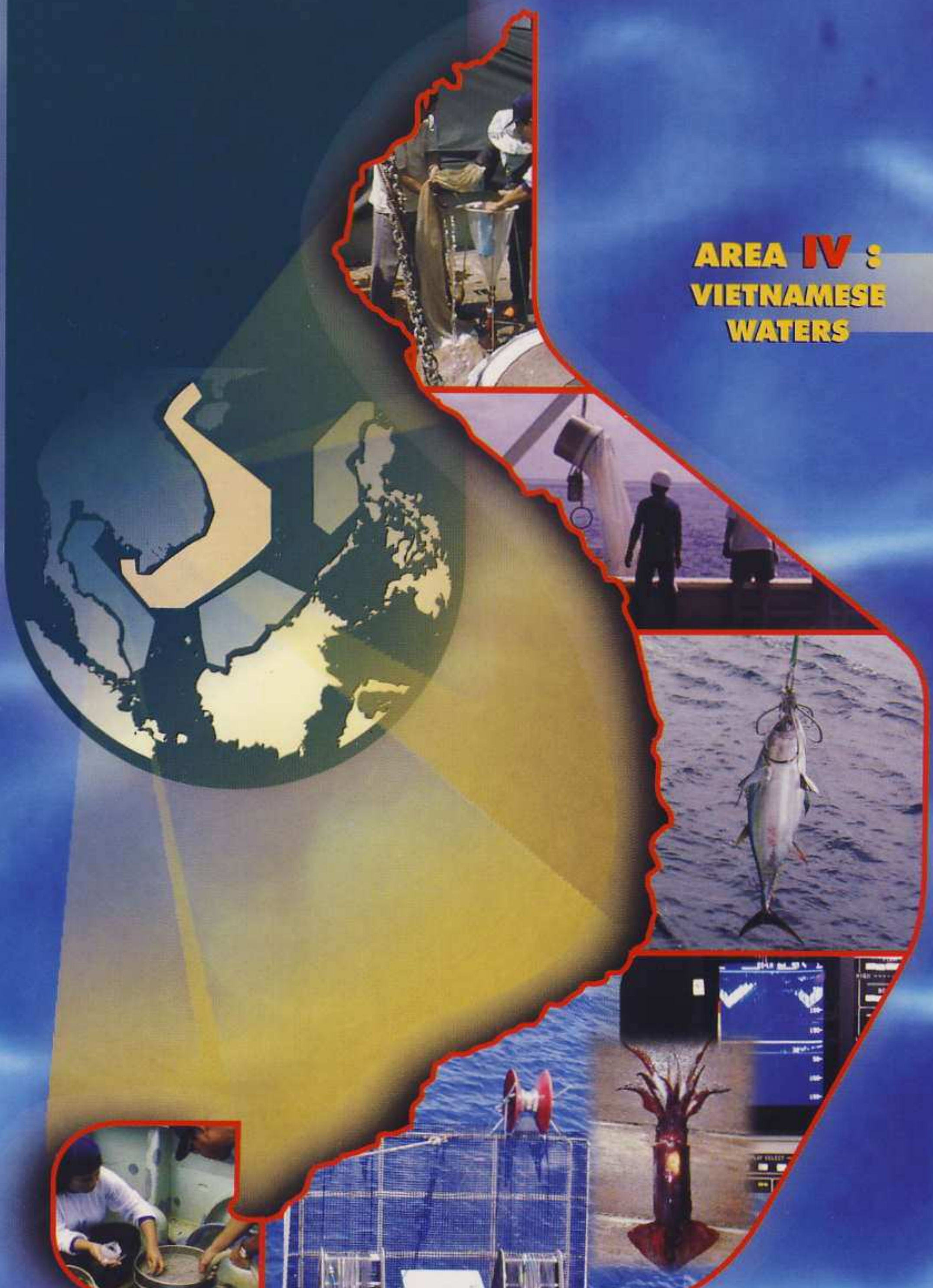
PROCEEDINGS OF THE 4th TECHNICAL SEMINAR ON MARINE FISHERY RESOURCES SURVEY IN THE SOUTH CHINA SEA

AREA IV : VIETNAMESE WATERS



THE SECRETARIAT
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
BANGKOK
APRIL 2001

TD/SP/29

SEAFDEC INTERDEPARTMENTAL COLLABORATIVE RESEARCH PROGRAM

Proceedings of the Fourth Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area IV: Vietnamese Waters

18 - 20 September 2000

A Collaborative Research Program between

MARINE FISHERY RESOURCES DEVELOPMENT AND MANAGEMENT DEPARTMENT/SEAFDEC KUALA TERENGGANU, MALAYSIA

and

TRAINING DEPARTMENT/SEAFDEC SAMUT PRAKAN, THAILAND

in cooperation with

RESEARCH INSTITUTE OF MARINE PRODUCTS, VIETNAM

**THE SECRETARIAT
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
BANGKOK, THAILAND**

APRIL 2001

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FOREWORD

This, the fourth in the series of Technical Seminars on Marine Resources Survey, continues the essential evaluation of marine resources available in the South China Sea. This latest seminar is an evaluation of the waters of Vietnam. In the series of surveys this is identified as Area IV. There are two vital results from the survey activities, the first of these is that the scope, species composition and biomass estimation of the regional waters are assessed. Secondly another aspect is emphasized, that of the element of cooperation between the nations of the region such that no one country is isolated. The knowledge derived from these surveys serves to augment the broad picture of the region by painting in the national and EEZ details of marine stocks of the regional countries. If policy decisions on fisheries are to be collectively taken in the region it is an essential feature of decision making that as much information as possible is known to find the decisions upon.

In this, the fourth area survey, undertaken in April and May 1999, the collaborative study involved The Research Institute of Marine Products (RIMP) of Vietnam, The Marine Fisheries Resources Development and Management Department of SEAFDEC (MFRDMD), Malaysia, and the Training Department of SEAFDEC (TD), Thailand. The tools used were the state of the art instrumentation available onboard MV. SEAFDEC backed up by fishing operations to confirm the instrumentation assessments. The area surveyed involved some 581,000 square kilometers with depths varying between 23 to over 4,000 meters in the deep-sea area off the coastline of Nha Trang.

The scope of the survey included the assessment of the dynamics of fish population and productivity through the primary production evaluation of nano, phyto and zooplankton with an assessment of ichthyoplankton giving an insight into the spawning success of various species. The oceanographic fundamentals of temperature, salinity and dissolved oxygen were measured at some 58 stations from approximately latitude $7^0.00 - 21^0.00$ N and longitudes of $103^0.00 - 112^0.00$ E using 16 East – West transects to cover the long coastline of Vietnam. Measurements were also taken to assess the pre sence, or otherwise, of chemical and metal concentrations in the water. Oil pollution surveys of both the water and the underlying sediment were similarly made.

The scientific papers submitted for presentation for the seminar were of an exceptionally high standard and represent a most valuable source of information on the waters. It is thus my pleasant duty to accord the most grateful thanks of SEAFDEC to all who participated in this expedition and contributed their most erudite and conscientious rendering of minutiae and detail to the overall success of the mission.

The information presented at this seminar forms a consolidated foundation for future investigations into fish stocks and will serve as part of the fundamental guide that determines the sustainability of marine resources and is another part of the puzzle that is regional fisheries. Gradually and carefully all the pieces are being assembled and the patterns of fisheries management are becoming clearer. The detailed information that has been derived from this survey is of immense value to the region, Vietnam and to the overall regional fisheries database assembled by SEAFDEC.

Panu Tavarutmaneegul
Secretary-General

THE OPENING STATEMENT

by

H.E. Dr. Ta Quang Ngoc

Minister of Fisheries

Socialist Republic of Vietnam

Dear Mr. Shogo Sugiura, SEAFDEC Deputy Secretary General, ladies and gentlemen. On behalf of the Ministry of Fisheries of the Socialist Republic of Vietnam I would like warmly to welcome all of you for attending this Technical Seminar to be held today at the Research Institute of Marine Products, Hai Phong City.

We are all knowing that SEAFDEC has carried out a large research programme in the water of its member contries in the South China Sea for many years. Within the framework of this collaborative research programme, the first surveying of Vietnamese waters was conducted by MV SEAFDEC and Bien Dong Research Vessel of the RIMP in April - May 1999. This seminar is organized to discuss about the research achieved from the above collaborative surveying of Vietnam and SEAFDEC scientists, from those to draw conclusions providing for the fisheries development and management of Vietnam and contribution for understanding about marine resources of other countries in the region. Beside of that, the research results are also contributed to research sector of oceanography and marine biology of the South China Sea.

For conclusion this SEAFDEC programme besides of the scientists from the Research Institute of Marine Products are experienced scientists of the Nha Trang Oceanography Institute, Hai Phong Oceanography Sub-Institute, Chemistry Institute, Geology Institute and experienced scientists of SEAFDEC, of Universities, Research Institutes of Thailand, Malaysia, Japan. Through working on the research vessel, analysing and editing of data, and preparing reports, all scientists involving in this program set an example for close cooperation and friendship.

On this occasion, I would like to congratulate SEAFDEC on successful organization of collaborative research survey in Vietnamese waters and highly appreciates all scientists involving in this Programme.

