailand is necessary for understanding the hydrographic features and the effects on marine organisms. It will be beneficial to ecology and fishery studies of the concerned countries.

The purpose of this study is to describe the species composition, abundance and distribution of phytoplankton in the Andaman Sea within the EEZs of Indonesia, Myanmar and Thailand.

MATERIALS AND METHODS

Phytoplankton samplings were carried out onboard M.V.SEAFDEC between 17th –24th November 2004 in 13 stations in the Andaman Sea within the EEZs of Indonesia, Myanmar and Thailand (Fig.1). The water samples were taken by Van Dorn water sampler from the surface, the starting depth of the thermocline and 20-35 m below the thermocline. The

			Sampling depth (m)	
	Sea depth	Surface	Thermocline	Below thermocline
1	1153	2	50	75
2	1037	2	40	75
3	1294	2	40	75
4	1001	2	50	80
5	1116	2	40	75
6	1615	2	40	75
7	2150	2	30	50
8	1136	2	30	50
9	726	2	30	50
10	346	2	30	50
11	370	2	30	50
12	385	2	40	75
13	500	2	50	no data

TABLE 1. **Sampling Depth at each station**

sampling depths followed the ICTD records. The starting depths of the thermocline were 40-50m in Indonesian and Thai waters and 30-40 m in Myanmar waters. The details of sampling depths are shown in **Table 1**. Thirty liters of water samples were filtered through 20 μm mesh phytoplankton net and preserved with 1-2 % formalin immediately. The samples were concentrated by sedimentation. Phytoplankton were identified and counted using a 0.25 ml counting slide under a compound microscope fitted with a phase contrast device, inverted microscope and electron microscope. A filament count was made for bluegreen algae.

RESULTS

Identification

A total of 69 genera with 165 species belonging to Class Cyanophyceae (bluegreen algae), Bacillariophyceae (diatom) and Dinophyceae (dinoflagellate) were identified. There were 56 genera with 109 species, 53 genera with 121 species, and 52 genera with 100 species found in Indonesian waters, Myanmar waters, and Thai waters, respectively. A taxonomic list and occurrence are given in **Table 2.**

Phytoplankton Abundance

Phytoplankton densities at the surface, thermocline, and below the thermocline are shown in Table 3. The densities in the surface layer were in the range of 735-7,814 cells/L. The highest was observed at station 11 in Myanmar waters. The cell number was also high (7,507 cells/L) at station 9 (Fig. 2). This station is located in Myanmar waters and had the highest cell density of 6,214 cells/L in the thermocline layer while the lowest was found to be 504 cells/L at station 4 in Thai waters (Fig. 3). Fig. 4 shows high cell densities of phytoplankton in Myanmar waters in the layer below the thermocline. The highest density was obtained from station 8 with a cell count of 8,658 cells/L while those from the neighboring stations were also high (station 8 : 8,208 cells/L, station 10 : 7,732 cells/L). Two lines of sampling stations as shown in Fig. 1 were studied for vertical cross section of phytoplankton density. The densities were high at high latitudes and the highest densities were found around 50 m depth in both lines (Fig. 5&6).

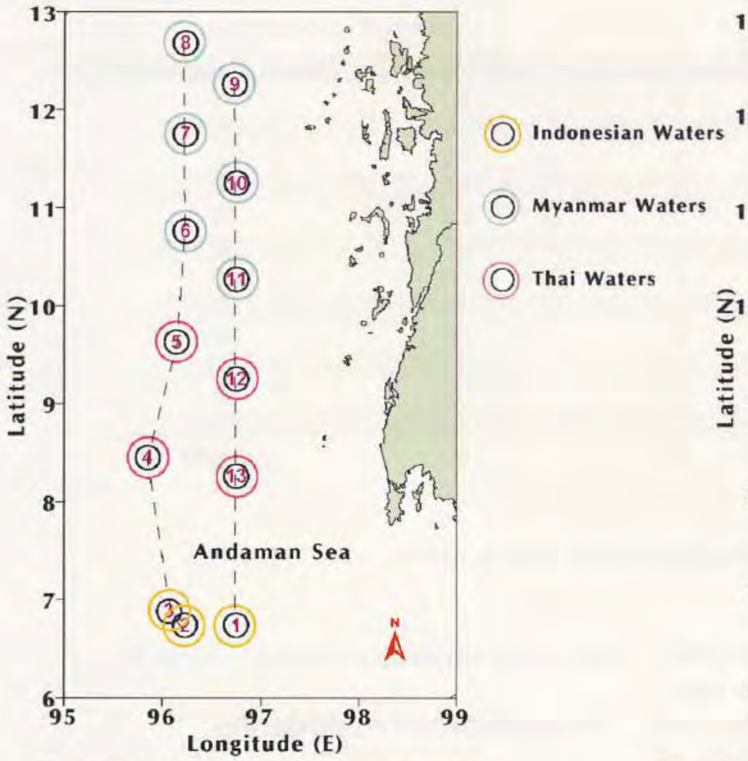


FIGURE 1. Location of sampling stations.

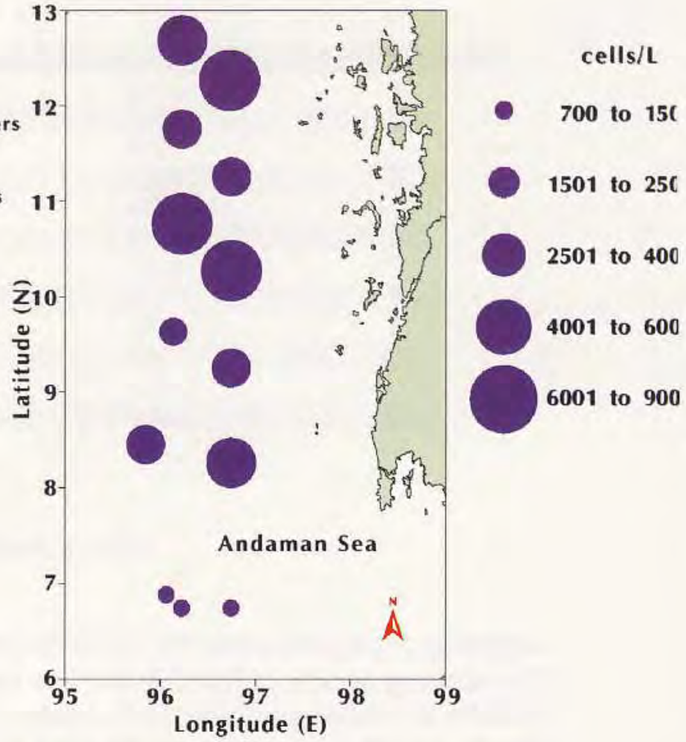


FIGURE 2. Phytoplankton density in the surface layer.

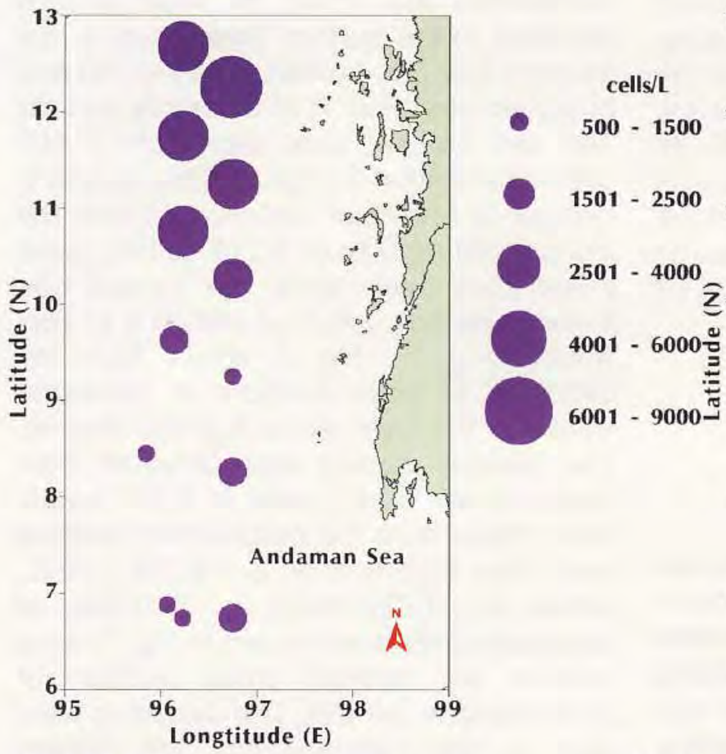


FIGURE 3. Phytoplankton density in the thermocline layer.

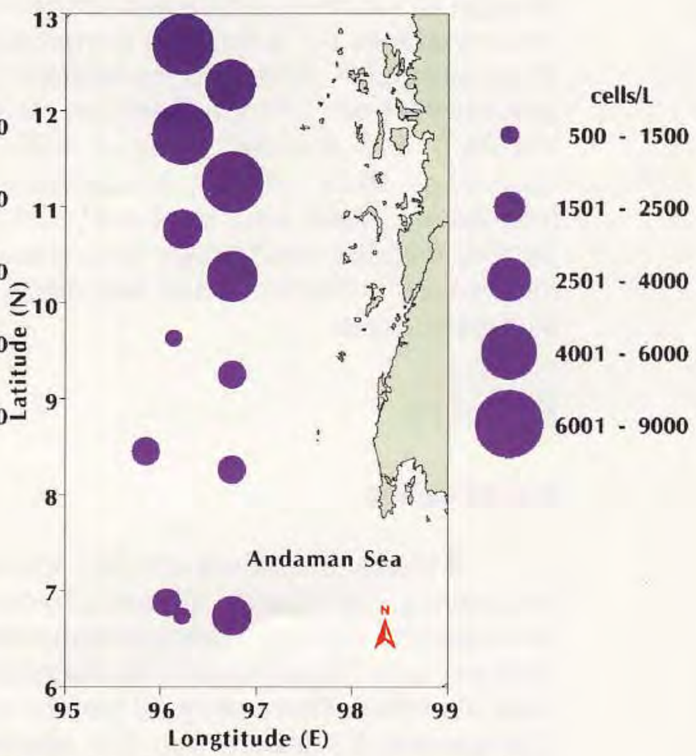


FIGURE 4. Phytoplankton density below thermocline.

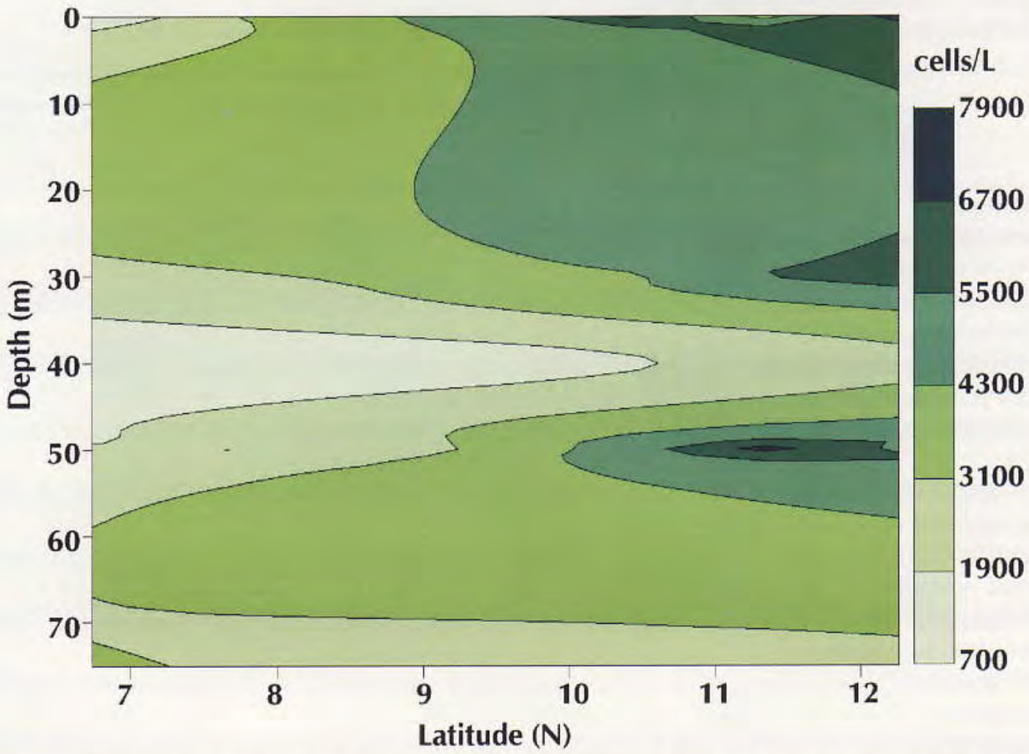


FIGURE 5. Vertical cross section of phytoplankton density along the inner line of sampling stations.

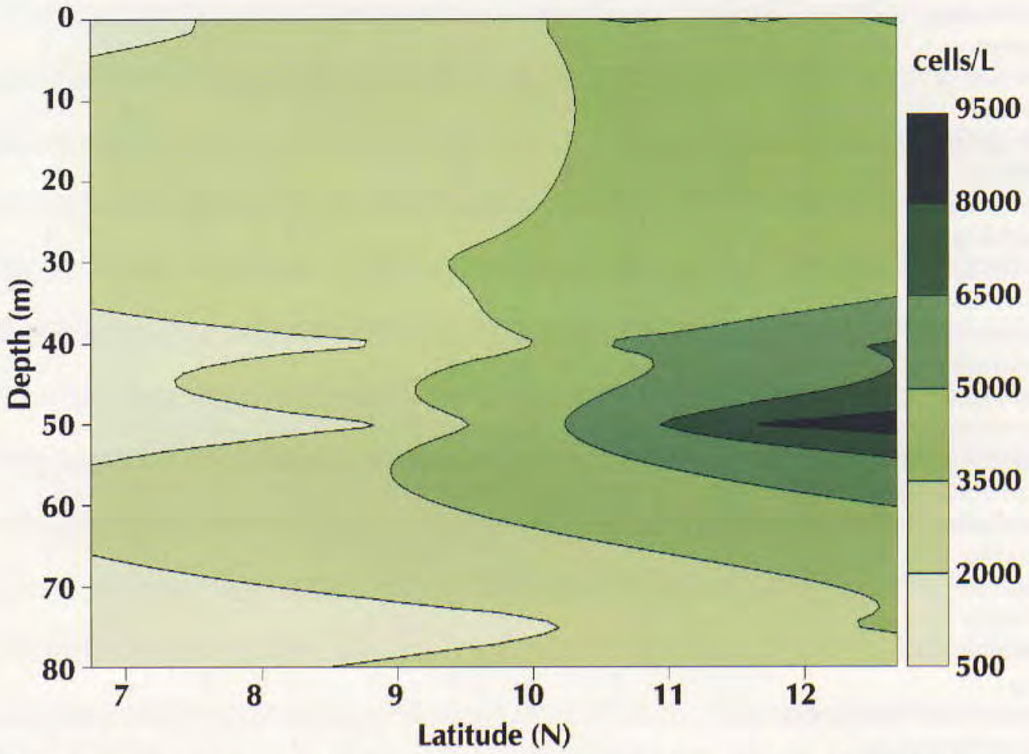


FIGURE 6. Vertical cross section of phytoplankton density along the outer line of sampling stations.

TABLE 2. Phytoplankton occurrence in the study area during 16-24 Nov. 2004.
(Number 1-5 represented the value of cell density as 1 = 1-50 cells/L 2 = 51-100 cells/L 3 = 101-500 cells/L 4 = 501-1000 cells/L 5 = >1000 cells/L)
Sampling depth : S = Surface , Th = Thermocline , Bth = 20 - 35m Below thermocline

TAXA	Indonesian waters			Myanmar waters			Thai waters		
	S	Th	Bth	S	Th	Bth	S	Th	Bth
Division Cyanophyta									
Class Cyanophyceae (Bluegreen algae)									
Calothrix crustacea	1	1	1	2	1	1	2	1	
Oscillatoria erythraea	4	3	1	5	5	5	5	4	1
Division Chromophyta									
Class Bacillariophyceae (Diatom)									
Actinocyclus spp.	1	1	2	2	1	1	1	1	2
Actinoptychus senarius				1		1			1
A. spp.			1						
Asterolampra marylandica		1	1				1	1	1
Asteromphalus flabellatus		1	1	1		1	1		
A. heptactis						1			1
Azpeitia nodulifera	1	1	1			1		1	1
Bacillaria paxillifer						1			1
Bacteriastrum comosum			1			2		1	1
B. delicatulum	1		1	3		3	1	1	1
B. elongatum						2	1	1	1
B. furcatum				1					
Cerataulina pelagica			1	1		1		1	1
Chaetoceros aequatorialis			1			2			1
C. affinis			1	2		3		1	1
C. coarctatus	1	1	1	1	1			1	
C. compressus						3		1	
C. curvisetus									1
C. dadayi							1	1	
C. decipiens			1						
C. densus	1		1	1	1		1		
C. denticulatus	1								
C. dichaeta					2	3		1	1
C. didymus		1	1	1	1				
C. diversus				1		1			
C. lorenzianus			1	2	2	3	3	3	2
C. messanensis			3	1	1	4		1	2
C. paradoxus				2		1			
C. peruvianus	1	1	1	1	1	1	1		
C. pseudocurvisetus			1	1	1				
C. pseudodichaeta		1	3		1	4	1	2	3
C. rostratus		1	1			1			
C. simplex			3			1		1	3
C. socialis					1			1	1
C. subtilis				2		3			
C. tetrastichon					2	1		1	
C. spp.	1	1	3	2	1	2	1	1	1
Climacodium biconcavum		1		2	1		1	1	
C. frauenfeldianum		3	2		1	3	1	1	1
Corethron hystrix s								1	1

Continue next page...

TABLE 2. (Cont.)

TAXA	Indonesian waters			Myanmar waters			Thai waters		
	S	Th	Bth	S	Th	Bth	S	Th	Bth
Coscinodiscus asteromphalus								1	
C. centralis		1		1		1			
C. granii			1						
C. jonesianus	1	1	1		1	1	1		1
C. perforatus	1				1				1
C. radiatus						1	1		1
C. spp.		1	1	1	1	1	1	1	1
Cylindrotheca closterium	1				1	1			
Dactyliosolen blavyanus			1	1		1			1
D. phuketensis			1						1
Ditylum sol									1
Eucampia cornuta				1	1	1			1
E. zodiacus			1						1
Fragilariopsis doliolus	1	3	3	2		3		3	3
F. spp.			2	2	2	1	2	1	1
Gossleriella tropica			1	1		1			
Guinardia cylindrus		1				1	1		1
G. delicatula							1		1
G. flaccida									1
G. striata		1		1			1		
Haslea gigantea	1	1	1	3	1	1	1	1	1
H. wawrikae	1	1		1	1		1	1	
Hemiaulus hauckii	1	1	1	1	1	1	1		
H. indicus				1	1				
H. membranaceaus	1	1					1	1	
H. sinensis		1	1	1	1	3	1	1	1
Hemidiscus cuneiformis			1			1			1
Lauderia annulata			1						
Leptocylindrus danicus		1	1	1	1	1	1		1
L. mediterraneus		2	2		1			1	3
Lioloma delicatulum		1	1		1	1			1
Melosira nummoloides			1						
Meuniera membranacea			1						1
Nitzschia spp.	1								1
Odontella sinensis	1	1					1		
Planktoniella blanda			1						
P. sol			3			3	1	1	3
Pleurosigma normanii			1						
P. spp.			1				1		1
Proboscia alata	1	1	1	3	2	2	1	1	1
Pseudo-nitzchia pungens			1			1			
P. spp.	1	1	1	1		1		1	
Pseudosolenia calcar-avis	1	1		1	1		1	1	
Rhizosolenia acuminata				1					
R. bergonii		1	1		1	2		1	1
R. clevei	1			1	1	1	1	1	
R. Formosa			1						
R. hyalina						1			

Continue next page...

TABLE 2. (Cont.)

TAXA	Indonesian waters			Myanmar waters			Thai waters		
	S	Th	Bth	S	Th	Bth	S	Th	Bth
Rhizosolenia imbricata		1		1	1			1	1
R. robusta			1						
R. setigara		1							
R. styliformis	1	1	1	1	1		1	1	1
Thalassionema frauenfeldii	1	2	2	3	2	3	3	1	3
T. nitzschioides		1	1			3			1
Thalassiosira eccentrica	1	1	1	2	1	2	1	1	2
T. linealata						1			
T. oestrupii									1
T. subtilis									1
T. thailandica						1			
T. spp.	1	1	3	2	2	2	2	2	2
Thalassiothrix longissima		1	1			1	1		1
Pennate diatom	1	1	1	1			1	1	1
Class Dinophyceae (Dinoflagellate)									
Alexandrium tamyavanichii	1	1			1			1	
A. spp.	1			1					
Amphisolenia bidentata	1	1			1		1	1	
A. schauinstandi	1				1				
Ceratium candelabrum	1								
C. carriense			1		1	1			
C. contortum								1	
C. declinatum	1	1				1	1		1
C. deflexum				1	1		1		
C. dens				1					
C. furca	1	1		1	1		1	1	
C. fusus	1	1		1		1		1	
C. gibberum			1	1	1				
C. hexacanthum						1			
C. horridum		1		1		1			
C. humile					1		1		
C. kofoidii	1	1		1					
C. macroceros							1		
C. massiliense	1	1			1				
C. pentagonum				1	1				
C. praelongum					1				
C. teres	1	1		1	1		1	1	
C. trichoceros			1		1		1	1	
C. tripos							1	1	
C. vulture	1				1			1	
Ceratocorys horrida									1
Corythodinium tesselatum					1				
Dinophysis hastata					1		1		
D. schuettii			1						
Diplopsalis lenticulata	1			1	1			1	1
D. spp.				1			1	1	
Dissodinium hamulus		1				1	1	1	
Fragilidium sp.	1								
Goniodoma polyedricum		1		1	1		1	1	

Continue next page...

TABLE 2. (Cont.)

TAXA	Indonesian waters			Myanmar waters			Thai waters		
	S	Th	Bth	S	Th	Bth	S	Th	Bth
Gonyaulax digitale							1		
C. fusiformis	1				1				
C. glyptorhynchus					1				
C. grindleyi								1	
C. hyalina				1	1				
C. polygramma	1	1		1	1				1
C. spinifera	1						1		
C. spp.				1	1	1		1	
Gymnodinium sanguinium				2	1	2			
G. spp.	1	1		1	1	1	1	1	
Gyrodinium spp.	1								
Lingulodinium polyedrum					1		1		
Ornithocercus magnificus				1	1				
O. thumii		1		1	1			1	
Oxytoxum scolopax		1			1				
O. subulatum	1							1	
Phalacroma argus	1								
P. cuneus						1			
P. doryphorum	1	1		1	1				
P. rotumdatum		1							
P. rudgeii	1								
Podolampas bipes				1	1		1		
P. palmipes	1				1	1		1	1
Pronoctiluca spp.				1					
Prorocentrum compressum	1	1	1	1	1		1	1	
P. emarginatum				1	1				
P. mexicanum	1	1		1	1		1		
P. spp.		1		1	1	1	1	1	1
Protoperidinium claudicans	1						1		
P. conicum		1		1					
P. crassipes				1					
P. depressum				1		1			
P. divergent	1			1		1			
P. elegans				1					
P. grande				1					
P. oceanecum	1			1					
P. pacificum								1	
P. pallidum		1							
P. paulsenii				1					
P. pellucidum	1								
P. spp.	1		1	1	1	1	1	1	
Pyrocystis fusiformis					1				
P. lunula		1	1		1	1	1	1	1
P. noctiluca				1	1			1	1
Pyrophacus horologium				1	1				
Scripsiella trochoidea	1	1		1	1				
S. spp.					1				
Spiraulax kofoidii		1							
Naked Dinoflagellate	1	1		1	1		1		

TABLE 3. Phytoplankton densities (cells/L) at 3 sampling depths

Station	Surface	Thermocline	Below thermocline
1	735	2050	3678
2	966	1278	1074
3	1368	1308	1516
4	3064	504	200
5	1651	2204	956
6	6070	5840	3072
7	2828	4408	8268
8	5616	4186	8658
9	7507	6214	5226
10	3176	5512	7332
11	7814	3836	4494
12	3586	1056	2436
13	4474	1808	no data

TABLE 4. Percentage of dominant species

Station	Surface		Thermocline		Below thermocline	
	Dominant species	%	Dominant species	%	Dominant species	%
1	*Oscillatoria erythraea*	30.33	*Fragilariopsis doliolus*	57.56	*Chaetoceros pseudodichaeta*	13.52
2	*Oscillatoria erythraea*	58.39	*Oscillatoria erythraea*	61	*Fragilariopsis doliolus*	21.23
3	*Oscillatoria erythraea*	77.26	*Oscillatoria erythraea*	29.97	*Chaetoceros pseudodichaeta*	12.74
4	*Oscillatoria erythraea*	90.86	*Oscillatoria erythraea*	32.54	*Chaetoceros pseudodichaeta*	12.35
5	*Oscillatoria erythraea*	55.99	*Oscillatoria erythraea*	84.94	*Fragilariopsis doliolus*	28.87
6	*Oscillatoria erythraea*	92.01	*Oscillatoria erythraea*	93.49	*Thalassionema frauenfeldii*	12.63
7	*Oscillatoria erythraea*	80.91	*Oscillatoria erythraea*	92.01	*Oscillatoria erythraea*	14.33
8	*Oscillatoria erythraea*	22.22	*Oscillatoria erythraea*	65.43	*Oscillatoria erythraea*	40.24
9	*Oscillatoria erythraea*	54.21	*Oscillatoria erythraea*	79.5	*Oscillatoria erythraea*	20.9
10	*Oscillatoria erythraea*	46.28	*Oscillatoria erythraea*	67.92	*Chaetoceros pseudodichaeta*	13.83
11	*Oscillatoria erythraea*	82.44	*Oscillatoria erythraea*	50	*Chaetoceros affinis*	12.8
12	*Oscillatoria erythraea*	70.59	*Chaetoceros affinis*	12.5	*Leptocylindrus mediterraneus*	11.43
13	*Oscillatoria erythraea*	70.13	*Fragilariopsis doliolus*	19.7	-	

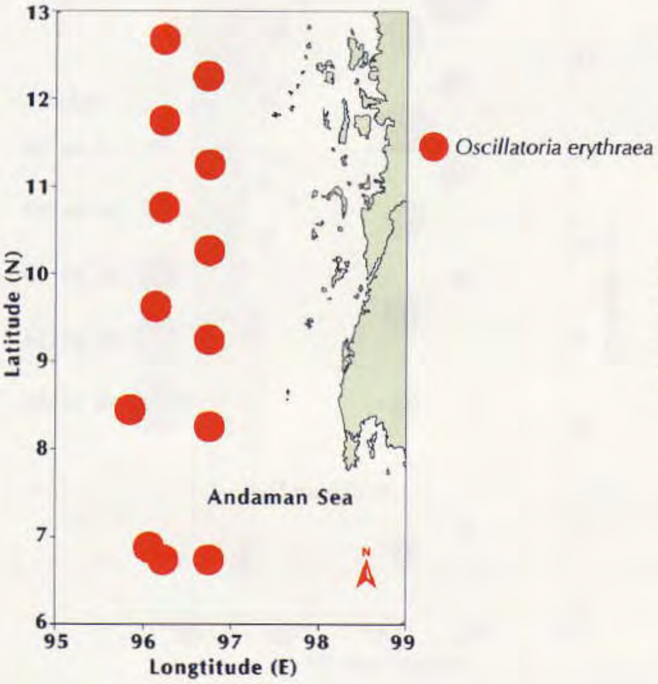


FIGURE 7. Distribution of dominant phytoplankton species in the surface layer.

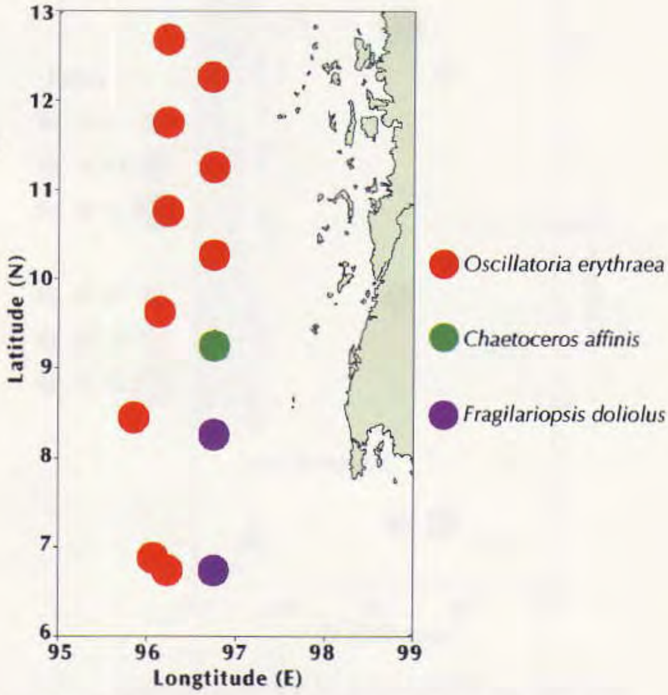


FIGURE 8. Distribution of dominant phytoplankton species in the thermocline layer.

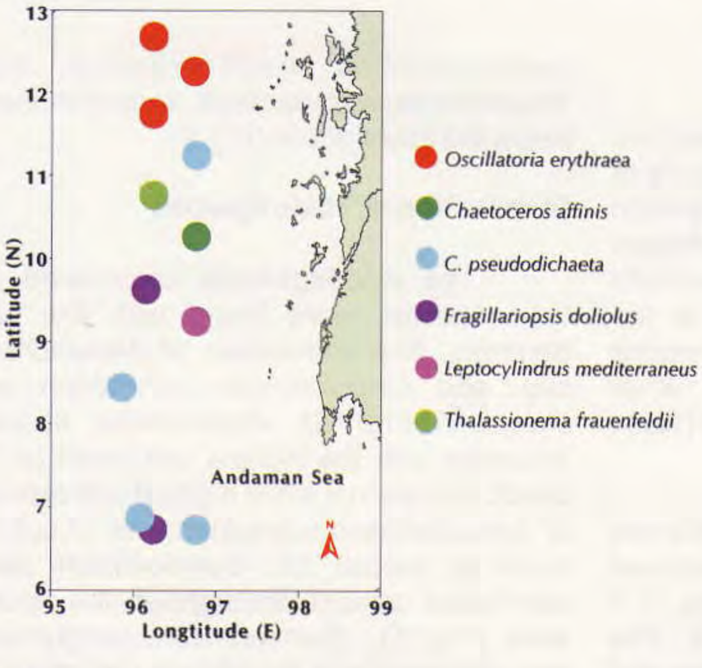


FIGURE 9. Distribution of dominant phytoplankton species below thermocline.

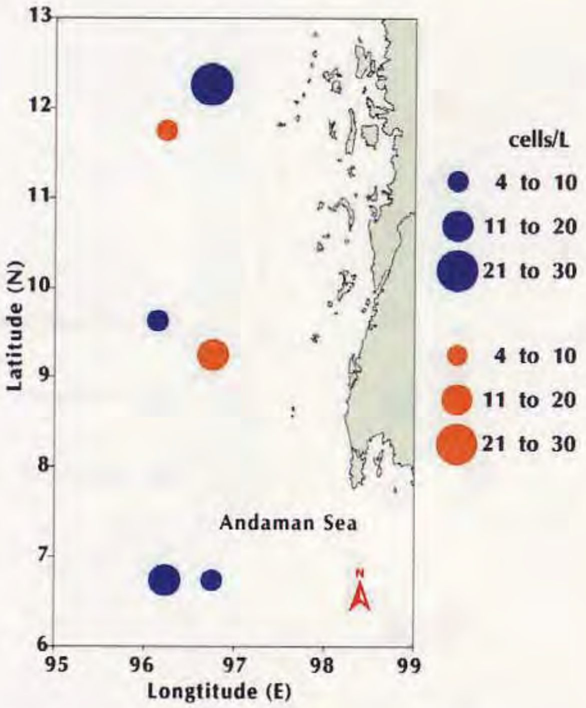


FIGURE 10. Distribution of *Alexandrium* spp. and *Lingulodinium* polyedrum.

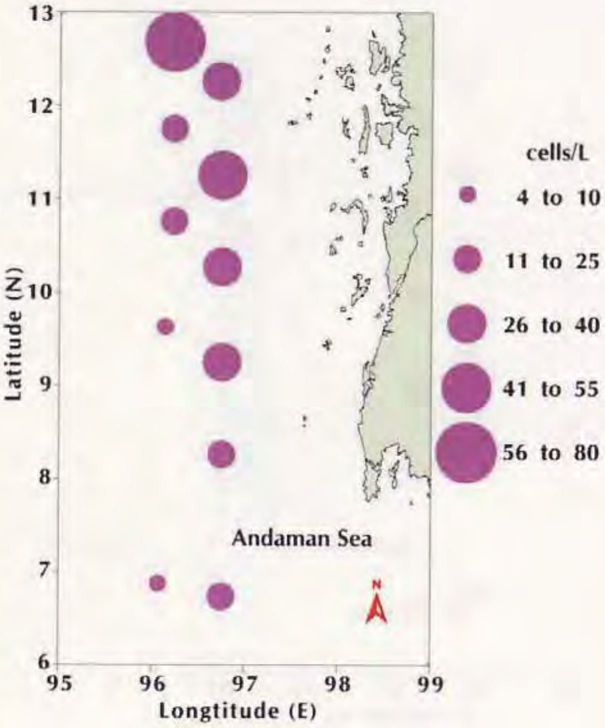


FIGURE 11. Distribution of *Gymnodinium* spp.

Distribution of Dominant Species

During the period of the survey, one species of bluegreen alga and 5 species of diatoms dominated the phytoplankton population in the study area. *Oscillatoria (Trichodesmium) erythraea* occurred with the highest percentage of 93.49 in the thermocline layer of station 6 (Myanmar waters) but the percentage of other dominant species were lower than 60 (Table 4).

In the surface layer, *Oscillatoria erythraea* was presented as the dominant species throughout the study area (Fig. 7). It distributed predominantly in the thermocline layer of almost all stations and remained dominant below the thermocline of the 3 northernmost stations. *Chaetoceros affinis* and *Fragillariopsis doliolus* were dominant in the thermocline layer and below the thermocline (Fig. 8). The other species, *Chaetoceros pseudodichaeta, Leptocylindrus mediterraneus*, and *Thalassionema frauenfeldii*, were dominant below the thermocline (Fig. 9).

Distribution of Toxic Species

The dinoflagellates considered as toxic species were found with low cell densities. The distribution of *Alexandrium* spp. and *Lingulodinium polyedrum* are shown in Fig. 10. *Alexandrium* sp.was observed with the highest cell count of 27 cells/L at station 9 while highest cell density of *Lingulodinium polyedrum* was 17 cells/L found at station 12. *Gymnodinium* spp. distributed almost throughout the study area (Fig.11). *Gymnodinium sanguinium* was observed with the highest cell count of 78 cells/L at station 8.

DISCUSSION AND CONCLUSION

Phytoplankton species investigated in the Andaman Sea within the EEZs of Indonesia, Myanmar, and Thailand were similar to those collected during May 1985 in the area from Langkawi Island through the coastal waters of Ranong Province (Boonyapiwat, 1987). High densities of phytoplankton in high latitude stations (Myanmar waters) indicated that this area was productive.

The thermocline plays a role in determining the biological properties of the water column. The thermocline zone has been observed to be a region of enhanced chlorophyll concentration. Phytoplankton densities in the thermocline layers were found to be higher than those in the surface layers in the waters of Sabah, Sarawak, Brunei Darussalum and Western Philippines where the chlorophyll maximum layers were presented at 20-35 m below the starting depths of the thermocline (Boonyapiwat, 1999; 2000). Then the sampling depth of below the thermocline in this study could be chlorophyll maximum depth. Furuya and Marumo (1983) noted that phytoplankton in the chlorophyll maximum layer of the Western North Pacific Ocean was found to be abundant and of high diversity. In this study, phytoplankton densities in the thermocline layers and below the thermocline were not higher than those in the surface layers in many stations. The reason is that upwelling possibly occurred during the survey period. Thus phytoplankton were abundant in the surface layers.

Oscillatoria erythraea was dominant with a wide distribution in May 1985 (Boonyapiwat, 1987) and occurred as the dominant species in the whole area in the present study. This species annually forms vast areas of discolored water or "red tide" in the open sea during warm months of the year in tropical or subtropical seas. The macroscopically visible scalelike colonies have been called "sea sawdust" and color the water, when abundant, yellowish, amber or red. They are of major importance in the basic productivity of these waters. Toxic compounds that may cause fish kill apparently are produced when the cells lyse, although some hold the opinion that fish kill is a result of gill clogging (Humm and Wicks,1980). However, during the survey period, there was no evidence of fish kill.

Many species of toxic dinoflagellate were found in this study. The cell counts were rather higher compared to those in the waters of Sabah, Sarawak, Brunei Darussalam, and Western Philippines (Boonyapiwat, 1999; 2000), but less than the samples collected in May 1985 from the station near the Similan Islands in the Andaman Sea. During that survey, *Alexandrium* (*Protogonyaulax*) *cohorticula* was recorded as the dominant species with 20.18 percentage of abundance but the effect on fish or human was not reported (Boonyapiwat, 1987). This species can be toxic or non-toxic (Balech, 1995).

It is concluded that the high latitude area was productive with high densities of phytoplankton. The red tide species, *Oscillatoria* (*Trichodesmium*) *erythraea*, occurred as blooms throughout the study area. Toxic dinoflagellates were found with low cell densities.

REFERENCES

Balech, E. 1995. The Genus *Alexandrium* Halim (Dinoflagellata). Sherkin Island Marine Station, Co. Cork, 151 pp.

Boonyapiwat, S. 1987. Species and Distribution of Phytoplankton in the Andaman Sea, in Proceedings of the 25th Seminar on Fisheries of Kasetsat University. Feb 1987. Kasetsart University, Bangkok. 12 pp.

Boonyapiwat, S. 1999. Distribution, Abundance and Species Composition of Phytoplankton in the South China Sea, Area II : Sabah, Sarawak and Brunei Darussalam, in Proceedings of the Second Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area II : West Coast of Sabah, Sarawak and Brunei Darussalam. 14-15 Dec. 1998, Kuala Lampur, SEAFDEC, p 177-196.

Boonyapiwat, S. 2000. Species Composition, Abundance and Distribution of Phytoplankton in the Thermocline Layer in the South China Sea, Area III : Western Philippines, in Proceedings of the Third Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area III : Western Philippines. Feb. 2000. SEAFDEC, p 197-216.