Distinguished participants,

The Vietnamese Fisheries sector is on the way of development, it is considered as one of the leading economic sector by Vietnamese Goverment. The Ministry of Fisheries is doing its best to manage the fisheries on the way for sustainable development. In order to achieve that we have to understand clearly about marine resources and ocean-biological characteristics of Vietnamese waters. Because of that, the Ministry of Fisheries of Vietnam always highly appreciates all contribution of all projects which can supply scientific results for the fisheries managment and for making appropriate national policies.

As you know, the South China Sea is located in the tropical monsoon zone, ocean-biological factor and marine resources have been fluctuated much according to the time of two monsoon seasons. The original program on marine resource research of SEAFDEC in the South China Sea determinded the research time for each sea area carried out in the period of the two monsoon seasons. That is good and necessary experience. The Ministry of Fisheries of Vietnam do hope to have adequate research surveyings in the two seasonal periods for getting essentail scientific data serving for our national fisheries management.

The Ministry of Fisheries and scientists of Vietnam strongly belive that further collaborative fisheries research in the region for the common economic development and for strengthening co-operation among SEAFDEC member country are stronger day by day.

Ladies and gentlemen,

I would like to wish the success of our Seminar and wish your fruitful working days in Haiphong Seaport City on wonderful autumn days in our country.

Now, I declare for opening the 4th SEAFDEC Technical Seminar on "Research on Marine Resources in the South China Sea, Vietnamese waters".

Thank you.

2001 SEAFDEC Council of Directors

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Program for the fourth Technical Seminar of the Interdepartmental Collaborative Research Program: Report on Marine Fishery Resources Survey in the South China Sea, Area IV: Vietnamese Waters

Research Institute of Marine Products, Hai Phóng, Vietnam

(18 - 20 September 2000)

Sept. 18 (Mon.) Day 1

0830-0900	:	Registration
0900-0910	:	Welcome Address by ***Minister of Fisheries H.E. Dr. Ta Quang Ngoc***
0920-0935	:	Address and Introduction by ***Deputy Secretary-General of SEAFDEC Mr. Shogo Sugiura***
0935-1000	:	Coffee Break
Session I	**:**	**Fishery Resources**
		Moderator : Mr. Rosidi Ali (SEAFDEC/MFRDMD)
1000-1020	:	Pelagic Stock Assessment by Hydroacoustic Method ***Mr. Raja Bidin Bin Raja Hassan (SEAFDEC/MFRDMD)***
1020-1040	:	Assessment of Relative Abundance of Fishes Caught by Gillnet ***Dr. Chu Tien Vinh (RIMP)***
1040-1100	:	Tuna Resource Exploration with Tuna Longline ***Mr. Pratakphol Prajakjitt (SEAFDEC/TD)***
Session II	**:**	**Fishery Biology**
		Moderator : Mr. Shunji Fujiwara (SEAFDEC/MFRDMD)
1100-1120	:	Fish Taxonomic Studies ***Mr. Osman Muda (SEAFDEC/MFRDMD)***
1120-1140	:	Species Composition, Abundance and Biomass Distribution of Zoobenthos ***Dr. Pham Dinh Trong (VN/HIO)***
1140-1200	:	Composition, Abundance and Distribution of Zooplankton ***Mrs. Jutamas Jivalak (TD/DOF)***
1210-1400	:	**Lunch**
		Moderator : Dr. Suchint Deetae (Kasetsart University)
1400-1420	:	Composition, Abundance and Distribution of Fish Eggs and Larvae ***Dr. Bui Dinh Chung (RIMP)***
1420-1440	:	Study of Biology of Tuna ***Dr. Chu Tien Vinh (RIMP)***
1440-1500	:	The Systematics and Distribution of Oceanic Cephalopods ***Dr. Anuwat Nateewathana (TD/DOF)***
1500-1520	:	Refreshment/Coffee Break
1520-1540	:	Exploration of Oceanic Squid, *Sthenoteutis oualaniensis* Resources ***Dr. Somboon Siriraksophon (SEAFDEC/TD)***
1800-2100	:	Welcome Party Hosted by RIMP

Sept. 19 (Tue.) Day 2

Session III	**:**	**Primary Production**
		Moderator : Mr. Somsak Chullasorn (TD/DOF)
0920-0940	:	Nanoplankton Distribution and Abundance ***Dr. Lokman Bin Shamsudin (MFRDMD/UPM)***
0940-1020	:	Sub-Thermocline Chlorophyll Maxima ***Dr. Suchint Deetae(TD/KU)***
1020-1040	:	Refreshment/Coffee Break
1040-1110	:	Distribution, Abundance and Species Composition of Phytoplankton ***Dr. Canh Tien Nguyen(VN)***
1110-1130	:	Species Composition, Abundance and Distribution of Phytoplankton in the Thermocline Layer ***Ms. Sopana Boonyapiwat (TD/DOF)***
Session IV	**:**	**Fishery Oceanography**
		Moderator : Dr. Bui Dinh Chung (RIMP)
1130-1200	:	Analysis and Pre-estimation of Nutrients in Seawater ***Dr. Le Lan Anh (VN)***
1210-1400	:	**Lunch**
1400-1420	:	Temperature, Salinity, Dissolved Oxygen and Water Masses ***Ms. Penjan Rojana-anawat (SEAFDEC/TD)***
1420-1440	:	Climatological Regime and Weather Condition Occured on the Cruise Expedition (May 1999) ***Dr. Bui Xuan Thong (VN)***
1440-1500	:	Geostrophic and Drift Current ***Dr. Pham Ninh Van (VN)***
Session V	**:**	**Environmental Studies**
		Moderator : Dr. Vu Van Trieu (RIMP)
1500-1520	:	Analysis and Estimation of Trace Metals in Sea Water ***Mr. Vu Duc Loi (VN/NÇST)***
1520-1540	:	Coffee Break
1540-1600	:	Sedimentological Characteristic of Bottom Sediment of Vietnam Coastline ***Dr. Dao Thi Mien (VN)***
1600-1620	:	Oil Pollution ***Dr. Dang Thi Cam Ha (VN)***
1620-1640	:	Closing address by ***Deputy Secretary-General of SEAFDEC Mr. Shogo Sugiura***

Discussion and Conclusion on the Results of the 4th Technical Seminar on Marine Fishery Resources in Vietnamese Waters

1640-1750	:	- Open the discussion led by ***Dr. Bui Dinh Chung*** - Opinion from each moderator in each session - Highlights of each session and conclusion

Sept. 20 (Wed.) Day 3

0900-1100	:	Steering Committee Meeting

Technical Paper

Pelagic Stock Assessment by Hydroacoustic Method in the South China Sea, Area IV: Vietnamese Waters

Raja Bidin Raja Hassan [1], Rosidi Ali [1], Nguyen Lam Anh [2], Vu Duyen Hai [2], Shunji Fujiwara [1], Kunimune Shiomi [1] and Nadzri Seman [1]

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ABSTRACT

A collaborative acoustic survey between the Research Institute of Marine Products (RIMP), Vietnam and the Marine Fishery Resources Development and Management Department (MFRDMD) of SEAFDEC, was carried out in Vietnam waters from April, 29 to May, 29 1999. Survey was conducted by using the scientific echo sounder, FQ70 installed on board of MV SEAFDEC. Survey transects were designed perpendicular to the coastline with standard length of 60 nautical miles. The vessel was cruised at 10 knot and stopped at each station for oceanographical sampling. During cruising, the back scattering strength, SV were collected and saved in multiple storage media. SV values were verified during data analyses by removing any noise and scattering layers. The back scattering values by area (SA) is calculated and the fish density by transects are produced. Using those parameters, the biomass of pelagic is estimated based on representative species from the sampling program and national fisheries statistics. Pelagic biomass in Vietnamese waters was estimated at 9.26 x 10^6 tonnes with the average density of 15.93 tonnes/km^2. This estimation is based on dominance species of *Decapterus maruadsi.*

Key words : Acoustic survey, SV, SA, representative species, biomass estimation

Introduction

Acoustic is a tool for fish stock assessment and becoming more important in the future. Its capability to cover wide area in short time duration may reduce the overall operation cost required for such assessment study. Hydroacoustic methods potentially provide a cost-effective assessment technique to obtain pelagic fishes abundance estimates within the South China Sea. Such methods are attractive since the estimates are independent of the fishery and it is feasible to obtain results rapidly. Furthermore, there are no alternative methods available with comparable pelagic fish sampling power.

SEAFDEC has ventured into this discipline of studies since 1995. The first survey in 1995 has covered the first area in the Gulf of Thailand and the East Coast of Peninsular Malaysia (Albert *et al*, 1998). The second survey confined in the area of Sarawak, Brunei and Sabah (Rosidi *et al*, 1998) , while the third survey was conducted in the western Philippines (Raja Bidin *et al*, 2000). Our recent survey in Vietnam waters was conducted in April/May 1999. These surveys were conducted using a scientific echo-sounder FQ-70 (FURUNO Company) to study the distribution and biomass estimation of multi species pelagic fish. It was an additional experience and information for SEAFDEC to develop a proper methodology for tropical multi species stock assessment by hydro-acoustic technology.

The fisheries industry plays the fourth most important role in Vietnam's international trade based economy. Furthermore, it supplies some 40 % of animal protein to the national diet (JICA, 1998).