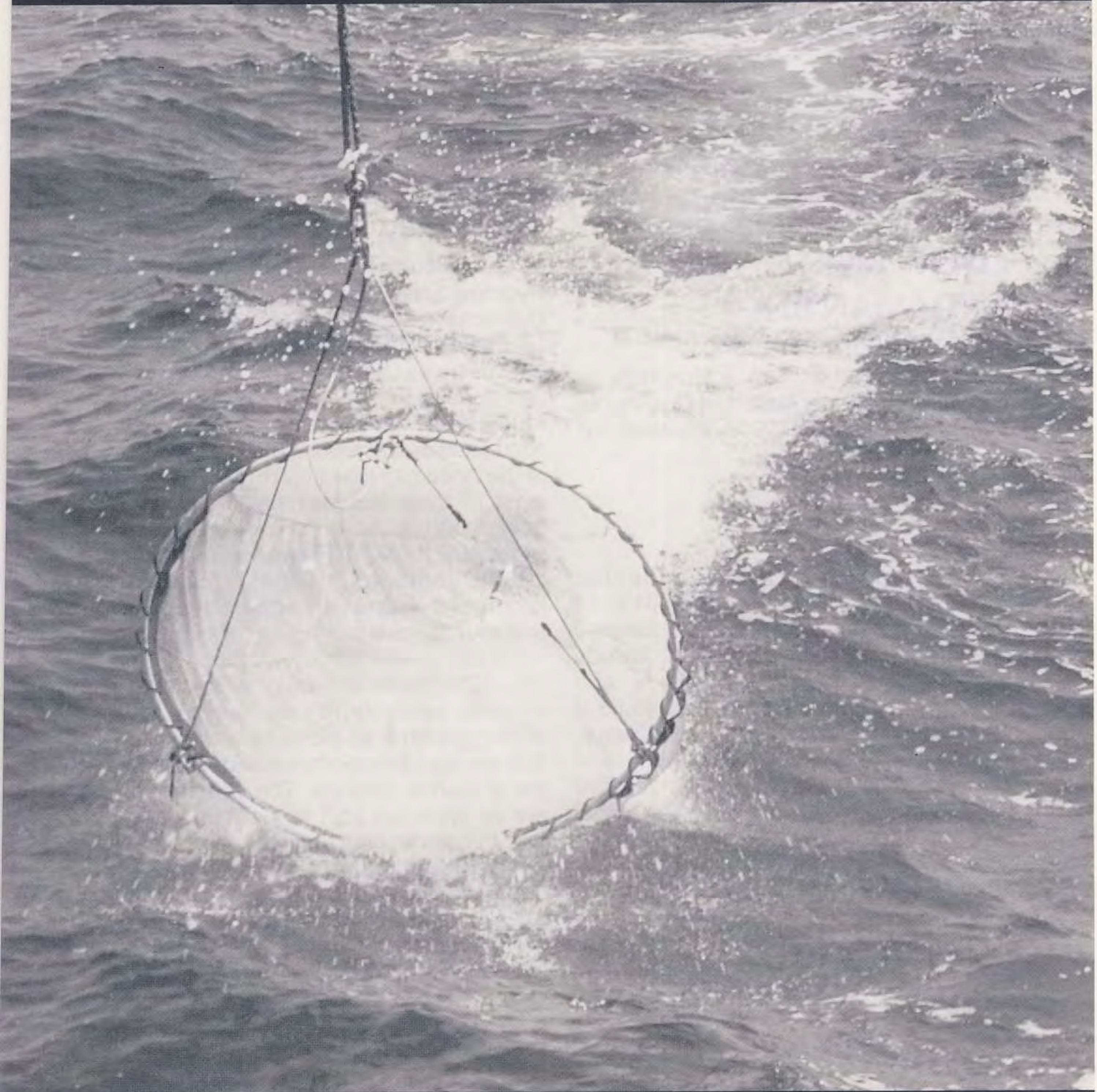
Furuya, K. and R. Marumo. 1983. The structure of the phytoplankton community in the subsurface chlorophyll maxima in the western North Pacific Ocean. J. Plank. Res., 5:393-406.

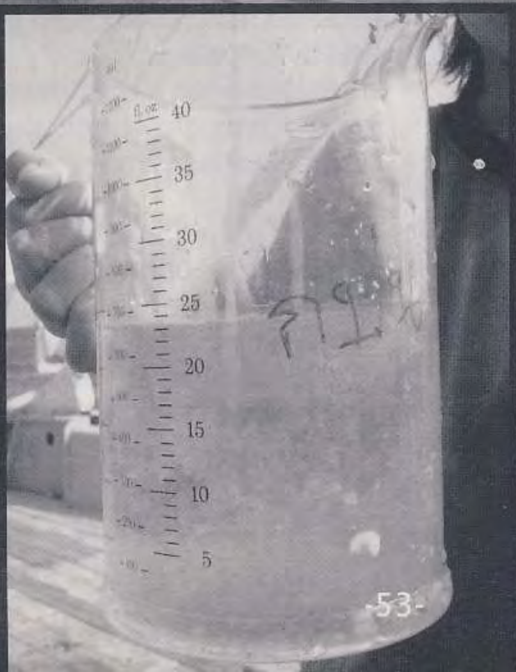
Humm, H. J. and S. R. Wicks. 1980. Introduction and Guide to the Marine Bluegreen Algae. John Wiley and Sons. New York. 194 pp.

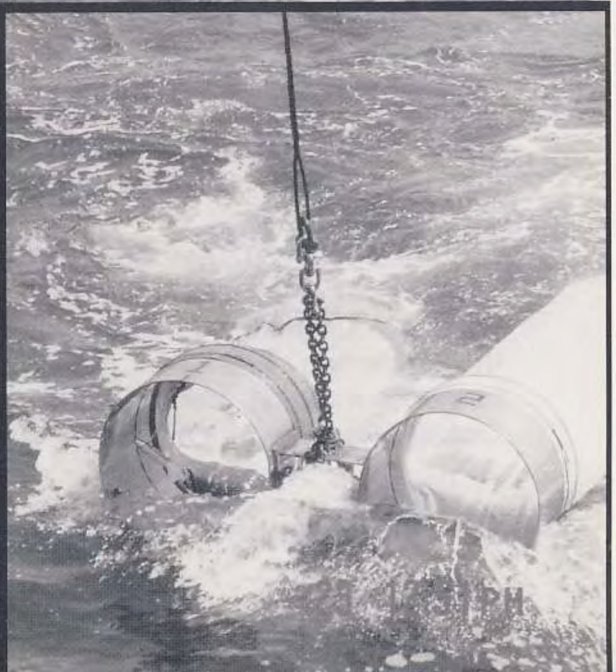
Rines, J. E. B., P. Boonruang and E. C. Theriot. 2000. Chaetoceros phuketensis sp. nov. (Bacillariophyceae) : a new species from the Andaman Sea. Phycological Research, 48 : 161-168.

Taylor, F. J. R. 1976. Dinoflagellates from the International Indian Ocean Expedition. E. Schweizerbart'sche Verlagbuchhandlung. 234 pp.

ZOOPLANKTON AND FISH LARVAE SAMPLING ACTIVITIES







COMPOSITION, ABUNDANCE AND DISTRIBUTION OF ZOOPLANKTON IN THE ANDAMAN SEA

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ABSTRACT

Zooplankton were collected between 14th –26th November 2004 in 13 stations in the Andaman Sea were sampled by M.V. SEAFDEC along the latitude between 6°43.81 - 12°40.80 N and longitude between 95°50.94 - 96°45.55 E that are located in the Exclusive Economic Zones of Indonesia, Myanmar and Thailand. The Zooplankton were identified into 65 taxonomic groups. The most common groups in this study area are copepods, chaetognaths, ostracods, pteropods, amphipods and euphausiids.

Keywords: Zooplankton, Andaman Sea, composition, abundance, distribution

INTRODUCTION

The Andaman Sea is a body of water to the southeast of the Bay of Bengal, south of Myanmar and west of Thailand: it is part of the Indian Ocean. It is roughly 1200 km. long (north-south) and 650 km. wide (east-west), with an area of 797,700 km^2. Its average depth is 870 m., and the maximum depth is 3,777 m. The very complete and famous zooplankton studies in and around the Andaman Sea was research work carried out during the International Indian Ocean Expedition (IIOE) 1959-1965 (Roa, 1973). Various studies on zooplankton in the Indian Ocean from this research have been published e.g. Copepod (Kasturirangan et al., 1973; Fleminger & Hulsemann, 1973); Amphipod (Nair et al., 1973; Bowman & McGuinness, 1982); Hydromedusae (Vannucci & Navas, 1973); Cumacea (Kurian, 1973); Euphausiids (Brinton & Gapalakishnan, 1973); Thecosomata (Sakthivel, 1973); Heteropod (Aravindakshan, 1973). Although some studies on zooplankton have been conducted in and around the coastal areas of the Andaman Sea adjacent to Thailand, most of them reported on the group of zooplankton e.g. Thecosomata (Vongpanich, 2001); Fish larvae (Janekarn, 1992; Janekarn, 1993), published information on zooplankton but composition and abundance is lacking.

Zooplankton occupy a key role in pelagic ecosystems as they control phytoplankton both biomass and diversity, they are also an important source of food for many marine nektons. The zooplanktons are an important part of the food web as they transfer energy to higher tropic levels. Zooplankton contributes by exporting organic matter through their grazing activity to the deep sea and the benthos, by faecal pellet production and vertical migrations, thus exerting control over biogeochemical cycles. The study of abundance and diversity of zooplankton largely determine the diversity, abundance and recruitment of pelagic fisheries resources including fish and squid etc. In addition to their significant role in the pelagic food chains, some groups of zooplankton like chaetognatha are well-known biological indicators of distinctive types in surface water.

This paper presents the result of the composition, abundance and distribution of zooplankton in the Andaman Sea. The research was conducted in the framework of the SEAFDEC project: "Harvesting of Under-Exploited Resources," Phase 1: Pelagic Fisheries Resources Survey in the

Andaman Sea. The project's overall objectives were investigating the potential of pelagic fisheries resources and collecting biological and oceanographic data in the Andaman Sea.

METHODS

Zooplankton samples were collected from 13 stations (Table 1, Fig 1.) between 6°43.81 and 12°40.80 N latitude and between 95°50.94 and 96°45.55 E longitude in the Andaman Sea. This was done using a Bongo Net (60 cm. in diameter and 330 um mesh size), equipped with flow meters attached at 1/3 of the mouthpart for estimating water volume that flows passed into the nets. The bongo net was towed in an oblique direction from the surface to 150 meters depth level. The zooplankton collected were fixed with a 10% formaldehyde solution in seawater and kept to be analyzed in the laboratory at the Faculty of Fisheries, Kasetsart University.

RESULTS

Zooplankton Abundance And Distribution

The abundance and distribution of zooplankton collected from the sampling stations in the Andaman Sea is shown in Table 2. The highest zooplankton abundance was observed at station 13 with 185.17 individuals/m^3, followed by stations 9 and 11 with 118.17 and 115.03 individuals/m^3, respectively. The lowest density was found at station 3 with 43.34 individuals /m^3.

Zooplankton Composition And Diversity

Total Zooplankton

Zooplankton samples were identified representing of 65 groups of zooplankton taxa (normally at family level), with some planktonic larvae with undeveloped main characteristics, which could not be identified to family level (Table 2). The copepods consistently occurred at all stations and were the most dominant taxon in terms of abundance and composition. The major groups of copepods are order of Calanoida with 17.7 – 58.93 individuals/m^3 abundance and composition 27.50-51.23 % of the total zooplankton population and order of Cyclopoida (consist of family Oithonidae, Oncaeidae, Corycaeidae and Sapphirinidae) with 8.15 – 73.98 individuals/m^3 abundance and composition 18.81-39.95 % of the total zooplankton population (Table 2 and 3). For higher taxa (phylum level), Arthopoda was

TABLE 1. Station for zooplankton during the MV SEAFDEC cruise in the Andaman Sea in November 2004

Station No.	Latitude-Longitude (start)	Latitude- Longitude (finish)
1	6°44.47N - 96°45.26 E	6°43.81N - 96°45.55 E
2	6°44.76N - 96°13.92 E	6°44.98N - 96°13.37 E
3	6°52.94N - 96°03.93 E	6°53.03N - 96°03.69 E
4	8°26.89N - 95°51.20 E	8°27.38N - 95°50.94 E
5	9°380.6N - 96°08.26 E	09°38.38N - 96°08.06 E
6	10°45.61N - 96°13.93 E	10°46.02N - 96°13.18 E
7	11°45.09N - 96°13.96 E	11°45.19N - 96°13.59 E
8	12°40.80N - 96°13.95 E	12°40.67N - 96°13.64 E
9	12°15.65N - 96°44.00 E	12°15.69N - 96°43.74 E
10	11°15.06N - 96°45.08 E	11°15.35N - 96°44.88 E
11	10°15.96N - 96°45.02 E	10°15.83N - 96°44.50 E
12	9°14.97N - 96°45.30 E	9°14.77N - 96°45.41 E
13	8°15.40N - 96°45.08 E	8°15.54N - 96°44.94 E

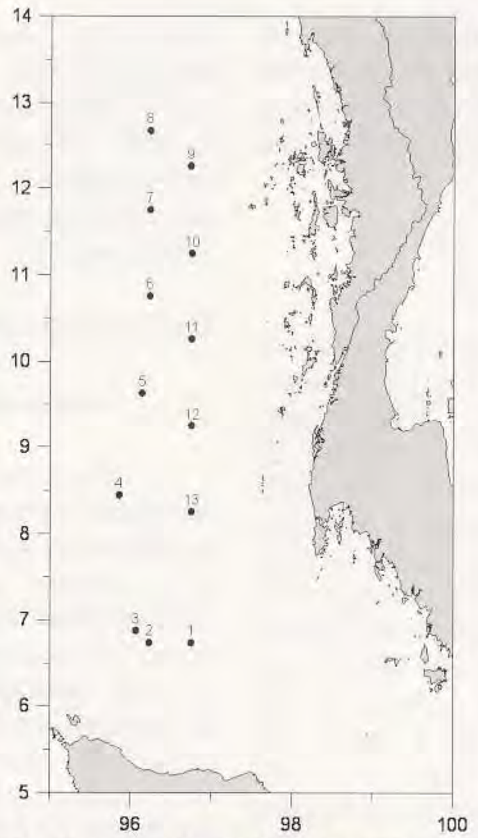

FIGURE 1. Sampling stations in Andaman Sea.

dominant in study areas (Table 4 and 5).

Individual Zooplankton

Phylum Sarcomastigophora

This phylum includes marine protozoa especially planktonic. Foraminifera occur in all pelagic environments. They are 2.4 % of the total zooplankton population (Table 3 – 5). In general, planktonic foraminifera are omnivorous, but some are carnivorous. Animal prey included microalgae ciliates, tintinnopsis, radiolarian and other marine zooplankton.

Phylum Cnidaria

This phylum includes Hydromedusae and Siphonophora, comprising collectively about 1.96 % of the total zooplankton population (Table 3 – 5). The Siphonophora are complex polymorphic hydrozoas cnidarian, and were identified into suborder Calycophorae, 2 families were Diphyidae and Abylidae. These are planktonic gelatinous zooplankton. Diphyidae and Abylidae were predominant in the samples, the majorities are truly oceanic, but a few species are neritic. They feed on small crustaceans and fish larvae. That were discharged with nematocyst.

Phylum Ctenophora

The comb jelly larvae that are called Cydippid larvae were found to be less than 0.03 % of the total zooplankton population (Table 3 – 5). The adults were not found in this study. These are planktonic with gelatinous soft bodies, carnivorous and feeding on marine zooplankton of various sizes, including copepods, euphausids, fish eggs and fish larvae.

Phylum Annelida

This phylum was found only in the

Class Polychaeta that include polychaete larvae and holoplanktonic polychaetes, especially Tomopterid polychaetes, comprising 0.56 % of the total zooplankton population (Table 3 – 5). They have developed to be pelagic and include small size long setae with enormous and complex eyes, flattened or gelatinous bodies. They were found in the open sea but some were in the neritic region. They feed on small zooplankton, siphonophores, chaetognathas and appendicularian.

Phylum Mollusca

The Marjory group is Thecosomata and Heteropoda that were the abundant group of this phylum, forming 2.53 % of the total zooplankton population (Table 3 – 5). Other groups are bivalve, gastropod and cephalopod larvae. The Heteropod comprising of 2 families are Atlantidae and Pterotracheidae. They are holopelagic prosobranch gastropods that were found in moderately low abundant and are mostly found in tropical and subtropical region. All heteropods are carnivorous and feed on marine zooplankton.

Thecosomata (shell pteropods) were found to be very common planktonic molluscs. They comprise the shell species, carnivorous and protandric hermaphrodites and some species are asexual reproductions. The majority groups are family Cavoliniidae.

Phylum Arthropoda.

A. Cladocera

The small group of crustaceans, in this study was found only in family Podonidae (Table 2 – 3). They are only 8 marine species. These are epiplanktonic zooplankton seasonally abundant in coastal, continental shelf and oceanic region. The populations are females and were of parthenogenesis generation.

B. Ostracoda

They were predominantly in the aquatic habitat, some were holoplanktonic, found very common in this Study (Table 2 – 3). All non selective planktivous and few species are predators.

C. Copepoda

The largest group of zooplankton population in this study (Table 2 – 3). They were identified into 4 orders of the majority marine copepods. That is small crustaceans usually between 0.2-12 mm. in length. They are neritic to oceanic, epipelagic to abyssal depths. They are important link in the marine food web, and are recognized as in discriminate or selective suspension or particle feeders and they may be herbivorous, predatory feeders (carnivorous), or omnivorous also saphroplages or coprophages, some copepods switch from one feeding mode to another according to circumstances.

D. Mysidacea

These were found at only few stations in this study (Table 2 – 3). They are more abundance in Northern Europe. The females are provided with maesupium between pairs of peuopods and keep their embryos in it until the juvenile stage. They feed on small algae, protozoan and small crustaceans.

E. Amphipoda

The Amphipods found in this study were identified into 5 families (Table 2 – 3). They are small crustaceans that have colonized in the pelagic region. Hyperiids amphipods are a significant component of epipelagic and mesopelagic communities. They are subsidiary in abundance, only to copepods, euphausiids, chaetograths and gelatinous zooplankton.

F. Euphausiacea

Euphausiids (krills) are holoplanktonic crustaceans that are distributed throughout the coastal sea and oceans of the world, but very few were found in the study areas (Table 2 – 3). They are an important source of food for many marine nektons. Euphausiids are truly omnivorous and feed on microalgae, protozoan to fish eggs and larvae.

G. Isopoda

The Isopods were very rare in the zooplankton communities. They were found at 3 stations (No. 1, 2 and 9). They are found in the pelagic habitat; the majorities are benthic and terrestrial.

Other Meroplankton.

This study found 19 crustacean larval groups and 5 echinoderm larval groups including Cyphonautes larva (Phylum Bryozoa) and Actinotrocha larva (Phylum Phronida) (Table 2 – 3).

Phylum Chaetognatha

This phylum comprised 7.51 % of the total zooplankton population (Table 2 – 5). They are carnivorous animals and play an important role in the food chains, their biomass in the pelagic world ocean is 30% of that of copepods. They are active predators and the rigid spines grasp their prey. Their diet of pelagic chaetognaths include a wide range of organisms; copepods, small crustaceans and fish larvae.

Phylum Chordata.

This phylum includes fish larvae and a large group of gelatinous zooplankton that is Urochordata and include 2 classes (Appendicularia and Thaliacea) (Table 2 – 3). Fish larvae or Ichthyoplankton are an important element of the aquatic food web. Appendicularians are planktonic tunicates that are recognized by the persistence of the notochord in the adult and the lack of a peribranchial cavity and cloaca. Thaliaceans are holoplanktonic colonial tunicates and some groups are an alternation of generation between asexual. (oozooids) and sexual (blastozooids) generation. They feed by filtering suspended particles from a stream of water through a mucous area.

TABLE 2. Total abundance of zooplankton (number/m^3) in each station from study areas in Andaman Sea.

TAXON	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Phylum Sarcomastigophora													
Foraminiferans	0.19	0.32	0.15	0.15	0.49	2.41	0.56	1.56	8.28	3.79	4.49	2.56	1.04
Phylum Cnidaria													
Hydromedusae	0.10	0.08	0.05	0.07		0.07		0.31	0.27	0.15	0.07	0.13	0.31
Family Diphyidae	0.29	0.80	0.39	0.22	0.49	1.93	1.75	1.31	2.79	0.36	1.12	2.88	1.47
Family Abylidae	0.10	0.16	0.24	0.37	0.21	1.17			0.45	0.05	0.99		
Phylum Ctenophora													
Cydippid larva							0.08	0.06			0.02	0.06	0.12
Phylum Annelida													
Family Tomopteridae	0.10		0.05	0.07	0.07	0.07	0.08	0.06	0.09	0.05	0.13	0.06	0.12
Family Alciopidae	0.10	0.08							0.09				
Family Typhloscolecidae		0.08	0.15	0.07									
Family Lopadorhynchidae			0.05										
Polychaete larva	0.29	0.08	0.05	0.15	0.07	0.34	0.64	0.12	1.62	0.04	0.59	0.32	0.18
Phylum Mollusca													
Family Atlantidae	0.10	0.08	0.05		0.07	0.07	0.08			0.05		0.06	0.06
Family Pterotracheidae	0.10	0.08	0.05		0.07	0.21	0.08	0.06	0.09		0.07		0.61
Family Cavoliniidae	0.39	0.72	0.49	0.37	0.35	0.83	0.40	0.37	1.53	1.18	2.51	0.51	1.29
Gastropod larva	0.58	0.64	0.49	1.03	0.49	0.62	1.11	0.25	1.80	0.07	1.92	0.77	3.25
Bivalve larva	0.19	0.02	0.01	0.01	0.01				0.27	0.02	0.26	0.06	0.18
Cephalopod	0.02	0.02	0.05	0.01	0.01	0.01	0.02	0.01	0.09	0.01	0.02	0.02	0.06
Phylum Arthropoda													
Family Podonidae	0.10	0.16	0.05		1.68	0.07		0.19	0.09		0.66		0.06
Ostracods	2.90	8.22	4.54	12.6	3.93	5.16	5.57	1.37	1.80	3.33	3.04	6.65	1.66
Calanoid copepods	17.7	21.3	21.2	35.6	20.4	35.8	44.7	18.6	35.91	32.2	58.93	27.0	50.91
Family Oithonidae	2.61	5.83	1.71	4.04	3.65	7.23	6.45	4.98	9.18	2.51	6.21	3.13	3.37
Family Miracidae	0.10	0.08	0.05	0.07			0.16						0.06
Family Clytemnestridae						0.07							
Family Oncaeidae	9.77	5.27	2.98	5.58	9.19	3.58	12.7	9.77	23.58	12.24	13.54	5.30	62.20
Family Sapphirinidae	0.97	2.00	1.42	2.06	0.77	4.82	3.42	0.87	3.69	0.72	2.25	2.62	2.09
Family Corycaeidae	3.10	4.63	2.00	4.33	3.51	3.37	4.30	1.49	4.86	3.23	4.23	4.66	6.26
Mysids						0.07	0.08			0.05	0.07		0.06
Family Vibiliidae	0.48	0.08	0.34	0.07		0.14				0.31	0.13	0.06	
Family Hyperiidae	0.87	0.24		0.29	0.42	0.62	0.40	0.06	0.54	1.18	0.33	0.45	0.80
Family Phronomidae	0.10												
Family Phrosinidae	0.10												
Family Oxycephalidae	0.10										0.07		
Family Euphausiidae	0.68	0.72	0.73	0.51	0.21	1.65	0.72	0.68	0.72	4.76	1.59	0.38	3.44
Isopods	1.06	0.24							0.09				
Phylum Arthopoda													
Family Luciferidae	0.10	0.08			0.07	0.07	0.08		0.18	0.05	0.07	0.06	0.80
Copepod nauplius					0.07	0.07	0.16						
Pontellanid larva													0.12

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TABLE 2.(cont.)

TAXON	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Cirripede nauplius		0.24	0.01	0.01		0.14	0.08	0.19	0.36		0.07	0.19	
Erichthus larva						0.01		0.01			0.02		0.06
Alima larva		0.02	0.01			0.01	0.02	0.01	0.02	0.01	0.07	0.02	0.02
Protozoea (Lucifer)	0.10	0.02	0.10	0.22	0.14	0.26	0.08				0.07		0.25
Acanthosoma larva		0.24	0.29	0.44	0.28	1.10	0.40	0.25	0.54		0.46	0.19	0.00
Calyptopis larva	0.48	0.48	0.49	0.66	0.21	0.28	0.32			0.77	0.99	1.09	0.00
Furcilia larva	0.29		0.29	0.66	0.01	0.48	0.64	0.75	1.26			0.32	0.37
Penaeid zoea	0.19	0.08							0.36	1.18	0.26	0.19	0.31
Caridean zoea							0.16						
Pagurid zoea							0.16		0.09			0.06	
Sergrstoidea zoea								0.06					
Phyllosoma larva						0.01			0.02	0.01			0.02
Porcellanid larva					0.01		0.02						0.02
Brachyuran zoea	0.02	0.02	0.01	0.01	0.01		0.02	0.06	0.27		0.20	0.06	0.06
Brachyuran megalopa	0.02	0.02	0.01	0.04	0.01		0.02	0.01	0.02	0.01	0.02	0.02	0.02
Decapod larva					0.14	0.55	0.08	0.12	0.27	0.10	0.40	0.19	0.92
Phylum Echinodermata													
Bippinnaria larva									0.99	0.41	0.20	0.06	1.66
Brachiolaria larva	0.68	0.40	0.05	0.07	0.63	0.76	1.99				0.13	0.26	0.74
Ophiopluteus larva	0.19	0.40			0.14		0.96		0.36	0.05	0.33	0.13	0.37
Echinopluteus larva		0.16				0.14	0.48	0.25	0.63	0.15	0.40	0.06	4.11
Doliolaria larva													0.61
Phylum Bryozoa													
Cyphonauteus larva		0.08					0.02	0.12	0.09	0.05	0.02		0.12
Phylum Chaetognatha													
Family Sagittidae	4.16	5.99	3.61	5.66	4.07	7.09	6.05	1.49	5.94	1.95	3.50	2.36	29.32
Phylum Phronida													
Actinotrocha larva										0.05			
Phylum Chordata													
Family Oikopleuridae	1.64	2.08	0.78	1.54	2.60	3.99	2.79	2.99	5.67	1.08	3.50	0.06	3.99
Family Pyrosomatidae		0.08	0.05	0.22	0.07	0.07	0.08	0.06	0.99		0.07	0.06	
Family Doliolidae	0.39	0.48	0.24		0.14	0.90	0.48	0.44	2.43	0.05	0.26	0.13	0.37
Family Salpidae	0.10	0.08	0.05			0.90	0.32	1.49			0.40	0.19	1.04
Fish larvae	0.07	0.09	0.09	0.08	0.07	0.25	0.08	0.07	0.15	0.21	0.39	0.03	0.27
Total	51.6	62.9	43.3	77.2	54.8	87.3	98.7	50.5	118.5	72.4	115.0	63.4	185.2

TABLE 3. Zooplankton composition (Percent composition) in each station from study areas in Andaman Sea

TAXON	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Phylum Sarcomastigophora													
Foraminiferans	0.38	0.51	0.34	0.19	0.90	2.76	0.56	3.08	6.99	5.23	3.91	4.03	0.56
Phylum Cnidaria													
Hydromedusae	0.19	0.13	0.11	0.10		0.08		0.62	0.23	0.21	0.06	0.20	0.17
Family Diphyidae	0.56	1.27	0.90	0.29	0.90	2.21	1.77	2.59	2.36	0.49	0.98	4.53	0.80
Family Abylidae	0.19	0.25	0.56	0.48	0.38	1.34			0.38	0.07	0.86		
Phylum Ctenophora													
Cydippid larva							0.08	0.12			0.01	0.10	0.07
Phylum Annelida													
Family Tomopteridae	0.19	0.00	0.11	0.10	0.13	0.08	0.08	0.12	0.08	0.07	0.11	0.10	0.07
Family Alciopidae	0.19	0.13							0.08				
Family Typhloscolecidae		0.13	0.34	0.10									
Family Lopadorhynchidae			0.11										
Polychaete larva	0.56	0.13	0.11	0.19	0.13	0.39	0.65	0.25	1.37	0.05	0.52	0.50	0.10
Phylum Mollusca													
Family Atlantidae	0.19	0.13	0.11		0.13	0.08	0.08	0.00		0.07		0.10	0.03
Family Pterotracheidae	0.19	0.13	0.11		0.13	0.24	0.08	0.12	0.08		0.06		0.33
Family Cavoliniidae	0.75	1.14	1.13	0.48	0.64	0.95	0.40	0.74	1.29	1.63	2.18	0.81	0.70
Gastropod larva	1.13	1.01	1.13	1.33	0.90	0.71	1.13	0.49	1.52	0.09	1.67	1.21	1.76
Bivalve larva	0.38	0.03	0.02	0.02	0.03				0.23	0.02	0.23	0.10	0.10
Cephalopod larva	0.04	0.03	0.11	0.02	0.03	0.02	0.02	0.02	0.08	0.01	0.01	0.03	0.03
Phylum Arthropoda													
Family Podonidae	0.19	0.25	0.11		3.07	0.08		0.37	0.08		0.57		0.03
Ostracods	5.63	13.07	10.47	16.26	7.17	5.91	5.64	2.71	1.52	4.60	2.64	10.48	0.89
Calanoid copepods	34.31	33.87	48.88	46.03	37.25	40.97	45.32	36.82	30.31	44.48	51.23	42.52	27.50
Family Oithonidae	5.06	9.26	3.94	5.23	6.66	8.27	6.53	9.85	7.75	3.46	5.40	4.94	1.82
Family Miracidae	0.19	0.13	0.11	0.10			0.16						0.03
Family Clytemnestridae						0.08							
Family Oncaeidae	18.94	8.37	6.87	7.23	16.77	4.10	12.82	19.34	19.90	16.90	11.77	8.36	33.59
Family Sapphirinidae	1.88	3.17	3.27	2.66	1.41	5.52	3.47	1.72	3.11	0.99	1.95	4.13	1.13
Family Corycaeidae	6.00	7.36	4.62	5.61	6.40	3.86	4.35	2.96	4.10	4.45	3.68	7.36	3.38
Mysids						0.08	0.08			0.07	0.06		0.03
Family Vibiliidae	0.94	0.13	0.79	0.10		0.16	0.00			0.42	0.11	0.10	0.00
Family Hyperiidae	1.69	0.38		0.38	0.77	0.71	0.40	0.12	0.46	1.63	0.29	0.71	0.43
Family Phronomidae	0.19												
Family Phrosinidae	0.19												
Family Oxycephalidae	0.19										0.06		
Family Euphausiidae	1.31	1.14	1.69	0.67	0.38	1.89	0.73	1.35	0.61	6.58	1.38	0.60	1.86
Isopods	2.06	0.38							0.08				
Family Luciferidae	0.19	0.13			0.13	0.08	0.08		0.15	0.07	0.06	0.10	0.43
Copepod nauplius					0.13	0.08	0.16						
Pontellanid larva													0.07
Cirripede nauplius		0.38	0.02	0.02		0.16	0.08	0.37	0.30		0.06	0.30	
Erichthus larva						0.02		0.02			0.01		0.03
Alima larva		0.03	0.02			0.02	0.02	0.02	0.02	0.01	0.06	0.03	0.01
Protozoea (Lucifer)	0.19	0.03	0.23	0.29	0.26	0.30	0.08				0.06		0.13
Acanthosoma larva		0.38	0.68	0.57	0.51	1.26	0.40	0.49	0.46		0.40	0.30	
Calyptopis larva	0.94	0.76	1.13	0.86	0.38	0.32	0.32	0.00	0.00	1.06	0.86	1.71	

Continue next page...

TABLE 3. (Cont.)

TAXON	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Phylum Arthropoda (cont.)													
Furcilia larva	0.56		0.68	0.86	0.03	0.55	0.65	1.48	1.06	0.00	0.00	0.50	0.20
Penaeid zoea	0.38	0.13							0.30	1.63	0.23	0.30	0.17
Caridean zoea							0.16						
Pagurid zoea							0.16		0.08			0.10	
Sergrstoidea zoea								0.12					
Phyllosoma larva						0.02			0.02	0.01			0.01
Porcellanid larva					0.03		0.02						0.01
Brachyuran zoea	0.04	0.03	0.02	0.02	0.03		0.02	0.12	0.23		0.17	0.10	0.03
Brachyuran megalopa	0.04	0.03	0.02	0.06	0.03		0.02	0.02	0.02	0.01	0.01	0.03	0.01
Decapod larva					0.26	0.63	0.08	0.25	0.23	0.14	0.34	0.30	0.50
Phylum Echinodermata													
Bippinnaria larva									0.84	0.57	0.17	0.10	0.89
Brachiolaria larva	1.31	0.63	0.11	0.10	1.15	0.87	2.02				0.11	0.40	0.40
Ophiopluteus larva	0.38	0.63			0.26		0.97		0.30	0.07	0.29	0.20	0.20
Echinopluteus larva		0.25			0.00	0.16	0.48	0.49	0.53	0.21	0.34	0.10	2.22
Doliolaria larva													0.33
Phylum Bryozoa													
Cyphonauteus larva		0.13					0.02	0.25	0.08	0.07	0.01		0.07
Phylum Chaetognatha													
Family Sagittidae	8.06	9.51	8.33	7.32	7.42	8.12	6.13	2.96	5.01	2.69	3.04	3.73	15.8
Phylum Phronida													
Actinotrocha larva										0.07			
Phylum Chordata													
Family Oikopleuridae	3.19	3.30	1.80	2.00	4.74	4.57	2.82	5.91	4.79	1.48	3.04	0.10	2.15
Family Pyrosomatidae		0.13	0.11		0.13	0.08	0.08	0.12	0.84		0.06	0.10	
Family Doliolidae	0.75	0.76	0.56	0.29	0.26	1.02	0.48	0.86	2.05	0.07	0.23	0.20	0.20
Family Salpidae	0.19	0.13	0.11			1.02	0.32	2.96			0.34	0.30	0.56
Fish larvae	0.14	0.14	0.21	0.10	0.13	0.29	0.08	0.15	0.13	0.29	0.34	0.05	0.15

TABLE 4. Zooplankton composition (Phylum level) in each station from study areas in Andaman Sea

TAXON	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Phylum Sarcomastigophora	0.38	0.51	0.34	0.19	0.90	2.76	0.56	3.08	6.99	5.23	3.91	4.03	0.56
Phylum Cnidaria	0.94	1.65	1.58	0.86	1.28	3.62	1.77	3.20	2.96	0.78	1.90	4.74	0.96
Phylum Ctenophora							0.08	0.12			0.01	0.10	0.07
Phylum Annelida	0.94	0.38	0.68	0.38	0.26	0.47	0.73	0.37	1.52	0.12	0.63	0.60	0.17
Phylum Mollusca	2.66	2.46	2.61	1.85	1.84	1.99	1.71	1.38	3.19	1.82	4.15	2.25	2.95
Phylum Arthropoda	81.1	79.4	83.6	86.9	81.6	75.0	81.7	78.2	70.8	86.5	81.4	83.0	72.3
Phylum Echinodermata	1.69	1.52	0.11	0.10	1.41	1.02	3.47	0.49	1.67	0.85	0.92	0.81	4.04
Phylum Bryozoa		0.13					0.02	0.25	0.08	0.07	0.01		0.07
Phylum Chaetognatha	8.06	9.51	8.33	7.32	7.42	8.12	6.13	2.96	5.01	2.69	3.04	3.73	15.8
Phylum Phronida										0.07			
Phylum Chordata	4.26	4.45	2.80	2.38	5.25	6.98	3.79	10.0	7.80	1.84	4.02	0.76	3.06

TABLE 5. Zooplankton composition (Phylum level) in Andaman Sea.

TAXON	PER CENT COMPOSITION
Phylum Sarcomastigophora	2.40
Phylum Cnidaria	1.96
Phylum Ctenophora	0.03
Phylum Annelida	0.56
Phylum Mollusca	2.53
Phylum Arthropoda	78.84
Phylum Echinodermata	1.75
Phylum Bryozoa	0.05
Phylum Chaetognatha	7.51
Phylum Phronida	0.005
Phylum Chordata	4.36
Total	99.995

DISCUSSIONS

Although the result of this study indicate that the Andaman Sea is rich in zooplankton containing at least 65 major taxa included holaplankton and meroplankton that belong to 11 Phylum, the abundance of zooplankton in the Andaman Sea was lower than in the Gulf of Thailand, East Coast of Peninsular Malasia (Jiwaluk, 1999 a), West Coast of Sabah, Sarawak and Brunei Darussalam (Jiwaluk, 1999 b). The abundance of zooplankton was also lower than in various studies in the Andaman Sea from IIOE (Zeitzschel, 1973). Nevertheless, the present results show that copepodes were the most dominant in terms of abundance and composition of zooplankton in the Andaman Sea, this agrees with many researches in the Andaman Sea and adjacent areas.

For distribution patterns of zooplankton, several zooplanktons showed no distinct distribution pattern. They were widely distributed at all stations, this group include Phylum Sarcomastigophora (foraminiferans), Cnidaria, Annelida (polychaete larvae), and many groups of Arthropoda, Chatnatha and Chordata. Another group were found at a few stations e.g. Cydippid larvae, Pagurid zoea, Phyllosoma larva, Annelida family Typhloscolecidae and Lopadorhynchidae (deep water distribution), Arthopoda family Clytemnestridae (found only at station 6.), Arthopoda family Phronomidae, Phrosinidae and Oxyceplidae (found only at station 1.), Actinotrocha larva (found only at station 10.)

From the present results of zooplankton in the Andaman Sea it is difficult to define a relationship of pelagic fisheries resources and zooplankton, also they did not clearly show that the differences of environment factor could contribute to the difference in abundance, distribution and composition. They only showed that zooplankton had abundance according to the depth, the sampling areas near neritic zone tending to have a higher density of zooplankton. Zooplankton data obtained from this research also supports as biological information in the Andaman Sea for the SEAFDEC database on fisheries oceanography. A limitation in the data was the lack of a sample series for studing about the monsoon effect. In the post-moonsoon period, many organisms were increased in number like the siphonophora, Cladocera, Ostracoda, Amphipoda, Mysidacea, Pteropoa and Gastropod larva. Some zooplankton abundance was found to be decreased such as Polychaete (Jiwaluk, 1999 a). More study on zooplankton abundance, distribution and composition is a recommended objective for future research in the area to give information about relationship between zooplankton and fisheries resources.

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REFERENCES

Aravindakshan, P.N. 1973. Distribution and Ecology of Pterotrachea coronata (Forskal),pp. 399-400. In B. Zeitzschel (ed.). The Biology of the Indian ocean. Springer-Verlag,Berlin.

Bowman, T.E. and M. Mc. McGiunness. 1982. Epipelagic Amphipods of the family Hyperiidae from the International Indian Ocean Expedition, 1959-1965. Smith. Cont. Zool. 359:1-53.

Brinton, E. and K. Gopalakirishnan. 1973. The Distribution of Indian Ocean Euphausiids, pp. 357-382. In B. Zeitzschel (ed.). The Biology of the Indian ocean. Springer-Verlag, Berlin.

Fleminger, A. and K. Hulsemann. 1973. Relationship of Indian Ocean Epiplanktonic Calanoids to the World Oceans, pp. 339-347. In B. Zeitzschel (ed.). The Biology of the Indian ocean. Springer-Verlag, Berlin.

Janekarn, V. 1992. Fish larvae in the vicinity of shelf front in the Andaman Sea. A paper presented at the annual Meeting, Department of Fisheries, 16-18 September 1992, Bangkok, Thailand. 34 pp (mimeo, in Thai)

Janekarn, V. 1993. A review of larval fish distribution and abundance in the Andaman Sea. Thailand, Phuket Marine Biological Center Research Bulletin. 44: 1-22.

Jivaluk, J. 1999a. Distribution, Abundance and Composition of Zooplankton in the South Cina Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia.pp. 256-284. In Proceedings of the first technical seminar on "Marine Fishery Resources Survey Area I: Gulf of Thailand and East Coast of Peninsular Malaysia".

Jivaluk, J. 1999b. Distribution, Abundance and Composition of Zooplankton in the South Cina Sea, Area II: Sabah, Sarawak and Bruni Darussalum Waters. pp. 288-309. In Proceedings of the second technical seminar on "Marine Fishery Resources Survey Area II: Sabah, Sarawak and Bruni Darussalum."

Kasturirangan, L.R. , M. Saraswathy and T.C. Gopalakrishnan. 1973. Distribution of Copepoda in the Indian Ocean, pp. 331-338. In B. Zeitzschel (ed.). The Biology of the Indian ocean. Springer-Verlag, Berlin.

Kurian, C.V. 1973. Cumacea of the Indian Ocean, pp. 329-330. In B. Zeitzschel (ed.). The Biology of the Indian Ocean. Springer-Verlag, Berlin.

Nair, K.K.C., P.G. Jacob and S. Kumaran. 1973. Distribution and Abundance of Planktonic Amphipods in the Indian Ocean, pp. 349-356. In B. Zeitzschel (ed.). The Biology of the Indian Ocean. Springer-Verlag, Berlin.

Rao, T.S.S. 1973. Zooplankton Studies in the Indian Ocean, pp. 243-255. In B. Zeitzschel (ed.). The Biology of the Indian Ocean. Springer-Verlag, Berlin.

Sakthivel,M. 1973. Studies on Limacina inflata d' Orbigny (Thecosomata, Gastropoda) in the Indian Ocean, pp. 383-397. In B. Zeitzschel (ed.). The Biology of the Indian Ocean. Springer-Verlag, Berlin.

Vannucci, M. and D. Navas. 1973. Distribution of the hydromedusae in the Indian Ocean, pp. 273-281. In B. Zeitzschel (ed.). The Biology of the

Indian Ocean. Springer-Verlag, Berlin.

Vongpanich, V. 2001. The Order Thecosomata (Mollusca: subclass opisthobranchia) in The Andaman Sea. Phuket Marine Biological Center Special Publication 25(2): 493-500.

Zeitzschel, B. (ed). 1973. The Biology of the Indain Ocean. Springer-Verlag, Berlin. 549 p.

COMPOSITION, ABUNDANCE AND DISTRIBUTION OF ICHTHYOPLANKTON IN THE ANDAMAN SEA

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ABSTRACT

An ichthyoplankton survey was conducted in the Andaman Sea aimed as supportable data for planning and action of sustainable fisheries for food security and to assist the investigation of under-exploited resources in the region. Composition, abundance and distribution of ichthyoplankton are reported based upon plankton samples taken by a pair of bongo nets at 13 stations in November 2004. A total of 1,304 eggs and 1,723 larvae representing 62 families were collected in the samples showing a high diversity. The Myctophidae followed by the Gonostomatidae and Scombridae dominated the abundance of larvae. The two former are oceanic fishes that play an important role in a fishery as they are preyed upon by commercial fishes. Amongst the 62 families, 20 appeared to be commercial fishes of which some inhabit inshore as adults. According to the constancy of occurrence, the ichthyoplankton of the study area was predominantly composed of accidental families, which mainly inhabit inshore as adults suggesting an unstable system in the study area. A map of the distribution of total fish eggs and total larvae and the top ten most abundant families are presented; occurrence of eggs and larvae over the study area indicate that spawning and hatching were widespread but the greater abundance occurred in the north (EEZ of Myanmar) than in the south (EEZ of Thailand and Indonesia). This study and previous studies indicated that the entire aquatic region of Andaman Sea is of vital importance to the well being of numerous species of fishes. Further study is recommended to find peaks in the spawning seasons and spawning grounds. Hopefully, this study will also more or less benefit other studies, which aim to compare the variation after the Tsunami of 26th December 2004 as this survey was undertaken one month before Tsunami hit Asia.

Key words: Andaman Sea, ichthyoplankton, composition

INTRODUCTION

Ichthyoplankton studies have been important since the 1940s when it was realized that valuable information on fisheries and ecology could be obtained from such studies. Ahlstrom and Moser (1976) stated that ichthyoplankton surveys are used to evaluate fish resources in general. Since the plankton net is not selective it collects the eggs and larvae of all kind of fishes with pelagic eggs and/or larval stages. It provides information on unexploited and exploited resources. In fact, with a few exceptions, it provides information on the whole spectrum of fishes in the area being surveyed. As a consequence, more than a thousand publications are listed in a selected bibliography of pelagic fish egg and larval surveys up to the late 1970s (Smith and Richardson, 1979). However, very little work has been carried out on the ichthyoplankton of the tropical Indian Ocean particularly in the east of the Andaman Sea.

SEAFDEC/TD conducted a Joint Research Survey on Pelagic Fisheries

Resources in the Andaman Sea within the EEZ of Indonesia, Myanmar and Thailand from 17th-24th November 2004 under the ASEAN-SEAFDEC program on Harvesting of under-exploited resources to support plans and actions of sustainable fisheries for food security and to assist investigation of under-exploited resources in the region. The ichthyoplankton survey is a part of such research due to their significance as valuable information for fisheries and ecology. Accidentally, this study was conducted one month earlier before the tragedy of the Tsunami hit Asia on 26th December 2004. The Andaman Sea is a part of the area where the Tsunami probably influenced the environment from both the biological and physical aspects. Consequently, the author hopes that this pre-Tsunami study will be useful for any researchers who will undertake further research to compare the variation before and after the Tsunami.

OBJECTIVES

Aims of this study were:

1. To determine the species composition of fish larvae;
2. To determine the abundance and spatial distribution of total fish larvae, total fish eggs and the top ten most abundant families of fish larvae.

MATERIALS AND METHODS

Sampling Procedure.

Ichthyoplankton samples were taken aboard the M.V. *SEAFDEC* from 17th to 24th November 2004 in the Andaman Sea at latitude 6°44.47'N to 12°40.80'N and longitude 95°51.20'E and 96°45.30'E where 13 stations were set out in this area (Figure 1). The study site is oceanic with approximately 77% of the area exceeding depths of 500 m.

All collections were made when the vessel arrived on stations, regardless of the time of the day; resulting in varied collection times (see Appendix 1). Double oblique plankton tows of about 30 min duration were taken at each station with a pair of bongo nets (60 cm mouth diameter with 500 µm and 330 µm mesh for ichthyoplankton and zooplankton samples respectively) and the tow was made to a depth of approximately 150 m at a speed of approximately 2-3 knots. The volume of water filtered through each net was measured with a calibrated flow meter fitted at the mouth of each net. The nets were washed at the end of each tow, and samples were fixed in a 5-10% formalin solution in seawater

For the environmental variables i.e. temperatures, salinities, phytoplankton production (chlorophyll-a concentration), nutrients i.e. nitrate and phosphate at surface water were measured at the same time as ichthyoplankton were sampled. Full details of the methods and the results are given in Laongmanee *et al.* (2005), Obromwan (2005) and Wisespongpand *et al.* (2005).

Laboratory Procedure.

Ichthyoplankton were sorted from the samples under a dissecting microscope and then stored in 70% alcohol after removal from the samples. Larvae were identified mainly to family level and to genera or species in some cases and counted. Identifications of larvae were based upon descriptions given in a variety of larval fishes including those of Fahay (1983), Moser *et al.* (1984), Ozawa (1986), Nishikawa and Rimmer (1987), Okiyama (1988), Neira *et al.* (1998), Leis and Carson-Ewart (2000). The term larva used in this paper included the preflexion, flexion and postflexion stages as described by Ahlstrom and Ball (1954). Larvae that could not be

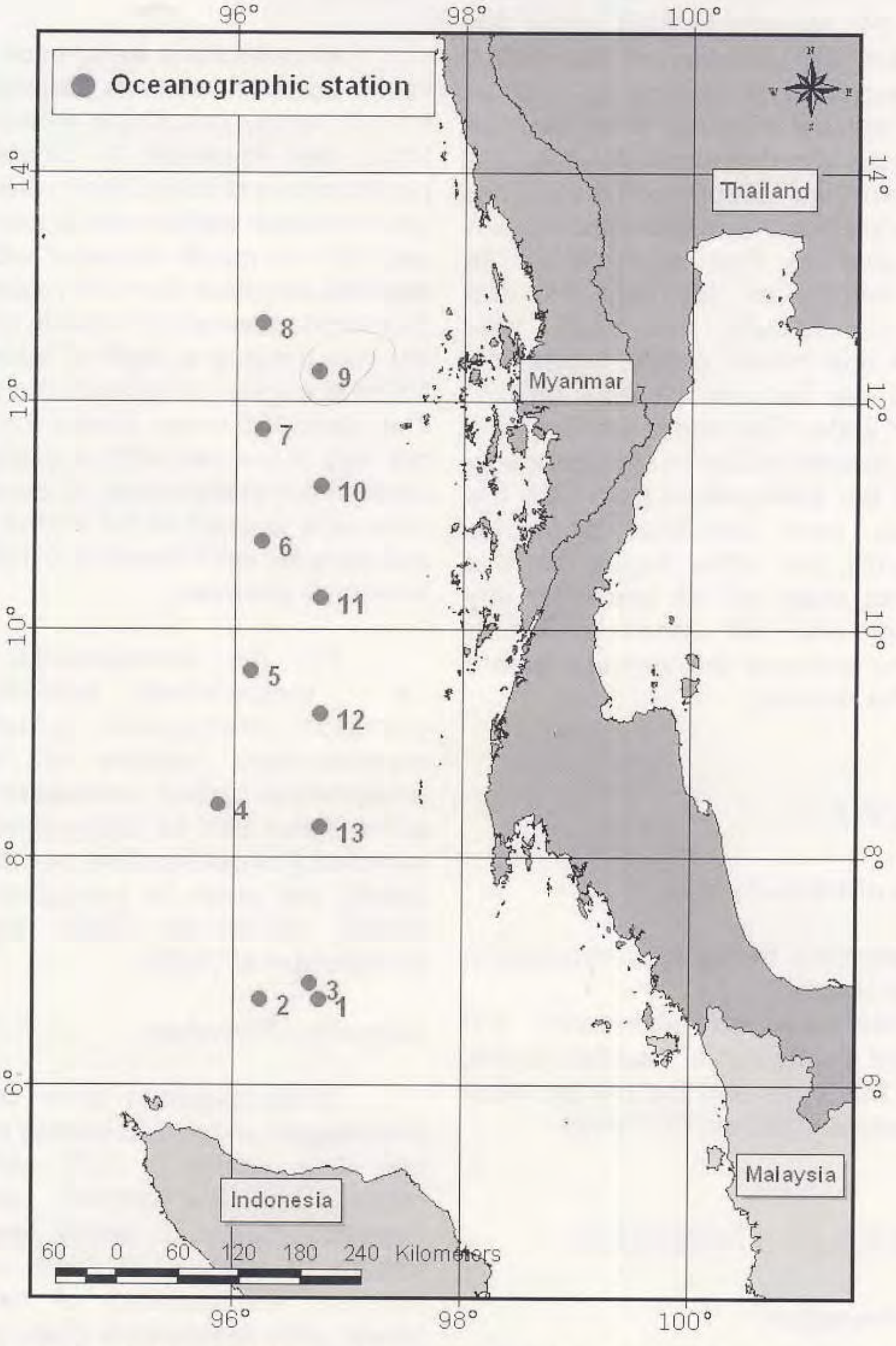

FIGURE 1. Ichthyoplankton sampling stations (solid circle and stations are numbered) in The Andaman Sea during November 2004.

identified even to family level were placed in two categories: 1) damaged specimens and tiny preflexion larvae whose identification was questionable were placed in the unidentifiable category and 2) larvae in good condition but could not be identified were placed in the unidentified category (Table 1). The numbers of eggs of all other fish were counted collectively.

Data Analysis

Prior to analysis, reported catches of fish eggs and larvae at each sampling station were standardized to numbers caught per 1000 m^3 of water volume filtered. The number of total fish larvae/eggs and the top ten most abundant families were then mapped for their spatial distribution.

Determination of the Constancy of Occurrence was calculated based upon the ecological index proposed by Dajoz (1983 cited after Schifino *et al.*, 2004):

$$C = P/Q \times 100$$

Where:

C = Constancy of Occurrence of the family (%)
P = Number of samples where the species occurred (sampling station)
Q = Total number of samples (total number of sampling station)

The families were then divided into three categories:

- Constants (when C > 50%)
- Accessories (when 25% ≤C ≤50%
- Accidental (when C < 25%)

A Cluster Analysis for comparison of larval fish assemblages by stations was applied aiming to investigate the existence of ichthyoplankton similarities of different stations in the survey area as expressed in the form of a dendrogram. The analyses used a squared Euclidean distance as a measure of proximity and followed an unweighted pair group method-arithmetic average for linkage as described by Pielou (1984). The software used for cluster analysis was Statistica for Windows 6.0 version (StatSoft, Inc. 1984-2001).

The influence of environmental factors on the abundance of fish larvae and fish eggs was not examined due to small sample size. However, the spatial pattern of the variation in concentration of environmental variables; nitrate, phosphate, phytoplankton production (chlorophyll-a), temperature and salinity were compared to the spatial pattern of the variation in the abundance of fish larvae and fish eggs.

Results And Discussions

Composition And Abundance Of Fish Larvae

A total of 1,732 fish larvae were caught during this study, representing 62 families of which 8 species could be assigned to particular species, 5 to genus (Table 1). The Myctophidae was the most abundant contributing 30.41% to the total number of larvae and the Gonostomatidae was the second most abundant family contributing 9.85% to the total number of larvae. These two families are mesopelagic fishes; abundant along the continental shelf in the Atlantic, Pacific, and Indian Ocean. The larvae of mesopelagic fishes all live the epipelagic zone and have higher survival among the early life stages than that of the epipelagic species possibly due to different advective losses (Salvanes and Kristoffersen, 2001). The early life stages of large epipelagic populations are passively transported long-distances which mean high advective loss. No particular long-distances drift pattern is yet known for mesopelagic fish and this may reflect lower advective losses and lower mortality (Salvanes and Kristoffersen, 2001).

The following additional 8 families ranked in the top 10 in occurrence or abundance: Scombridae, Bothidae, Bregmacerotidae, Lutjanidae, Nomeidae, Gobiidae, Congridae, and Ophichthidae of which each contributed between 6.03 and 2.06% to the total number. The dominance of offshore fishes reflects the oceanic character of the area. It is therefore not surprising to find that of the 62 families recorded here, 20 inhabit deep sea as adults (Table 2).

The establishment of a list of species is the first significant point to be considered in the study of a fish larval composition since the Andaman Sea comprises a rich ichthyofauna. FishBase (2005a, 2005b) listed 537 and 5,436 fish species occurring on the system of the Andaman Sea and of the Indian Ocean respectively. Larval fish showed a high diversity in the present study, although the samplings were done in a short period (17 sampling days). Sixty-two families were presented when compared to Termvidchakorn (1987) who collected fish larvae in May 1985 from the area overlapping with the present study and reported 52 families appeared in the Andaman Sea which 30 families shared in the present study. He found bregmacerotids (vertical haul) and engraulids, hemi-ramphids, mullids and carangids (surface horizontal haul) dominant. The dominant species from his investigation differs from the present study most likely because of a difference in sampling method and sampling time. The oblique haul operated in this study is a more efficient and suitable sampling method than a surface horizontal haul and a vertical haul because it can catch fish larvae from the whole water column in a wider area whereas the surface and vertical haul can catch fish larvae in a limited area. Janekarn (1988) caught 70 families of larval fish along the Andaman Sea coast which 33 families were shared with the present study. Janekarn and Kiorboe (1991) reported 69 families occurring along the Andaman Sea coast with 37 families shared with the present study. Janekarn (1992) reported 99 families occurring across shelf slope region (43-310 m deep) in the Andaman Sea. Unfortunately, it is not known what number of families shared with the present study because the species composition was not shown in his report. Puewkhoa (1997) reported 59 families occurring along the Andaman Sea coast from Phuket to Satul province which 32 families were shared with the present study. 6 of 32 families in his study were offshore species, which indicated oceanic influence in his study area whereas the neritic influence also intrudes into the present study area because the inshore species were found. Lirtvitayaprasit *et al.* (2001) recorded 58 families occurring in the Andaman Sea along the continental shelf at Latitude 6° 45.53′ to 8°45.88′ N and Longtitude 95° 30.03′ to 97°41.94′ E, 38 families were shared with the present study. Lirtvitayaprasit *et al.* (2004) reported 32 families occurring in the northeastern Indian Ocean from January to March 2002; 23 families were shared with the present study. Janekarn (1992) estimated a number of families of fish larvae found in Andaman Sea based upon his and other studies. He summarized 123 families of fish larvae found in the Andaman Sea indicating the high diversity of the area. In summary, from the present study and previous studies it is indicated that the Andaman Sea is rich in fish larval diversity and the effect of water current may play an important role in the composition, abundance and distribution of the larvae.

Based upon the values of frequency of occurrence of species, among the 62 captured families, 7 were considered constant, 14 accessories and 41 accidental (Table 1). The Myctophidae, Gonosto matidae, Bothidae, Bregmacerotidae, Congridae, Ophichthidae, Paralepididae were constant; the Scombridae, Callionymeidae, Scorpae-nidae, Gobiidae, Nomeidae, Gempylidae, Champso-

TABLE 1. Numbers Of The Different Taxon Of Larval Fish Caught In Andaman Sea

TAXA	Total Number of Larvae	Mean Number of Larvae	SD	Percentage of Total Catch	Rank	Frequency of Occurrence (%)	Classification According to Constance of Occurrence		
							1	2	3
Anguillidae (C)	2	0.15	0.55	0.12	47	7.69			x
Muraenidae (MC)	2	0.12	0.43	0.09	53	7.69			x
Congridae (MC)	40	3.05	6.27	2.29	9	53.85	x		
Ophichthidae	36	2.74	4.82	2.06	10	53.85	x		
Gonostomatidae	171	13.13	13.32	9.85	2	92.31	x		
Stomiidae	7	0.53	1.12	0.40	25	23.08			x
Astronesthidae									
unidentified sp.	1	0.10	0.36	0.076					
Astronesthes cyaneus	3	0.23	0.57	0.176					
total	4	0.34	0.64	0.252	31	23.08			x
Melanostomiidae	3	0.22	0.53	0.162	43	15.38			x
Idiacanthidae	5	0.36	0.71	0.274	29	23.08			x
Synodontidae (C)	27	2.08	4.91	1.565	14	30.77		x	
Chlorophthalmidae (MC)	1	0.09	0.33	0.070	60	7.69			x
Scopelarchidae	34	2.59	5.67	1.941	12	46.15		x	
Myctophidae	527	40.51	42.99	30.410	1	100.00	x		
Neoscopelidae	3	0.23	0.57	0.175	41	15.38			x
Paralepididae									
Sudis hyalina	3	0.24	0.18	0.18					
unidentified spp.	32	2.45	1.84	1.84					
Total	35	2.69	2.02	2.02	11	69.23	x		
Hemiramphidae	10	0.80	0.60	0.60	23	30.77		x	
Bregmacerotidae	85	6.52	4.89	4.89	5	84.62	x		
Carapidae	2	0.13	0.10	0.10	50	7.69			x
Ophidiidae						0.00			
unidentified sp.	1	0.11	0.40	0.08		0.00			
Parophdion schmidti	2	0.15	0.55	0.12		0.00			
total	3	0.27	0.66	0.20	37	15.38			x
Berycidae (C)	1	0.11	0.40	0.08	55	7.69			x
Sphyraenidae (C)	11	0.88	1.79	0.66	22	23.08			x
Acropomatidae(MC)	20	1.53	3.55	1.14	15	30.77		x	
Serranidae (C)						0.00			
Sacura sp.	2	0.12	0.44	0.09		0.00			
Unidentified sp.	2	0.12	0.44	0.09		0.00			
total	3	0.24	0.88	0.18	39	7.69			x
Apogonidae	12	0.92	2.00	0.69	21	23.08			x
Callanthiidae	4	0.31	1.11	0.23	32	7.69			x
Carangidae (C)	17	1.32	2.86	0.99	17	30.77		x	
Coryphaenidae (C)	13	1.03	1.77	0.77	19	38.46			x
Leiognathidae (MC)	1	0.10	0.36	0.08	56	7.69		x	
Bramidae (C)	6	0.46	0.89	0.35	26	23.08		x	
Emmelichthyidae (C)	3	0.24	0.88	0.18	39	7.69			x
Sciaenidae (C)	5	0.37	1.00	0.28	28	15.38			x
Mullidae (C)	1	0.09	0.33	0.07	60	7.69			x
Lutjanidae (C)	56	4.33	12.56	3.25	6	23.08			x
Microcanthidae	1	0.10	0.36	0.08	56	7.69			x
Teraponidae (C)	1	0.09	0.33	0.07	60	7.69			x
Lethrinidae (C)	2	0.15	0.55	0.12	47	7.69			x
Pomacentridae	2	0.13	0.48	0.10	50	7.69			x
Cepolidae	4	0.30	1.09	0.23	33	7.69			x
Labridae						0.00			
Cirrhilaburs temminckii	5	0.40	1.45	0.30		0.00			
unidentified spp.	3	0.27	0.96	0.20		0.00			
Total	9	0.67	2.41	0.50	24	7.69			x

Continue next page...

TABLE 1. Numbers Of The Different Taxon Of Larval Fish Caught In Andaman Sea

TAXA	Total Number of Larvae	Mean Number of Larvae	SD	Percentage of Total Catch	Rank	Frequency of Occurrence (%)	Classification According to Constance of Occurrence		
							1	2	3
Scaridae						0.00			
unidentified sp.	2	0.13	0.48	0.10		0.00			
Scarus sp.	2	0.15	0.54	0.11		0.00			
total	4	0.28	0.69	0.21	36	7.69			x
Champsodontidae	12	0.95	1.71	0.71	20	30.77		x	
Ammodytidae	2	0.19	0.67	0.14	46	7.69			x
Scombrolabracidae	3	0.25	0.60	0.18	38	15.38			x
Scombridae (C)						0.00			
unidentified spp.	3	0.27	0.96	0.20		0.00			
Katsuwonus pelamis	3	0.21	0.51	0.15		0.00			
unidentified tuna	23	1.73	4.07	1.30		0.00			
Euthynnus sp.	26	2.00	6.31	1.50		0.00			
Auxis spp.	50	3.83	13.34	2.88		0.00			
total	104	8.03	19.76	6.03	3	46.15		x	
Gempylidae (C)						0.00			
unidentified spp.	13	0.98	2.57	0.73		0.00			
Gempylus serpen	3	0.24	0.59	0.18		0.00			
total	16	1.22	2.54	0.91	18	30.77		x	
Trichiuridae (C)						0.00			
Benthodesmus elongatus pacificus	2	0.12	0.43	0.09		0.00			
unidentified sp.	1	0.10	0.36	0.08		0.00			
total	3	0.22	0.54	0.16	42	15.38			x
Acanthuridae (C)	5	0.40	1.45	0.30	27	7.69			x
Nomeidae (C)	47	3.63	9.85	2.73	7	23.08		x	
Gobiidae	42	3.26	5.06	2.45	8	46.15		x	
Mugiloididae						7.69			
Parapercis sp.	2	0.12	0.43	0.09	53	7.69			x
Blenniidae	1	0.10	0.36	0.08	56	7.69			x
Scorpaenidae	17	1.34	2.12	1.00	16	38.46		x	x
Synanceiidae	2	0.12	0.44	0.09	52	7.69			x
Congiopodidae	1	0.10	0.36	0.08	56	7.69			x
Aploactinidae	3	0.21	0.52	0.16	44	15.38			x
Platycephalidae (C)	4	0.29	0.70	0.22	35	15.38			x
Callionymidae	30	2.27	3.95	1.71	13	38.46		x	
Bothidae (C)	87	6.66	11.75	5.00	4	53.85	x		
Cynoglossidae (C)	4	0.34	0.66	0.26	30	23.08			x
Balistidae (C)	4	0.29	1.06	0.22	34	7.69			x
Monacanthidae	2	0.15	0.54	0.11	49	7.69			x
Tetraodontidae	3	0.20	0.73	0.15	45	7.69			x
Unidentifiable	134	10.34	10.64	7.76					
Unidentified	30	2.23	3.61	1.74					
Total fish larvae	1732	133.21	106.94	100.00					
Total fish eggs	1304	100.31	46.13						

(1) Constant species (2) Accessories species (3) Accidental species
(C) - Commercial species, (MC) – minor commercial species

dontidae, Bramidae, Coryphae-nidae, Carangidae, and Acropomatidae considered accessory families and the rest were accidental families. The relative occurrence of constant, accessory and accidental families was 11, 23 and 66 (Table 1). The study area presented a relatively low number of constant species suggesting the system appears not to be stable. The larvae seem to be reproduced inshore and distributed to offshore by water current while their adult habitats are inshore (Table 1 and 2). Larvae of some families are a constant occurrence (e.g. Myctophidae, Gonostomatidae, Paralepididae, Table 1), this might permit spawning grounds to be located.

The type of fish larvae taken from the samples can be grouped into 6 categories based on the adult's habitat and mode of spawning (Table 2). Group 1: Pelagic bay and neritic species, most of which spawn pelagic eggs; Group 2: inshore reef species with nonpelagic eggs (i.e., brooded or demersal); Group 3: inshore reef species with pelagic eggs; Group 4: offshore species (oceanic and deep benthic), which presumably spawn pelagic eggs; Group 5: fresh water species with pelagic eggs spawned in the open ocean; and Group 6: brackish to oceanic species with pelagic eggs. The mode of spawning was made on the basis of literature accounts (primarily Anonymous, 1974; FishBase, 2005a, 2005b; Leis and Miller, 1976). Seven attributions (ammodytids, congiopodids, aploactinids, callanthids, emmelichthyids mugiloid and synanceiids) were assumed. Some families (e.g. Labrids) are known to include some species which spawn pelagic eggs while others spawn demersal eggs (Leis and Miller, 1976). On the basis of the above categories, this study area was dominated by species included in Group 3 and 4 followed by Group 2. The offshore occurrence of Group 3 and 2 larvae are of great importance in planning and executing ichthyoplankton surveys in tropical areas as suggested by Leis and Miller (1976) which confirmed Dekhnik et al. (1966, cited after Leis and Miller, 1976)'s finding indicating Group 3 larvae being found offshore off northern Cuba. Leis and Miller (1976) reported offshore distribution of larvae categorized in Group 3 around the Hawaiian Islands. The above pattern may be widespread in the tropics. This is attested by this study as the same pattern of Group 3 and 2 larvae being found offshore with high numbers of some families (Acropomatidae, Bothidae, Callionymidae, Congridae, Lutjanidae, Ophichthidae, Scorpaenidae and Synodontidae). Therefore, plankton survey in near shore areas aims to sample Group 3 larvae, which are often important commercial and sport species, must be designed to include offshore stations. This infers that the larval fish catch in a given area will most likely not reflect the adult population. The areas other than the adult habitats must therefore be sampled (Leis and Miller, 1976). The diversity among larvae of demersal fish was considerably higher than the diversity among larvae of pelagic and mesopelagic fish which is a trend also found in other parts of the Andaman Sea and in other open tropical seas (Janekarn and Kiorboe, 1991)

Twenty-eight families of fish larvae caught in this study appear to be commercial fishes, they are mostly inshore fishes and are accidental families of occurrence (Table 1 and 2), indicating that inshore currents intrude into the area or some fishes do their spawning in this study area. However, the dominant species of this study: myctophids and gonostomatids are not commercial fishes (Table 1). As said earlier, they are mesopelagic fishes in which most populations have their daytime depths somewhere between 200 and 1000 m. The large fisheries therefore are not developed, due to the combination of technology limitations and a high proportion of wax-esters, of limited nutritional value, in many species (Salvanes and Kristoffersen, 2001). Nevertheless, the mesopelagic fishes are still important to interdisciplinary

TABLE 2. Fish grouping based on adult habitat and mode of spawning.

GROUP 1 Pelagic and Neritic species	GROUP 2 Inshore reef species with non-pelagic eggs	GROUP 3 Inshore reef species with pelagic eggs	GROUP 4 Offshore (oceanic and deep benthic) species	GROUP 5 Freshwater fish	GROUP 6 Pelagic from Brackish to Oceanic species
Carangidae	Apogonidae	Acanthuridae	Astronesthidae	Anguilldae	Bregmacerotidae
Hemiramphidae	Ammodytidae*	Aploactinidae*	Bramidae		
	Blennidae	Acropomatidae	Berycidae		
	Balistidae	Bothidae	Champsodontidae		
	Congiopodidae*	Callionymidae	Cepolidae		
	Gobiidae	Callanthiidae*	Coryphaenidae		
	Monacanthidae	Carapidae	Chlorophthalmidae		
	Pomacentridae	Congridae	Gonostomatidae		
	Tetraodontidae	Cynoglossidae	Gempylidae		
		Emmelichthyidae*	Idiacanthidae		
		Labridae	Myctophidae		
		Lethrinidae	Melanostomiidae		
		Lutjanidae	Nomeidae		
		Leiognathidae	Neoscopelidae		
		Mullidae	Ophidiidae		
		Muraenidae	Paralepididae		
		Microcanthidae	Stomiidae		
		Mugiloididae*	Scombridae		
		Ophichthidae	Scopelarchidae		
		Platycephalidae	Scombrolabracidae		
		Scaridae	Trichiuridae		
		Scorpaenidae			
		Serranidae			
		Sphyraenidae			
		Synodontidae			
		Synanceiidaea			
		Sciaenidae			
		Teraponidae			

*Assumed

ecosystem studies (Salvanes and Kristoffersen, 2001).
Most mesopelagic fishes species are small, usually 2 – 15 cm long, suggesting an important prey for many marine fishes and mammals (LarvalBase, 2005) like tunas (Alverson, 1963 cited after Ahlstrom et al., 1976), rockfishes, (Pereya et al., 1969 cited after Ahlstrom et al., 1976), and fur seals (Nead and Taylor, 1953 cited after Ahlstrom et al., 1976). Some species of mesopelagic fish aggregate in large numbers at certain times during their life cycle and at such times may be available to a fishery (Ahlstrom et al., 1976).

Comparison Of Larval Fish Assemblages By Stations

The species diversity varied substantially between stations. At station 8, 9, 10 and 11, which are in the EEZ of Myanmar, were the most diverse with 25-26 families recorded. Eleven to eighteen families each were found at station 2, 3, (within EEZ of Indonesia) 5, 6 and 7 (within EEZ of Myanmar). Only 5 to 7 families each were recorded at station 1 (EEZ of Indonesia), 4, 12 and 13 (within the EEZ of Thailand). The diversity was higher in the northern than in the southern region of the study area (Table 1). Due to the diversity of families between stations, similarity cluster is used to compare larval fish assemblage by stations.

The similarity cluster (Figure 2 top) indicated the presence of two major groups based on larval numbers in families with roughly similar abundances. The first group was characterized by 2 stations .10 and 11 . in which myctophids were the most, and gonostomatids the second most abundant. Station 10 and 11 comprised 26 and 25 taxa respectively, and were very similar sharing several fish families namely Congridae, Ophichthidae, Synodontidae, Scopelarchidae, Paralepididae, Bregmacerotidae, Apogonidae, Lutjanidae, Scombridae, Gobiidae, Bothidae and Cynoglossidae. These stations were in front of Mynmar and close to the shore. The second group comprises the rest of the stations. The distinction from the other group could possibly be due to then sampling time of these two stations. They were made during the dusk and night time while the rest were sampled during daytime (Appendix 2). Collection of fish larval samples 16 during night time obtained greater numbers of larvae than those collected during the day (Alhstorm, 1954; Bridger, 1955, 1956).

Due to a difference in sampling time possibly causing a difference in numbers of larvae, station 10 and 11 were excluded from the cluster analyses to minimize error in statistical analyses. It is however evident that the dendrogram did not have any change (Figure 2 bottom), the stations other than station 10 and 11 were still grouped in the same manner suggesting the time of sampling does not much affect the abundance of larvae, the other factors like food availability, water current etc. may play important roles in the abundance of fish larvae. The stations grouped into the second group can be divided into 3 sub-groups with two runts. Station 1 and 4 formed the first sub-group. Station 2, 3, 12, 5 and 7 formed the second sub-group and station 8 and 9 formed the third sub-group. Station 13 and 6 are called "runt" because they do not enter any group (Figure 2 top

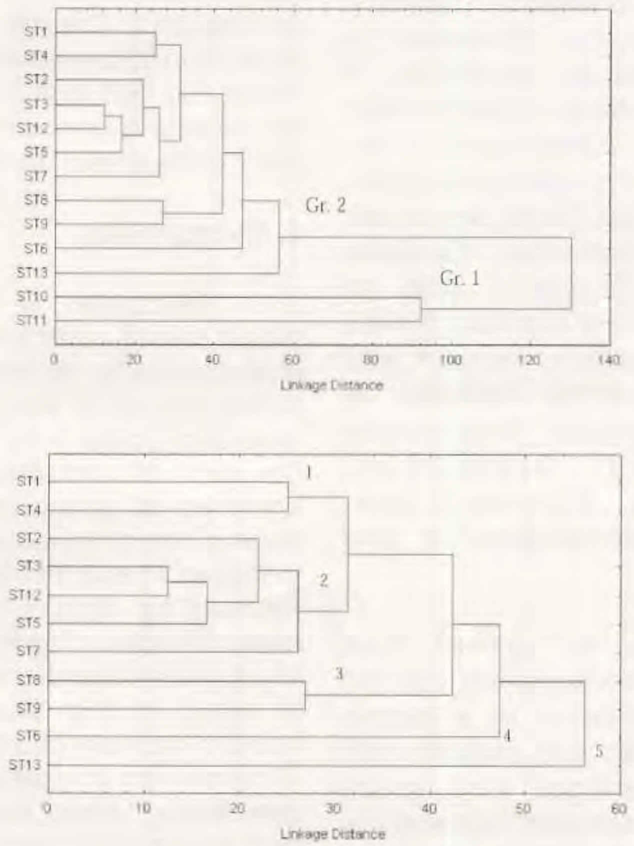

FIGURE 2. Similarity dendrogram of fish larvae between 13 stations (top) and 11 stations (bottom excluding station 10 and 11).

and below). Station 1 and 4 comprised 6 and 7 taxa respectively, and were very similar in sharing several fish families, namely Gonostomatidae, Myctophidae, Hemiramphidae and Coryphaenidae. Station 4 was an offshore station in Thai waters whereas station 1 was in Indonesian waters. Station 2, 3, 5, 7 and 12 comprised 13, 11, 12, 18 and 5 taxa respectively and share three fish families namely Gonostomatidae, Myctophidae and Bregmacerotidae. Station 8 and 9 was dominated by bothids followed by myctophids. These two stations comprised 25 taxa and were very similar sharing several fish families, namely Congridae, Ophichthidae, Synodontidae, Myctophidae, Paralepididae, Bregmacerotidae, Carangidae, Champsodontidae, Scombridae, Gobiidae, Callionymeidae and Bothidae. Station 8 and 9 were in front of Mynmar and close to station 7. Station 6 was not in any group, it is dominated by Myctophidae, followed by Nomeidae. It comprised 11 taxa, namely Ophichthidae, Gonostomatidae, Astronesthidae, Myctophidae, Paralepididae, Bregmacerotidae, Ophidiidae,Berycidae, Champsodontidae, Nomeidae, Gobiidae and Aploactinidae. Station 6 was an offshore station in front of Mynmar. Station 13 was in Thai waters, which was dominated by myctophids followed by gonostomatids. It comprised 7 taxa, namely Gonostomatidae, Stomiidae, Scopelarchidae, Myctophidae, Paralepididae, Bregmacerotidae and Gobiidae.

Comparison of larval fish assemblages by station suggests that the assemblages are arranged in a certain order in Figure 2 such that stations with similar larval assemblages tend to be located adjacent to each other showing the patchy distribution of fish larvae suggesting that stations where high numbers were found close to the spawning sites. This reflects the ecology of larval fish. Other than sampling at dusk and dawn maximizing 17 abundance of larvae at station 10 and 11, the other potential factor like food availability, water mass (temperature and salinity), water current, chlorophyll concentration, etc. May play an important role.

Spatial distribution of total fish larvae and the top ten family accounts

1. Total fish larvae

Fish larvae were obtained every net tow but were very variable in abundance. The number of fish larvae per haul differed substantially between stations ranging from 30 to 400 larvae (Figure 3 and Appendix 1), with the greatest total number of larvae at station 11 (n = 400) followed by station 10 (n = 299) due largely to a high abundance of Myctophidae (Appendix 1). Station 6, 7, 8, 9 and 13 had more than 100 larvae per station and station 2, 3 and 5 had less than 100 but more than 50 larvae while the rest (station 1, 4 and 12) had less than 50 larvae. All fish larvae tend to concentrate more in the north (EEZ of Myanmar) than in the south.

2. Myctophidae

Myctophid is a mesopelagic fish, which is not commercial fish but it is an important prey of many larger fish in the ocean. Larvae of this family with 527 larvae recorded (mean = 41 ± 42.99 larvae) were the most abundance of any family and occurred at every station. The greatest abundance of myctophid larvae was found at station 11 with 141 larvae being recorded, followed by station 10 where 122 larvae were collected (Figure 4 and Appendix 1). Myctophids naturally migrate to the surface at night, in this study myctophids were found to be most abundant at station 10 and 11 where the samplings were done at dusk and during night time consequently the occurrence of myctophid larvae was high at these stations. Myctophid larvae were more concentrated in the northern half of the study area than in the south (mean = 59 ± 56.87 larvae, n = 6 for the north and mean =

25 ± 18.82 larvae, n = 7 for the south).

2. Gonostomatidae

Gonostomatid is also a mesopelagic fish, its larvae were the second most abundant family of fish larvae collected in this study (mean = 13.13 ± 13.32). They were widely distributed throughout the survey area where 12 of 13 sampling stations were observed with the greatest number recorded at station 13 (46 larvae), followed by station 1, 2 and 11 where 24 -25 larvae were recorded. No Gonostomatid larvae occurred at station 8. In summary, gonostomatid larvae were more concentrated in the south than in the north (Figure 5 and Appendix 1).

3. Scombridae

This family are highly commercially important fishes in the Andaman Sea (FishBase, 2005). In this study, scombrid larvae were ranked 3rd in percentage of occurrence. They were found at only 6 of 13 stations with the highest number being 19 recorded at station 10 due largely to high abundance of *Auxis* spp. (Figure. 6, Appendix 1). They appeared to occur only in the northern part of the study area.

Larvae of this family were identified to lower taxa, which are discussed below.

Katsuwonus pelamis — Only two skipjack larvae were taken at station 5 and 10 (Figure 5 and Appendix 1). Larvae of this species are restricted to waters with surface temperatures of 15°C to 30°C, they spawn throughout the year in the tropics (FishBase, 2005). Although the water temperature in this study was between 29 and 30°C, only two larvae of this species were found. A possible explanation is the unsuitable time of sampling. Stequert and Marsac (1989) reported the greatest abundance of skipjack larvae in eastern Indian Ocean in February.