Following these circumstances, fish stock assessment program becomes one of the most high priority projects to be carried out. With JICA cooperation in 1995, a marine resource study in Vietnam waters was conducted by the Research Institute of Marine Products (RIMP) using RV Bien Dong. The study has set their main objective to investigate relative stock abundance of pelagic fishery resources in the EEZ of Vietnam. Additional objective was to clarify coastal fishery condition through landing site survey at selected major fish landing sites (JICA, 1998). Previous survey revealed the abundance of pelagic fishes such as skipjack tuna, dolphin fishes and frigate mackerels were caught by the drift gillnets. However, results from the previous study (JICA, 1998) do not indicate the volume of fish stocks. Its only report the qualitative abundance of pelagic fish and their species composition. Therefore, the current study is very important to provide those lacking information.

In Vietnam, the principle fishing gears used are the trawl, gill net, purse seine, lift net, set net, casting net, long-line and hand line. The different gears used by fishers basically targetted for different species. Figure 1 indicates the trend of pelagic fish landings (all gear combined) in Vietnam which increasing annually at the average rate of 6.7 %. The highest landing recorded so far is 720,000 tonnes, given the average annual production of 636,004 tonnes (1995 to 1999). The positive trend shows that the surface fishery is very important for Vietnam peoples. (Fig.1)

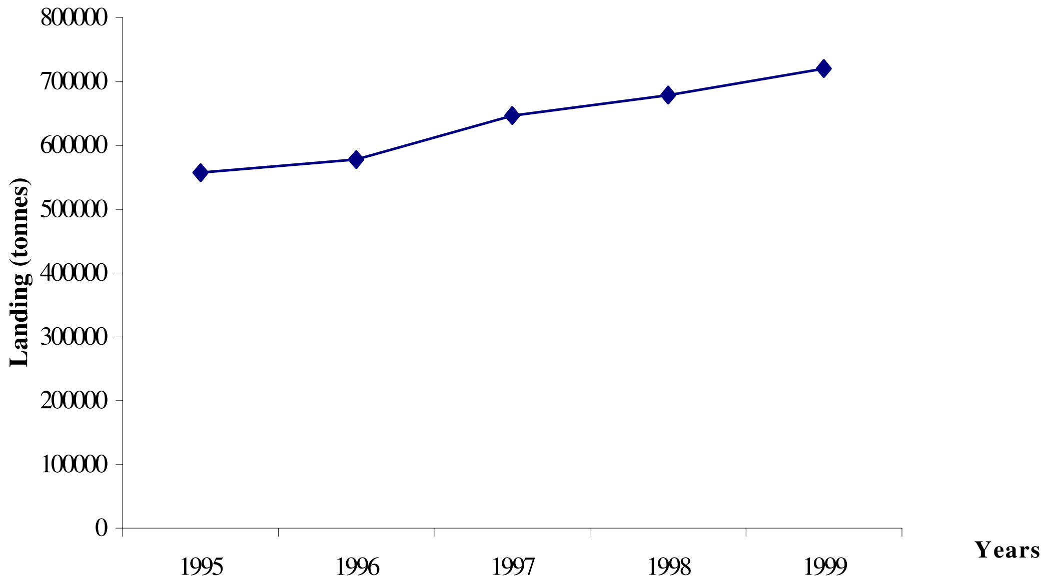

Fig. 1. Trend of pelagic landings in Vietnam.

The main objectives of the current study are to estimate the biomass and to study the distribution pattern of pelagic fishes in Vietnam waters.

Materials and Methods

Equipment Calibration

Calibration procedure is very important to ensure the collected raw data are reliable and meaningful. It is necessary to accurately estimate the resource volume. Calibration works for FQ-70 was conducted off Tonkin Bay, exactly located at Latitude 20° 36' N and Longitude 107° 15' E prior to survey cruise. Calibration was done for both transducers of 50 kHz and 200 kHz frequency. Output parameters measured during calibration process were used for collection of SV data by FQ-70. These include the source level, receiving sensitivity and the gain of amplifier. Comparatively the low frequency transducer has produced higher receiving sensitivity as shown in Table 1.

Table 1. Parameters settings after calibration work of the scientific echo sounder.

Parameters	Frequency	
	50 kHz	200 kHz
Source Level (dB)	215.2	211.1
Pulse Duration (ms)	1.2	1.2
Beam Width (dB)	-14.5	-16.1
Absorption Coefficient (dB)	10.8	89.9
Receiving Sensitivity (dB)	-185.1	-201.3
Amplifier Gain (dB)	49.3	49.7

Survey area and transects

A total of 43 acoustic transects (33 transects of 60nm and 10 transects of 30nm) were conducted within the survey duration from 30th April to 29th May 1999. These transects were shown in Fig. 2. Using the ESSR technique, the total survey area was estimated at 581,146 km^2. The area is quite big as Vietnam has a long coast line extending 3,260 km.

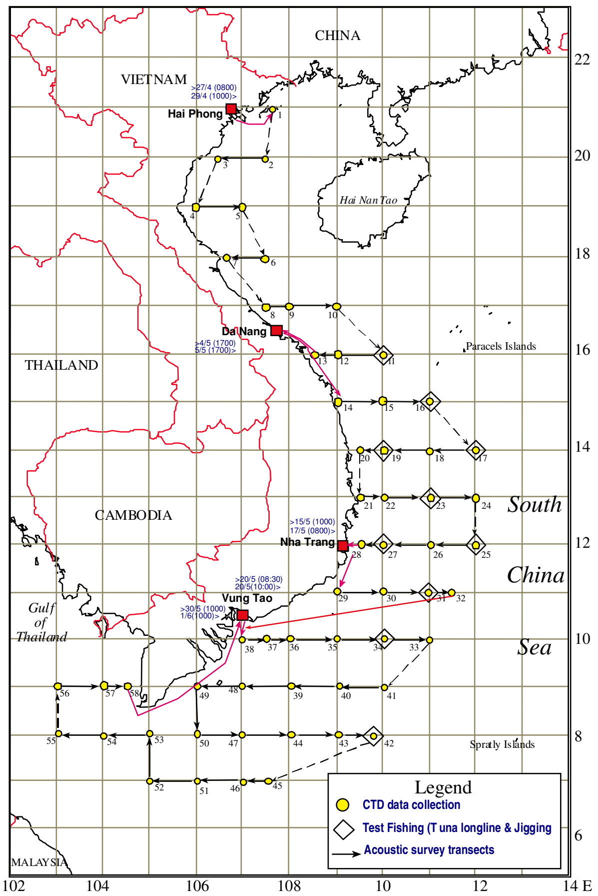

Fig. 2. Survey transects in Vietnamese waters.

The raw data of volume backscattering strength (SV) were recorded by FQ-70 for every integration interval of 0.1 nautical mile along the transects. At the same time, the vertical distribution curves (VDC) were recorded on recording paper and also displayed by the second steep integration.

Layer setting

Five types of layer setting are used for collection of SV data. Each layer setting is applied to a respective layer depth of each transects. It means each transect may use different layer setting depending on their depth condition. The maximum depth is set at 200m. While the upper layer is set at 10m below the transducer. Table 2 shows the different layer setting for respective maximum depth. Layer 9 and 10 were used for bottom layers.

Table 2. Five types of layer setting used for acoustic survey in Vietnam.

	Layer Setting 1	Layer Setting 2	Layer Setting 3	Layer Setting 4	Layer Setting 5
Max depth	**50m**	**60m**	**70m**	**100m**	**200m**
Layer No					
1	10 - 15	10 - 20	10 - 20	10 - 20	10 - 20
2	15 - 20	20 - 25	20 - 30	20 - 30	20 - 40
3	20 - 25	25 - 30	30 - 35	30 - 40	40 - 60
4	25 - 30	30 - 35	35 - 40	40 - 50	60 - 80
5	30 - 35	35 - 40	40 - 45	50 - 60	80 - 100
6	35 - 40	40 - 45	45 - 50	60 - 70	100 - 130
7	40 - 45	45 - 50	50 - 60	70 - 80	130 - 160
8	45 - 50	50 - 60	60 - 70	80 - 100	160 - 200
9	B 5 -10	B 5 -10	B 5 -10	B 5 -10	B 5 -10
10	B 5 - 1	B 5 - 1	B 5 - 1	B 5 - 1	B 5 - 1

Note : B 5-1 = One to five meter from bottom
B 5-10 = Five to ten meter from bottom

Data collection and recording media

Echogram and integrated raw SV data were collected by FQ-70 and stored into several storage media, including VHS video tape, magnetic optical disk (MO), floppy diskette, data catridge (DAT) and normal echo sounder recording paper. VHS and DAT tapes are capable to playback for a fine verification or secondary recording when required.

Species verification

Two approaches were adopted to verify the dominant pelagic species and its biological parameters. The first method is conducting fishing operations by using gillnet of different mesh sizes. Fishings were conducted by RV Bien Dong from 1st - 20th May 1999 at predetermined station. The second method is implementing landing place survey at major landing places in Vietnam from April 28 to May 19, 1999. However, both methods produced insufficient data for the species verification. Therefore, determination on dominant species was depended on statistical information provided by RIMP. It was decided that *Decapterus maruadsi* is the dominant pelagic species in Vietnam with the average standard length (SL) and body weight (W) of 15.4cm and 63g respectively.

Data Processing

A similar procedure used for Area II (Hadil *et al*, 1999) and Area III (Raja Bidin *et al*, 2000) were applied for data processing in Vietnam. The raw data is checked thoroughly to remove any mechanical noise and unlock bottom echoes. The processed data then run using macro program. Small modifications were made in macro program as compared to earlier procedure due to multiple layers setting used for integrated SV data collection. As the layer depth is not similar, so calculated SA values were used instead of SV for the calculation of pelagic fish density.