Euthynnus spp. — These larvae were found at station 8, 10 and 11 with the highest numbers at station 10 (23 larvae, Figure 6 and Appendix 1).

Auxis spp. — Larvae of this taxa were found in greater numbers than other species of this family. They were not widely distributed, found at only 2 stations (7 and 10) and had high abundance at station 10 with 48 larvae being recorded (Appendix 1). *Auxis* spp. are small tuna which are widely distributed in the Indian Ocean, they are always caught together with *Katsuwonus pelamis* (Exploratory Division, 1997). *Auxis* spp. larvae found in this study indicates a spawning ground for this family.

Unidentified tuna — Twenty-three larvae are in the preflexion stage, which could not be identified below the generic level (Table 1). They were found in high numbers at station 9 with 14 larvae being recorded (Appendix 1). Scombrid larvae in the genus *Thunnus* are difficult to identify at species level. However, in the eastern Indian Ocean, skipjack: *Katsuwonus pelamis* are greater in abundance than other tuna (Somsathan, 1998) followed by yellowfin tuna: *Thunnus albacares*, and bigeye tuna: *T. obesus* and albacore: *T.alalunga*. Termvidchakorn (1987) reported that most scombrid larvae collected in the Andaman Sea were *Thunnus* spp. Consequently, unidentified tuna larvae in this study might be *Thunnus* as they are abundant in the Indian Ocean particularly in the Andaman Sea.

Unidentified Scombridae. Three larvae could not be identified below the family level (Table 1). They were found only one station with 3 larvae being recorded at station 11 (Appendix 1).

Scombridae is among the most important of commercial and sport fishes (FishBase, 2005a, 2005b). Occurrence of the larvae of this family suggests a

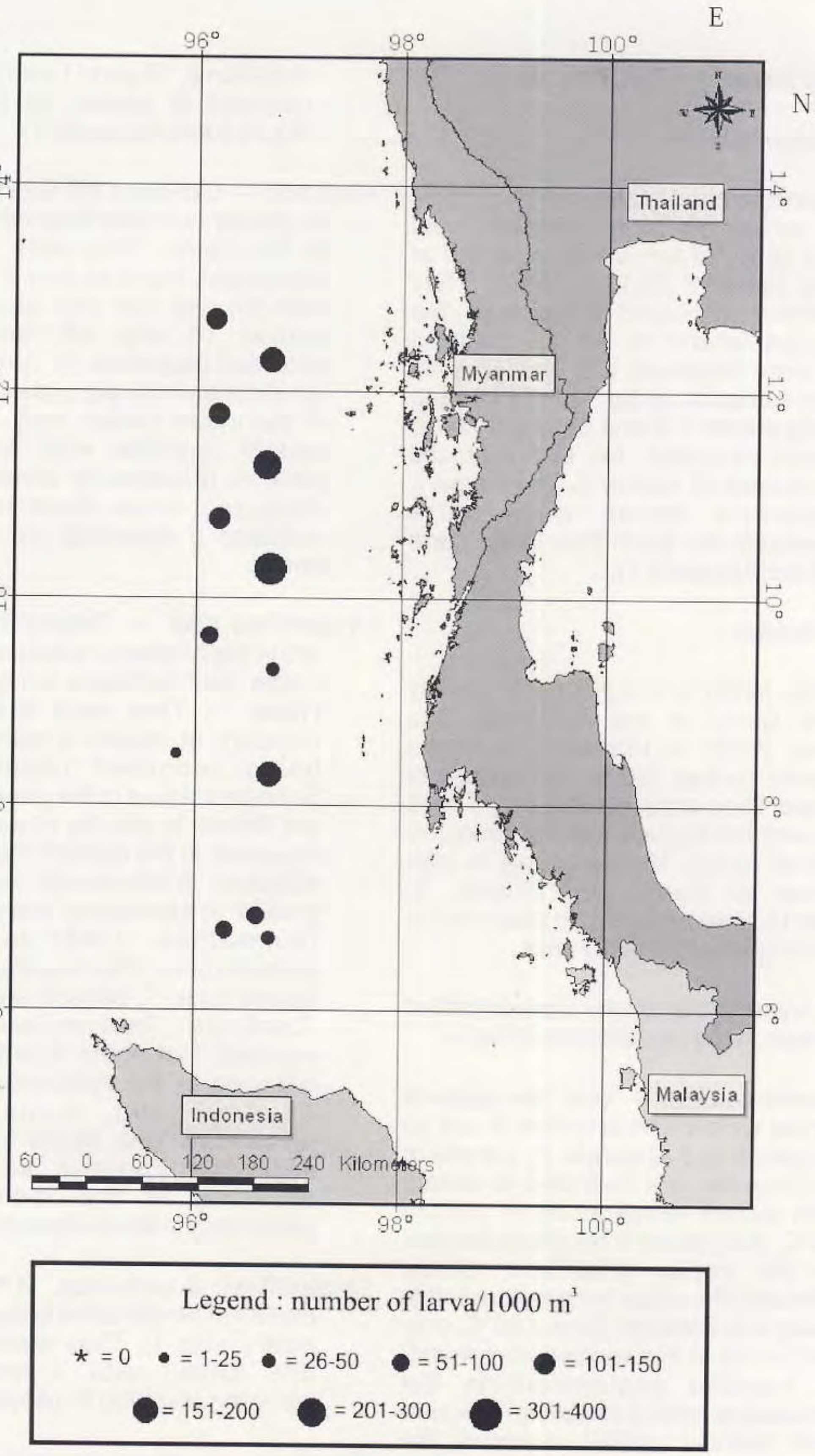

FIGURE 3. Distribution of total fish larvae Catches in November 2004 in the Andaman Sea.

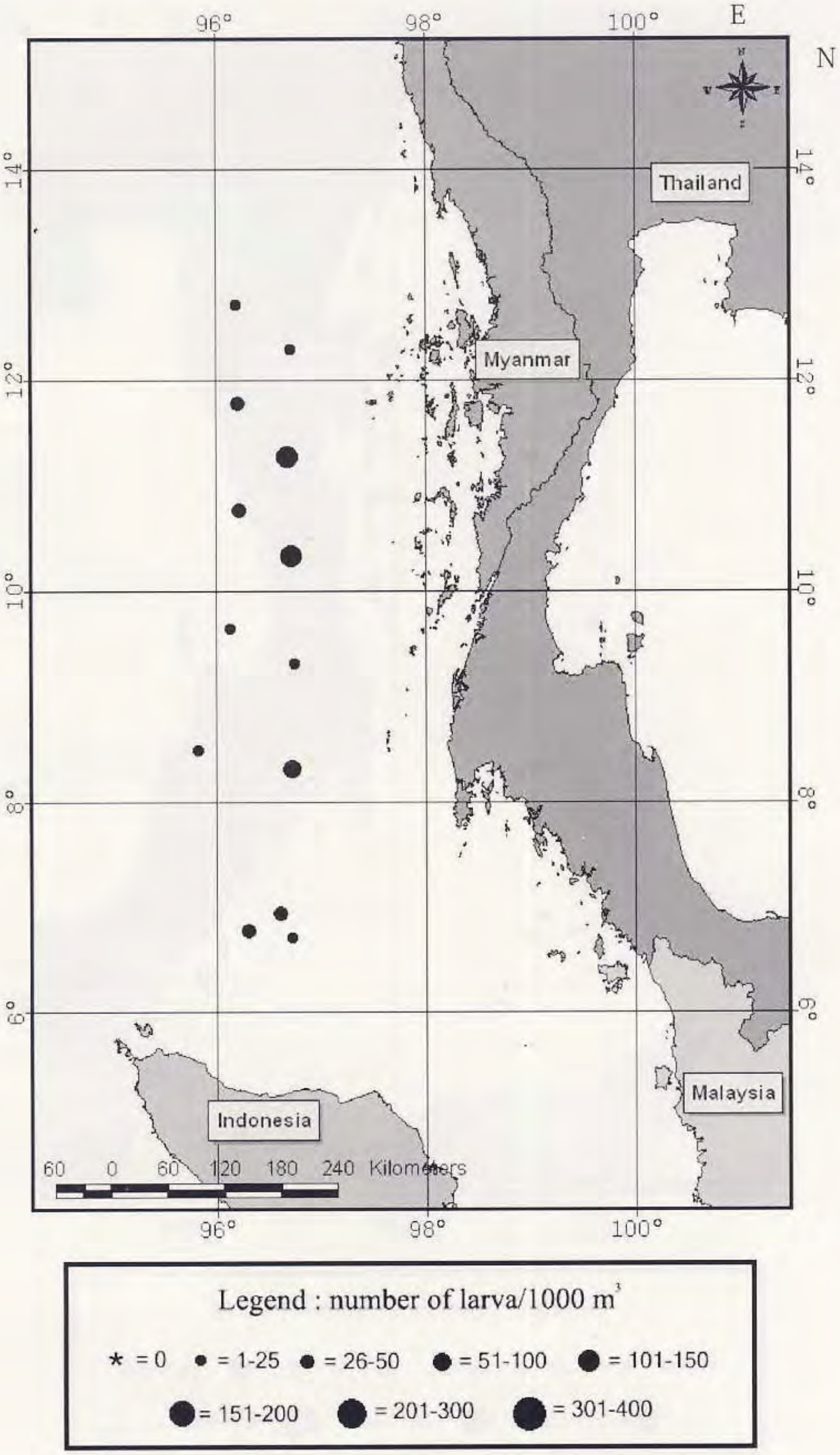

FIGURE 4. Distribution of Myctophid larvae catches in November 2004 in Andaman Sea.

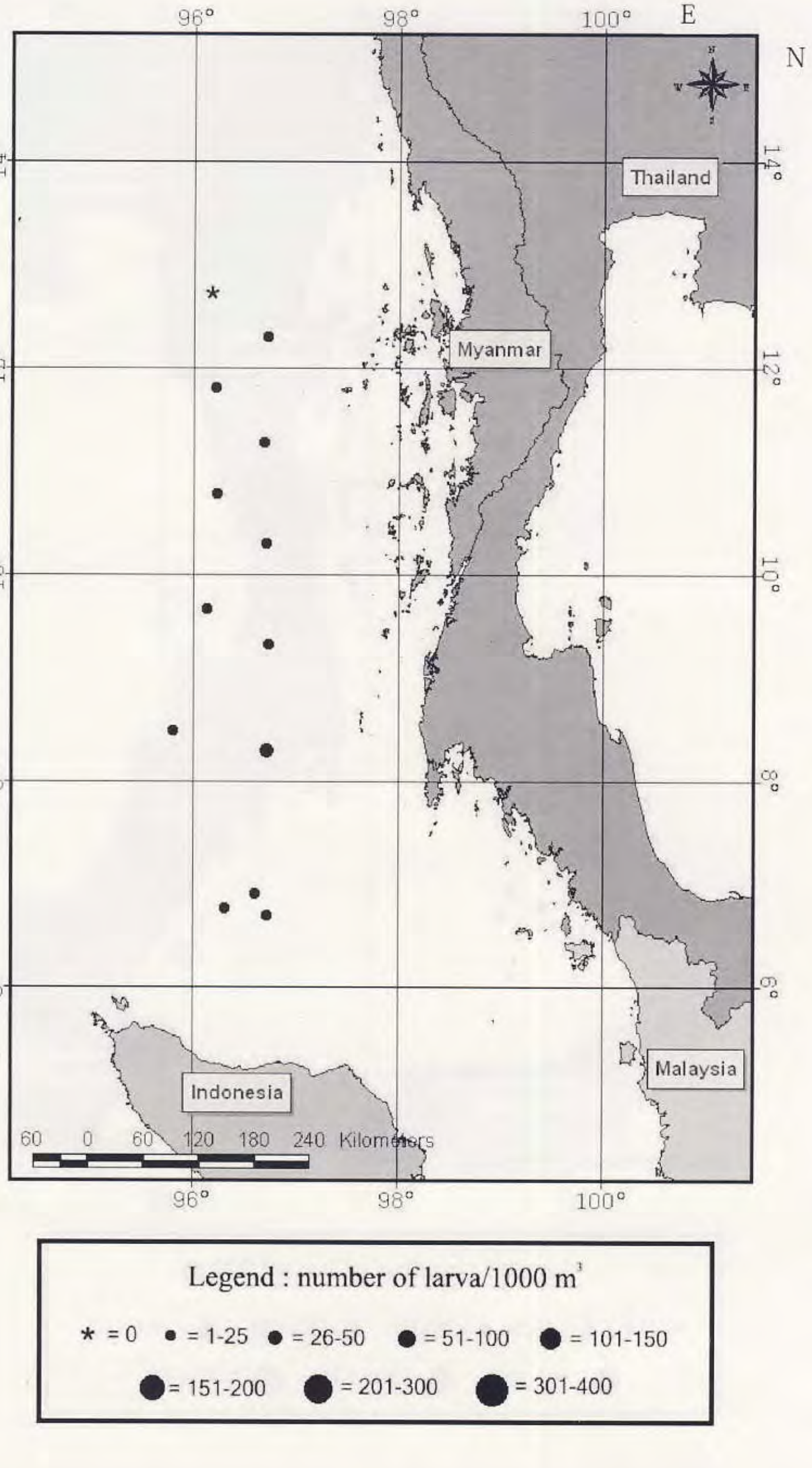

FIGURE 5. Distribution of Gonostomatid larvae catches in November 2004 in the Andaman Sea.

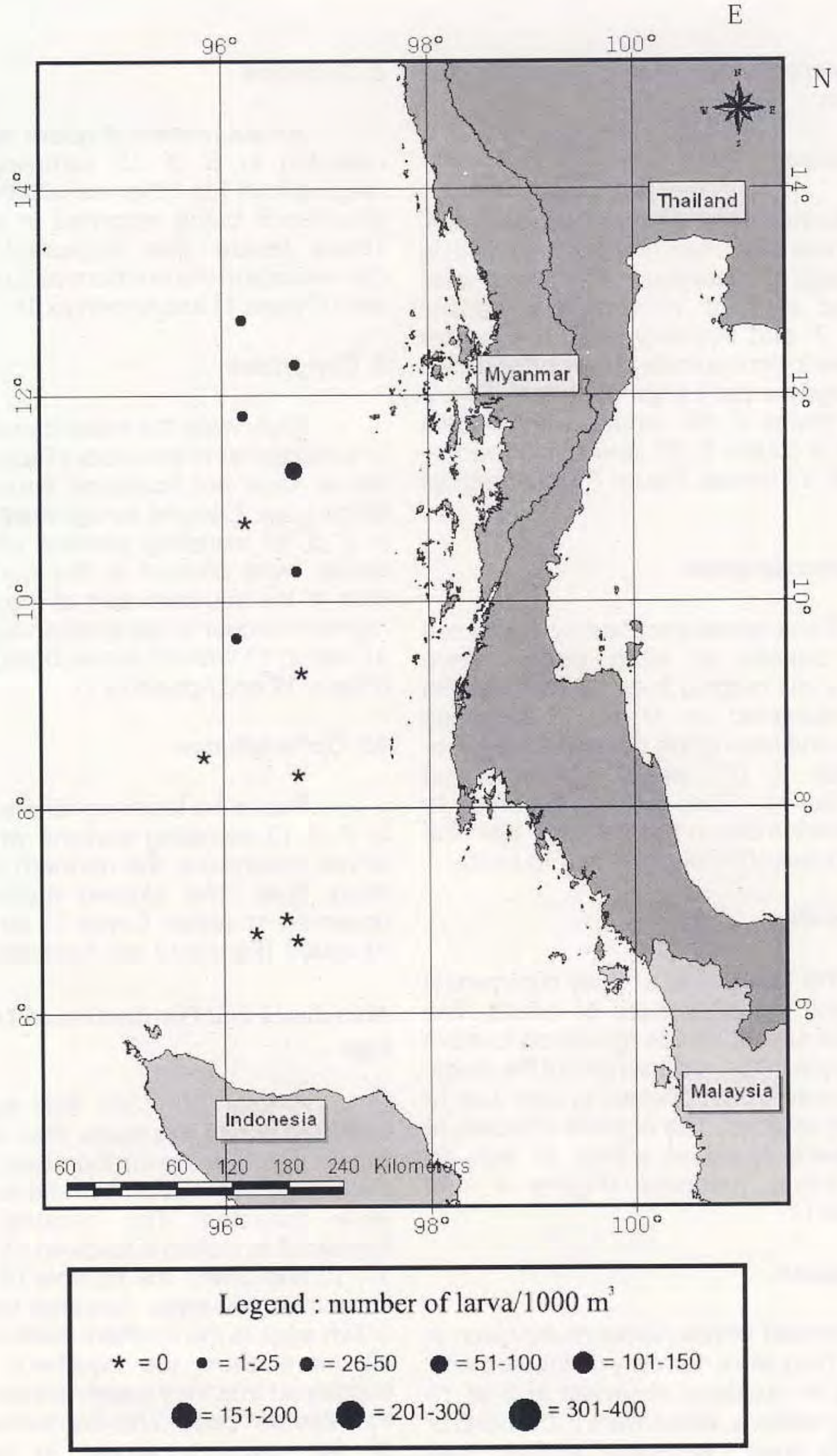

FIGURE 6. Distribution of Scombrid larvae catches in November 2004 in the Andaman Sea.

spawning and nursing ground in the area.

4. Bothidae

Bothids are commercial demersal fish. Larvae of this family were ranked 4th in percentage of occurrence. The larvae were observed in 7 of 13 sampling stations (Figure 7 and Appendix 1). The larvae appeared to concentrate in the northern part of the study area. Larval abundance were mostly found < 50 larvae with highest number at station 9 (36 larvae) followed by station 8 (24 larvae, Figure 7 and Appendix 1).

5. Bregmacerotidae

These larvae were widely distributed but the density at each station were relatively low ranging from 1-22 larvae with larvae observed in 11 of 13 sampling stations and having the highest abundance at station 10 (22 larvae, Figure 8 and Appendix 1). The larvae seemed to concentrate more in the northern than the southern part of the study area (Figure 8).

6. Lutjanidae

This family is of a highly commercial fish, which inhabit inshore as adults. The density of lutjanid larvae appeared to more concentrate in the northern part of the study area. Larvae were collected in only 3 of 13 sampling stations. The highest numbers of larvae were found at station 11 with 45 larvae being recorded (Figure 9 and Appendix 1).

7. Nomeidae

Nomeid larvae numbers are given in Table 1. They were narrowly distributed with only few in numbers observed in 3 of 13 sampling stations, which were in the north of the study area. Like some families, they appeared to more concentrate in the northern than in the southern part of the study area (Figure 10 and Appendix 1).

8. Gobiidae

An abundance of gobiid larvae were collected in 6 of 13 sampling stations ranging from 1 to 16 larvae with the greatest abundance being recorded at station 10. These larvae also appeared to more concentrate in the northern part of the study area (Figure 11 and Appendix 1).

9. Congridae

They were the most abundant family of leptocephali in this study (Table 1). These larvae were not scattered throughout the study area. Congrid larvae were observed in 7 of 13 sampling stations where more larvae were present in the northern part than in the southern part of the area. The highest number of congrid larvae occurred at station 11 with 23 larvae being recorded (Figure 12 and Appendix 1).

10. Ophichthidae

Snake eel leptocephali were present in 7 of 13 sampling stations where more larvae occurred in the northern part of the study area. The highest numbers were observed at station 6 with 17 larvae being recorded. (Figure 13 and Appendix 1),

Abundance and Distribution of Total Fish Eggs

A total of 1,304 fish eggs were collected during this study. Fish eggs were widely distributed over the study area with the exception of station 1 where no fish eggs were collected. The greatest number appeared at station 6 followed by station 4, 11, 10 and 3 with the number of fish eggs more than 100 eggs. Although the number of fish eggs in the northern zone was a little bit more than the southern zone, it suggested that they mainly concentrated in the northern zone. The distribution pattern of fish eggs is similar to fish larval distribution patterns (Figure 14 and Appendix 1).

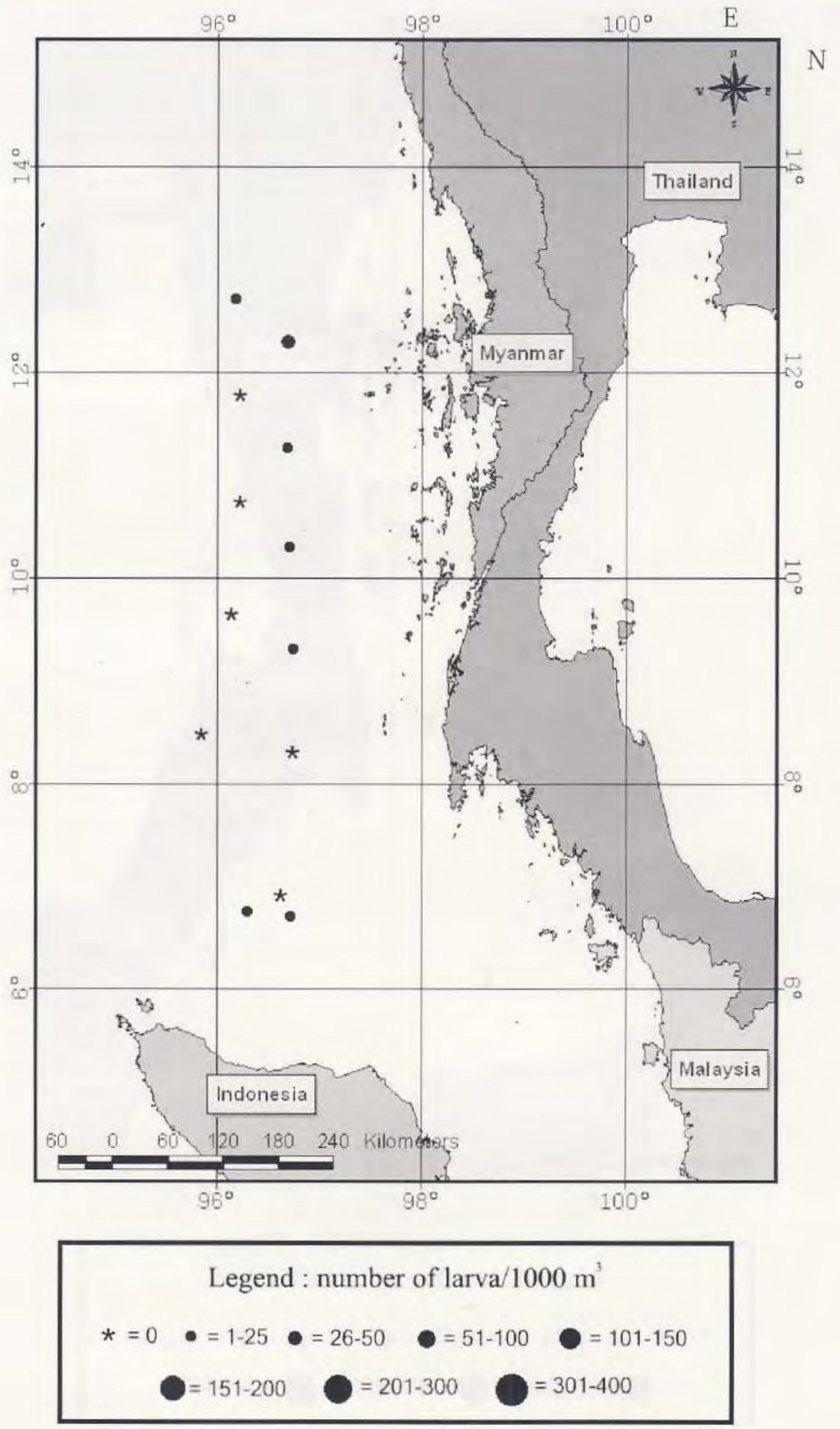

FIGURE 7. Distribution of Bothid larvae catches in November 2004 in the Andaman Sea.

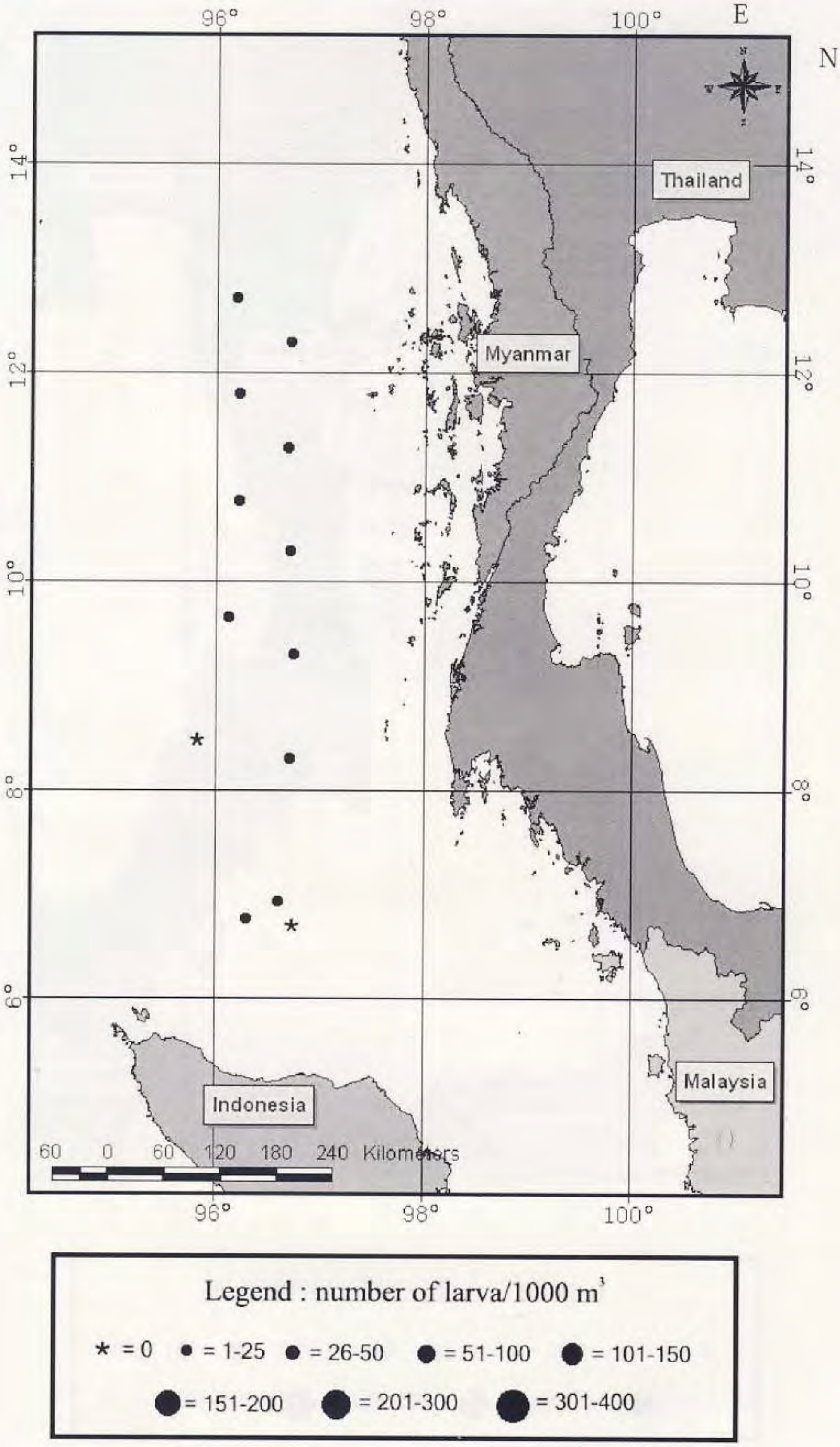

FIGURE 8. Distribution of Bregmacerotid larvae catches in November 2004 in the Andaman Sea.

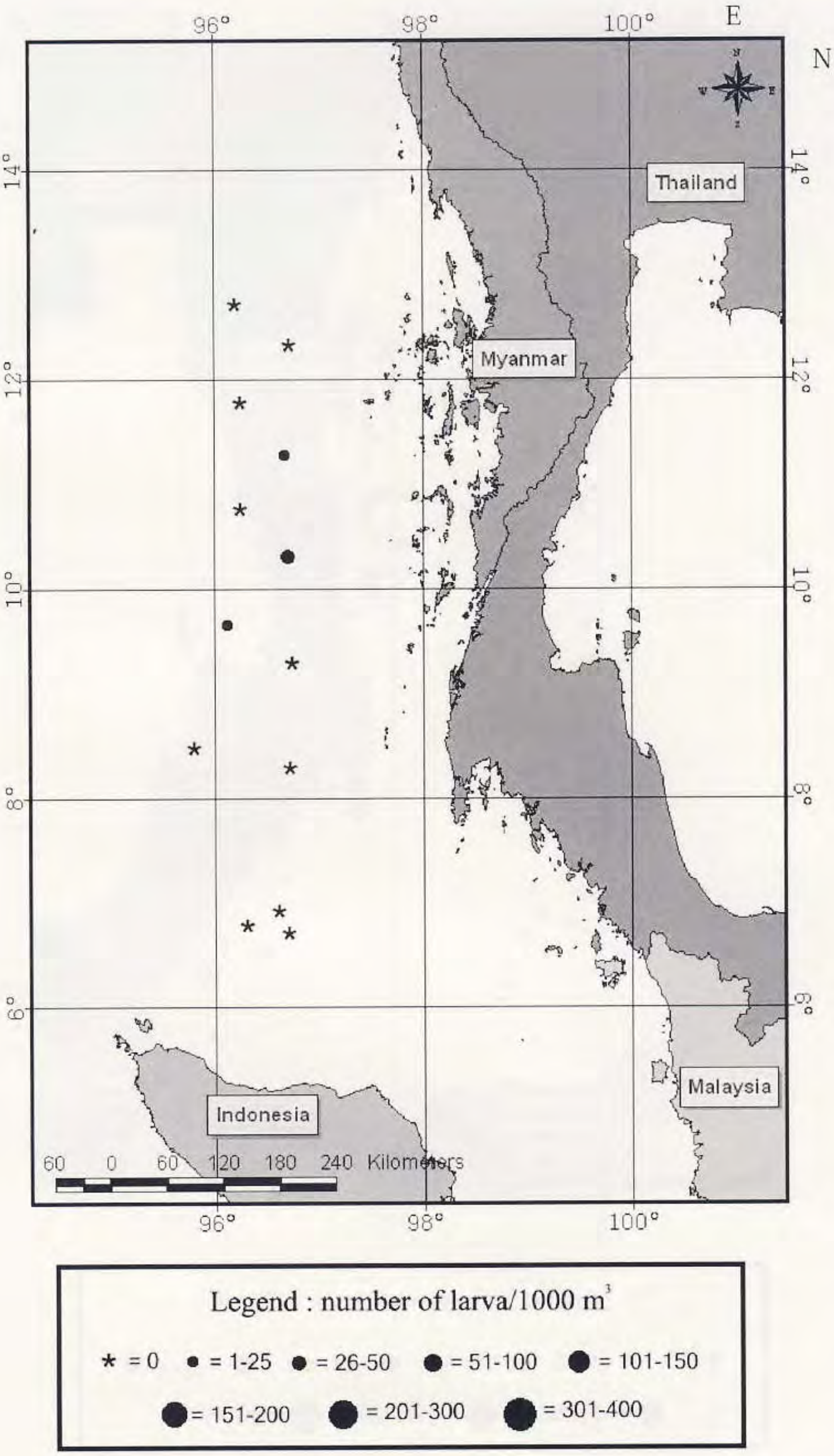

FIGURE 9. Distribution of Lutjanid larvae catches in November 2004 in the Andaman Sea.

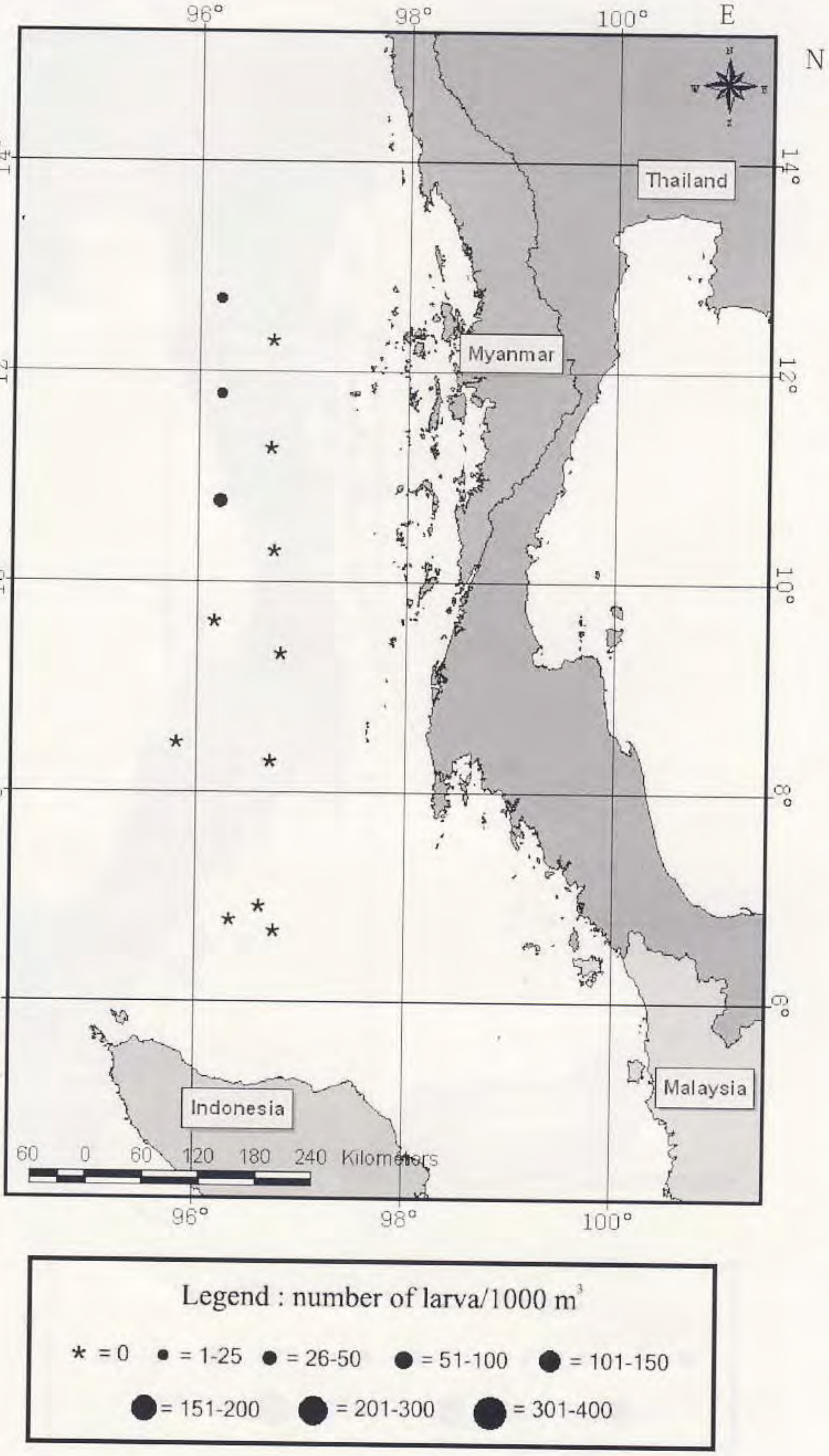

FIGURE 10. Distribution of Nomeid larvae catches in November 2004 in the Andaman Sea.

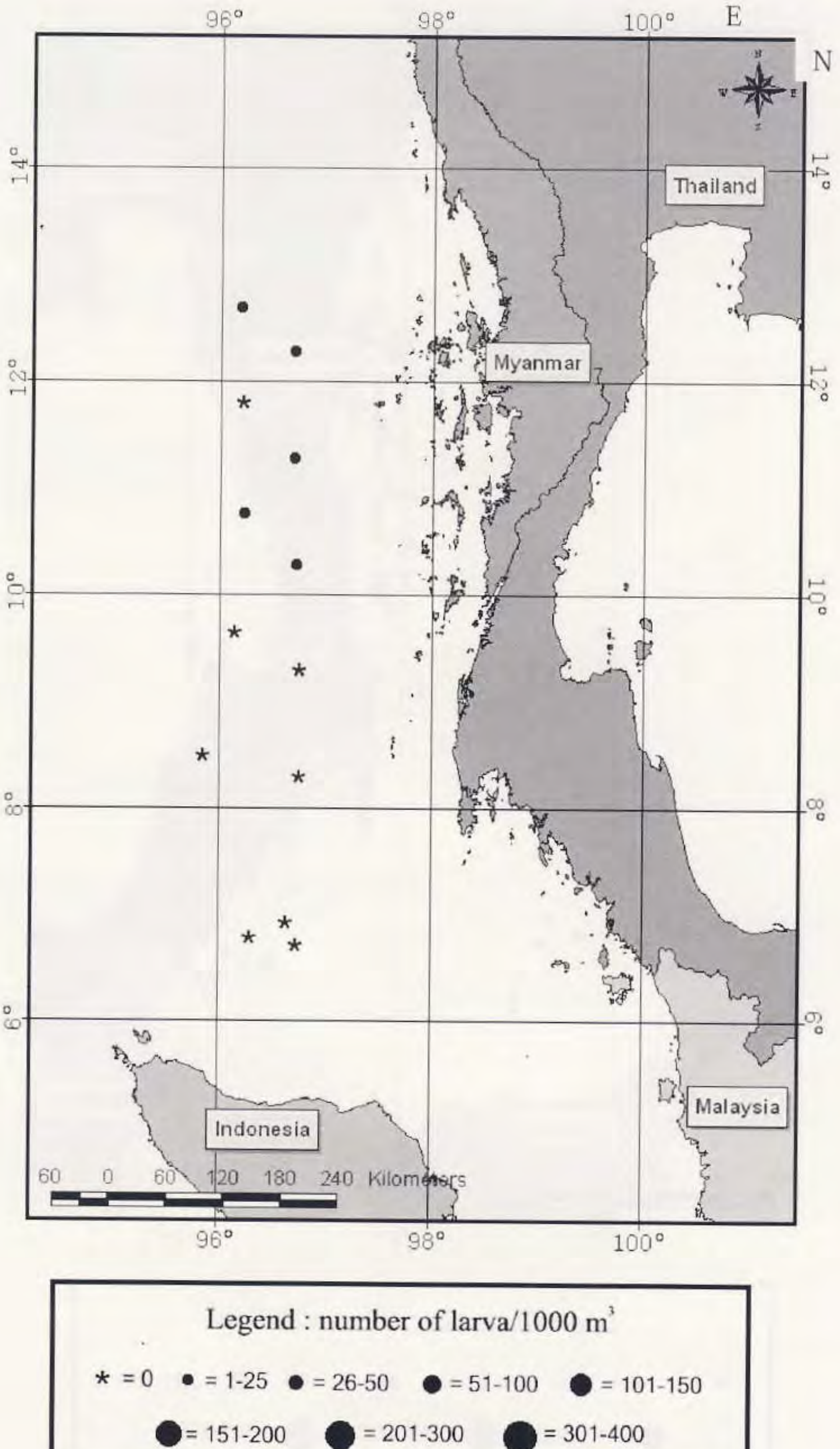

FIGURE 11. Distribution of Gobiid larvae catches in November 2004 in the Andaman Sea.