Target strength (TS)

Currently there are no target strength database was established for tropical fishes in this region. Therefore, the target strength of *Decapterus maruadsi* that selected as dominant species in this study was determined using the empirical formula derived by Furusawa (1990) as follows;

$TS = 20 \text{ Log }_{10} (SL) – 66$ where
TS = Target strength (dB)
SL = Average standard length (cm)

Using the biological information provided by RIMP, the calculated target strength based on given assumptions for *Decapterus maruadsi* was –42.25dB.

Fish density

The fish density is calculated based on assumptions that the SA values are free from noise and interferences. Calculated and corrected SA values were used later for pelagic fish density and biomass estimation. Calculation for the pelagic fish density was based on following formula:

$$\text{Density} = 10^{((SA-TS)/10)} * W$$

Where, SA = Average area backscattering (dB)
TS = Target strength (dB)
W = Average fish weight (g)

The pelagic fish density distibution in Vietnam water is shown in Fig. 4. It was plotted using the “Marine Explorer” program.

Biomass Estimation

The biomass estimation is calculated using the following formula;

Q = Average Density x Total Area , where

Q = Total Biomass in tonnes
Average Density in tonnes/km^2 was calculated based on Table 3
Total Area (using ESSR technique) in km^2

Results

Distribution Pattern of SA

Fig. 3 indicates the distribution of SA in Vietnam waters based on high frequency (200 kHz) transducer performance. Distribution of SA may also represent the density pattern of pelagic fish in the study area. As the low frequency transducer may record some reflection from bottom, which is very difficult to remove, therefore the results presented here merely depended on high frequency transducer outputs. SA values in coastal waters of the North and South region were estimated higher than –45 dB/m^2. In deeper water more than 200m, SA values were recorded smaller than –45 dB/m^2. It was clearly shown that density of pelagic concentrated in coastal waters than the offshore areas. During the survey period, more pelagic fish was clearly distributed in the North and South of Vietnam, where the water depth is less than 50m. However, it was observed also that pelagic is quite abundance off Nha Trang in the water not exceeding 100m depth.

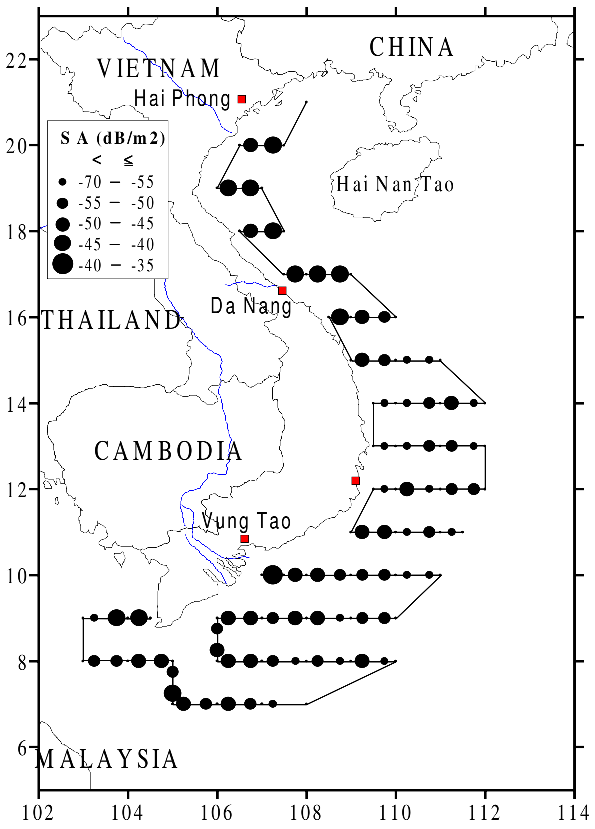

Fig. 3. Distribution pattern of SA (high frequency) in Vietnamese waters.

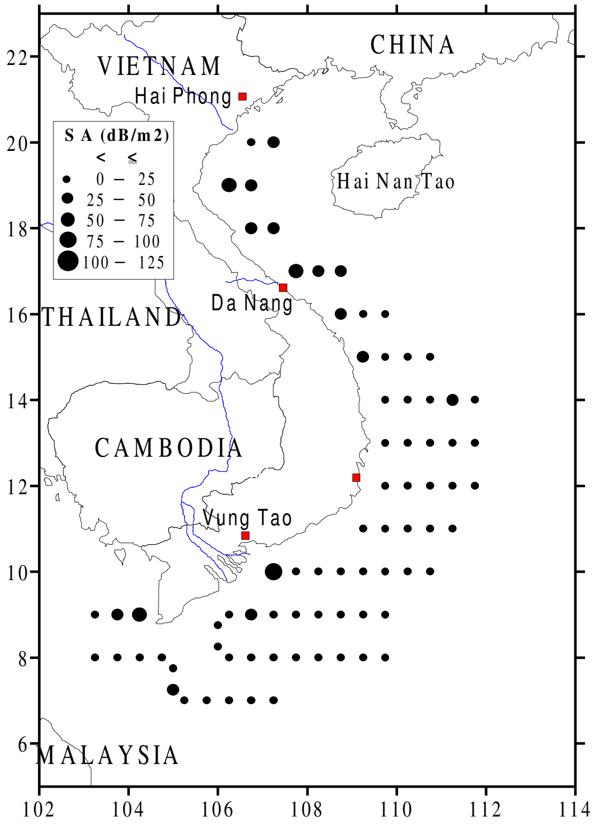

Fig. 4. Density ditribution of pelagic fish in Vietnamese waters.

Pelagic Fish Density

Table 3 and Fig. 4 indicate the distribution pattern of pelagic fish density in Vietnam waters based on high frequency transducer outputs as applied in the earlier surveys (Hadil *et al*, 1999 and Raja Bidin *et al*, 2000).

In general observation, about 27.6% of the survey area recorded relatively high density of pelagic exceed 20 tonnes/km^2. The maximum density recorded was 113.0 tonnes/km^2 while the minimum value was 0.1 tonnes/km^2. Using the high frequency band, the average density of pelagic was estimated at 15.93 tonnes/km^2. It was apparent also that a small addition in SA would change the average density significantly. This result is in consistent with the earlier report by Levy (1991).

Fig. 4 indicates the pelagic fish density concentrated in the North and South of Vietnam waters. Two transects located in these areas recorded the density larger than 90 tonnes/km^2. Whereas the other transects recorded not more than 25 tonnes/km^2.

Table 3. SA and density values by transect (high frequency).

Assumption parameters;

Average length (SL)	15.40 cm
Average weight	63 g
TS in dB	-42.25

Based on dominant species *Decapterus maruadsi*

Date	Station			Avg. SA(H)	Density
	From		To	in dB unit	tonnes/km^2
30-Apr	2	-	3	-44.09	41.3
30-Apr	2	-	3	-46.77	22.2
1-May	4	-	5	-43.24	50.1
1-May	4	-	5	-43.97	42.4
1-May	6	-	7	-46.27	25
1-May	6	-	7	-40.59	92.4
2-May	8	-	9	-42.1	65.3
2-May	9	-	10	-44.65	36.2
2-May	9	-	10	-44.9	34.2
3-May	11	-	12	-54.7	3.6
3-May	11	-	12	-49.32	12.4
3-May	12	-	13	-44.11	41.1
6-May	14	-	15	-45.28	31.4
6-May	14	-	15	-53.72	4.5
6-May	15	-	16	-58.92	1.4
6-May	15	-	16	-56.72	2.3
8-May	17	-	18	-58	1.7
8-May	17	-	18	-45.77	28
8-May	18	-	19	-53.69	4.5
9-May	18	-	19	-58.09	1.6
10-May	19	-	20	-64.28	0.4
10-May	21	-	22	-63.51	0.5
10-May	22	-	23	-55.14	3.2
10-May	22	-	23	-51.95	6.7
12-May	23	-	24	-53.42	4.8
12-May	23	-	24	-67.43	0.2
13-May	25	-	26	-51.34	7.8
13-May	25	-	26	-50.71	9
13-May	26	-	27	-59.27	1.3
13-May	26	-	27	-49.69	11.4
14-May	27	-	28	-59.14	1.3
17-May	29	-	30	-49.11	13
17-May	29	-	30	-47	21.1
18-May	30	-	31	-66.11	0.3
18-May	30	-	31	-51.86	6.9
19-May	31	-	32	-55.34	3.1
20-May	38	-	37	-39.71	113
20-May	37	-	36	-47.44	19.1
20-May	36	-	35	-48.9	13.6

Date	Station			Avg. SA(H)	Density
	From		To	in dB unit	tonnes/km^2
21-May	36	-	35	-53.53	4.7
21-May	35	-	34	-52.97	5.3
21-May	35	-	34	-52.83	5.5
22-May	34	-	33	-64.02	0.4
22-May	34	-	33	-68.54	0.1
22-May	41	-	40	-53.05	5.2
23-May	41	-	40	-51.45	7.6
23-May	40	-	39	-57.94	1.7
23-May	40	-	39	-46.76	22.3
23-May	39	-	48	-48.23	15.9
23-May	39	-	48	-52.94	5.4
23-May	48	-	49	-45.9	27.2
24-May	48	-	49	-49.82	11
24-May	49	-	50	-53.81	4.4
24-May	49	-	50	-47.99	16.8
24-May	50	-	47	-48.65	14.4
24-May	50	-	47	-48.65	14.4
24-May	47	-	44	-53.11	5.2
24-May	47	-	44	-57.3	2
25-May	44	-	43	-54.63	3.6
25-May	44	-	43	-62.74	0.6
25-May	43	-	42	-48.29	15.7
25-May	43	-	42	-63.57	0.5
26-May	45	-	46	-59.94	1.1
27-May	46	-	51	-51.05	8.3
27-May	46	-	51	-47.19	20.2
27-May	51	-	52	-51.85	6.9
27-May	51	-	52	-46.45	23.9
27-May	52	-	53	-43.87	43.4
27-May	52	-	53	-53.98	4.2
28-May	53	-	54	-47.49	18.8
28-May	53	-	54	-49.52	11.8
28-May	54	-	55	-54.54	3.7
28-May	54	-	55	-53.77	4.4
28-May	56	-	57	-56.56	2.3
28-May	56	-	57	-43.91	43
29-May	57	-	58	-43.2	50.6
Average					**15.93**

Estimated Biomass

Based on the recent survey and available informations, the biomass of pelagic fish in Vietnam waters was estimated at 9.26 million tonnes. However, precautionary approach should be adhering that the estimated biomass may include other marine organisms in addition to pelagic fish. The coastal zone which is a productive fishing ground only cover 24,000 km^2 (JICA, 1998). Using the average pelagic fish density from the current survey, estimated biomass for this area is about 420,000 tonnes. Therefore it was presumed that more than 8 million tonnes of pelagic fish biomass is available outside the coastal waters of Vietnam.

Discussion and Conclusion

The highest pelagic fish concentration was found in the coastal waters of the North and South regions. The average density for pelagic in Vietnamese waters was estimated at 15.93 tonnes/km^2, which is almost on the similar scale, compared to the western coast off Philippines (Raja Bidin *et al*, 2000). One consistent feature in the patterns of distribution observed during these surveys is that pelagic abundance is generally high in inshore of less 100m isobath. This was also reported during the Marine Resource Study in Vietnam in 1997 (JICA, 1998). However, further study is deem necessary to verify and confirm our results.

In acoustic, the echo verification is very important to determine the dominant species for each particular transects. Unfortunately, our recent study could not provide enough information to verify the species, therefore, it is not possible to derive biomass by single pelagic fish species. Therefore the biomass peresented is comprises of several pelagic fish species. A proper fish sampling methodology is deem necessary and strongly recommended for future survey. With those valuable informations, comprehensive biomass estimation would be produced. As the final result, it may reduce errors to the final outputs.

The success of hydroacoustic technique to evaluate fish stock depends on understanding the capacity of fish being investigated. The reflecting properties of both target strength and volume back scattering strength of the fish and how these properties change due to environment, behaviour and physiology have not been satisfactorily explored. The most critical source of error in abundance estimates derived from echo integration method is the lacking of appropriate knowledge on target strength characteristics of the fish being surveyed (Nainggolan, 1993). SEAFDEC needs further study in acoustic especially on target strength determination and species identification. Improvements on these requirements are vital for more meaningful results which basically important for pelagic fishery management. Concerning this urgent requirement, MFRDMD has started an intensive TS measurement study beginning in April 2000. The objectives are to develop TS measurement system and to measure TS for targeted pelagic species.

Acoustic approach is a potential method to assess the pelagic fish stock in the South China Sea area. However, many precautions need to be considered before and after conducting the acoustic research. The value of biomass is very much dependent on the target strength (TS) and SA values.

Acknowledgements

The authors would like to thank SEAFDEC for providing fund to implement this study in Vietnam waters. We are also grateful for the cooperation shown by the crew of MV SEAFDEC while collecting raw data. Thanks are also due to our colleagues from RIMP in Vietnam for providing us with the information on pelagic fishery.

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Assessment of Relative Abundance of Fishes Caught by Gillnet in Vietnamese Waters

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ABSTRACT

The fisheries resources in near shore waters of Vietnam are reported to be overexploited resulting on the decrease of CPUE. It is important to develop the off-shore fisheries in Vietnam now. However information on off-shore fisheries resources in Vietnam was still very limited. This study was designed in order to supply such kind of information.

The study area was in off-shore waters of Vietnam. R/V BIEN DONG(1500 Hp) with gillnet of 5 different mesh-size (73, 95, 123, 150 and 160 mm) was used for survey.

The species and catch composition, distribution of promising species, relative abundance of target species were described. As a results, 98 species belonged to 32 families have been identified. Skipjack tuna was dominant (18.5 %). Distribution of relative abundance of some major species were given.

Key words : Composition, catch, abundance, mesh-size

Introduction

The marine capture fisheries of Vietnam has developed rapidly in last decade by increasing number of both artisanal and motorized fishing boats.

At the end of 1998, number of motorized fishing vessels was around 72,000 units with the total engine capacities of nearly 2 millions Hp. The total production of marine capture fisheries of Vietnam in 1998 was exceeded one million tons. [MOFI,1999].

Due to the almost of fishing vessels are concentrated their activities only in near-shore waters, the fisheries resources in near-shore waters seemed to be overexploited resulting on the decrease of the catch per unit of effort (CPUE).

As a result of these facts, the Ministry of Fisheries of Vietnam is planning to make a sustainable fisheries development program relating to coastal and off-shore fisheries in order to manage sustainable coastal fisheries and at the same time to develop off-shore fisheries.

One of the important issue for development of off-shore fisheries is to identify the species and catch composition, the distribution of economically promising species, to determine their relative abundance as well as estimate the potential of fisheries resources herein and then to develop the appropriate fishing fleets. However, information on off-shore fisheries resources in Vietnam was very limited.

Since 1995, the Research Institute of Marine Products (RIMP) has been conducting some research programmes on off-shore fisheries resources under the support of the Vietnamese Government or with the assistance of JICA , DANIDA and SEAFDEC.This paper presents some results of those studies.

Materials and Methods

The materials were collected mainly during the implementation of the Project entitled " Study on the marine resources study in Vietnam " in 1995-1997. This project was carried out jointly by the Vietnamese-Japanese Study Team on R/V " BIEN DONG " (1500 Hp) of RIMP. Drift gillnets of 5 different mesh-size were used : mesh-size of 73mm, 95 mm, 123 mm, 150 mm and 160 mm. Construction of used gillnets was shown in Fig. 1.

The study area was limited by $8^{0}00'$ N to $18^{0}00'$ N and from 40 m depth to $112^{0}00'$ E within the Exclusive Economic Zone (EEZ) of Vietnam and was divided into 35 one-degree quadrangles.

One test fishing by gillnet and an oceanographic station were conducted at each station. The gillnets were set before sunset and hauled at sunrise of the next day. It was intended to set 100 tans of 5 mesh-sized nets, each consisting of 20 tans. (one tan is about 50m long)

The time of soaking of gillnets were standardized by mean time of all operation and Catch Per Unit of Effort of each operation was converted to the value of 100 tans of standardized by soaking time and then to calculate CPUE per tan.

Species composition and catch rate of each haul were recorded by mesh-size. For species composition, catches of four cruises conducted in yeas of 1995-1997 were used. However, for relative abundance assessment , only catches in the Southwest monsoon and Northeast monsoon of 1966 were used.

The relative abundance (in term of weight of fish caught by one tan of drift gillnet) is synonyms of the Catch per Unit of Efforts (CPUE) and was estimated as follows:

RAi (weight) = Wij / Nij

Where:

RAi : Relative abundance in term of weight (kg) of fish caught by all mesh- size of gillnets used in survey.

Wij : Weight of speciment of a species caught by gillnet of J-mesh-size employed at i-th station.

Nij : Number of nets of J-mesh-size employed at i-th station

The passages of the R/V BIEN DONG during the S-W monsoon and N-E monsoon in 1996 were shown in [Fig.2 and Fig.3].

Results

Species composition

98 species belonged to 32 families have been identified, of which 96 fish species belonged to 30 families and 2 squid species belonged to two cephalopods families [Table 1]. Besides, 3 species of sea turtles and 5 species of Dolphin were incidentally caught also.

The highest number of species was Carangidae(18 species), followed by Scombridae(12 species) and Exocoetidae(10 species).

Catch rate

Catch rate of species caught by gillnets with 5-different mesh-size in the S-W and N-E monsoons 1996 was shown in the [Table 2] and the 14 major species of highest catch rate was shown in [Table3].

In the S-W monsoon, 62 species belonged to 22 families and in the S-W 48 species of 23 families have been identified. It is clear that the number of families was similar but number of species in N-E monsoon was less than in the S-W monsoon.

However, catch rate of species caught in the N-E was higher than in the S-W monsoon, it was 92.40% and 84.20 % respectively.

For the whole year, catch rate of Skipjack tuna was highest (18.51 %), then followed by Devil ray (15.60%), Common dolphinfish (9.07%), etc [Fig. 4] . Catch of only 14 species accounted for 86.80% of the total catch by gillnets of 5-mesh-size used.

Above species are considered as the most promising target pelagic species in off-shore waters of Vietnam. Therefore, appropriate fishing gears and method should be developed for off-shore fishing program of Vietnam.

Relative abundance of major species caught by gillnets

In the S-W monsoon period, the lowest catch per haul/night was 2.0 kg and highest was 288.0 kg with the average of 100 kg. The lowest relative abundance per tan was 0.1 kg/tan, highest was 3.5 kg/tan and average catch was 1.2 kg/tan. Distribution of relative abundance (kg/ tan) of all species of pelagic fishes caught by gillnets of 5 different mesh-size was shown in the [Fig. 5].