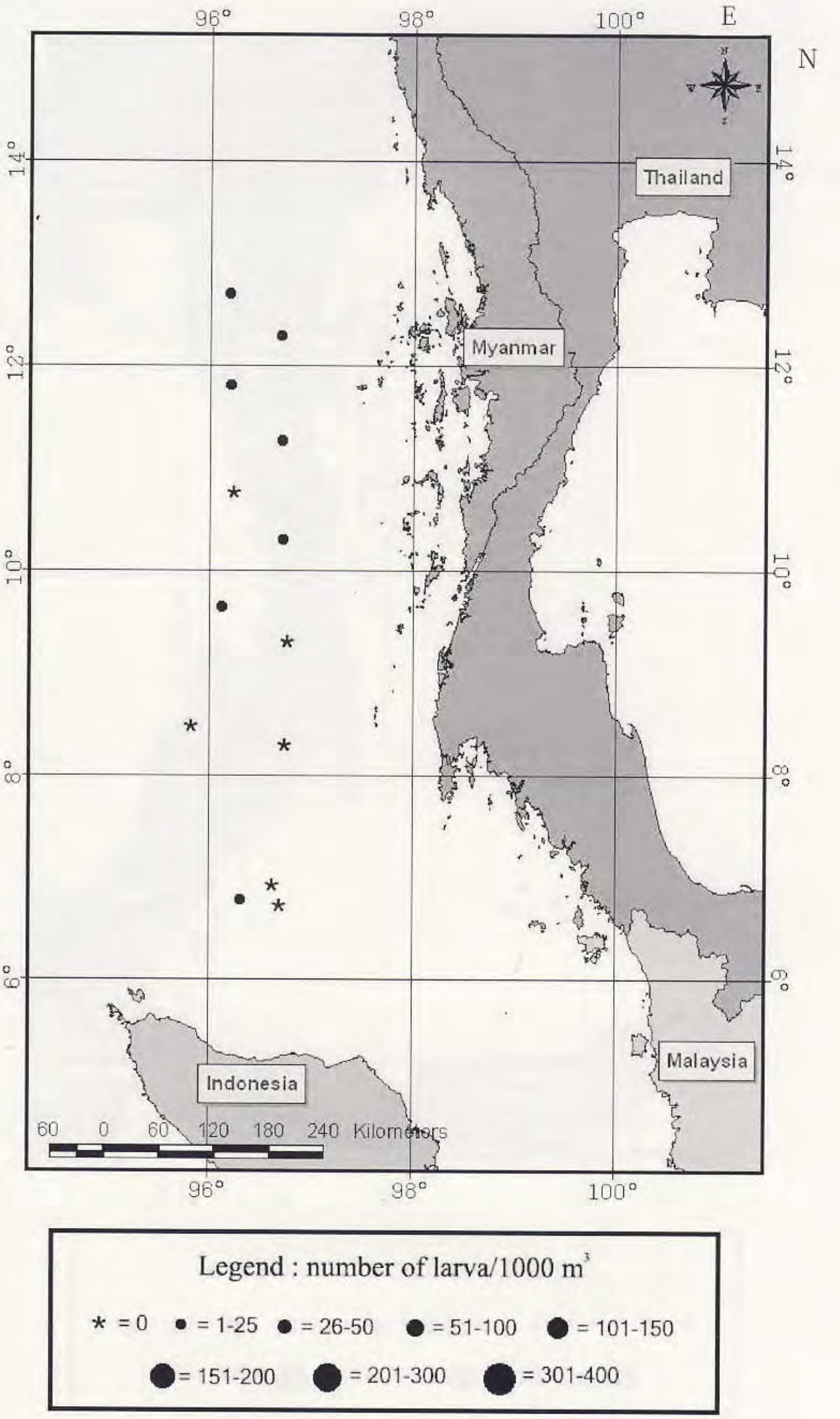

FIGURE 12. Distribution of Congrid larvae catches in November 2004 in the Andaman Sea.

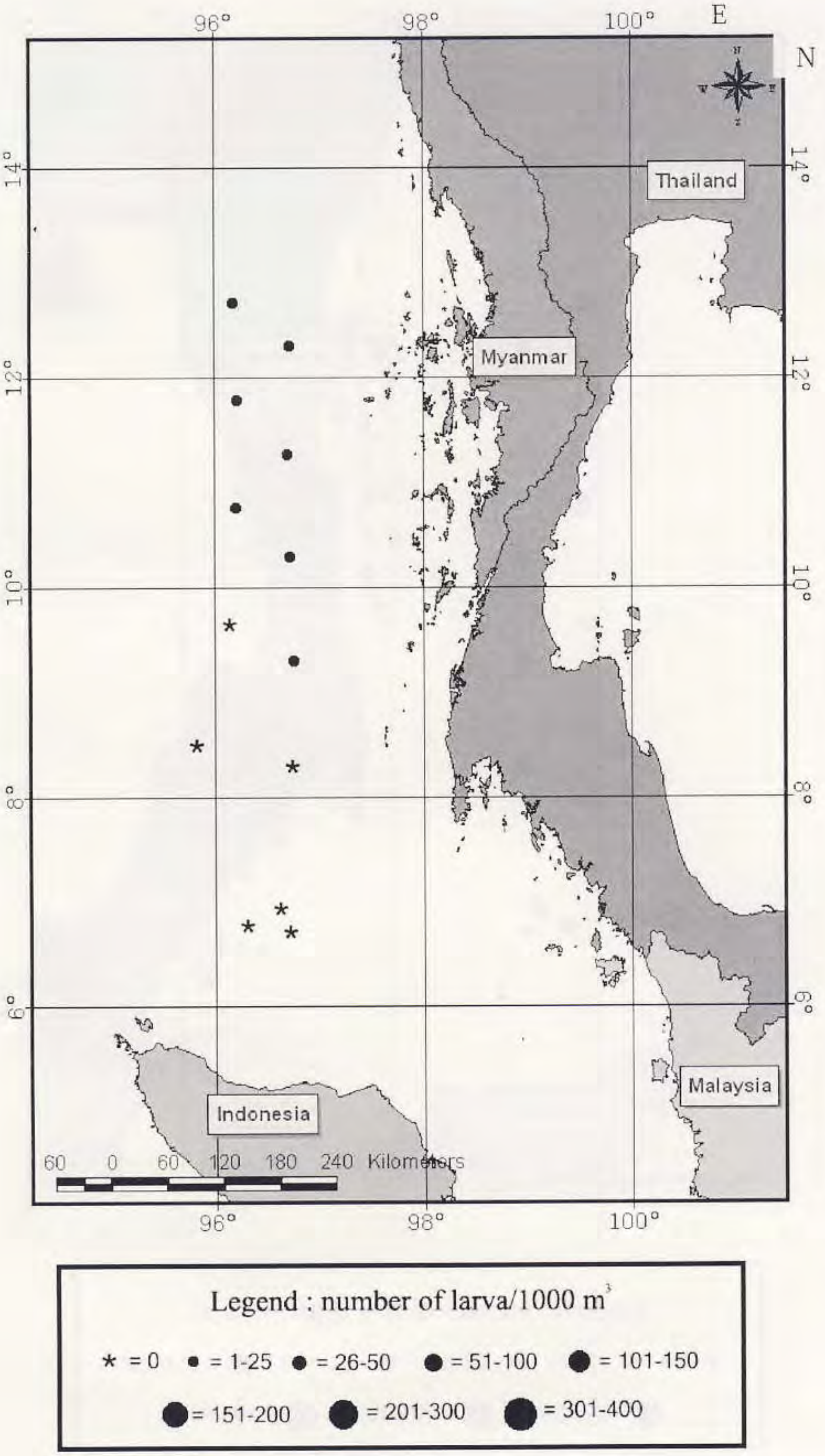

FIGURE 13. Distribution of Ophichthid larvae catches in November 2004 in the Andaman Sea.

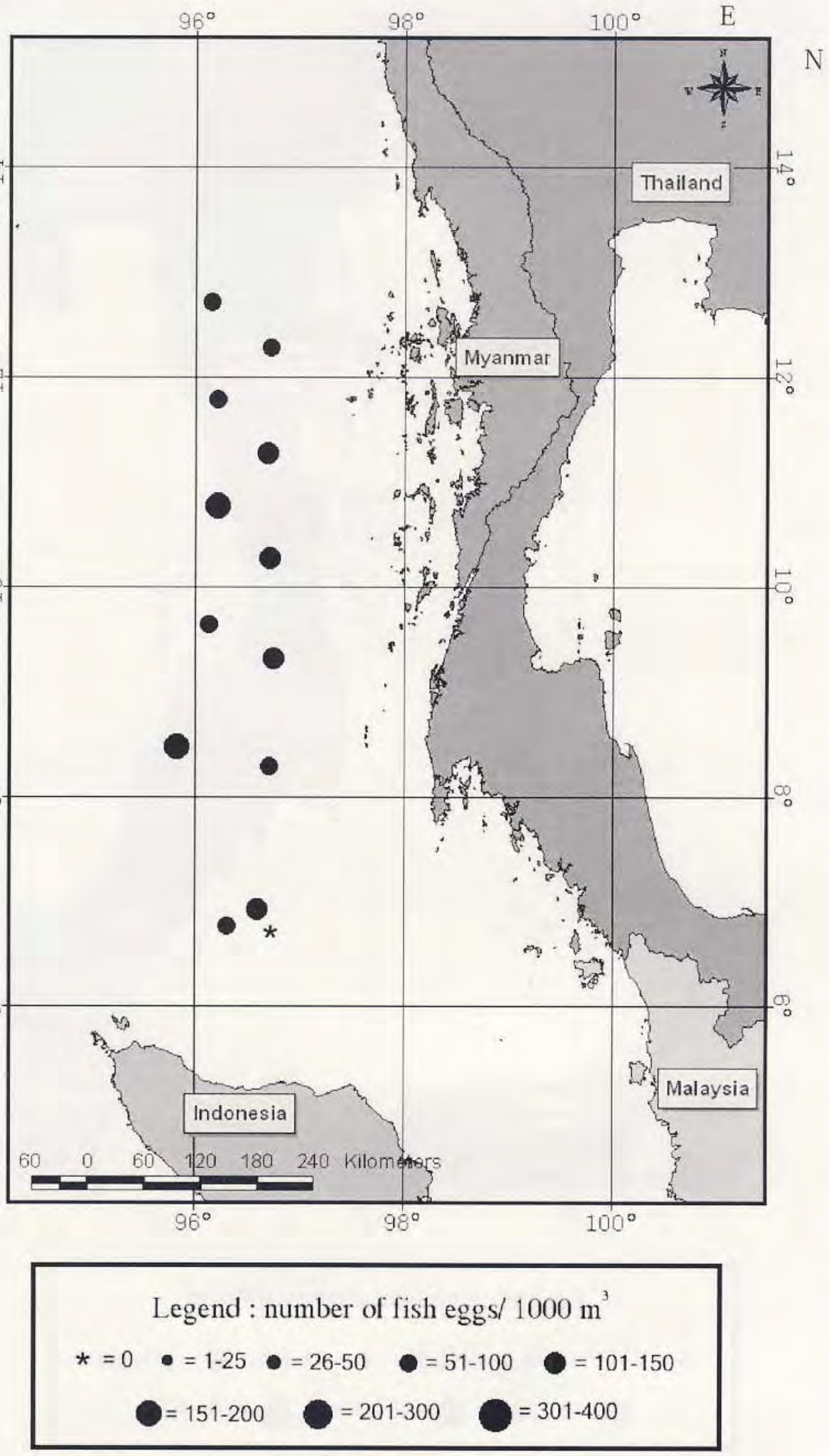

FIGURE 14. Distribution of fish eggs catches in November 2004 in the Andaman Sea.

Environmental variable observations

Nitrate and Phosphate concentration

The nitrate concentration ranged from 3.5864 to 12.1483 ìm with a mean of 7.0371 ìm and the phosphate concentration ranged from 0.0426 to 2.0323 ìm with a mean of 0.4915 ìm. No observations of nitrate and phosphate concentration were done at station 2. The spatial pattern of variation in nitrate concentration differed markedly between station whereas phosphate levels were generally low and rarely fluctuated with the exception of station 7, 8, 9 and 10 having high concentration with peaking at station 8 (Figure 15 and Appendix 2).

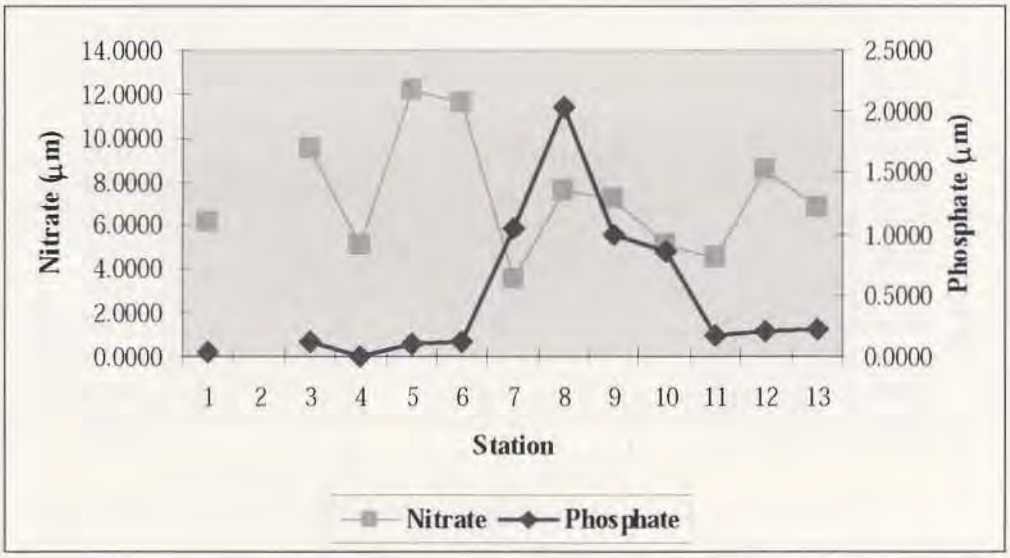

FIGURE 15. Spatial pattern of variation in nitrate and phosphate concentrations at surface water during 17th to 24th November 2004 in the Andaman Sea.

The concentraion of phytoplankton production (Chlorophyll-a)

Phytoplankton production, as measured by chlorophyll-a, was distinctly highest at station 1, while the other 12 stations had much lower concentrations with similar levels (Figure 16 and Appendix 2).

Surface water temperature and salinity

Surface water temperature ranged from 29 to 30.01°C during study period. The highest water temperature occurred at station 5 and the lowest at station 3. Surface water salinity ranged from 28.27 to 32.81 psu. with the highest salinity at station 12 and the lowest at station 8 (Figure 17 and Appendix 2). From the pattern of water temperature and water salinity in the study area, it can be characterized four different water masses intruded to the area, i.e. (1) the water mass with low temperature and high salinity occurred at 35 station 1, 2, 3 and 4 and occurred again at station 10, 11, 12 and 13, (2) the water mass with high temperature and intermediate salinity appeared at station 5, 6 and 7, (3) the water mass with high temperature and low salinity at station 8, and (4) the water mass with intermediate temperature and intermediate salinity at station 9 (Figure .17).

The statistical analyses for relationships between all environmental variables and abundance of total fish larvae, the top ten most abundant families or fish eggs were not conducted due to small sample sizes. The identification work is difficult and time consuming, the

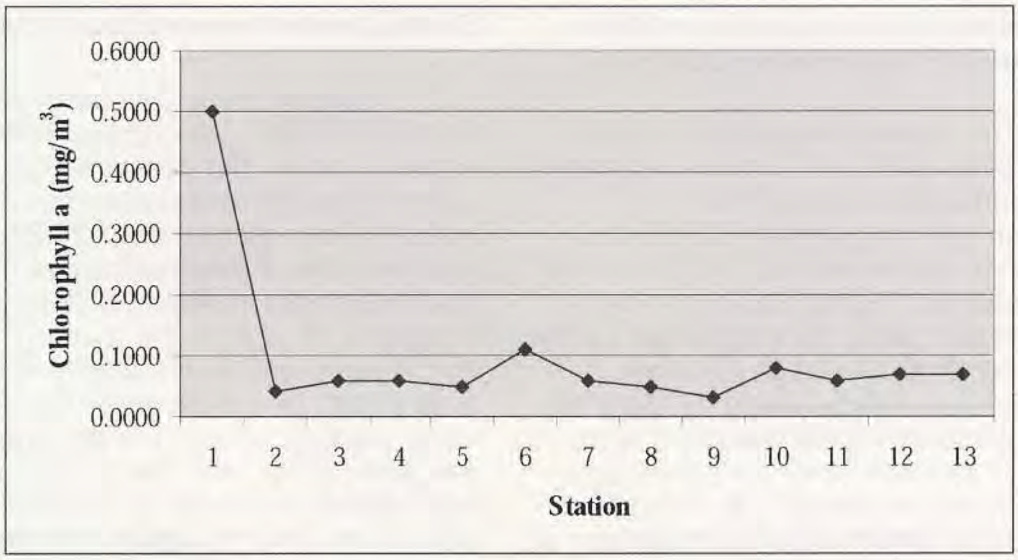

FIGURE 16. Spatial pattern of variation in phytoplankton production (chlorophyll-a concentrations) at surface water during 17th to 24th November 2004 in the Andaman Sea.

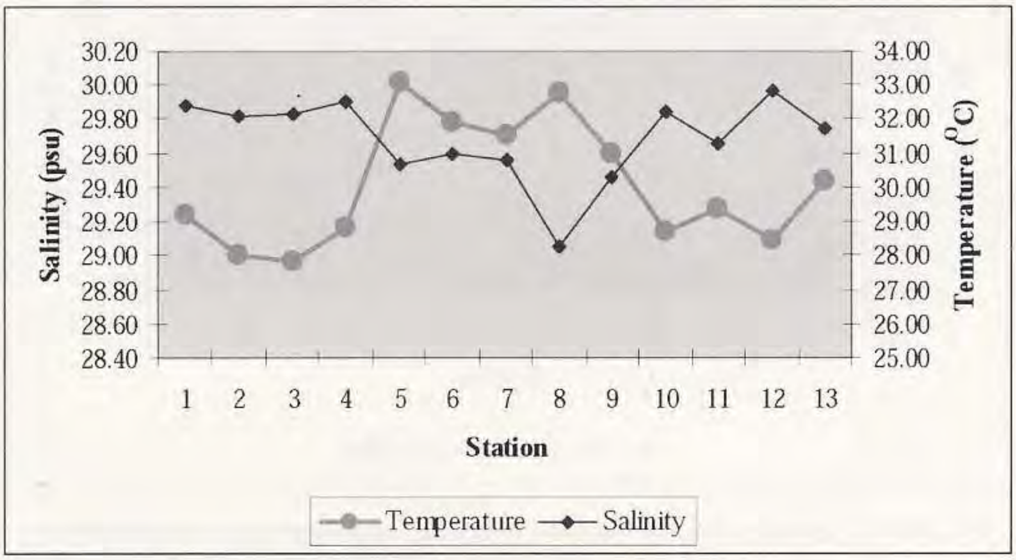

FIGURE 17. Spatial pattern of variation in surface water temperature and salinity during 17th to 24th November 2004 in the Andaman Sea.

tremendous diversity and the relatively low abundance of individual families or species make quantitative work very difficult; for example, a little more than one individual per family per sample in this study and in other studies. The low numbers of larvae caught limited the analyses of relations to environmental parameters even at the family level.

Although there were no statistical analyses conducted for relationships as mentioned above, the spatial pattern of variation in concentration of nutrients, phytoplankton productions (chlorophyll-a concentrations), temperature and salinity were considerably compared with the spatial pattern of variation in abundance of total fish larvae, the top ten most abundant families and fish eggs (Figure 18 to Figure 21).

Overall consideration of the relative patterns in a broad scale, there seem to be no consistent relationships between nutrient levels, phytoplankton production (chlorophyll-a) and larval abundance. The lack of a clear relationship in this study was in agreement with Bainbridge *et al.* (1974) who found no clear relationship between the seasonal abundance of either clupeid (*Clupea hagengus* L.) or scombrid (*Scomber scombrus* L.) larvae and the seasonal pattern of phytoplankton biomass over a 20 year period in sea areas of the North East Atlantic. O'Boyle *et al.* (1984) stated that larval food supply (measured as phytoplankton) did not regulate larval populations of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), silver hake (*Merluccius bilinearis*) and red fish (*Sebastes* spp.). They suggested that currents may have a larval retention mechanism and these play an important part in the maintenance of stocks. In this study there were no such relationships between phytoplankton production and nutrients with the larval abundance, this suggests that some of physical factors might affect the spatial variation in abundance of larvae.

The four different water masses as mentioned earlier did not seem to affect spatial patterns of variation in abundance of all fish larvae and fish eggs (Figure 17 and Figure 18- 21). Other factors such as water current and wind directions may have masking effect on larval abundance. Unfortunately, the water current and wind directions were not examined in this study.

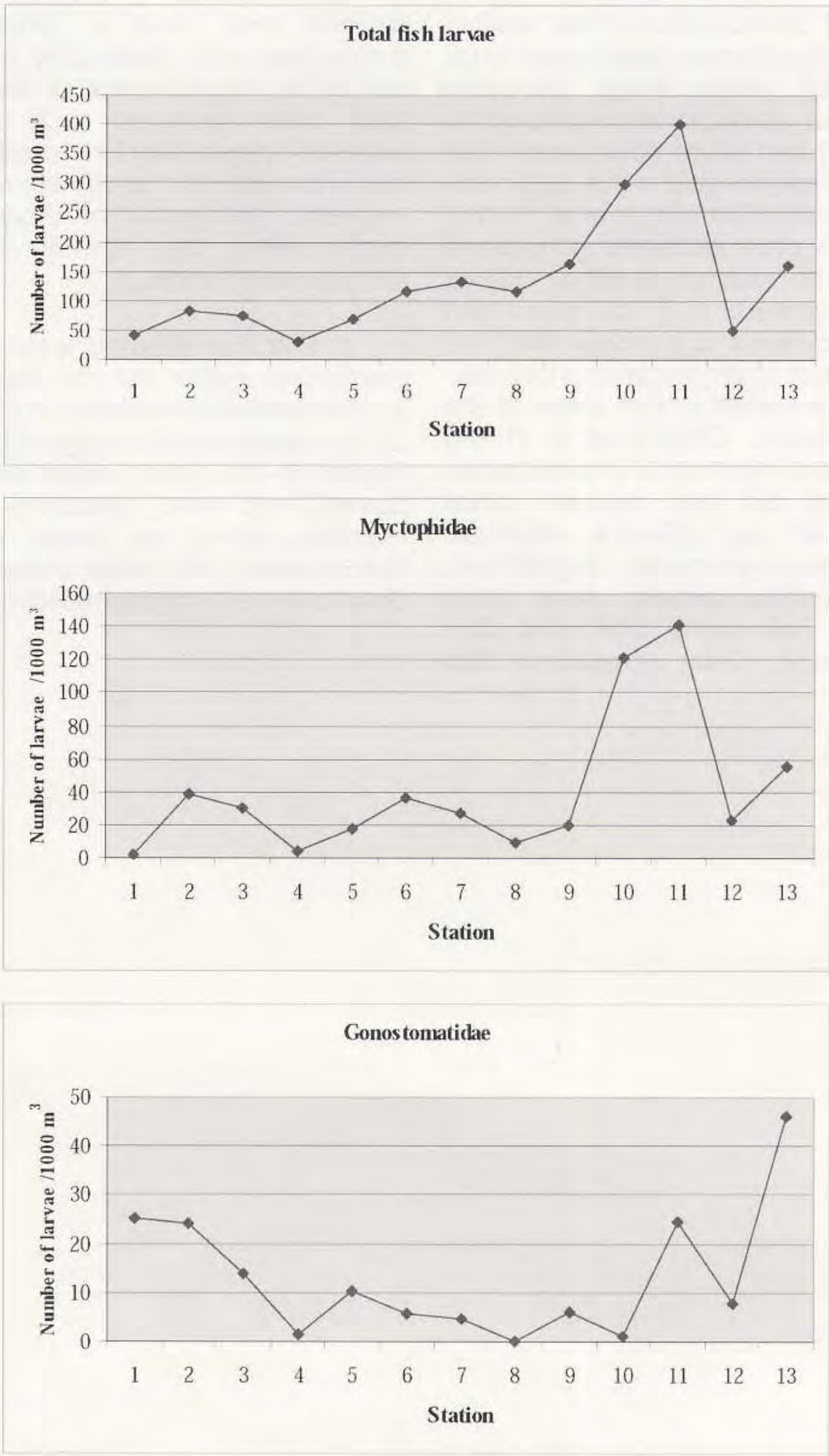

FIGURE 18. Spatial pattern of variation in abundance of total fish larvae (top), myctophid (middle) and gonostomatid larvae (bottom) in the Andaman Sea during 17th to 24th November 2004.

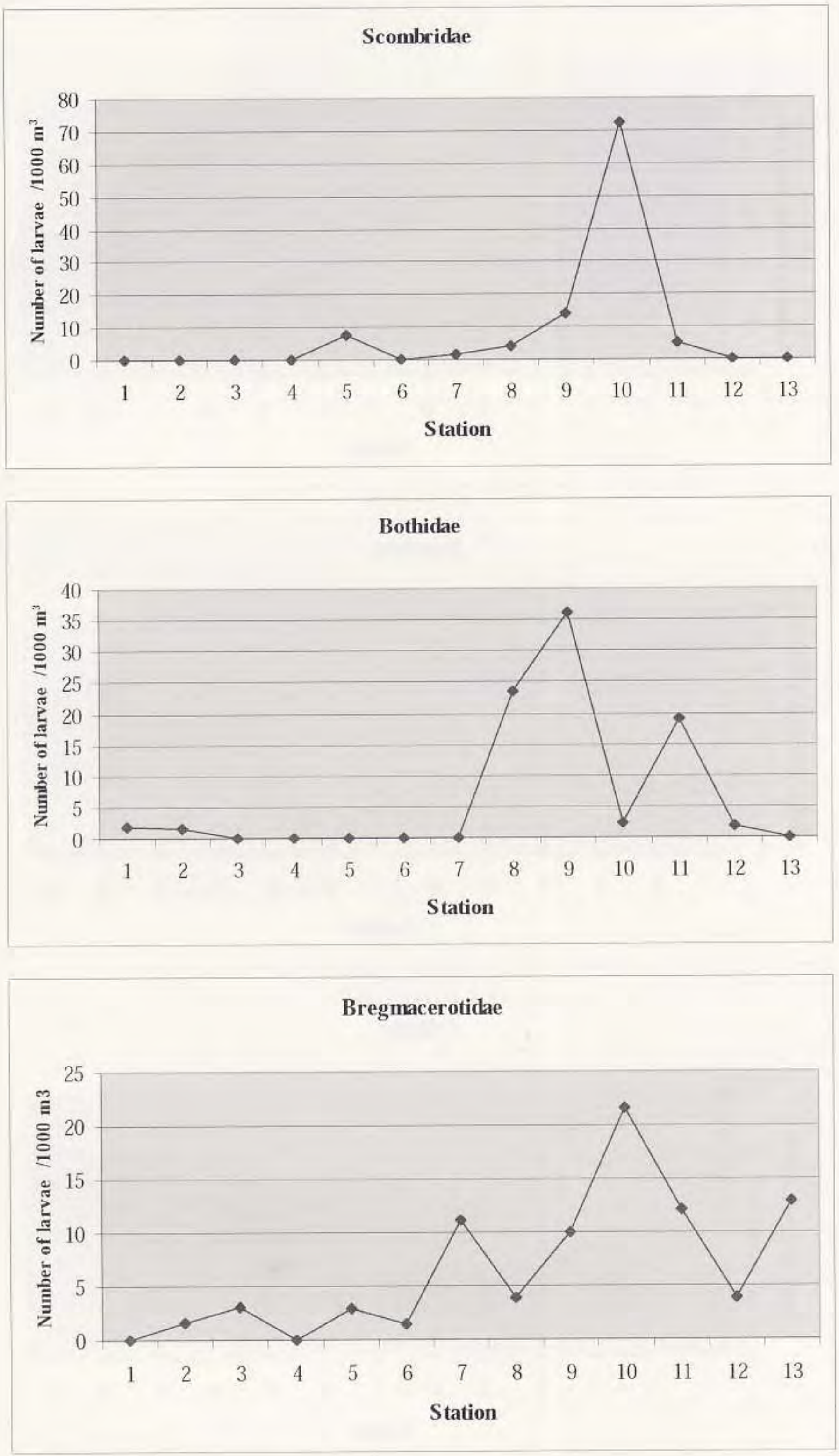

FIGURE 19. Spatial pattern of variation in abundance of scombrid (top), bothid (middle) and bregmacerotid larvae (bottom) in the Andaman Sea during 17th to 24th November 2004.

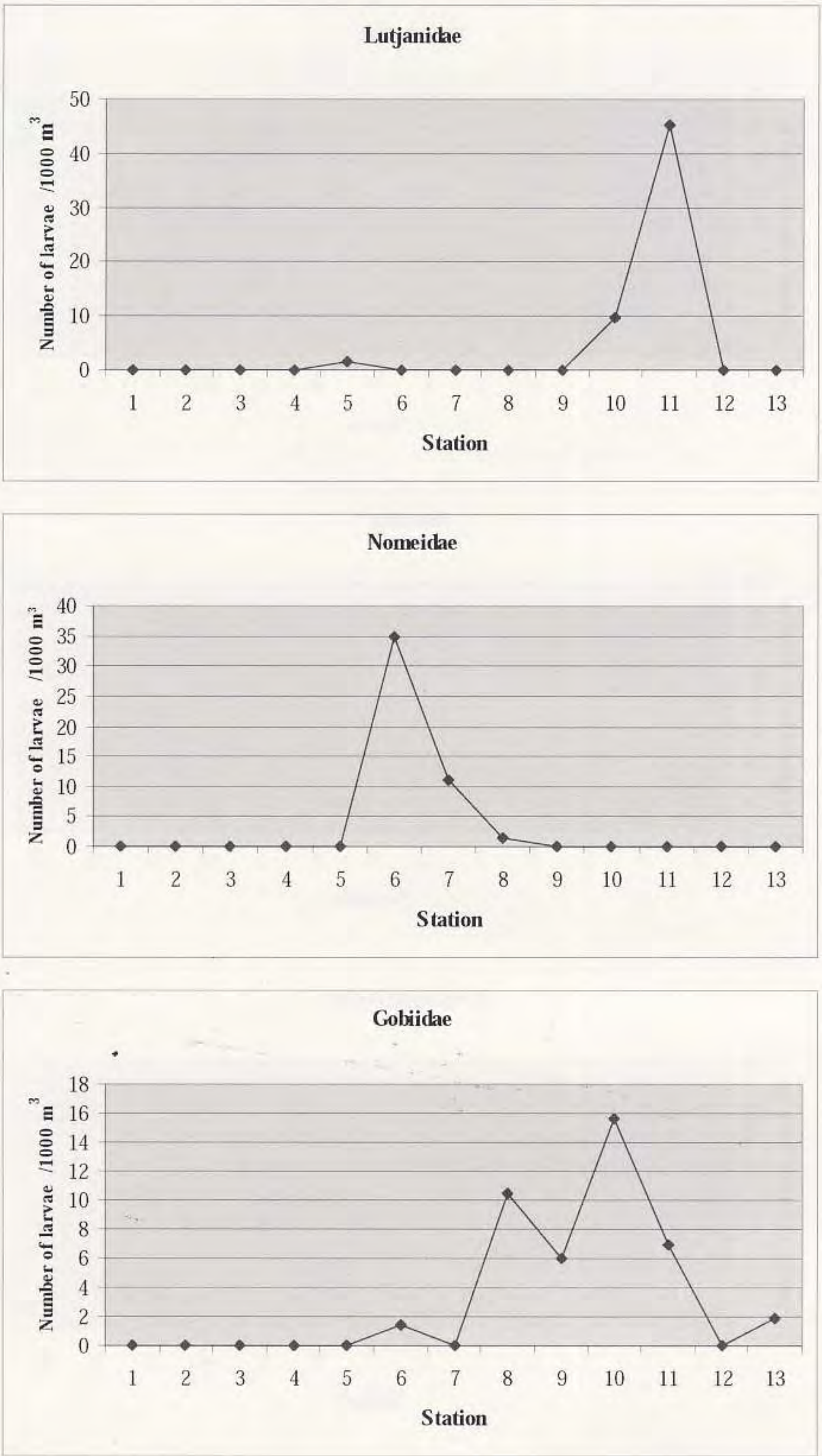

FIGURE 20. Spatial pattern of variation in abundance of lutjanid (top), nomeid (middle) and gobiid larvae (bottom) in the Andaman Sea during 17th to 24th November 2004.

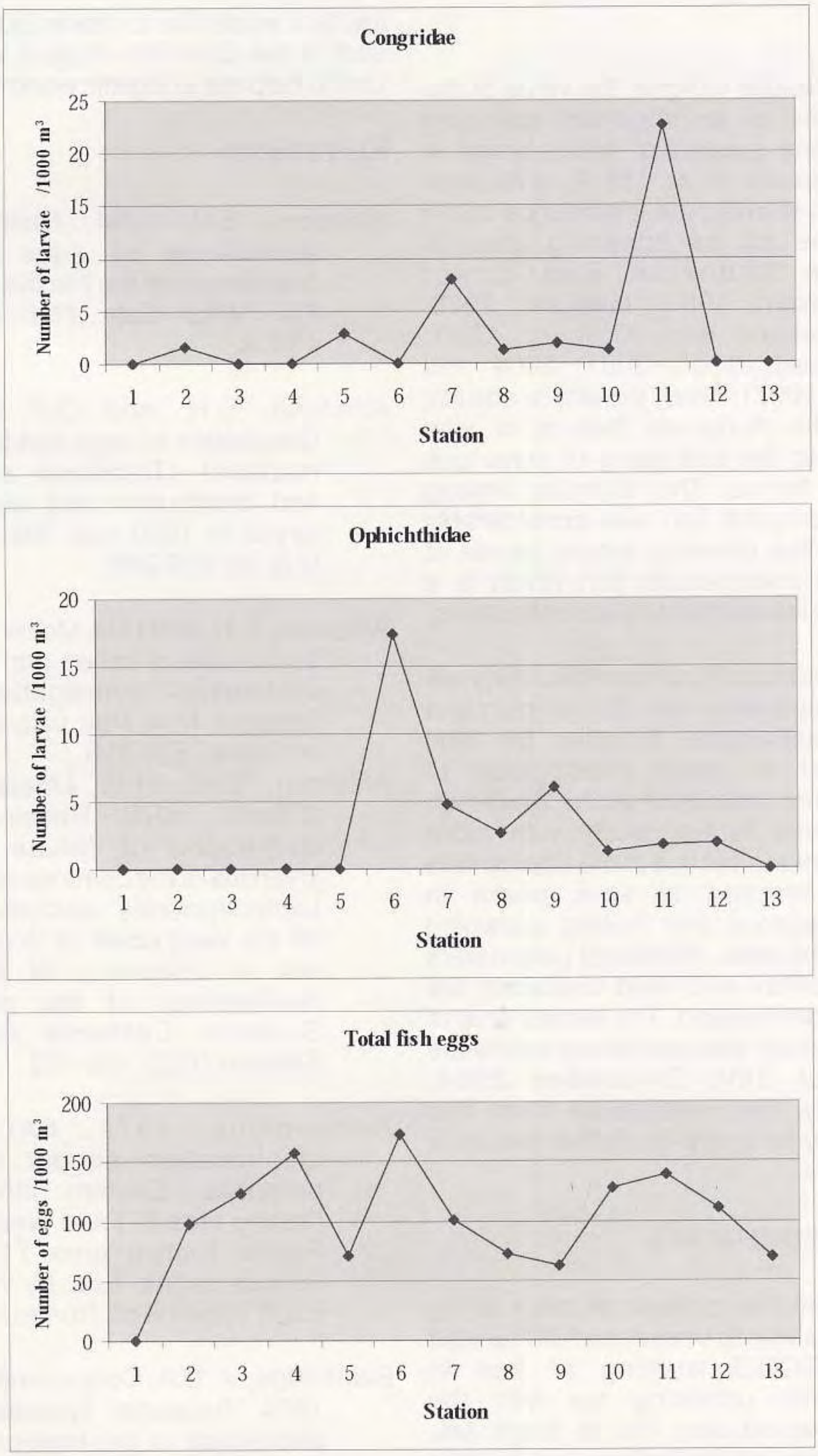

FIGURE 21. Spatial pattern of variation in abundance of congrid (top), ophichtid larvae (middle) and all fish eggs (bottom) in the Andaman Sea during 17th to 24th November 2004.

SUMMARY

The results indicate the value of the offshore zone as an important spawning area for many species of fishes which is similar to Houde *et al.* (1979) and other authors who showed the importance of the coastal zone as the spawning grounds along the Andaman Sea Coast (Termvidchakorn, 1987; Janekarn, 1988, 1992; Janekarn and Kiorboe, 1991; Lertvitayaprasit *et al.*, 2001, 2004 and Puewkhao, 1997). Thus, the entire aquatic region of the Andaman Sea is of vital importance to the well-being of numerous species of fishes. The diversity among larvae of demersal fish was considerably higher than the diversity among larvae of pelagic and mesopelagic fish which is a trend also found in other tropical collections.

The valuable data from this study will serve as supportable data for planning and action of sustainable fisheries for food security and to assist investigation of underexploited resources in the Andaman Sea. However, further study with more sampling stations set in a more appropriate system is required to seek peaks in spawning seasons and finding spawning grounds in the area. Additional parameters i.e. water current and wind directions are strongly recommended. The survey time of the present study was carried out before the Tsunami of 26th December 2004; consequently, the information from this study is likely for useful for further research after Tsunami.

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REFERENCES

Alhstrom, E.H. 1954. Distribution and abundance of eggs and larval populations of the Pacific sardine. U.S. Fish. Wildl. Serv., *Fish. Bull.* 56: 83-139. 42

Alhstrom, E.H. and O.P. Ball. 1954. Description of eggs and larvae of jack mackerel (*Trachurus symmetricus*) and distribution and abundance of larvae in 1950 and 1951. *Fish. Bull.* U.S. 56: 209-245.

Ahlstrom, E.H. and H.G. Moser. 1976. Eggs and larvae of fishes and their role in systematic investigations and in fisheries. *Rev. Trav. Inst. Peches marit* 40(3 et 4): 379-398.

Ahlstrom, E.H., H.G. Moser and M.J. O'Toole. 1976. Development and distribution of larvae and early juveniles of the commercial lanternfish, *Lampanyctodes hectoris* (Gunther), off the west coast of Southern Africa with a discussion of phylogenetic relationships of the genus. *Bull. Southern California Academy of Science* 75(2): 138-152.

Anonymous, 1974. FAO species identification sheets for fishery purposes. Eastern Indian Ocean (fishing area 57) and Western Central Pacific (fishing area 71), Vol. I-IV. Various pages. Eds. by W. Fischer & P.J.P. Whiethead. Rome: FAO. 808 pp.

Bainbridge, V., G.A. Cooper and P.J.B. Hart, 1974. Seasonal fluctuations in the abundance of the larvae of mackerel and herring in the Northeastern Atlantic and North Sea. **In:** J.H.S. Blaxter (Editor), "The early life history of fish". Springer-Verlag, New York, pp. 159-170.

Exploratory Division, 1997. Report of the joint experimental tuna fishing survey with the fishermen onboard RV *Mahidol* in the Indian Ocean, 1995-1996. Technical Paper no. 043. 143 pp. (in Thai, English abstract).

Fahay, M.P. 1983. Guide to the early stages of marine fishes occurring in the Western North Atlantic Ocean, Cape Hatteras to the Southern Scotian Shelf. *J. Northw. Atl. Fish. Sci.* 4: 423 pp.

FishBase, 2005a. Fish Species in Indian Ocean. Http://www.larvalbase.org/

FishBase, 2005b. Fish Species in Andaman Sea. Http://www.larvalbase.org/

Houde, E.D., J.C. Leak, C.E. Down, S.A. Berkely and W.J. Richards. 1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. A report to the BLM, 546 pp.

Janekarn, V. 1988. Biogeography and environmental biology of fish larvae along the west coast of Thailan. A Master degree dissertation. The University of Newcastle. 107 pp.

Janekarn, V. and T. Kiorboe. 1991. The distribution of fish larvae along the Andaman Coast of Thailand. *Phuket mar. boil. Cent. Res. Bull.* 56: 41-61. 43

Janekarn, V. 1992. Fish larvae in the vicinity of shelf front in the Andaman Sea. **In**:Proceeding: The Seminar on Fisheries, 16-18 September 1992, Department of Fisheries. 343-353.

LarvalBase, 2005. The Myctophidae. Http://www.larvalbase.org/

Leis, J.M. and B.M. Carson-Ewart. 2000. The Larvae of Indo-Pacific Coastal Fishes: An identification guide to marine fish larvae. Fauna Malesiana; Vol. 2. Leiden; Boston; Koln: Brill. 850 pp.

Leis, J.M. and J.M. Miller 1976. Offshore distributional patterns of Hawaiian fish larvae. *Mar. Biol.* 36, 359-367.

Lirdwitayaprasit, P, R. Sujitosakul and P. Chouywong. 2001. Kind and distribution of fish larvae in tuna fishing ground in the Andaman Sea. Technical Paper no. 76/2001, Oceanic Fisheries Division, Department of Fisheries. 27 pp. (in Thai, English abstract).

Lirdwitayaprasit, P, J. Neangsang, S. Makeaw and S. Chumnan. 2004. Species composition and distribution of fish larvae in the Indian Ocean. Technical Paper no.12/2004, Marine Fisheries Research and Development Bureau, Department of Fisheries. 23 pp. (in Thai, English abstract).

Laongmanee, P., S. Obromwan, N. Arunrat and S. Limpuanglaew. 2005. Oceanographic condition during the Pelagic Fisheries Resources Survey in the Andaman Sea. **In**:Preliminary Results on the Large Pelagic Fisheries Resources. November 2005. 10 pp.

Moser, H.G., W.J. Richards, D.M. Cohen, M.P. Fahay, A.W. Kendall Jr. and S.L. Richardson. (eds.). 1984. Ontogeny and Systematic of Fishes. An International Symposium Dedicated to the Memory of E.H. Ahlstrom, Special Publication no. 1, American Society of Ichthyologists and Herpetologists. 760 pp.

Niera, F.J., A.G. Miskiewicz and T. Trnski. 1998. Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification. University of Western Australia Press. 474 pp.

Nishikawa, Y. and D.W Rimmer. 1987.

Identification of larval tunas, billfishes and other scombroid fishes (suborder Scombroidei): an illustrated guide. CSIRO Marine Laboratories Report 186, 20 pp.

O'Boyle, R.N., M. Sinclair, R.J. Conover, K.H. Mann and A.C. Kohler, 1984. Temporal and spatial distribution of ichthyoplankton communities of the Scotian Shelf in 44 relation to biological, hydrological, and physiographic features. *Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 183,* 27-40.

Obromwan, S. 2005. Spatial sistribution of nutrients in the Andaman Sea. **In:** Preliminary Results on the Large Pelagic Fisheries Resources. November 2005. 19 pp.

Okiyama, M. 1988. An Atlas of the Early Stage Fishes in Japan. Tokai University Press. 1157 pp. (in Japanese).

Ozawa, T. 1986. Studies on the Oceanic Ichthyoplankton in the Western North Pacific. Kyushu University Press. 430 pp.

Pielou, E.C. 1984. The interpretation of ecological data: a primer on classification and ordination. John Wiley & Sons Ltd., Worcester. 263 pp.

Puewkhao, 1997. Abundance and distribution of fish larvae in the southern part of the Andaman Sea. Master Thesis, Kasetsart University, 285 pp (in Thai, English abstract).

Salvanes, A.G.V. and J.B. Kristoffersen. 2001. Mesopelagic Fishes. In: Steele J. *et al.* (eds). Enclycopedia of Ocean Sciences, Vol. 3 Academic Press, pp. 1711-1717.

Schifino, L. C., C.B Fialho and J.R. Verani. 2004. Fish community composition, seasonality and abundance in Fortaleza Lagoon, Cidreira. *Braz, Arch. Biol. Technol.* 47(5): 11 pp.

Smith, P.E. and S.L. Richardson. 1979. Selected bibliography on pelagic fish egg and larva surveys. FAO Fish. Circ. No. 706. 175 pp.

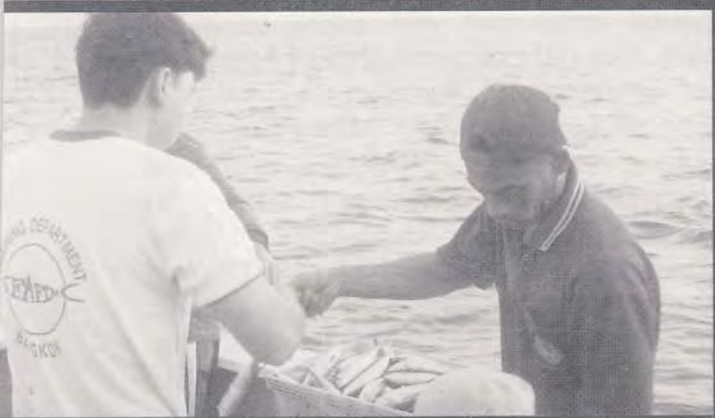
Somsathan, A. 1998. Research on tuna caught by R/V "Mahidol" in eastern Indian Ocean and western Pacific Ocean during 1995-1997. Technical Paper no. 58/1998. Oceanic Fisheries Division, Department of Fisheries. 35 pp. (in Thai).

Stequert, B. and F. Marsac. 1989. Tropical tuna surface fisheries in the Indian Ocean. FAO Fisheries Technical Paper no. 282. pp. 7-238.

Termvidchakorn, A. 1987. The distribution of the fish larvae in Andaman Sea. Exploratory Division, Department of Fisheries, Thailand. 37 pp (in Thai, English abstract)

Wisespongpand, P., S. Deetae, S. Patarajinda and R. Prommats. 2005. Sub-thermocline Chlorophyll Maximum in the Andaman Sea. **In:** Preliminary Results on the Large Pelagic Fisheries Resources. November 2005. 15 pp.

PELAGIC LONG LINE ACTIVITIES



LARGE PELAGIC FISH SURVEY IN THE ANDAMAN SEA USING PELAGIC LONGLINE

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ABSTRACT

Due to the heavily exploited in coastal fisheries resource in the Southeast Asian region, the project aims to investigate potential of large pelagic fish resource in Andaman Sea for a new fishing ground. Seven fishing operations of pelagic longline were carried out using nylon monofilament mainline in the 'reel system'. Number of hook deployed in each station vary from 458-682. Shooting gear was done at dusk, using scad size 8-10 pieces per kilogram as bait, then gear was retrieved in the next morning Total catch by weight is 2,692.8kg, 93 pieces by individual number. Main catch, by weight and by individual number is swordfish (*Xiphias gladius*) at 1,219.2kg (41 pieces) followed by bigeye thresher (*Alopias pelagicus*) of total 1,033kg (17 pieces) and yellowfin tuna (*Thunnus albacares*) at 109.0kg (2 pieces). Average catch rate is 2.29 (piece/100 hooks). The highest catch rate (4.55) found in station number 5 at latitude 10o°46.3N longitude 096°11.4 E whilst lowest catch rate (0.40) found in station number 3 at latitude 08°25.5N longitude 095°52.4E. The catch rate of swordfish is comparatively high to commercial longline fleet. It shows high potential yield for swordfish longline fishing in the survey area.

Consider the catch result and data of Temperature and Depth Sensor, attached to the hookline in order to investigate the fishing depth and temperature; it was found that optimum temperature at hook depth for swordfish and bigeye thresher is between 20-25°C which is related to their diurnal migration behavior. For tunas species which its catch rate found very low in the survey, different fishing technique in further survey such as daytime operation and increasing number of hookline per basket in order to cover wider range of fishing depth is suggested to practice to confirm its abundant in this area

INTRODUCTION

The ASEAN-SEAFDEC program on Harvesting of under-Exploited resource has been developed to support plan of action on sustainable fisheries for food security. New fishing ground is considered to explore to support increasing population and decreasing of marine fisheries production due to heavily exploitation in the coastal fishing. According to FAO information, moderately exploited or under-exploited fish resources exists in Eastern Indian Ocean. These stocks are thought to be mainly pelagic species such as Tunas and Billfishes species which are highly migratory species. Andaman Sea is assumed as one of the areas where fisheries resources are under-exploited status. The right of ownership of Andaman Sea belongs to 4 countries namely Indonesia, Malaysia, Myanmar and Thailand. Therefore, SEAFDEC proposed to conduct the joint research survey on Pelagic Fisheries Resources in the Andaman Sea where depth of water beyond 700 meters. Investigation for large pelagic fish resource is one object to clarify the capability in future fishing. Pelagic longline is one of the most selective fishing gears. The gear itself is not complicate and fishermen in the region could effort and install it by little modifying their fishing boat. New technology of longline also reduces hands employed and time spent in fishing period. This survey aims to investigate potential of large pelagic fish by using pelagic longline gear together with proper fishing technique and oceanographic parameters consideration. Determine the relative abundance and size composition of the commercially important species. Biology observation of all catch was carried out such as length-weight of sample, stomach content and sex determination.

MATERIALS AND METHODS

The fishing gear using in this survey is so called 'American Style' longlining system. Mainline, which is 4.0mm diameter nylon monofilament, is reeled in the 2.0m width hydraulic driven spool. When shooting the line, mainline will be pulled out through the line shooter located at stern. Hookline also made from nylon monofilament (12.0m length, 2.0mm diameter), stored in the hookline bin. Blocks are used for guiding mainline to the desired direction in the vessel.

Shooting operated at dusk. Scad (*Decapterrus* sp.) size 8-10 pieces per kilogram are used as bait. Baitfish is hooked at the end of its skull to secure it with the hook. Line shooter speed is calculated related to the vessel speed in order to maintain the mainline sac at proper fishing depth. One Temperature & Depth Sensor is attached in the middle of basket (the deepest position of the sac) to investigate the actual depth and temperature. Gear is soaked overnight then hauling was done at dawn. Usually the finish shooting end will be retrieved first. Mainline is hauled thru side roller (installed at starboard side foredeck) then pass blocks to the reel. All catch hauled on board were identified, measured, weighted. Some biological data such as stomach content, sex identification of sample and etc. were collected by biologists. Oceanographic condition of each station was observed using ICTD and recorded in oceanographic logsheet. Other fishing related factors and also catch information were recorded in fishing logsheet.

RESULTS

Seven fishing operations were carried out during the survey. First station was done at latitude 06°45.12N longitude 096°45.02E. Then others were done northern up respectively until latitude 12°40.78N longitude 096°12.03E. Depths of water are varying from 800-2,100m (from navigation chart). Position of fishing operations are shown in fig.1

Fishing Operations Result

Hooklines deployed in each fishing operation were varying from 458-682 lines. Shooting and hauling time usage were between 65-109 and 165-271 minutes, respectively. Average shooting rate is 7.025 hooks/minute and average hauling rate is 2.626 hooks/minute. The fishing depths together with temperature were investigated by Temperature & Depth sensor. Average depths from sensor of operation 1 to 7 are 120.17, 80.75, 145.62, 105.65, 81.08, 74.18 and 105.87m respectively. Temperature and depth profiles from sensor attached with mainline each station are show in fig.3.

Catch result Total catch of 7 pelagic longline fishing operations are 93 pieces, totalweight 2,692.8 kg. Catch are specified to two groups; catch and bycatch (FAO, 1996). In first group, catch found in this survey namely Swordfish (*Xiphias gladius*), Yellowfin tuna (*Thunnus albacares*), Striped marlin (*Tetrapturus audax)* and Sailfish *(Istiophorus platypus)*.

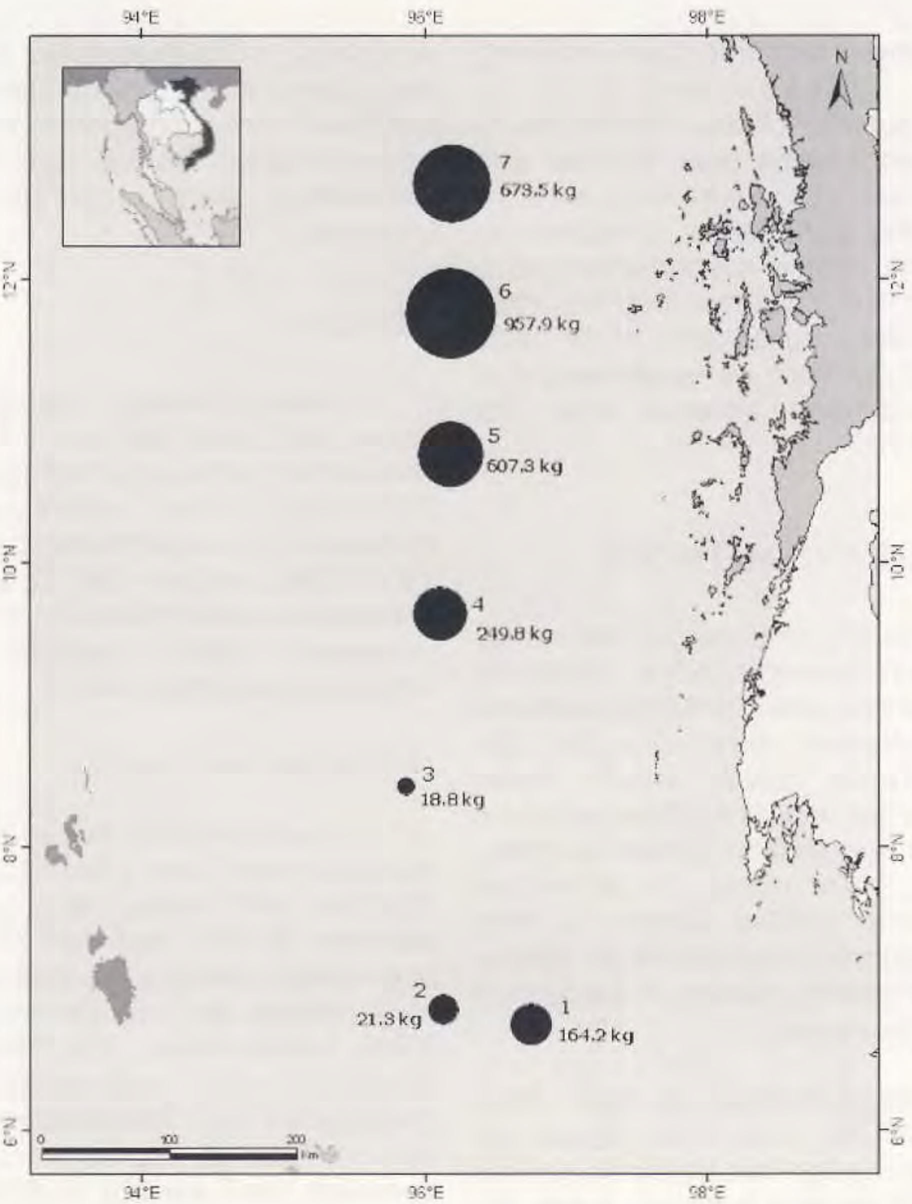

FIGURE1. Operation positions and catch result (by weight)

The dominant catch in this group is swordfish total 41 pieces (1,216.2kg) followed by yellowfin tuna 2 pieces (109.0kg), 3 pieces of sailfish (64.0kg) and a striped marlin (40.5 kg). For bycatch group, Bigeye Thresher (*Alopias pelagicus*) comes first with total 17 pieces (1,033.0 kg) followed by White-tipped shark (*Carcharhinus longimanus*) 2 pieces (110.0kg), Escolar 8 pieces (52.8kg), Pelagic stingray (*Dasyatis* sp.) 12 pieces (45.6kg), Common dolphinfish (*Coryphaena bipinnulata*) 2 pieces (11.2kg) and Snake mackerel (*Gympylus surpens*) 5 pieces (10.5kg).

Regarding by station, 31 pieces of fish (957.9kg) were caught in station 5 which is the highest catching station. The lowest catching station is station 3 where can catch only 2 pieces (18.8kg). Detail of catch amount by species in each station is show in table 2 and 3.

Swordfish is the most dominant specie as mentioned. Average BL (Body length) is 132.5cm and they average weight is 30.5kg. The most frequency BL found is in between 110-119cm (total 8 pieces). Length and weight relationship is plotted in graph, trendline was drawn and its coefficient is 3.25(fig. 4&5).

TABLE 1. Catch and total catch rate in each station

STATION	NUMBER OF HOOK	CATCH NUMBER (pcs)	BYCATCH NUMBER (pcs)	CATCH RATE (catch in pcs/100 hooks)	TOTAL CATCH RATE (total catch in pcs/100 hooks)
1	602	4	6	0.66	1.66
2	500	1	2	0.20	0.60
3	500	1	1	0.20	0.40
4	512	2	7	0.39	1.76
5	617	16	6	2.59	3.57
6	682	15	16	2.20	4.55
7	458	8	8	1.75	3.49

DISCUSSION

From the catch result, considering hook rate (number of fish per 100 hooks) in table1, it was found that the highest catch rate is on station 5 (2.59) and lowest is on station 2 and 3 (0.20). In term of total catch, the highest hook rate found in station 6 (4.55) whilst station 3 came last at 0.40.

Considering station 5&6 which were best catch result during the survey, catch composition of these two stations mostly are swordfish and bigeye thresher (20 and 11 of total 53 pieces, respectively) or 85.12% of total catch weight. The bigeye thresher is often caught as bycatch of swordfish fisheries. A shark will often dislodge several baits before impaling or hooking itself. (NOAA, 1999). According to the graph in fig.2, in station number 5, 6 and 7 which are better catch rate than the rest stations. Average temperature at hook operating depth is in between 21-24°C which is optimum temperature for swordfish and also bigeye thresher in its ascending to upper layer in nighttime. In station number 1, 3 and 4 which average temperature at hook operating depth is in between 13-15°C which are too low temperature for these two species while in station number 4, average temperature is about 26°C which is higher

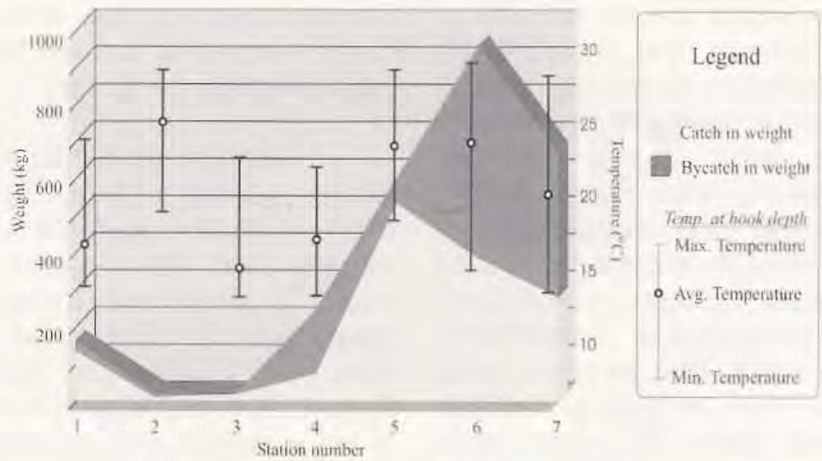

FIGURE 2. Catch amount in weight and temperature at hook layer from Temp.&Depth Sensor

than mentioned optimum temperature.

There was an experiment on billfish hooking depth measured by small bathythermograph systems attached to longline gear (Mutsumoto et al, 2001) which took place in Western Indian and Pacific Ocean in the year 1995-2000. TDR (Time–Depth Recorder) of 10 to 163 sensors were attached at hookline in each fishing operation. Total more than 300 operations were carried. A total of 22 billfish were hooked right on the hookline which TDR sensor was attached. Among this number, there were 5 swordfish caught. Two of them were hooked in daytime (at 1147 and 1552 hrs) where the depth of hooking is more than 180m. The rest of swordfish were caught during night (2240-0435 hrs) and hooking depth is all shallower than 120m. From several research studies, behavior of swordfish and bigeye thresher is quite similar. Takahashi et al.(2005) and Brill et al.(2005) found that swordfish swim in could water (3-6°C) during daytime at depths of up to 650m and migrate vertically to stay near the warmer surface water (21–26°C) at night. This diurnally migration is similar to bigeye thresher which is reported that it will ascend to depth of 35 to 150 m at night (NOAA, 1999). This information is in consonance with catch result and hook depth data archived from Temperature & Depth sensors which attach to mainline of the gear. Ward *et al* (2005) explains the comparisons of catchability for day and night operations which reveals patterns of diel variation among the mesopelagic species that probably represent vertical migration. The catch result of these species increases with depth during the day, whereas it shows a much more uniform distribution at night. The interpretation is that visibility is critical to vertical distribution of large predators in the open ocean. They have several physiological adaptations, such as large eyes, that provide acute vision and allow them to hunt at low light level. They feed below the sunlit zone during day where they can avoid detection by their prey. At night, they range more widely because the ocean is almost dark

. Besides understanding the target fish behavior to gain better catching result, fishing technique is also very important subject. Even fishing boat deploying top quality bait but in the layer that target fish would not swim and feeding, it will be unsuccessful fishing. The basic principal of longline operation is the confrontations between baits and target fishes, therefore the catch rate could be vary, highly or poorly, according to the ability of the fishermen in order to arrange that confrontations. Scientists assumed that the mainline formed a catenary curve between floats in one basket. Estimation the depth of each hook by applying formula to the longline dimension was presented by Suzuki (Suzuki et al 1977; Ward and Myers, 2005). It was assumed that the shape of catenaty curve did not systematically vary along each longline or during each longline fishing operation. Observed depths and predicted depths are known to vary, with ocean current in multi-layers and wind having the most importance influence on hook depth. Bigelow (Bigelow et al 2002; Ward and Myers, 2005) estimated that hook number three and ten of longline gear with 13 hooks between floats shoaled by 20% when subjected to a current velocity of $0.4 m.s^{-1}$ while Ward and Myers (2005) suggested to reduce all depth predicted by catenary curve formula by 25% in their experiment. Therefore, knowledge and experience of longline operator for set the gear at the proper depth is necessary.

Considering CPUE (Catch per Unit Effort = number of fish caught/1000hooks) from French's commercial swordfish longline fleet that operated over 4 million hooks in Southwest Indian Ocean each year, their CPUE declined continuously from 16 in 1994 to 8 in 1999 (Poisson and Taquet, 2000). Compare to the catch result in the surveyed area specifically in station number 5, 6 and 7 that CPUE for swordfish is 22.7, 17.6 and 15.3 respectively, shows the high potential yield for swordfish longline fishing. For Tuna species, there were 2 pieces caught in station no 5. Both of them are yellowfin tuna weighted 45 and 64kg each. It was a disappointing result for tuna catching rate in this survey. Catch rate (catch in piece/100 hooks) for tuna is only 0.05 (2 pieces of total 3,871 hooks deployed). For 7 fishing operations on this survey it might be too few operations too conclude that very less large tuna species abundant in this area. From Department of Fisheries (Thailand) survey data on tunas species using tuna longline gear in Andaman Sea within Thai EEZ in December 1999, RV Chulaborn deployed totally 3,360 hooks in 7 stations and caught yellowfin tuna 27 pieces (total weight 755 kg) which average catch rate for tuna species is 0.80 (Uttayamakul ,2001). Thus, this information confirms the existence of large yellowfin tuna in Andaman Sea in that period. Changing of fishing technique during survey is one suggestion to explore tuna species. Ward and Myers (2005) mentioned in his research paper that information from NMFS (US National Marine Fisheries Service) found that commercial fishing tuna longliners in 1990s to present operated in daytime by shot their gear about an hour before dawn and retrieved it about two hours before dusk while their fishing gear ranged 27-600m depth by increasing number of hook per basket to 26-30. It could not conclude which is the proper technique in each fishing area until has been practiced several times and have got better average catch result than others. Therefore, further survey with different fishing technique is recommended to explore large tuna resource in Andaman Sea.

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REFERERENCES

Brill, R.W. and K.A. Bigelow.,et.al. 2005. Bigeye tuna (*Thunnus obesus*) behavior and physiology and their relevance to stock assessments and fishery biology. International Commission for the Conservation of Atlantic Tunas (ICCAT). Collective Volume of Scientific Papers, 57, 2: 142-161

FAO, 1996. Fisheries Bycatch and Discards. Committee on Fisheries 22nd Session. FAO http://www.fao.org/ docrep/meeting/w3862e.htm

Musumoto, T., Uozumi, Y, Uosaki and Okazaki M. 2001. Preliminary review of billfish hooking depth measured by small bathythermograph systems attached to longline gear. Col.Vol. Sci. Pap .ICCAT, 53: 337-344

NOAA. 1999. Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks. NOAA Fisheries Service. **www.nmfs.noaa.gov/sfa/hms/finalFMP/HMSch6.pdf**

Poisson F. and Taquet M. 2000. French Swordfish Longline Fishery in Southwest Indian Ocean: Preliminary results from the PRR Program. IOTC Proceedings no.3: 169-201

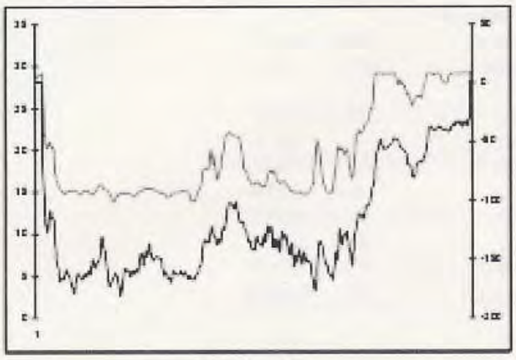
Takahashi, M., H. Okamura., K. Yokawa and Okazaki M. 2005. Swimming behavior and migration of a swordfish recorded by an archival tag. CSIRO Publishing Marine Freshwater Research, 54 ,4: 527-534

Uttayamakul W. 2001. Longline fishing : An alternative for responsible fishing in Andaman Sea. Oceanic Fisheries Division, Department of Fisheries (Thailand). 44pp.

Ward, P. and R. A. Myers. 2005. Inferring the depth distribution of catchability for pelagic fishes and correcting for variations in the dept of longline fishing gear. Can. J. Fish. Aquat. Sci. 62:1130-1142

Worm, B. and Myers R. A. 2005. Scientists Discover Global Pattern of Big Fish Diversity on Open Oceans. Dalhousie University. Http://www.seaweb.org

Station 1



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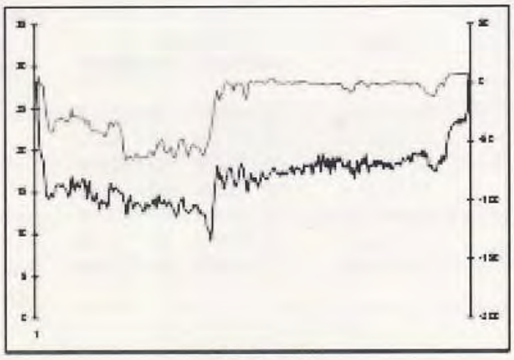

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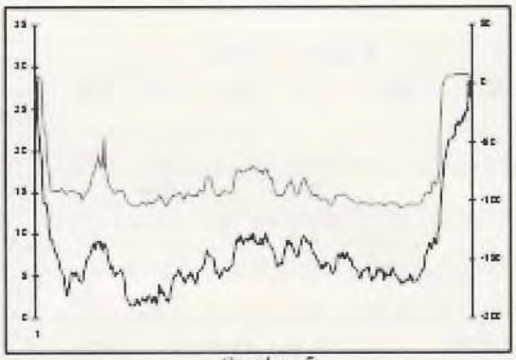

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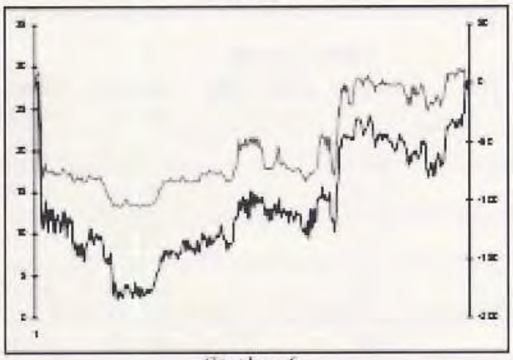

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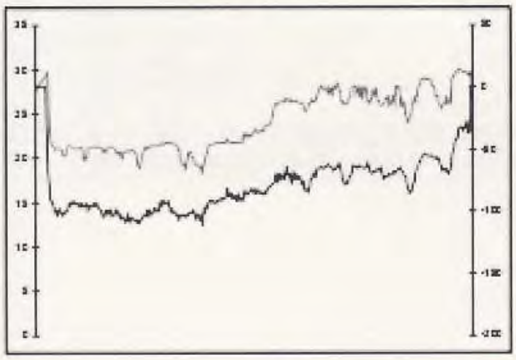

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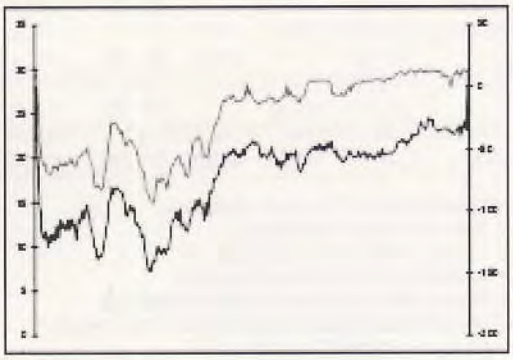

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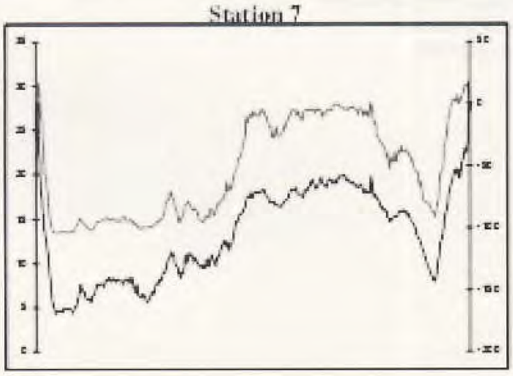


Table 2. Detail of fishing operation

Station number	Date	Position		Number of hook deployed (hooks)	Total Catch	
		Latitude	Longitude		(pcs)	(kg)
1	16 Nov 04	06_45.1N	096_45.0E	602	10	164.2
2	17 Nov 04	06_51.5N	096_08.3E	500	3	21.3
3	18 Nov 04	08_25.5N	095_52.4E	500	2	18.8
4	19 Nov 04	09_38.7N	096_06.5E	512	9	249.8
5	20 Nov 04	10_46.3N	096_11.4E	617	22	607.3
6	21 Nov 04	11_45.7N	096_11.3E	682	31	957.9
7	22 Nov 04	12_40.8N	096_12.0E	458	16	673.5
				Grand total	**93**	**2,692.8**

Table 3. Catch result in number and weight by species

Station	YFT	Catch> pcs (kg)					Bycatch> pcs (kg)							
		SWF	STM	SAF	Sub-total (pcs/%)	Sub-total (kg/%)	BTS	WTS	STR	DOL	ESC	SMK	Sub-total (pcs/%)	Sub-total (kg/%)
1	-	4	-	-	4	133.8	-	-	2	-	4	-	6	30.4
		(133.8)			(40.00)	(81.49)			(5.0)		(25.4)		(60.00)	(18.51)
2	-	1	-	-	1	8.2	-	1	1	-	-	-	2	13.1
		(8.2)			(33.33)	(38.50)		(10.0)	(3.1)				(66.67)	(61.50)
3	-	1	-	-	1	17.0	-	-	-	-	-	1	1	1.8
		(17.0)			(50.00)	(90.43)						(1.8)	(50.00)	(09.57)
4	-	2	-	-	2	75.0	2	-	3	1	-	1	7	174.8
		(75.0)			(22.22)	(30.02)	(158.0)		(6.9)	(5.1)		(4.8)	(77.78)	(69.98)
5	2	14	-	-	16	532.9	1	-	2	-	2	1	6	74.4
	(109.0)	(423.9)			(72.73)	(87.75)	(51.0)		(9.4)		(13.0)	(1.0)	(27.27)	(12.25)
6	-	12	-	3	15	385.2	10	-	4	1	1	-	16	572.7
		(321.2)		(64.0)	(48.39)	(40.21)	(536.0)		(21.2)	(6.1)	(9.4)		(51.61)	(59.79)
7	-	7	1	-	8	277.6	4	1	-	-	1	2	8	395.9
		(237.1)	(40.5)		(50.00)	(41.22)	(288.0)	(100.0)			(5.0)	(2.9)	(50.00)	(58.78)
	2	**41**	**1**	**3**	**47**	**1,429.7**	**17**	**2**	**12**	**2**	**8**	**5**	**46**	**1,263.1**
	(109.0)	**(1,216.2)**	**(40.5)**	**(64.0)**	**(50.54)**	**(58.52)**	**(1,033.0)**	**(110.0)**	**(45.6)**	**(11.2)**	**(52.8)**	**(10.5)**	**(49.46)**	**(41.48)**

YFT = Yellowfin tuna (*Thunnus albacares*)
SWF = Swordfish (*Xiphias gladius*)
SAF = Sailfish (*Istiophorus platypus*)
STM = Striped marlin (*Tetrapturus audax*)
BTS = Bigeye thresher shark (*Alopias pelagicus*)
WTS = White-tipped shark (*Carcharhinus longimanus*)
STR = Pelagic stingray (*Dasyatis* sp.)
DOL = Common Dolphinfish (*Coryphaena bipinnulata*)
ESC = Escolar (*Lepidocybium flavobrunneum*)
SMK = Snake mackerel (*Gympylus surpens*)

Table 4. Measurements of individual catch

No.	Species	TL (cm)	FL (cm)	SL (cm)	UDL (cm)	HL (cm)	BD (cm)	Girth (cm)	Weight (kg)	Sex (M/F)
1	*Thunnus albacares*	150	136	126	34	30	33	90	45.0	M
2	*Thunnus albacares*	170	154	141	40	35	34	90	64.0	M
3	*Xiphias gladius*	217	203	187	139	39	28	69	28.8	F
4	*Xiphias gladius*	245	226	208	152	42	32	84	52.0	F
5	*Xiphias gladius*	236	223	207	147	40	28	74	37.0	M
6	*Xiphias gladius*	147	136	125	89	28	18	45	8.2	F
7	*Xiphias gladius*	188	177	163	117	33	21	58	17.0	M
8	*Xiphias gladius*	229	213	197	146	41	30	77	41.0	M
9	*Xiphias gladius*	234	211	195	143	39	27	74	34.0	M
10	*Xiphias gladius*	160	151	143	101	29	19	46	11.0	M
11	*Xiphias gladius*	165	147	132	103	31	21	53	12.1	M
12	*Xiphias gladius*	265	238	221	162	46	29	85	46.0	F
13	*Xiphias gladius*	247	227	210	158	43	30	79	48.0	F
14	*Xiphias gladius*	176	161	149	110	33	23	44	14.4	M
15	*Xiphias gladius*	300	273	252	188	50	37	101	80.0	F
16	*Xiphias gladius*	199	182	169	121	37	25	66	20.0	F
17	*Xiphias gladius*	183	169	156	110	32	22	55	14.0	M
18	*Xiphias gladius*	194	178	167	120	33	24	63	19.3	M
19	*Xiphias gladius*	211	192	178	131	37	27	72	31.7	F
20	*Xiphias gladius*	192	172	159	117	36	24	57	15.0	F
21	*Xiphias gladius*	244	229	213	157	43	29	83	45.0	F
22	*Xiphias gladius*	223	204	189	140	37	28	70	33.0	M
23	*Xiphias gladius*	268	255	234	174	47	41	97	70.0	F
24	*Xiphias gladius*	245	228	211	150	44	30	83	44.0	F
25	*Xiphias gladius*	248	229	213	160	44	30	84	48.0	F
26	*Xiphias gladius*	183	178	165	119	35	20	59	17.2	F
27	*Xiphias gladius*	253	228	208	156	42	28	85	56.0	M
28	*Xiphias gladius*	187	170	156	112	33	21	56	15.0	M
29	*Xiphias gladius*	210	199	184	138	37	28	74	34.0	M
30	*Xiphias gladius*	128	121	112	79	22	14	34	4.0	F
31	*Xiphias gladius*	202	185	171	123	38	24	61	18.0	M
32	*Xiphias gladius*	215	200	184	137	38	26	68	30.0	M
33	*Xiphias gladius*	160	145	135	96	28	21	51	11.0	M
34	*Xiphias gladius*	208	191	177	127	37	26	68	23.0	F
35	*Xiphias gladius*	210	190	177	135	40	29	67	21.0	F
36	*Xiphias gladius*	202	189	175	130	39	26	67	23.0	M
37	*Xiphias gladius*	187	178	176	126	34	22	61	21.0	M
38	*Xiphias gladius*	199	186	173	124	36	24	64	23.0	M
39	*Xiphias gladius*	266	250	230	172	45	33	81	63.0	M
40	*Xiphias gladius*	275	254	232	178	48	34	94	70.0	F
41	*Xiphias gladius*	186	169	154	116	33	24	58	19.6	M
42	*Xiphias gladius*	189	172	158	122	34	22	58	17.5	M
43	*Xiphias gladius*	182	170	153	119	32	20	55	16.0	M
44	*Tetrapturus audax*	236	217	202	18	44	31	70	40.5	F
45	*Istiophorus platypus*	250	225	210	195	44	29	61	27.0	F
46	*Istiophorus platypus*	220	200	187	168	38	23	54	18.0	F
47	*Istiophorus platypus*	218	198	186	174	41	26	51	19.0	F

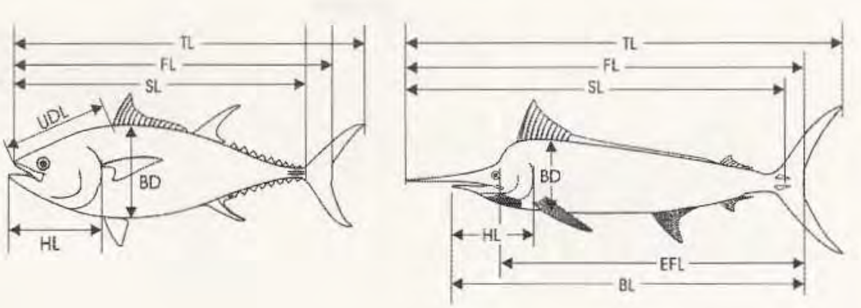


Figure 4. Size distribution (BL) of swordfish caught in survey

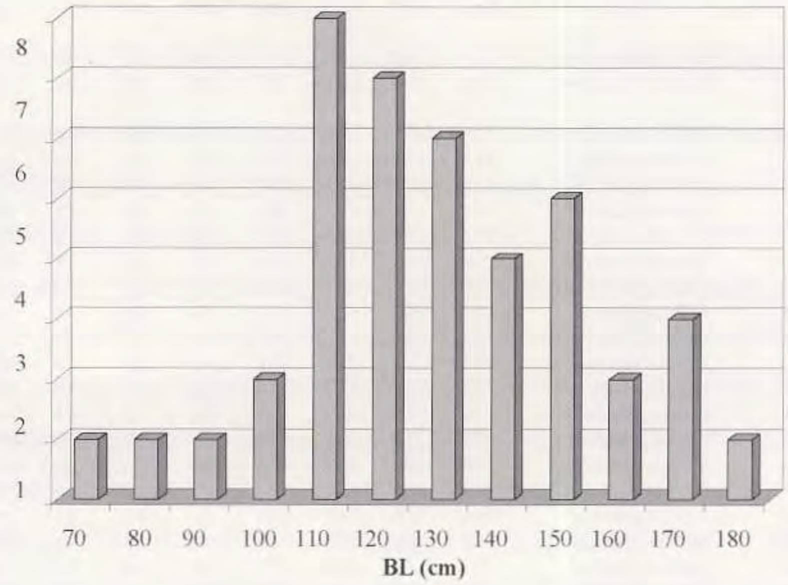
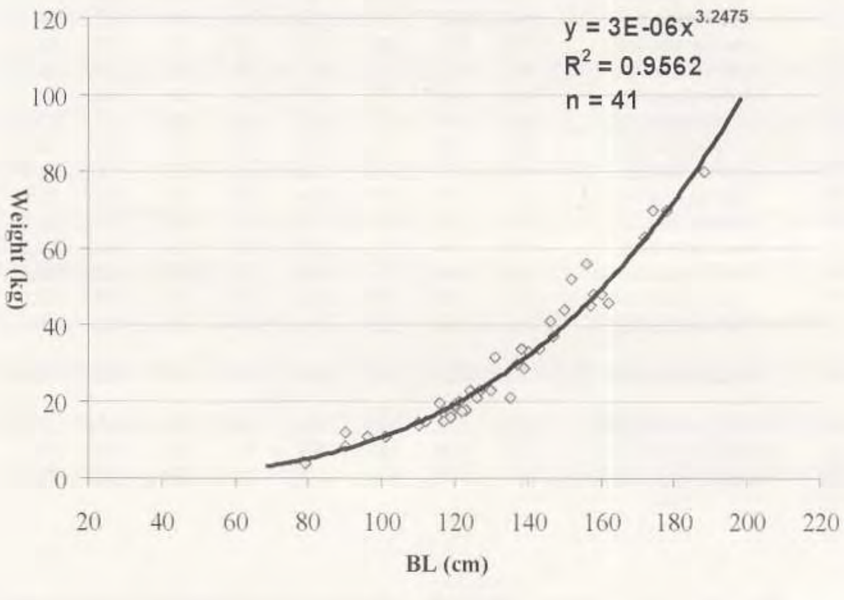


Figure 5. Length-weight relationship of swordfish caught in survey



PRELIMINARY STUDY ON THE STOMACH CONTENT OF YELLOWFIN TUNA IN THE ANDAMAN SEA

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ABSTRACT

Two yellowfin tuna (*Thunnus albacares*) were caught at latitude 10°37.39' to 10°44.32' N longitude 95° 02.05' to 96° 07.34' E. The sizes of the tuna samples were 136 and 154 centimeter in fork length, 45 and 64 kilogram in weight, respectively. The results provided an example of interesting items concerning tuna feeding in the Andaman Sea. Both the tuna samples were examined for the stomach contents and presented the largest proportions in numbers of content is Pisces (52.8%) which comprise Tetraodontidae (30.40%) Priacantidae (11.20%) Balistidae (10.40%) and Syngnathidae (0.80%). Another item of content was Cephalopod (47.2%) which comprised Loligiidae (23.2%) and Teuthoidea (24.0%). Some specimens were almost completely digested. The rest of the content was 40 g of unidentified pieces or 6% of total weight. However, Cephalopod had the highest percentage in total weight of content (77.26% of total weight).