It was clear that in the S-W monsoon, the highest CPUE (kg/tan) for all combined species was distributed in the quadrangles B-28; B- 33 and B-13, then followed by quadrangles B-6; B-8; B-12; B-15 and B-16.

In the Northeast monsoon, the lowest catch was 3.2 kg /haul/night and highest catch was 302.6 kg, average catch was 88.7 kg. The average CPUE by kg/tan was 0.84 kg/tan, lower than in the S-W monsoon. Distribution of relative abundance (kg/tan) of all combined species caught by 5 mesh size gillnet was shown in [Fig.6]. The highest CPUE was found in the quadrangles B-26; B-27 and B-03, then followed by quadrangles B-13; B-14; B-15; B-16; B-18; B-22 and B-33.

Relative abundance of major species by kg/tan were as follow:

Skipjack tuna (*Katsuwonus pelamis*):

[Fig. 7] shows CPUE in weight in each quadrangle in S-W monsoon. The highest CPUE was obtained in the quadrangles B-10; B-17; B-28; B-29 and B-33 and ranged 0.5-1.0 kg/tan.

[Fig. 8] shows CPUE in weight in each quadrangle in N-E monsoon. The highest CPUE was found in the quadrangles B-11; B-16; and B-33 and ranged 0.5-1.0 kg/tan.

Frigate mackerel (*Auxis thazard*) :

The higher CPUE in S-W monsoon was obtained only in the quadrangle B-06(1.0 kg/tan) [Fig.9], and in N-E monsoon in the quadrangle B-26 (1.0 kg/tan) [Fig. 10].

Common dolphinfish (*Coryphaena hippurus*)

In S-W monsoon [Fig. 11], the CPUE was highest in the quadrangles B-8 (0.4 kg/tan) and in N-E monsoon [Fig. 12] in the quadrangles B-3, B-13 where CPUE ranged 0.4-0.5 kg/tan.

Bigtooth pomfret (*Brama orcini*)

Bigtooth pomfret did not appear near the Gulf of Tonkin in the North and near the Mekong Delta in the South, it indicated that this species avoid low salinity and distributed mainly in high salinity waters.

In S-W monsoon [Fig. 13], low CPUE (< 0.1 kg/tan) was obtained in whole survey area and In N-E monsoon [Fig. 14], the higher CPUE was in the quadrangles B-12, B-18 and B-23 (ranged 0.1-0.3 kg/tan).

Triple tail (*Lobotes surinamensis*)

The highest CPUE was obtained in the S-W monsoon [Fig. 15] in the quadrangles B-6 and B-29, where CPUE ranged 0.1-0.5 kg/tan and in N-E monsoon [Fig. 16] only found in the quadrangles B-3 (0.12 kg/tan).

Flying squid (*Sthenoteuthis oualaniensis*)

Like bigtooth pomfret, flying squid did not appear in the vicinity of the Gulf of Tonkin in the North nor the Mekong Delta in the South of Vietnam.

In S-W monsoon [Fig. 17], the higher CPUE (ranged 0.04-0.1 kg/tan) was observed in the quadrangles B-10, B-12, B-28 and B-25 and in N-E monsoon [Fig. 18] only in central waters of Vietnam in the quadrangles B-17 and B-18 (0.1-0.2 kg/tan).

Discussion

It was the first time, study on off-shore pelagic fish by using different mesh-size gillnets was conducted in Vietnam. The results showed the similar species composition in off-shore waters of Vietnam compared with adjacent waters of the South China Sea.

Although more than 100 species were identified, some of 14 species have had high catch rate only, among them Skipjack tuna, Frigate mackerel, Dolphinfish, Devil ray, Marlin, Swordfish, Bigtooth pomfret, Flying squids ,etc. were the most promising target species for off-shore pelagic fish capture fishery of Vietnam.

According to the results of the Japan Marine Resources Research Center (JAMARC) obtained from trial fishing conducted with surface gillnets of different mesh-size (73-250 mm) in different areas of the Pacific Ocean during 1978-1990, the CPUE of catch in weight for some species like Bigtooth pomfret, Slender tuna, Albacore, Blue shark was ranged from 3.8 to 20.0 kg/tan.

The results obtained from our survey by gillnets of 5 mesh-size in off-shore waters of Vietnam in 1996 showed lower value of CPUE (0.84 - 1.2 kg/tan). Low CPUE in off-shore waters of Vietnam was caused by different reasons: Due to the scattered concentration of pelagic fishes schools in off shore waters of Vietnam, gillnet's selectivity, and in appropriate fishing methods, etc.

Therefore for pelagic fish exploitation in off-shore waters of Vietnam, fishing gears like gillnet, purse seine, long line, lift net, etc. were in the first priority.

For purse seine , it is important to concentrate fish by fish aggregating devices (FAD) and payao's . For gillnet, selectivity of different mesh-size to different species and for lift net, the reaction of different species on light should be studied.

Table 1. Species composition of catch by gillnets in offshore waters of Vietnam.

Ord.	Scientific name of Families and species	Common English name
I	**ACANTHURIDAE**	
1	*Naso breviostris* (Valenciennes)	Spotted unicornfish
II	**BELONIDAE**	
2	*Ablennes hians* (Valenciennes)	Flat needlefish
3	*Tylosurus acus melanotus* (Bleeker)	Blackfin needlefish
III	**BRAMIDAE**	
4	*Brama orcini* Cuvier	Bigtooth pomfret
IV	**CARANGIDAE**	
5	*Alectis ciliaris* (Bloch)	Threadfin trevally

Table 1. (Continued).

Ord.	Scientific name of Families and species	Common English name
6	*Atule mate* (Cuvier)	Slender-scaled scad
7	*Carangoides ferdau* (Forsskal)	Blue travelly
8	*C. orthogrammus* (Jordan et Gilbert)	Yellow-spotted crevalle
9	*Decapterus maruadsi* (Temminck et Schlegel)	Round scad
10	*D. kurroides* Bleeker	Red-tail scad
11	*D. macrosoma* Bleeker	Layang scad
12	*Elagatis bipinnulata* (Quoy et Gaimard)	Rainbow runner
13	*Megalaspis cordyla* (Linnaeus)	Hard-tail scad
14	*Naucrates ductor* (Linnaeus)	Pilot fish
15	*Scomberoides lysan* (Forsskal)	Double dotted queenfish
16	*S. commersonnianus* Lacepede	Talang queenfish
17	*S. tol* (Cuvier)	Leatherskin queenfish
18	*Selar crumenophthamus* (Bloch)	Bigeye scad
19	*Seriola rivoliana* Valenciennes	Almaco jack
20	*Seriolina nigrofasciata* (Ruppell)	Black band jack
21	*Trachinotus baillonii* (Lacapede)	Black-spotted dart
22	*Uraspis helvola* (Forster)	Whitemouth kingfish
V	**CALLIONYMIDAE**	
23	*Pseudocalliurichthys* sp.	Variegated dragonet
VI	**CARCHARHINIDAE**	
24	*Carcharinus brevipinna* (Muller et Henle)	Spiner shark
25	*C. falciformis* (Bibron)	Silky shark
26	*C. sorrah* (Valenciennes)	Spot-tail shark
27	*Galeocerdo cuvier* (Perdo et Le Sueur)	Tiger shark
28	*Prionace glauca* Linnaeus	Blue shark
29	*Pseudocarcharias kamoharai (Matsubara)*	Crocodile shark
VII	**CHIROCENTRIDAE**	
30	*Chirocentrus dorab* (Forsskal)	Wolf herring
VIII	**CORYPHAENIDAE**	
31	*Coryphaena equiselis* Linnaeus	Pompano dolphinfish
32	*C. hippurus* Linnaeus	Common dolphinfish
IX	**DALATIIDAE**	
33	*Isistius brasiliensis* (Quoy et Gaimard)	Black shark
X	**DIODONTIDAE**	
34	*Diodon eydouxii* Brissout et Barneville	Porcurine fish
35	*D. hystrix* Linnaeus	Porcurine fish
36	*D. holocanthus* Linnaeus	Fleckled sucker
XI	**ECHENEIDIDAE**	
37	*Echeneis naucrates* Linnaeus	Shark sucker
38	*Remora remora* (Linnaeus)	Remora
39	*Remorina albescens* (Temminck et Schlegel)	White remora
XII	**EXOCOETIDAE**	
40	*Cypselurus atrisignis* (Jenkins)	Greaterspotted flyingfish
41	*C. cyanopterus* (Valenciennes)	Margined flyingfish
42	*C. longibarbus* (Parin)	Coast flyingfish
43	*C. naresii* (Grunther)	Uchida's flyingfish
44	*C. poecilopterus* (Valenciennes)	Yellowfin flyingfish
45	*C.* sp.	Flyingfish
46	*C. spilonotopterus* (Bleeker)	Flyingfish
47	*C. unicolor* (Valenciennes)	Bigeye flyingfish
48	*Exocoetus volitant* Linnaeus	Cosmopolitan flyingfish

Table 1. (Continued).