INTRODUCTION

Usually it is difficult to collect tuna's stomach content on commercial fisheries. As tuna from longliners are eviscerated, and for the purse seiners most of the tuna's stomach samples were empty that concerns the fishing time that operate in very early morning when tuna have not yet eaten. As yellowfin are apparently sight-oriented predators, their feeding tends to occur in surface water during daylight (http://www.flmnh.ufl.edu). Also tuna have a high metabolic rate and digest their food quickly (Allain, 2005). For the these reasons, Praulai *et al.* (2001) found 85% of the stomach content of the yellowfin tuna from a purse seiner were empty; in addition Potier *et al* (2003) reported the number of empty stomachs were high among the tuna caught from floating object schools. Although various studies reported that yellowfin tuna is an euriphagic predator, which practice no discrimination on prey type or size. Their prey items include fish, cephalopods and crustaceans. Fish species consumed by yellowfin tuna include dolphin, pilchard, anchovy, flying fish, mackerel, lancetfish, and other tunas. Other prey items are cuttlefish, squid, octopus, shrimp lobster and crabs. (Allain, 2005; Grubbs *et al.* 2001, Grubbs *et al.* 2002; Potier, 2003; Praulai 2001). However, yellowfin tuna live in different ecosystems throughout the Indian Ocean and they adapt their feeding habit to what is available in their environment, especially there are a few of studied in the Andaman Sea. So this present a study is the initial basis of understanding the yellowfin tuna diet in the Andaman Sea and the concern of their habits with the environment.

MATERIALS AND METHODS

ON BOARD

On SEAFDEC cruise number 71-1/2004, two yellowfin tuna (*Thunnus albacares*) was caught at latitude 10°37.39' to 10°44.32' N longitude 95°02.05' to 96°07.34' E. The sizes of the yellowfin tuna were 136 and 154 centimeter in fork length and 45 and 64 kilogram in weight, respectively. The stomach contents were collected by opening the peritoneal cavity through the opercula opening then removed the entire stomach. This was put in a sealed plastic bag and stored in MV SEAFDEC's freezer. A label with the main characteristics was enclosed with the bag.

AT THE LABORATORY

The stomachs were defrosted before analysis in three steps.

1. The stomach content was sorted into large categories as Pisces Cephalopod or Crustaceans.

2. The different items constituting the categories were sorted and counted for each, remarkable organ are used to determine the number of prey in the stomach such as left or right otolith of fish, and upper or lower beaks of cephalopods. Specimens of fish were preserved in a 10% buffer formalin solution for 24 hour then changed to 70%alcohol. However the beaks of the cephalopods were kept in 70% alcohol at the initial step to prevent decalcification.

3. Different items are determined to the lowest taxon.

RESULTS

The result provided examples of interesting items concerning tuna feeding in the Andaman Sea, and the details of observed data were recorded. Both of the yellowfin tuna samples were examined for stomach content. The largest proportions in numbers of content is Pisces (52.80%) comprising Tetraodontidae (30.40%) Priacantidae(11.20) Balistidae (10.40%) and Signathidae (0.80%). Other content was Cephalopod (47.20%) comprising Loligiidae (23.20%) and Teuthoidea (24.00%). Some specimens were almost finished the digestion process. The rest were 40 g of unidentified pieces of specimen or 6% of the total weight. However, Cephalopod is the highest percentage in total weight of content. (Table 1 and Fig. 1-6)

TABLE 1. Stomach contents of yellowfin tuna.

CONTENTS	NUMBER	WEIGHT (g)	% OF TOTAL NUMBER	% OF TOTAL WEIGHT
Pisces	66	111.43	52.80	16.74
Tetraodontidae	38	76.22	30.40	11.45
Priacantidae	14	10.94	11.20	1.64
Balistidae	13	12.24	10.40	1.84
Syngnathidae	1	1.44	0.80	0.22
Pieces of Pisces	-	10.59	-	1.59
Cephalopoda	59	514.37	47.20	77.26
Loliginidae	29	470.15	23.20	70.61
Beak of Teuthoidea	30	0.44	24.00	0.07
Pieces of Cephalopod	-	43.78	-	6.58
Unidentified specimen	-	40	-	6.00
TOTAL	**125**	**665.80**	**100**	**100**

DISCUSSION AND FUTURE DIRECTION

This is an initial basis for future research. For the future, longliner sampling should be continued to gain data for associated fish from longline fisheries, especially from the research vessels. Although the stomach samples from the purse seiner showed a high percentage to be generally empty, it still needs to be recorded for a more complete picture of the complex trophic dynamics of tuna aggregation. Then we can explain exactly some of the feeding habits of yellowfin tuna in the Andaman Sea.

ACKNOWLEDGMENT

This preliminary study would not be possible without the support of SEAFDEC, including funding and allowing sampling on board. Especially thanks the Captain and staff of MV SEAFDEC for providing an efficient facility onboard.

REFERENCES

Allain, V. 2005. What tuna eat? A tuna diet study. SPC Fisheries Newsletter #12- January/ March 2005. Noumea, New aledonia. pp. 20-22.

Grubbs, D. R., K. Holland and D. Ittano. 2001. Food habits and trophic dynamics of structure associated aggregation of yellowfin and bigeye tuna (*Thunnus albacares* and *Thunnus obesus*) in the Hawaiian Island: Project description, rationale and th preliminary results. SCTB 14 Working Paper. 15th Meeting of Standing Committee on Tuna and Billfish. 9-16 August 2001. 5 p.

Grubbs, D. R., K. Holland and D. Ittano. 2002. Comperative trophic ecology of yellowfin and bigeye tuna associated with natural and man made aggregation site in th Hawaiian waters. SCTB 15 Working Paper. 15th Meeting of Standing Committee on Tuna and Billfish 22-27 July 2002. 20 p.

Potier, M., R. Sabatie, F. Menard and F. Marsac. 2003. Preliminary results of tuna diet rd studies in the West equatorial Indian Ocean. The 3rd session of the IOTC Working th Party on Tropical Tunas. June 19-27th, 2001. Seychelles.

Praulai, N., S. Panjarat, S. Hoimuk and W. Singtongyam. 2001. Thai tuna Purse Seine Fishery, Mukmanee, in the Indian Ocean, 1998 to 2000.

Vaske, Jr. T, J. P. Castello. 1998. Stomach contents of yellowfin tuna, *Thunnus albacares*, during winter and spring in Southern Brazil. Bras. Biol. Vol. 58 no. 4. 8 p.

http://www.flmnh.ufl.edu.

FIGURE 1. Tetraodontidae

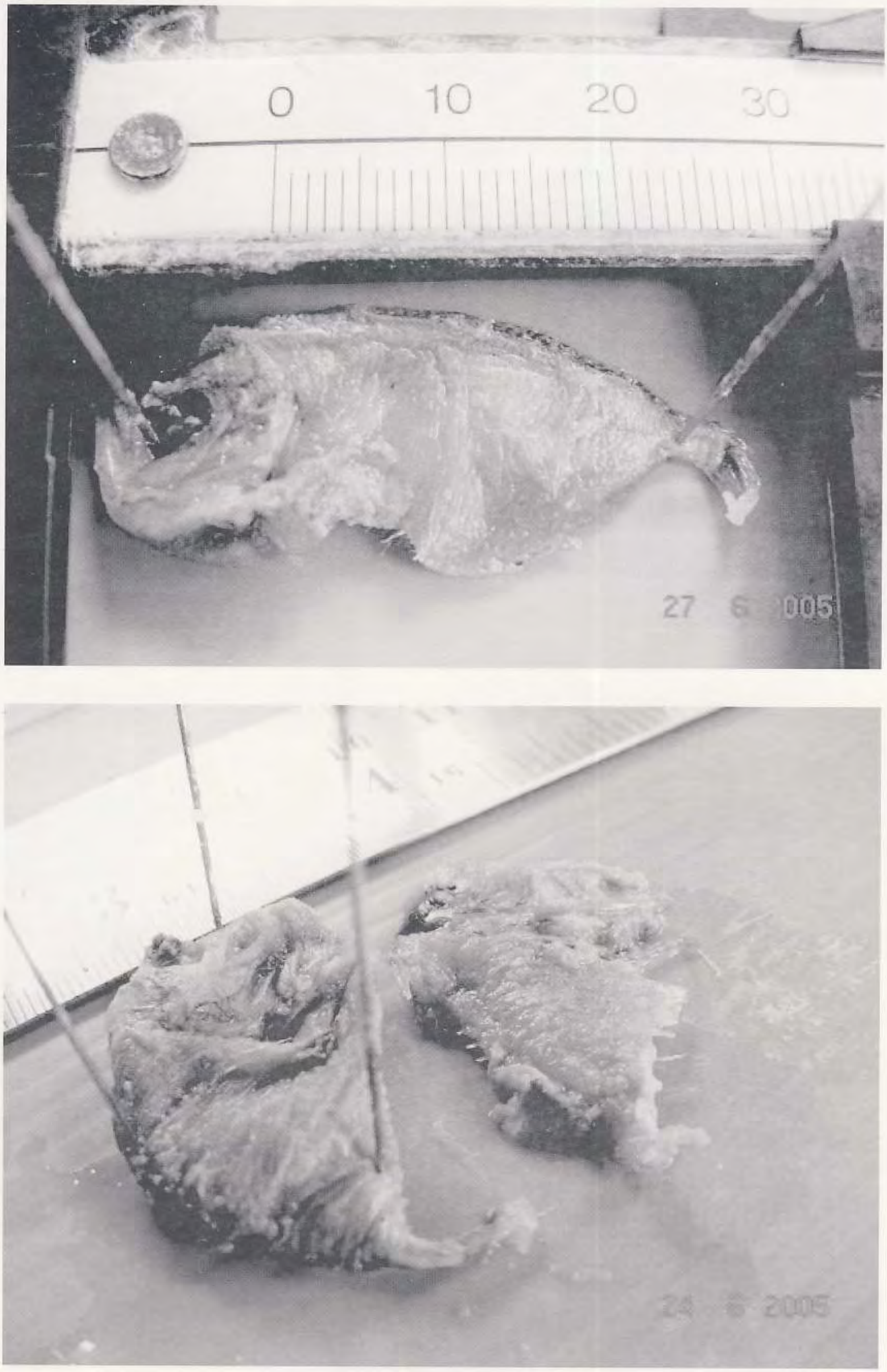


FIGURE 2. Priacantidae

FIGURE 3. Balistidae

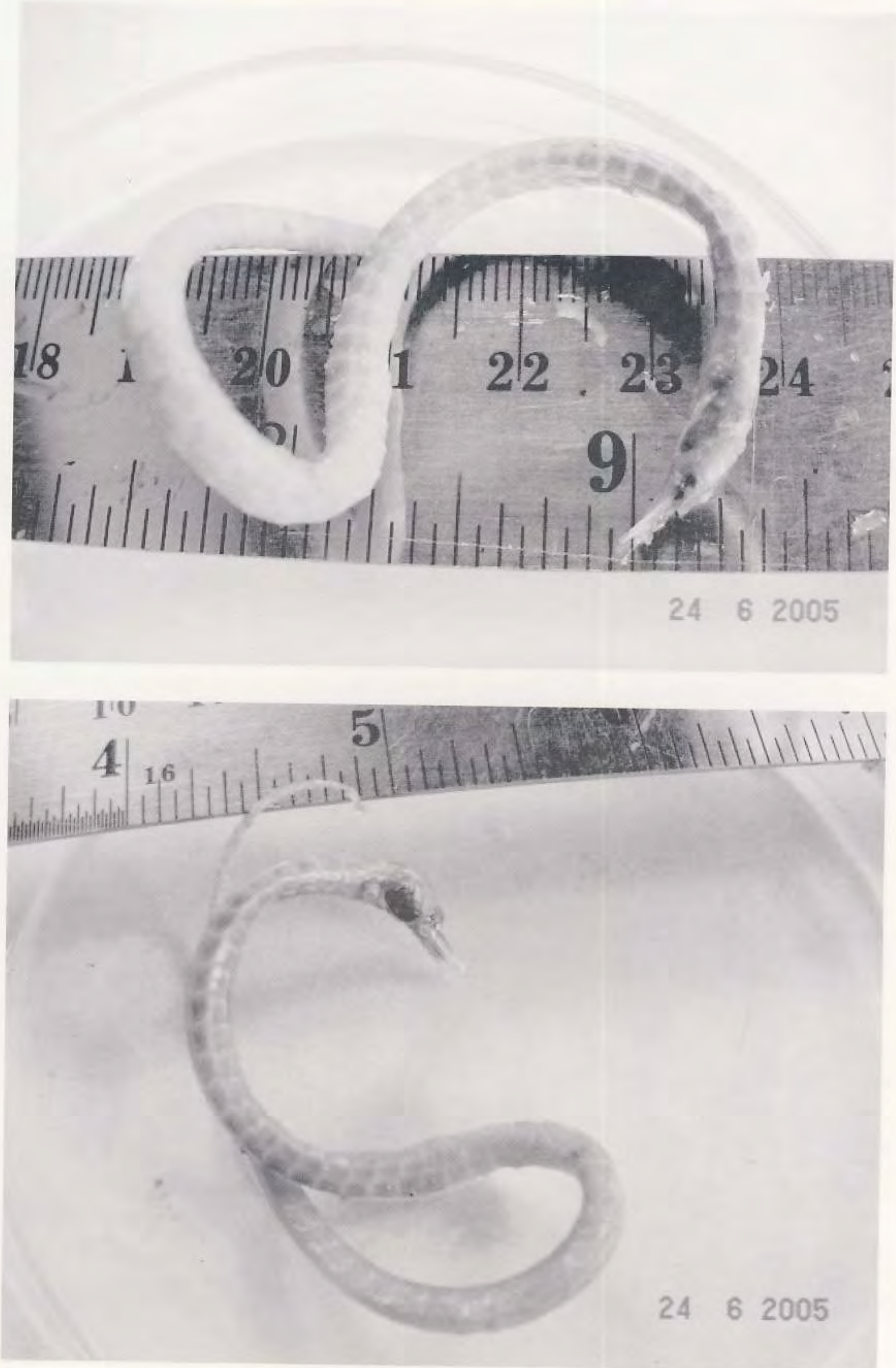
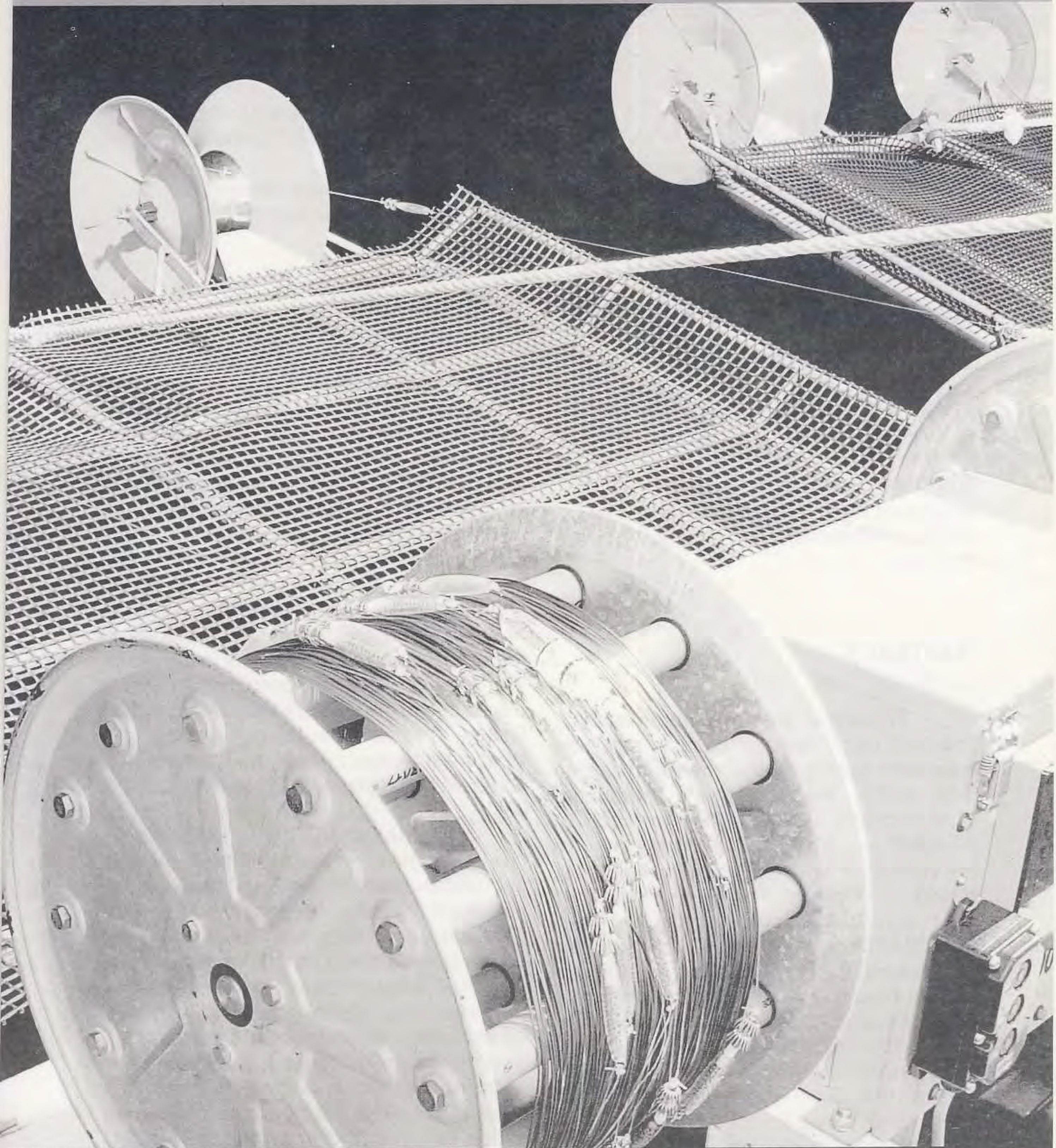
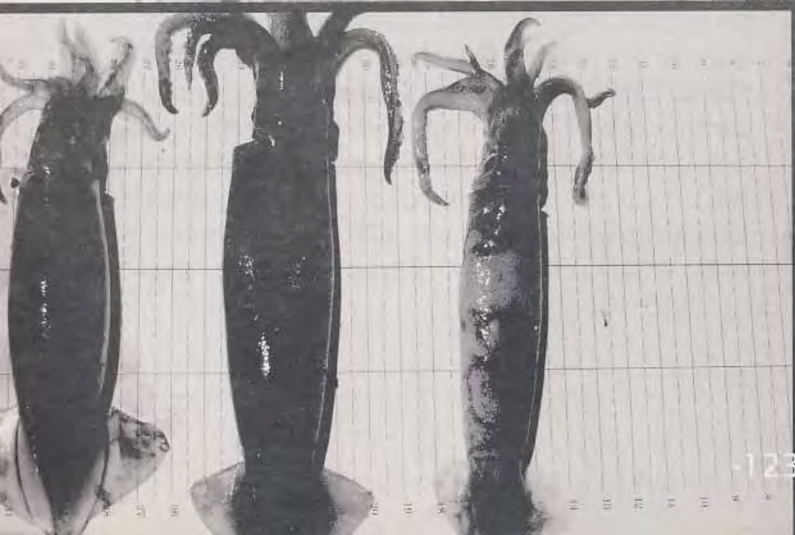


FIGURE 4. Syngnathidae

FIGURE 5. Cephalopod

FIGURE 6. Beak of Cephalopod





OCEANIC SQUID, *STHENOTEUTHIS OUALANIENSIS*, RESOURCES SURVEY IN ANDAMAN SEA WITHIN THE WATER OFF INDONESIA, MYANMAR AND THAILAND.

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ABSTRACT

This paper presents the preliminary result of catch rate for oceanic squid by automatic jigging method in the Andaman Sea within the water off Indonesia, Myanmar and Thailand. This was part of ASEAN – SEAFDEC program on Harvesting of under- Exploited Resource, Phase I: Pelagic Fisheries Resources Survey. The research vessel M.V.SEAFDEC covered 13 stations for oceanographic and 7 stations for fisheries survey. Results from 7 sampling show that only one specie of the purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) were caught by automatic squid jigging gear. Two machines were use at each station varied from 3 – 4 hours.

The distribution and abundance of the purpleback flying squid in term of the CPUE (number of squid per line hour) are presented. The CPUE of the squids were ranged between 2.00 – 8.49 squids per line hour. Angling depth where the squid were abundant range between 75- 100 m. A total of catch in male and female were 17 and 113 squids, respectively. Mostly of catch was female, accounting for 87 % of all squid.

Keywords : purpleback flying squid, Andaman sea, Squid jigging

INTRODUCTION

The ASEAN – SEAFDEC program on Harvesting of under- Exploited Resource, Phase I: Pelagic fisheries Resources Survey in the Andaman Sea by using automatic squid jigging machine on M.V.SEAFDEC. The flying squids (Roper *et al.*,1984) of the family Ommastrephidae (Suborder Oegopsida) account for about 65% percent of the world's commercial cephalopods (Brunetti, 1990). It is an important in the marine ecosystem and has been targeted by commercial fisheries in many costal and pelagic waters in the world. The flying squid is an oceanic squid widely distributed in the western Pacific and Indian Ocean. It covers throughout tropical and temperate waters of both the northern and southern hemispheres (Roper *et al.*, 1984).

The Andaman Sea is assumed as one of the areas where fisheries resources are under-exploited status. The member countries namely Indonesia, Malaysia, Thailand and Myanmar were area of Andaman sea coast line. To date, there is little knowledge on the ecosystem (fisheries resources and oceanographic data) based on fisheries management in the Andaman Sea. Investigation for the ecosystem and fisheries resources in the Andaman Sea therefore is essential for those concerned countries. For this reason, SEAFDEC proposes to conduct the joint research survey on pelagic fisheries resources in the Andaman Sea where the depth of waters is deeper than 700 m. The main target species are large pelagic fishes and oceanic squid while fish and squid larvae and oceanographic data will also be collected and analyzed. This paper reports the experimental fishing on the automatic squid jigging gear which was carried out in Andaman Sea located in the Exclusive Economic Zone of Indonesia, Myanmar and Thailand by M.V.SEAFDEC from 16 – 25 November 2004.

MATERIALS AND METHODS

SURVEY AREA

Experimental fishing and oceanographic conditions were conducted by M.V.SEFDEC in the Andaman Sea is locate in the Exclusive Economic Zone of Indonesia, Myanmar and Thailand from 16 – 25 November 2004. All 13 oceanographic survey stations and 7 experimental fishing stations were designed covered from 06_30 to 13_00 N Latitude and from 095_30 to 097_00 E Longitude as shown in Figure 1.

FISHING GEAR

Squid sampling were conducted by two automatic squid jigging machines, installed at the port side consisting of two main line per one machine. Each main line was attached a small underwater-lamp then a series of 25 typical Japanese squid jigs, which 5 colors. Distance between jigs is about 1 meter by mono-filament, leader's size 1.19 mm in diameters (No.50) as shown in Figure 2. The jigs were lowered to the desired depth and the line moved up and down approximately 1 m inboard and 5 m above the machine. Bulbs were 500 w and were spaced 70 – 80 cm apart down the length of the port side of the vessel where the machines were set. 16 lights or a total of 8 kW were used. The fishing operation were done when the vessel drifting. To started luring before started jigging 1 hour. The depth was ranged from 75 m to 100 m.

DATA COLLECTION

Catch data were collected at each fishing operations. The samples were separated from each jigging machine. To counted and measured of all samples to extrapolate the total catch weight at each station. Effort was recorded in line and hours, which were calculated by multiplying the number of lines actively fishing by the length of time finished. The number of squid lost due to drop-off for a given period of time was also observed.

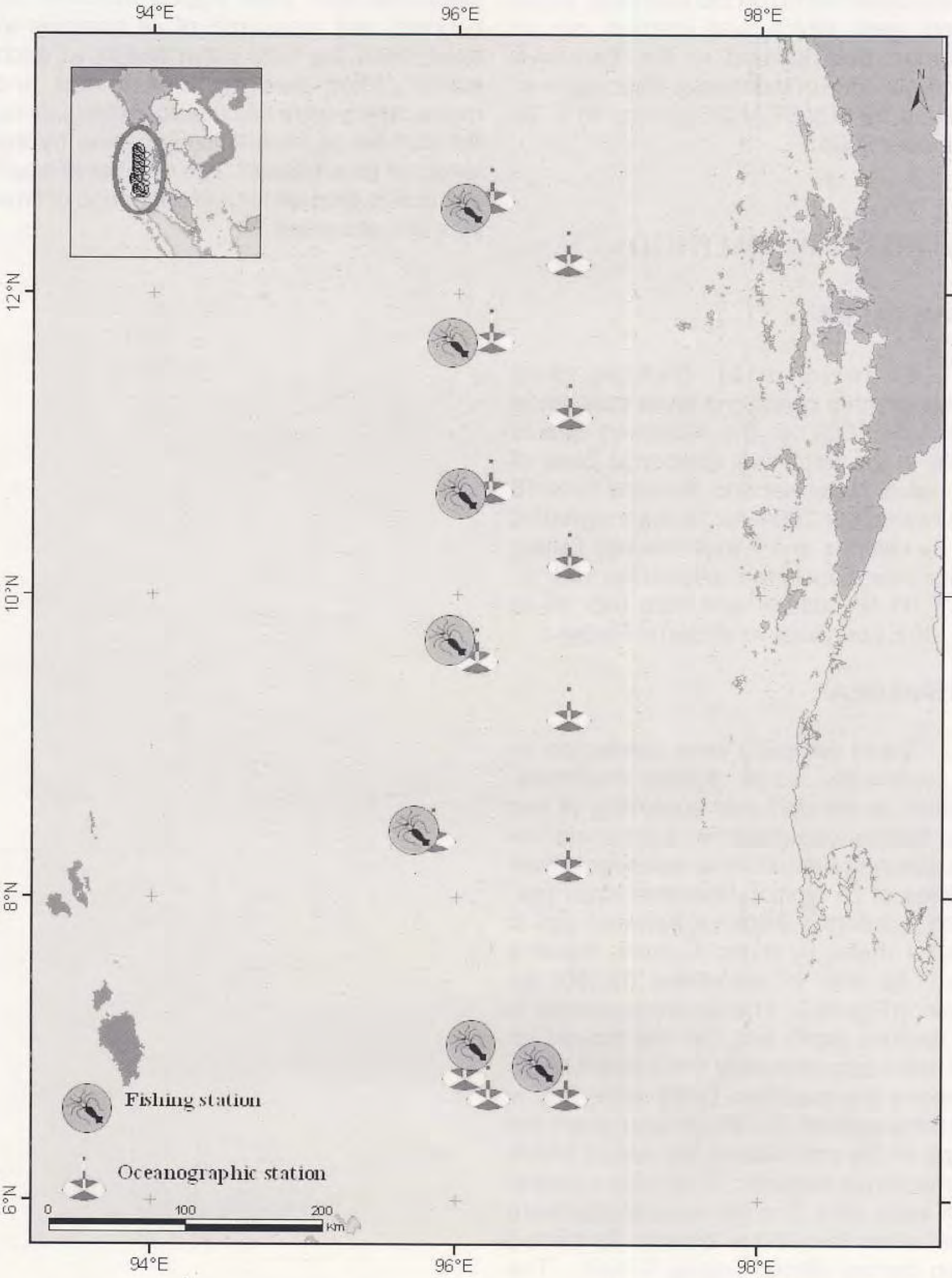
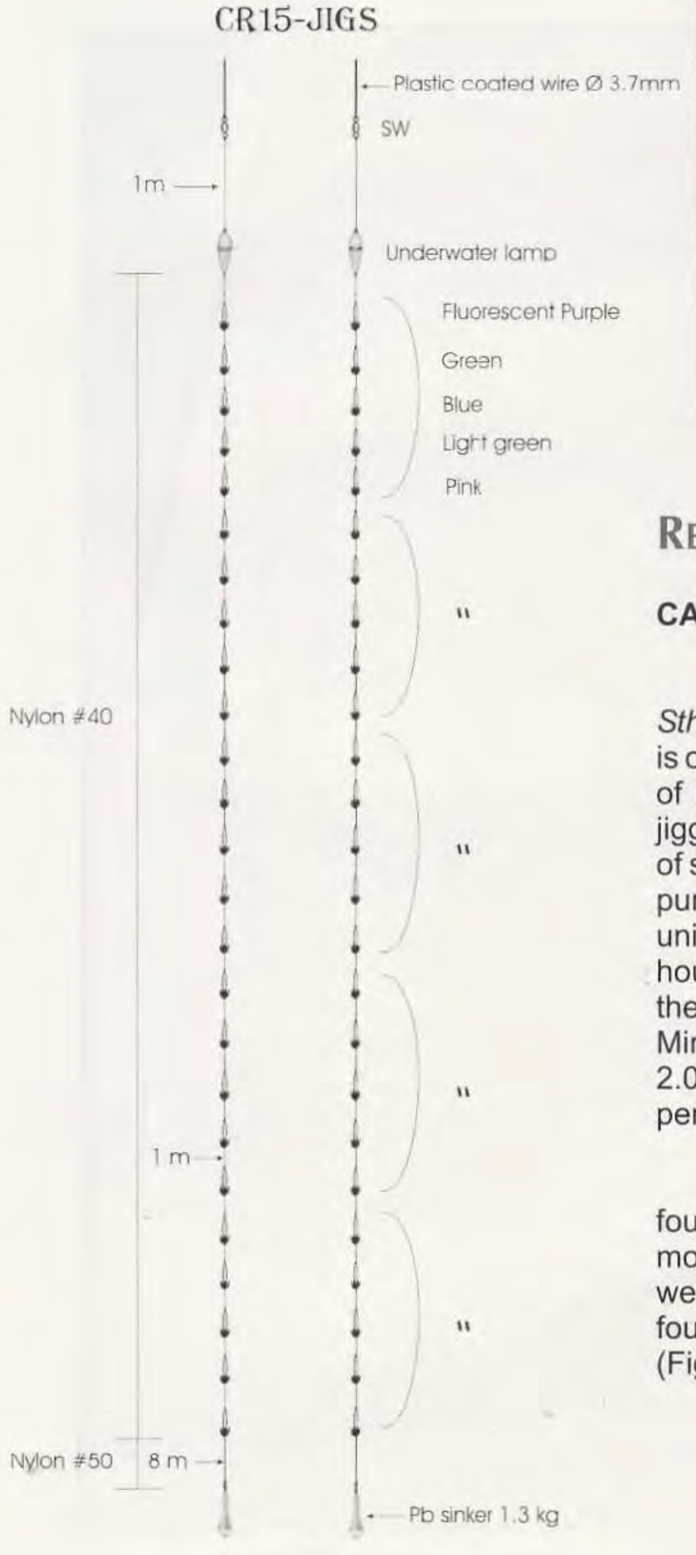


FIGURE 1. Fish sampling and oceanographic survey station in the Andaman Sea during 16 -25 November 2004



CR15 New Kaio Hook and Under water lamp

FIGURE 2. Arrangement of squid jig line and types of squid jig used in the experiment.

RESULTS AND DISCUSSION

CATCH

The purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) is only one species from 7 sampling stations of the survey, caught by automatic squid jigging gear. Table 1 shows the information of sampling stations and catch results of the purpleback squid in term of the catch-per-unit-effort (CPUE, number of squid per line hour). Over the entire survey area, CPUE of the squid average 5.57 squids/line hour. Minimum of the CPUE of the squid were 2.00 squids per line hour and 8.39 squids per line hour were the Maximum.

From the 7 sampling station it was found that almost were high in CPUE which more than 5 squids per line hour. The CPUE were less than 5 squids per line hour were found only two stations at St. #3 and St. #7 (Fig. 3).

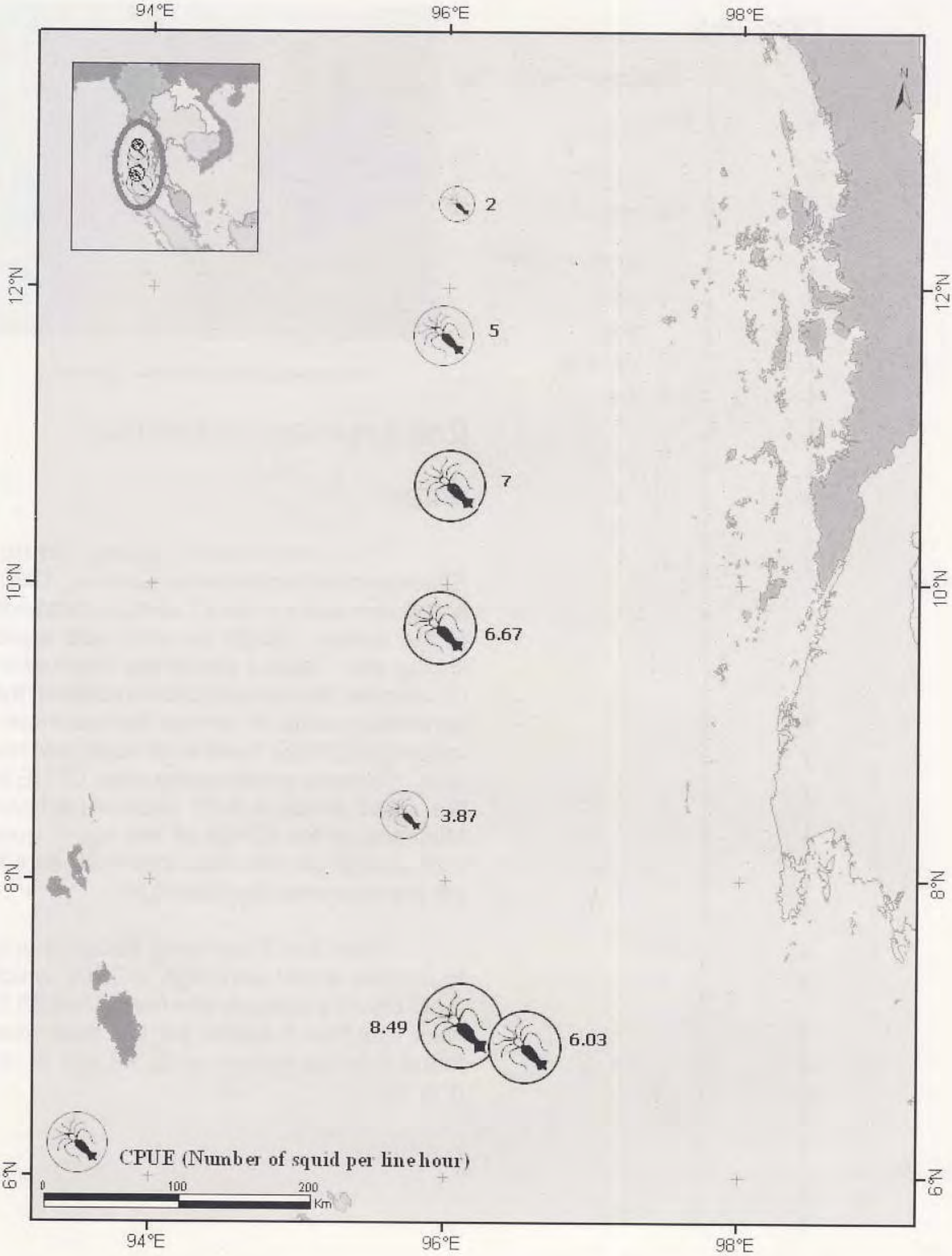


FIGURE 3. CPUEs distribution of the purpleback flying squid in the Andaman Sea

TALBE 1. Information for sampling stations and catch results of the purpleback flying squid in the Andaman Sea

Station no.	Date (year 2004)	LOCATIONS Lat. (N)	Long. (E)	Dept (m)	No. of line	No. of jig	Effort (h)	TOTAL CATCH weight	number	CPUE (ind./line/hr)
1	16-Nov	06_53.06	96_33.46	1,160	4	100	3.15	3.45	19	6.03
2	17-Nov	07_01.48	96_06.75	1,037	4	100	3.18	4.08	27	8.49
3	18-Nov	08_26.67	95_43.47	1,237	4	100	3.1	1.7	12	3.87
4	19-Nov	09_42.38	95_57.31	1,141	4	100	3.3	3.47	22	6.67
5	20-Nov	10_40.07	96_01.53	2,456	4	100	4	2.73	28	7.00
6	21-Nov	11_40.61	95_58.19	2,367	4	100	3	1.27	15	5.00
7	22-Nov	12_34.07	96_03.18	2,334	4	100	4	0.75	8	2.00

REPRODUCTIVE BIOLOGY OF THE PURPLE-BACK FLYING SQUID, *STHENOTEUTHIS OUALANIENSIS* (LESSON, 1830) IN THE ANDAMAN SEA

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ABSTRACT

Purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) were captured by automatic jigging gear during the ASEAN SEAFDEC program on "Harvesting of Under- Exploited Resource, Phase I: Pelagic fisheries Resources Survey in the Andaman Sea" investigated by M.V.SEAFDEC in November 2004. A total number of 129 squid were measured ML and weight, females from 86.00 to 197.00 mm and 19.00 to 346.00 g and males from 103.00 to 126.00 mm and 35.00 to 106.00 g. Length-weight relationship of female and male equal $W = 0.0000014016\ ML^{3.6716}$ and $W = 0.0000000999\ ML^{4.2631}$. Females dominated more than males in the catch being 88% of total number of squid. The males were smaller than the females.