Ord.	Scientific name of Families and species	Common English name
49	*Paraexocoetus* sp.	Sailfin flyingfish
XIII	**GEMPYLIDAE**	
50	*Gempylus serpens* Cuvier	Snake mackerel
51	*Lepidocybium flavobrumneum* (Smith)	Escolar
52	*Promethichthys prometheus* (Cuvier)	Snake-mackerel
53	*Ruventtus pretiosus* Cocco	Oil fish
XIV	**ISTIOPHORIDAE**	
54	*Istiophorus platypterus* (Shaw et Nodder)	Indo-Pacific sailfish
55	*Makaira indica* (Cuvier)	Black marlin
56	*M. mazara* (Jordan et Snyder)	Blue marlin
57	*Tetrapterus audax* (Philippi)	Striped marlin
XV	**KYPHOSIDAE**	
58	*Kyphosus vaigiensis* (Quoy etGaimard)	Bass seachub
XVI	**LOBOTIDAE**	
59	*Lobotes surinamensis* (Bloch)	Tripletail
XVII	**MENIDAE**	
60	*Mene maculata* (Bloch et Schneider)	Moon fish
XVIII	**MOBULIDAE**	
61	*Manta birostric* (Donndoff)	Manta ray
62	*Mobula japonica (Muller et Henle)*	Devil ray
XIX	**MONACANTHIDAE**	
63	*Aluterus monoceros* (Linnaeus)	Unicom leatherjacket
64	*A. scriptus* (Osbeck)	Leatherjacket
65	*Canthidermis maculata* (Bloch)	Ocean triggerfish
XX	**MYCTOPHIDAE**	
66	*Diaphus gigas* Gibert	Brightnose headlightfish
67	*D. watasei* Jordan et Starks	Latern fish
XXI	**NOMEIDAE**	
68	*Arioma indica* (Day)	Indian driftfish
69	*Cubiceps baxteri* McCulloch	Drift fish
70	*C. pauciradiatus* Gunther	Chunky fathead
71	*C. squamiceps* (Lloyd)	Fathead
72	*Nomeus gronovii* (Gmelin)	Man-of-War fish
73	*Psenes arafurensis* Grunther	Eyebrowfish
74	*P. cyanophrys* Valenciennes	Black driftfish
75	*P. maculatus* Lutken	Blue eyebrowfish
XXII	**ORECTOLOBIDAE**	
76	*Stegostoma fasciatum (Hermann)*	Zebra shark
XXIII	**PRIACANTHIDAE**	
77	*Priacanthus macracanthus* Cuvier	Large-spined bigeye
XXIV	**RACHYCENTRIDAE**	
78	*Rachicentron canadum* (Linnaeus)	King fish
XXV	**SCOMBRIDAE**	
79	*Acanthocybium solandri* (Cuvier)	Wahoo
80	*Auxis rochei* (Risso)	Bullet tuna
81	*A. thazard* (Lacepede)	Frigate mackerel
82	*Euthynnus affinis* (Cantor)	Eastern little tuna
83	*Katsuwonus pelamis* (Linnaeus)	Skipjack tuna
84	*Rasrelliger kanagurta* (Cuvier)	Indian mackerel
85	*Thunnus albacares* (Bonnaterre)	Yellowfin tuna
86	*T. obesus* (Lower)	Bigeye tuna
87	*T. tonggol* (Bleeker)	Longtail tuna

Table 1. (Continued).

Ord.	Scientific name of Families and species	Common English name
88	*Sarda orientalis* (Temminck etSchlegel)	Striped bonito
89	*Scomber australasicus* Cuvier	Blue mackerel
90	*Scomberomorus commerson* Lacepede	Spanish mackerel
XXVI	**SPHYRNIDAE**	
91	*Sphyrna lewini* (Griffth et Smith)	Hammerhead shark
XXVII	**SYNODOTIDAE**	
92	*Saurida undosquamis* Richardson	True lizardfish
XXVIII	**TETRADONTIDAE**	
93	*Lagocephalus* sp.	White-tail blowfish
94	*L. oceanicus* Jordan et Flower	Spotted blowfish
XXIX	**THERAPONIDAE**	
95	*Therapon jarbua* (Forsskal)	Jarbua terapon
XXX	**XIPHIIDAE**	
96	*Xiphias gladius* Linnaeus	Broadbill swordfish
XXXI	**OMMASTREPHIDAE**	
97	*Sthenoteuthis ovalaniensis* Lesson	Flying squid
XXXII	**THYSANNOTEUTHIDAE**	
98	*Thysanoteuthys rhombus* Troschel	Diamonback squid

Table 2. Catch rate by gillnet in offshore waters of Vietnam in S-W and N-E monsoons of 1996.

Ord.	Scientific name of Families and species	Common English name	Catch rate (%) S-W monsoon	N-E monsoon
I	**ACANTHURIDAE**		**0.01**	
1	*Naso breviostris* (Valenciennes)	Spotted unicornfish	0.01	
II	**BELONIDAE**		**0.09**	**0.18**
2	*Ablennes hians* (Valenciennes)	Flat needlefish	0.01	0.18
3	*Tylosurus acus melanotus* (Bleeker)	Blackfin needlefish	0.08	
III	**BRAMIDAE**		**1.42**	**5.20**
4	*Brama orcini* Cuvier	Bigtooth pomfret	1.42	5.20
IV	**CARANGIDAE**		**0.70**	**0.56**
5	*Alectis ciliaris* (Bloch)	Threadfin trevally	0.01	
6	*Carangoides ferdau* (Forsskal)	Blue trevlly	0.003	
7	*C. orthogrammus* (Jordan et Gilbert)	Yellow-spotted crevalle	0.01	0.09
8	*Decapterus maruadsi* (Temminck et Schlegel)	Round scad	0.01	
9	*D. kurroides* Bleeker	Red-tail scad		0.001
10	*D. macrosoma* Bleeker	Layang scad		0.03
11	*Elagatis bipinnulata* (Quoy et Gaimard)	Rainbow runner	0.13	
12	*Megalaspis cordyla* (Linnaeus)	Hard-tail scad	0.03	
13	*Naucrates ductor* (Linnaeus)	Pilot fish	0.02	0.07
14	*Scomberoides lysan* (Forsskal)	Double dotted queenfish	0.13	
15	*S. tol* (Cuvier)	Leatherskin queenfish	0.08	
16	*Selar crumenophthamus* (Bloch)	Bigeye scad	0.02	0.03
17	*Seriola rivoliana* Valenciennes	Almaco jack	0.20	0.31

Table 2. (Continued).

Ord.	Scientific name of Families and species	Common English name	Catch rate (%)	
			S-W monsoon	N-E monsoon
18	*Uraspis helvola* (Forster)	Whitemouth kingfish	0.06	0.03
V	**CARCHARHINIDAE**		**3.67**	**2.84**
19	*Carcharinus brevipinna* (Muller et Henle)	Spiner shark	0.02	
20	*C. falciformis* (Bibron)	Silky shark	0.50	2.30
21	*C. sorrah* (Valenciennes)	Spot-tail shark	0.15	
22	*Galeocerdo cuvier* (Perdo et Le Sueur)	Tiger shark	0.72	
23	*Prionace glauca* Linnaeus	Blue shark	2.28	
24	*Pseudocarcharias kamoharai* (Matsubara)	Crocodile shark		0.54
VI	**CHIROCENTRIDAE**		**0.04**	**0.13**
25	*Chirocentrus dorab* (Forsskal)	Wolf herring	0.04	0.13
VII	**CORYPHAENIDAE**		**7.04**	**12.01**
26	*Coryphaena equiselis* Linnaeus	Pompano dolphinfish	0.20	0.72
27	*C. hippurus* Linnaeus	Common dolphinfish	6.84	11.29
VIII	**DALATIIDAE**		**0.01**	
28	*Isistius brasiliensis* (Quoy et Gaimard)	Black shark	0.01	
IX	**DIODONTIDAE**		**0.04**	**0.02**
29	*Diodon eydouxii* Brissout et Barneville	Porcurine fish	0.04	0.02
X	**ECHENEIDIDAE**		**0.04**	**0.04**
30	*Echeneis naucrates* Linnaeus	Shark sucker	0.04	0.04
XI	**EXOCOETIDAE**		**0.08**	**0.08**
31	*C. cyanopterus* (Valenciennes)	Margined flyingfish	0.04	0.08
32	*C. poecilopterus* (Valenciennes)	Yellowfin flyingfish	0.003	
33	*C.* sp.	Flyingfish	0.01	0.001
34	*C. spilonotopterus* (Bleeker)	Flyingfish	0.01	0.003
35	*C. unicolor* (Valenciennes)	Bigeye flyingfish	0.01	
36	*Exocoetus volitant* Linnaeus	Cosmopolitan flyingfish	0.004	
XII	**GEMPYLIDAE**		**0.20**	**0.24**
37	*Gempylus serpens* Cuvier	Snake mackerel	0.03	0.20
38	*Lepidocybium flavobrumneum* (Smith)	Escolar	0.15	
39	*Ruventtus pretiosus* Cocco	Oil fish	0.02	0.04
XIII	**ISTIOPHORIDAE**		**21.77**	**22.38**
40	*Istiophorus platypterus* (Shaw et Nodder)	Indo-Pacific sailfish	7.79	5.10
41	*Makaira indica* (Cuvier)	Black marlin	5.24	10.38
42	*M. mazara* (Jordan et Snyder)	Blue marlin	8.74	6.90
XIV	**KYPHOSIDAE**			**0.01**
43	*Kyphosus vaigiensis* (Quoy et Gaimard)	Bass seachub		0.01
XV	**LOBOTIDAE**		**2.59**	**2.60**
44	*Lobotes surinamensis* (Bloch)	Tripletail	2.59	2.60
XVI	**MENIDAE**			**0.03**
45	*Mene maculata* (Bloch et Schneider)	Moon fish		0.03
XVII	**MOBULIDAE**		**23.76**	**13.00**
46	*Manta birostric* (Donndoff)	Manta ray	5.56	
47	*Mobula japonica* (Muller et Henle)	Devil ray	18.20	13.00
XVIII	**MONACANTHIDAE**		**0.11**	**1.10**
48	*Aluterus monoceros* (Linnaeus)	Unicom leatherjacket	0.06	0.99
49	*A. scriptus* (Osbeck)	Leatherjacket	0.04	0.01
50	*Canthidermis maculata* (Bloch)	Ocean triggerfish	0.01	0.07
XiX	**MYCTOPHIDAE**			**0.001**
51	*Diaphus gigas* Gibert	Brightnose headlightfish		0.001
XX	**NOMEIDAE**		**0.70**	**0.11**

Table 2. (Continued).