The maturity of squid found that stage 4 dominated in females and males. In addition, the proportion of mature and immature females was equal but in males cannot be seen. The GSI value will be increasing upon an increase of ML in median sizes (150-200 ML mm). Size at first maturity of females and males that was observed from the sampling data equal 98 mm (38 g) and 104 mm (36 g), which is smaller than the estimate as females 150 mm and males 128 mm. The sex ratio found more females than males and varies from 78.57-100%.

INTRODUCTION

Purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830), is oceanic squid distributed in the western Pacific and the Indian Ocean (Figures1 and 2). It occurs throughout tropical and temperate waters of both the northern and southern hemispheres (Roper et al., 1984). Nine species of oceanic squid were found in the Andaman Sea, Thailand (Nateewathana and Hylleberg, 1989; Sawata and Phongsuwan, 1994; Nateewathana, 1995). The classification of Purpleback flying squid follows http://www.cephbase.utmb.edu/ as:

Kingdom Animalia
Phylum Mollusca
Class Cephalopoda Cuvier, 1797
Subclass Coleoidea Bather, 1888
'Cohort' Neocoleoidea Haas, 1997
Superorder Decapodiformes Young et al., 1998
Order Teuthida Naef, 1916
Suborder Oegopsina Orbigny, 1845
Family Ommastrephidae Steenstrup, 1857
Subfamily Ommastrephinae Posselt, 1891
Genus *Sthenoteuthis* Verrill, 1880

The Purpleback flying squid is important in the marine ecosystem and is an economic species in the Japanese and Taiwanese shellfish markets.

FIGURE 1. The purpleback flying squid (S. oualaniensis Lesson, 1830)
(http://www.zen-ika.com/zukan/41-50/p43.htm)

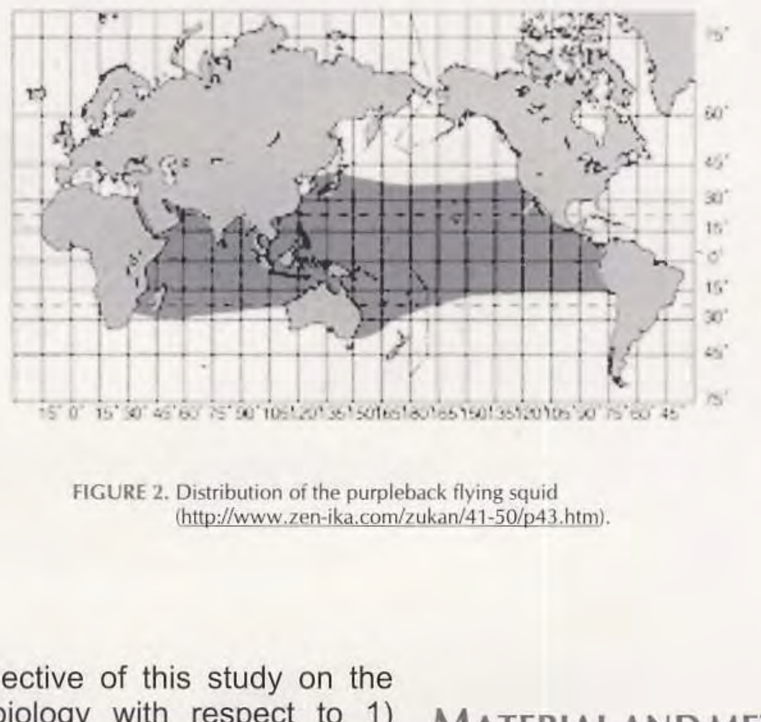


FIGURE 2. Distribution of the purpleback flying squid
(http://www.zen-ika.com/zukan/41-50/p43.htm).

The objective of this study on the reproductive biology with respect to 1) length frequency distribution 2)length-weight relationship 3) maturity stage 4) fecundity 5) sex ratio and 6) stomach content of purpleback flying squid was investigated in the Andaman Sea using the automatic squid jigging gear on M.V. SEAFDEC from 16th-25th November 2004. The outcome of present study will improve the understanding of ecology and oceanic squid resources in the Andaman Sea.

MATERIAL AND METHODS

Survey Area

Experimental fishing and oceanographic conditions were conducted by M.V.SEFDEC in the Andaman Sea located in the Exclusive Economic Zones of Indonesia, Myanmar and Thailand from 16th-25th November 2004. All 13 oceanographic survey stations and 7 experimental fishing stations were designed to cover from 06°30' to 13°00' N Latitude and from 95°30' to 97°00' E Longitude as shown in Figure 3 (Promjinda, 2005).

Data Collection And Analysis

Squid samples were captured by the automatic squid jigging gear at each station and were frozen on board. All of the samples were carried to the Andaman Sea Fisheries Research and Development

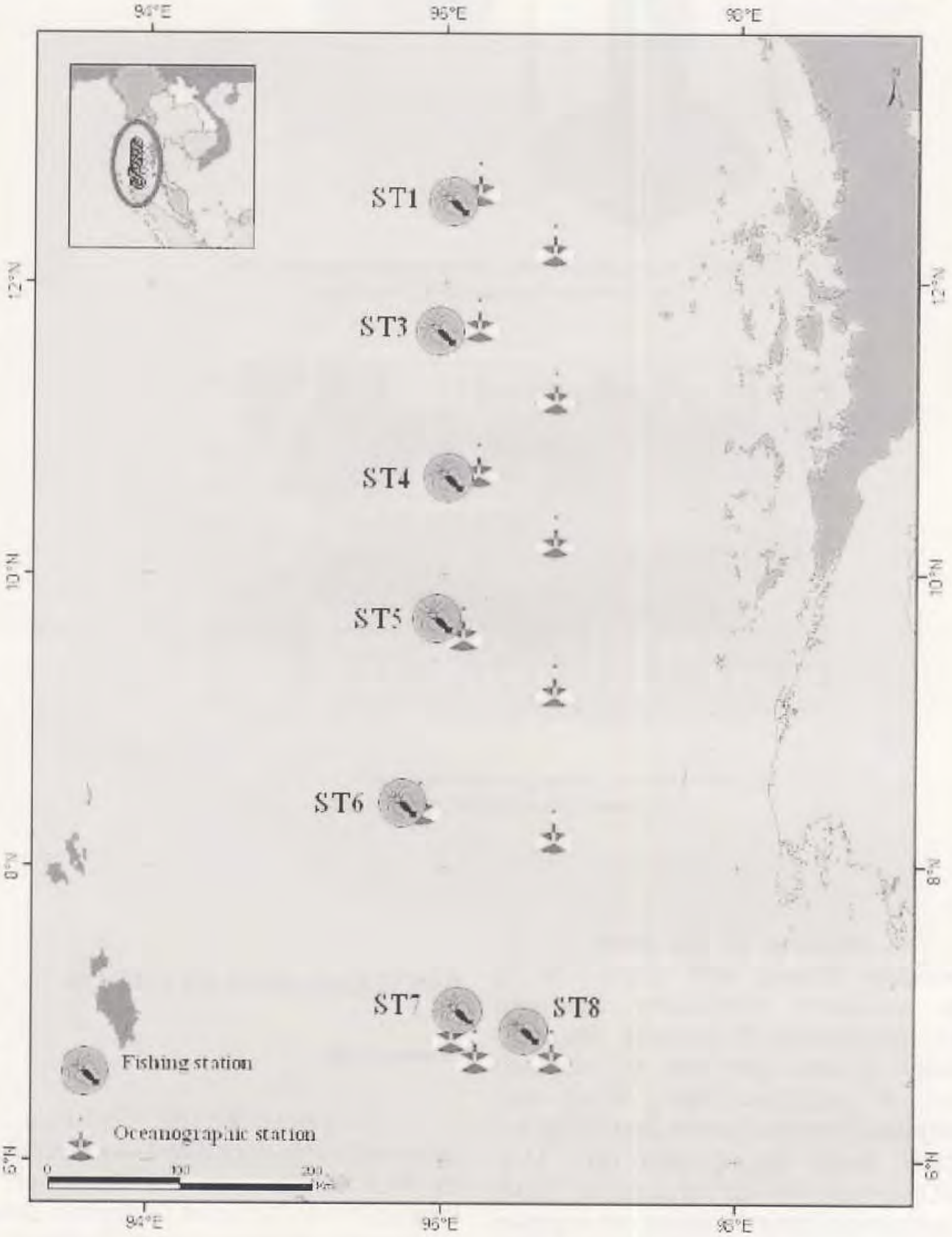
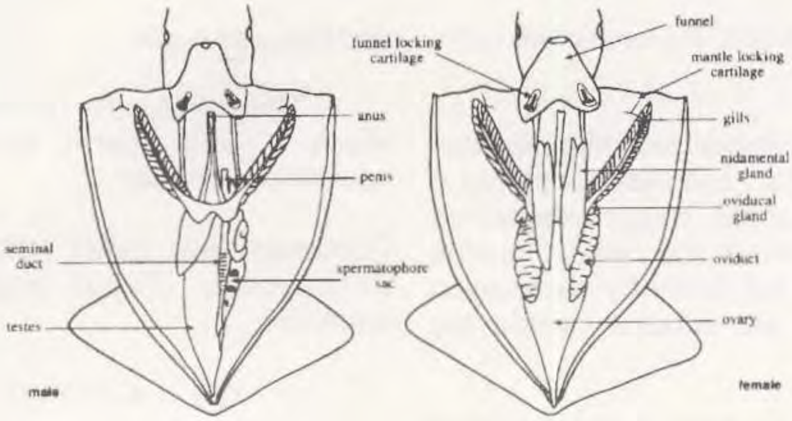


FIGURE 3. Oceanic squid sampling and oceanographic survey station in the Andaman Sea during 16th - 25th November 2004 (Promjinda, 2005)



a) Typical squid

FIGURE 4. Major features of the mantle cavity of a typical squid and the reproductive tract of the female purpleback flying squid.

Center (AFRDEC) laboratory where the samples were identified to be family, genus and/or species. The sex was determined by the presence of hectocotylized arms for males and by observation of the reproductive system. Body weight (BW) in gram units and mantle length (ML) in millimeter units were measured and the length-weight relationship of males and females were calculated by linear regression analysis (Ricker, 1975).

$$W_i = a\,ML_i^b$$

When:

W_i	=	Individual weight (gram)
ML_i	=	Mantle length (millimeter)
a , b	=	Coefficients from regression analysis

Data of ML measurement was examined for length frequency distribution of males and females and plotted on a graph.

Figure 4 shows the reproductive structure of a typical squid and the Purpleback flying squid (*S. oualaniensis* Lesson, 1830) ; a) the reproductive organ of males and females which have the paired nidamental glands (white elongate structures) and paired white oviductal glands and oviducts in the anterior part of the mantle. b) the female reproductive tract of S. oualaniensis (Lesson, 1830).

Gonad (GW) was weighed and determined to the 1-5 maturity stage of males and females. The macroscopic appearance of gonad used the scheme of Juanico (1983) as follows:

Ovary: Stage 1 Immature, Ovary is not clear for determination by external observation. Oviduct and nidamental gland is a translucent sheet, the ovary like milky fascia.

Stage 2 Immature, Musky/rather white ovary. Oviduct and nidamental gland is an expanded sheet, colour milky/white. The Oviduct is coiled and clear to enable determination of the ovary by observation but cannot see the structure inside the ovary.

Stage 3 Immature, Oviduct is more coiled than in 2 stage. The Nidamental gland is bigger and covers part of other organs and oocytes appear.

Ovary: Stage 4 Mature, Nidamental gland is larger and covers a part of the kidney and the liver, oocytes appear in the oviduct. Oocytes is a milky/white colour and moves to oviduct. Oocyst has developed along the ociduct.

Stage 5 Mature ovary like stage 4, but oocysts are more translucent than in the previous stage (>60%), especially in the area near the oviduct. Vicious fluid appears in the nidamental gland.

Testis: Stage 1 Immature, Testis is not clear to be determined by external observation. Spermatophoric complex found translucent/white spot. Testis is a translucent fascia.

Stage 2 Immature, Testis is milky/white colour. Spermatophoric complex is clearly separated. Size of testis is small and not clear for observation inside the testis.

Stage 3 Immature, Translucent testis. Vas deferens is white/milky white colour. Spermatophoric organ is a white line.

Stage 4 Mature, Vas deferens is bigger than in the previous stage, white in colour and coiled. Spermatophoric sac is long and appears to have white particles inside. Sperm doesn't appear. Testis is ridge and fastness tissue.

Stage 5 Mature, Testis is the same as stage 4 and sperm appears in the spermatophoric sac.

Gonadosomatic Index (GSI) follows the Bakhayokho (1983) method as the equation:

$$GSI = (GW/BW) \times 10^3$$

Size at first maturity was estimated to follow Bakhayokho (1983), 50 % of maturity stages 4-5 of female and male were used to be the initial value for estimation. The proportion of the maturity stage each frequency of length class followed Somerton (1980) the equation is:

$$Y = \frac{1}{(1 + e^{(A+Bx)})}$$

When:

Y = Proportion of maturity stage from total number at Ml_x.,
X Mode of ML in each class interval.
A, B = Coefficient valves from regression analysis.

Fecundity study, the ovaries at stage 5 were fixed in 10% formalin and counted (Fulton, 1981).

Sex ratio: the proportion of males and females at each station was used to assume the spawning capability of the fish (Hamano and Matsuura, 1987). In this study the sex ratio in percentage was calculated by using the formula:

$$\text{Sex Ratio (\%)} = 100 * F / (M + F)$$

When:

F = Number of female
M = Number of Male

Stomach content samples were removed from the stomach of the purpleback flying squid, had measured for ML and BW already, after that fixed in 10% formalin. The composition of the prey was identified and calculated for percentage of food by the gravimetric method.

RESULT AND DISCUSSION

1. Target Species

Result from 7 sampling stations of the survey area show that only the purpleback flying squid, *S. oualaniensis* (Lesson, 1830) were caught by the automatic squid jigging gear. This species was confirmed and followed previous reports of Nateewathana (1997) and Carpenter and Niem (1998).

2. Length Frequency Distribution

Figure 5 shows the length frequency distribution for the purpleback flying squid at each fishing station. At all the stations, the number of the females was quite obviously more than the males. The result found that males ranged from 103.00 mm to 126.00 mm and the females ranged from 86.00 mm

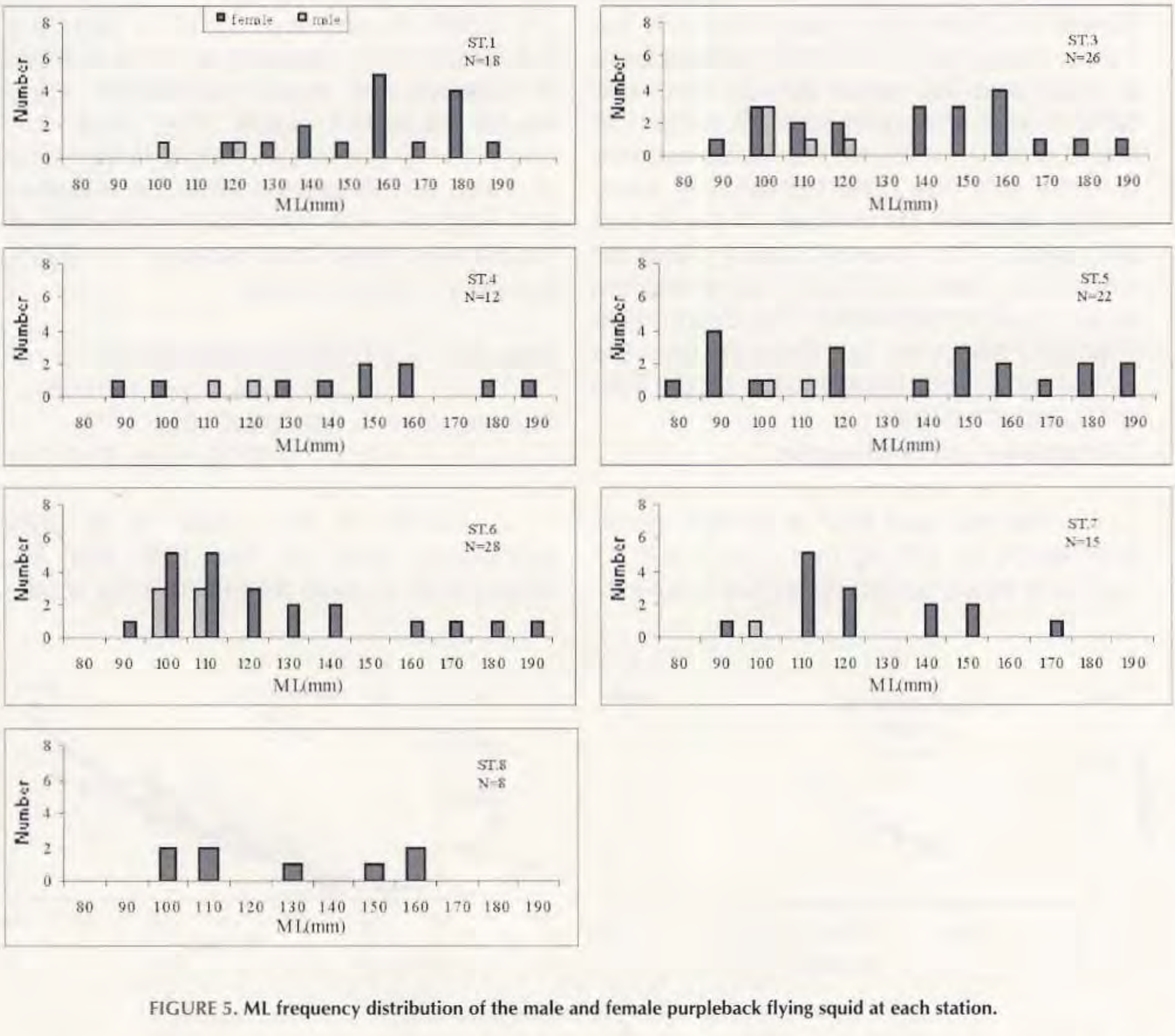


FIGURE 5. ML frequency distribution of the male and female purpleback flying squid at each station.

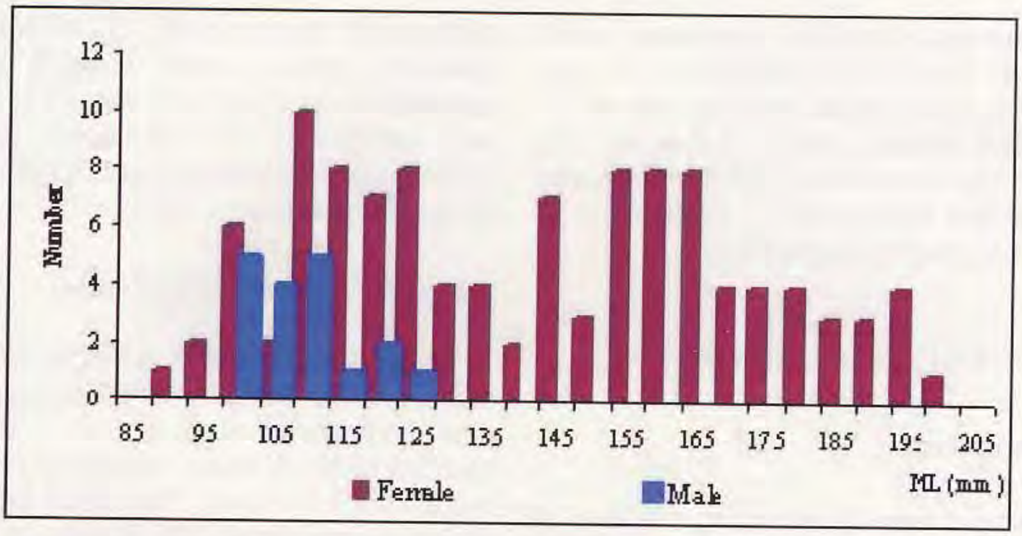


FIGURE 6. ML frequency distribution of the male and female purpleback flying squid in the Andaman Sea.

to 197.00 mm in Figure 6. Two modes of female ML distribution were found in the survey area. About 75% of the females were of small size (ML range 80-150 mm.) and the rest were of medium size (ML range 150 and 200 mm). However, the males seemed to show only one cohort present at every station, because the numbers of males was too small. The present study reported similarly to Basir (2000) and Siriraksophon et. al. (2001) in the South China Sea and the Western Philippines but there the reported size of purpleback flying squid is bigger than in the Andaman Sea.

3. Length-weight Relationship

The ML and BW of female varied from 86.00 to 197.00 mm (140.31±28.87 mm) and 19.00 to 346.00 g (129.50±84.27 g), males from 103.00 to 126.00 mm (111.89±6.99 mm) and 35.00 to 106.00 g (55.89±17.17 g), respectively. The number of females and males purpleback flying squid samples were 111 and 18, respectively. The length-weight relationship of males and females is shown in equation and Figure 7. The correlation coefficient of female was higher than males (r^2 = 0.9295, female; r^2 = 0.8944, male).

Male, W = $0.0000000999\ ML^{4.2631}$ (r^2 = 0.8944, t-test $P<0.05$)

Female, W = $0.0000014016\ ML^{3.6716}$ (r^2 = 0.9295, t-test $P<0.05$)

Result of the t-test at a 95% confidence level on the BW and ML relationship showed that BW-ML for males

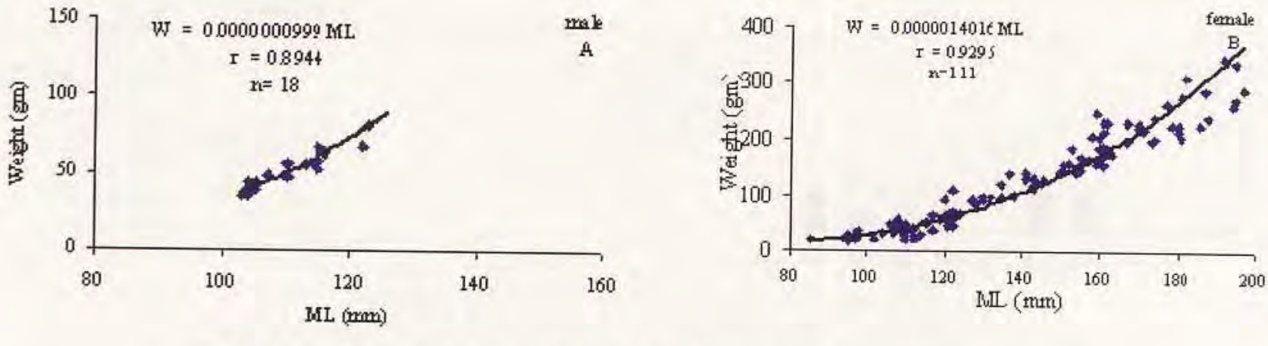


FIGURE 7. Length-weight relationship for males (A) and females (B) of the purpleback flying squid.

and females were significantly ($P<0.05$) different from 3. That means the growing allometrically in males and females (increasing in all dimension at not the same rate). This result is the same as the previous report of Basir (2000) and Siriraksophon et. al. (2001) who studied on S. oualaniensis (Lesson, 1830) in the South China Sea and the Western Philippines.

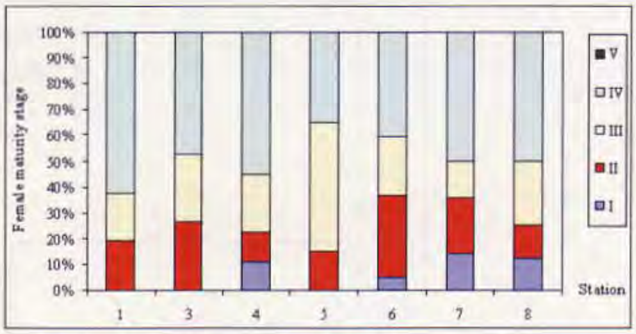


FIGURE 8. Percentage of female maturity stage of purpleback flying squid in Andaman Sea.

4. Maturity Stage

At all stations, there are 126 samples that can determine sex by reproductive organs from 129 samples, 108 females and 18 males. Stage 4 dominated by female and male maturity but not found at stage 5 in this study (female:4.63%, 21.30%, 26.85%, 47.22% and 0.00% in stage 1-5, male 0.00%, 5.56%, 33.33%, 61.11% and 0.00%) (Figure 8). Figure 9 shows the percentage of maturity of male and female squid at each station. At all stations, the mature and immature females were equal. However the number of male samples was small, it was impossible to note and distinctly the difference between mature and immature. Figure 10 presents the results of the GSI and ML of females, GSI is separated into two groups, small (80-150 ML mm) and medium (150-200 ML mm) size of the purpleback flying squid. In addition, the GSI value will increase upon an increase of ML in the median size.

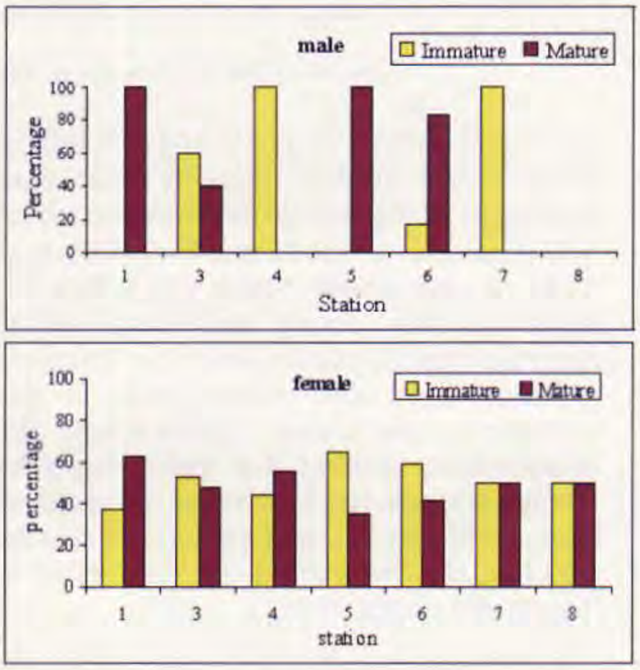


FIGURE 9. Percentage of mature and immature female purpleback flying squid in Andaman Sea.

Size at first maturity of females and males was observed from sampling data

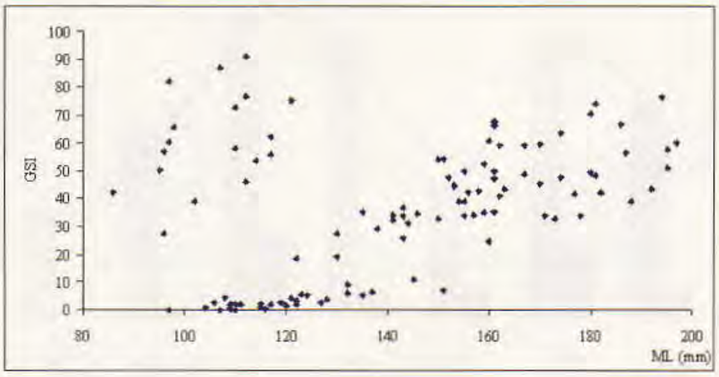


FIGURE 10. Change of GIS and ML of female purpleback flying squid in Andaman Sea.

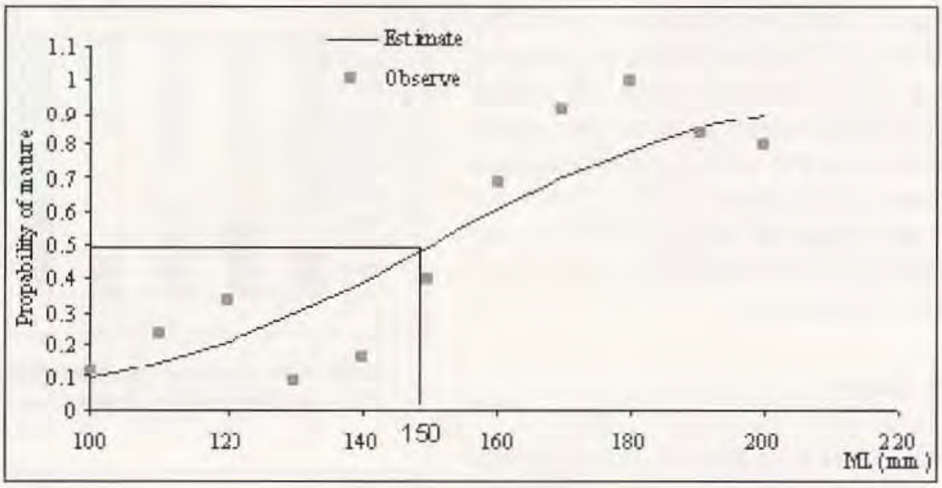


FIGURE 11. Size at first maturity of female purpleback flying squid in the Andaman Sea.

and equal 98mm (38 g) and 104 mm (36 g). While, size at first maturity that was estimated of the female and male to equal 150 (Figure 11, r^2= 0.85 and P=0.009)) and 128 mm, respectively, that is longer than the observed data. Young and Hirota (1998) reported that *S. oualaniensis* continuously matures eggs and stores them in the oviducts between spawning. *S. oualaniensis* around the main Hawaiian Islands and reaches maturity at the smallest size of 158 mm ML and the largest size as 200 mm ML (Herman *et. al.*,1989: cited in Young and Hirota, 1998).

6. Fecundity

This survey doesn't have an ovary stage 5 following the Fulton (1981) method studies on fecundity. Then, there is no result fecundity of purpleback flying squid in the Andaman Sea.

Herman et. al. (1989: cited in Young and Hirota, 1998) reported that a 300 mm ML female carries about 250,000 eggs in its oviducts. The extra large (XL) form of the squid, *S. oualaniensis* from the Arabian Sea has a potential fecundity ranged between 2-5 million eggs and the holding capacity of the oviducts was approximately 300,000 eggs. A strong correlation between ovary mass and ML was found (r^2= 0.64). Poor correlation was found between the mantle length and oviduct mass (r^2= 0.128) and potential fecundity (r^2= 0.07) (Snyder,

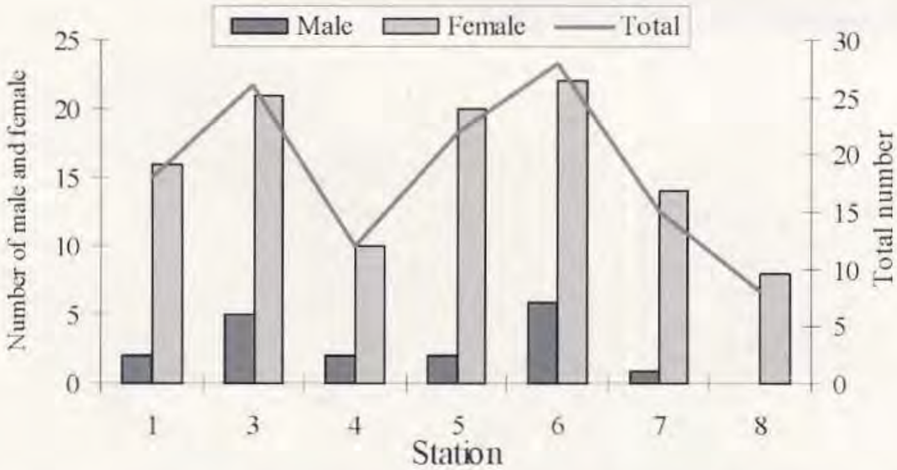


FIGURE 11. Sex composition of purpleback flying squid caught during the survey in the Andaman Sea.

1998).

7. Sex Ratio

Figure 11 shows the sex composition of purpleback flying squid captured in the waters of the Andaman Sea. The number of females outnumbered the males at all stations. The percentage sex ratio of purpleback flying squid in Andaman Sea varies between 78.57-100% by females. The whole populations seemed to be dominated by females, which are much longer than males, the results showed a natural sexual dimorphism of this species. All results conformed to the previous report of Basir (2000) and Siriraksophon et. al. (2001).

8. Stomach Content

On board, the stomach content wasn't removed from the purpleback flying squid samples before freezing, as the freezer in the AFRDEC laboratory doesn't work well. Thus, the stomach contents of the squids had been digested and damaged. We cannot study the stomach content of the purpleback flying squid .

For the *S. oualaniensis* (Lesson, 1830) in the waters off the western Philippines, the main prey of the squids were crustaceans, fishes (mainly flying fish) and squid (including *S. oualaniensis*). They migrate upwards to the surface for feeding at dusk and night and downwards to the deep layer before dawn and daytime (Basir, 2000 and Siriraksophon et. al., 2001). Shchetinnikov (1992) studied the purpleback flying squid from the Eastern Tropical Pacific and found that a rapid decline of crustaceans in the squids diet and their frequency of occurrence and proportion of contents in stomach for squid between 100 and 150 mm ML, in squid size greater than 150 mm the diet consisted predominantly of fishes (70%) and squids (30%). Young (1975) reported *S. oualaniensis* (Lesson, 1830) caught off the leeward side of Oahu fed predominantly on fishes.

REFERENCES

Bakhayokho, M. 1983. Biology of the Cuttlefish *Sepia officinalis hierredda* in the Senagalese Coast. Advances in the Assessment of the World Cephalopod Resource. FAO Fish. Tech. Pap., 231: 204-263.

Basir, S. 2000. Biological feature of Oceanic Squid, S. *oualaniensis* in the South China sea, Area III: Western Philippines. In the Proceedings of the Third Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area III: Western Philippines. Special Paper No. SEC/SP/41, SEAFDEC, Bangkok. pp. 135-147.

Carpenter, K.E. and V.H. Niem. 1998. Cephalopods In : FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 2. FAO, Rome. pp. 688-826.

Fulton, T.W. 1981. The comparative fecundity of Sea-fishes. Fish. Bd. Scotland, 9th. Ann., Pt 3 p., 243-268.

Hamano, T. and S. Matsuura. 1987. Sex ratio of the Japanese mantis shrimp in Hakata Bay. Nippon Suisan Gakkaishi, 53(12): 2279.

Herman, R. F., R. E. Young, S. B. Reid, K. M. Mangold, T. Suzuki & R. F. Hixon, 1989. Evidence for multiple spawning in the tropical oceanic squid *Sthenoteuthis oualaniensis (Teuthoidea: Ommastrephidae)*. Marine Biology, 101:513-519.

Juanico, M. 1983. Squids maturity scales for population analysis. In : Advances in Assessment of World Cephalopod Resources, J. F. Caddy (ed). FAO Fisheries Technical Paper No. 213. F and Agriculture Organization of the united Nations. Rome, pp. 314-378.

Nateewathana, A. and J. Hylleberg.1989. Fish Record of oceanic squids, *Thysanoteuthis rhombus* Troschel, 1857 (Cephalopoda : Teuthoidea) in Thai water. The Natural History Bulletin of the Siam Society 37(2): 227-233.

Nateewathana A. 1995. New Record of oceanic squids from Thai waters, the Andaman Sea. Phuket Marine Biological Center Research Bulletin 60 : 1-19.

Nateewathana A. 1997. Two species of oceanic squids from the Andaman Sea, Indian Ocean. *Phuket mar. biol. Center Special* Publ. No.. 17 (2) : pp.453-464

Promjinda, Sayan. 2005. Oceanic squid, *Sthenoteuthis oualaniensis* resources survey in Andaman Sea within the water off Indonesia, Myanmar and Thailand. (Unpublished manuscript)

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191. Department of the Environment Fisheries and Marine Service. Pp. 207-215.

Roper, C.E.F., Sweeney, M.J. and Nauen, C. 1984. Cephalopods of the World, Vol. 3, An annotated and illustrated catalogue of species of interest to fisheries. FAO Fisheries Synopsis No. 125, Rome, 277 pp.

Sawata, H. and N. Phongsuwan. 1994. Occurrence of *Nautilus pompileus* in the eastern part of Indian Ocean Andaman Sea. Phuket Marine Biological Center Research Bulletin 59 : 99-100.

Shchetinnikov, A.S. 1992. Feeding spectrum of squids *Sthenoteuthis oualaniensis* (Oegopsis) in the Eastern Pacific. Jour. Mar. Biol. ass. U.K. 72:849-860.

Siriraksophon, S., N. Sukramongkol and Y. Nakamura. Exploration of Oceanic Squid, *Sthenoteuthis oualaniensis* Resources in the South China Sea, Vietnamese Waters. In the Proceeding of the Fourth Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area IV: Vietnamese Waters. Special Paper No. SEC/SP/44, SEAFDEC, Bangkok. pp. 181-197.

Somerton, D.A. 1980. A computer technique for estimating the size of sexual maturity in crabs. Can. J. Fish. Aquat. Sci. 37:1488-1494.

Snyder, R. 1998. Aspects of the biology of the giant form of *Sthenoteuthis oualaniensis* (Cephalopoda: Ommastrephidae) from the Arabian Sea. Journal of Molluscan Studies, Vol 64: 21-34

Young, R.E. 1975. A brief review of the biology of the oceanic squid, *Symplectoteuthis oualaniensis* (Lesson). *Comp. Biochem. Physiol.*, 52B: 141-144.

Young, R.E. and Hirota, J. 1998. Review of the ecology of *Sthenoteuthis oualaniensis* near the Hawaiian Archipelago. In the International Symposium on Large Pelagic Squids. Japan Marine Fishery Resources Research Center, Tokyo. pp. 131-143.

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