Ord.	Scientific name of Families and species	Common English name	Catch rate (%)	
			S-W monsoon	N-E monsoon
52	*Cubiceps baxteri* McCulloch	Drift fish	0.01	0.09
53	*C. pauciradiatus* Gunther	Chunky fathead	0.01	
54	*Psenes arafurensis* Grunther	Eyebrowfish	0.03	
55	*P. cyanophrys* Valenciennes	Black driftfish	0.04	0.02
56	*P. maculatus* Lutken	Blue eyebrowfish	0.01	
XXI	**PRIACANTHIDAE**		**0.06**	**0.02**
57	*Priacanthus macracanthus* Cuvier	Large-spined bigeye	0.06	0.02
XXII	**RACHYCENTRIDAE**		**0.15**	
58	*Rachicentron canadum* (Linnaeus)	King fish	0.15	
XXIII	**SCOMBRIDAE**		**24.21**	**36.12**
59	*Acanthocybium solandri* (Cuvier)	Wahoo	0.13	0.04
60	*Auxis rochei* (Risso)	Bullet tuna	1.83	0.71
61	*A. thazard* (Lacepede)	Frigate mackerel	4.81	8.93
62	*Euthynnus affinis* (Cantor)	Eastern little tuna	0.57	1.21
63	*Katsuwonus pelamis* (Linnaeus)	Skipjack tuna	16.21	20.80
64	*Rasrelliger kanagurta* (Cuvier)	Indian mackerel		0.02
65	*Thunnus albacares* (Bonnaterre)	Yellowfin tuna	0.39	2.60
66	*T. obesus* (Lower)	Bigeye tuna	0.19	0.35
67	*T. tonggol* (Bleeker)	Longtail tuna		1.42
68	*Sarda orientalis* (Temminck et Schlegel)	Striped bonito	0.07	
69	*Scomber australasicus* Cuvier	Blue mackerel	0.01	
70	*Scomberomorus commerson* Lacepede	Spanish mackerel		0.04
XXIV	**SYNODOTIDAE**		**0.002**	**0.03**
71	*Saurida undosquamis* Richardson	True lizardfish	0.002	0.03
XXV	**TETRADONTIDAE**			**0.02**
72	*Lagocephalus oceanicus* Jordan et Flower	Spotted blowfish		0.02
XXVI	**OMMASTREPHIDAE**		**1.06**	**2.57**
73	*Sthenoteuthis ovalaniensis* Lesson	Flying squid	1.06	2.57

Table 3. Catch rate(%) of major species caught by gillnet in off-shore waters of Vietnam in S-W and N-E monsoons 1996.

Ord.	Common English name/ Scientific name	S-Wmonsoon	N-E monsoon
1	Skipjack tuna *(Katsuwonus pelamis)*	16.21	20.80
2	Devil ray *(Mobula japonica)*	18.20	13.00
3	Common dolphinfish *(Coryphaena hippurus)*	6.84	11.29
4	Black marlin *(Makaira indica)*	5.24	10.38
5	Blue marlin *(M. mazara)*	8.74	6.90
6	Frigate mackerel *(Auxiz thazard)*	4.81	8.93
7	Indo-pacific sailfish *(Istiophorus platypterus)*	7.79	5.10
8	Bigtooth pomfret *(Brama orcini)*	1.42	5.20
9	Manta ray *(Manta biostric)*	5.56	0.00
10	Triptail *(Lobotes surinamensis)*	2.59	2.60
11	Flying squid *(Sthenoteuthys ovalsniensis)*	1.06	2.57
12	Yellowfin tuna *(Thunnus albacares)*	0.39	2.60
13	Silky shark *(Carcharinus falciformes)*	0.50	2.30
14	Bullet tuna *(Auxis rochei)*	1.83	0.71
	Grand total	**81.20**	**92.40**

Fig. 1. Construction of surface gillnets of five mesh-sizes used for study.

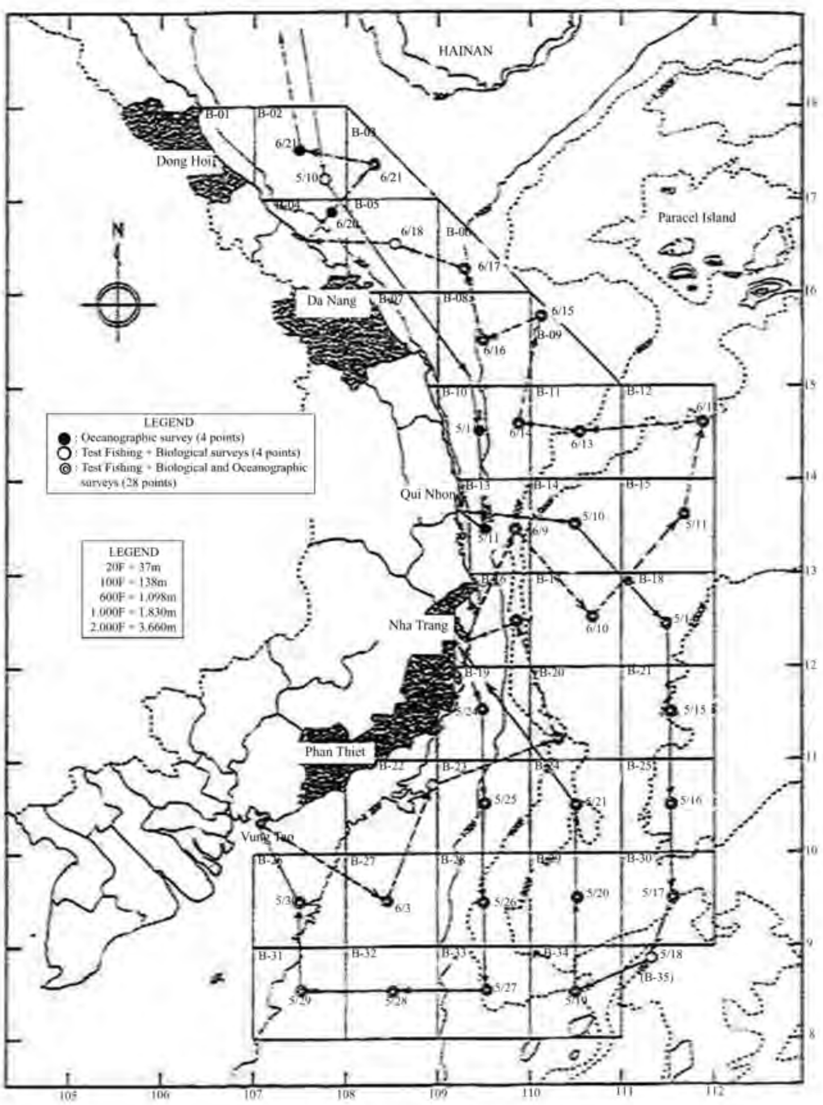

Fig. 2. Sailing track and test fishing stations in S-W monsoon.

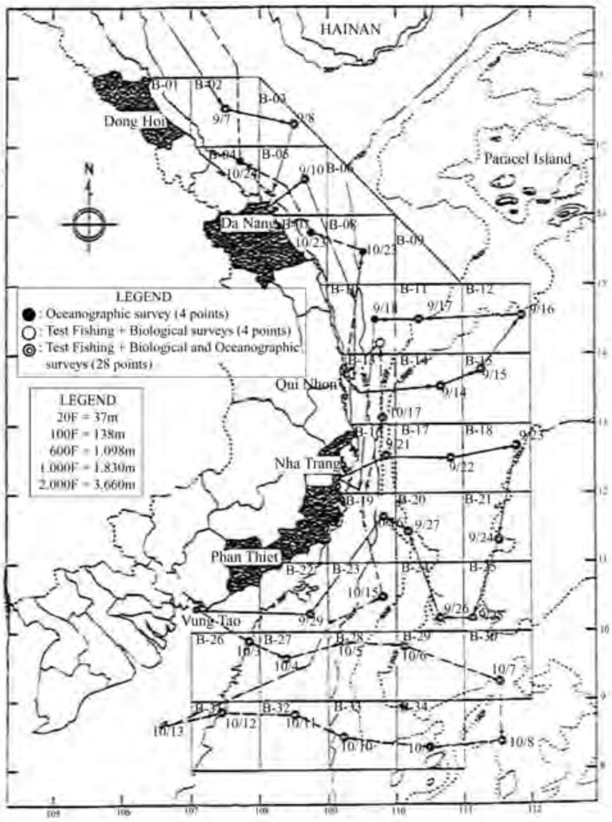

Fig. 3. Sailing track and test fishing stations in N-E monsoon.

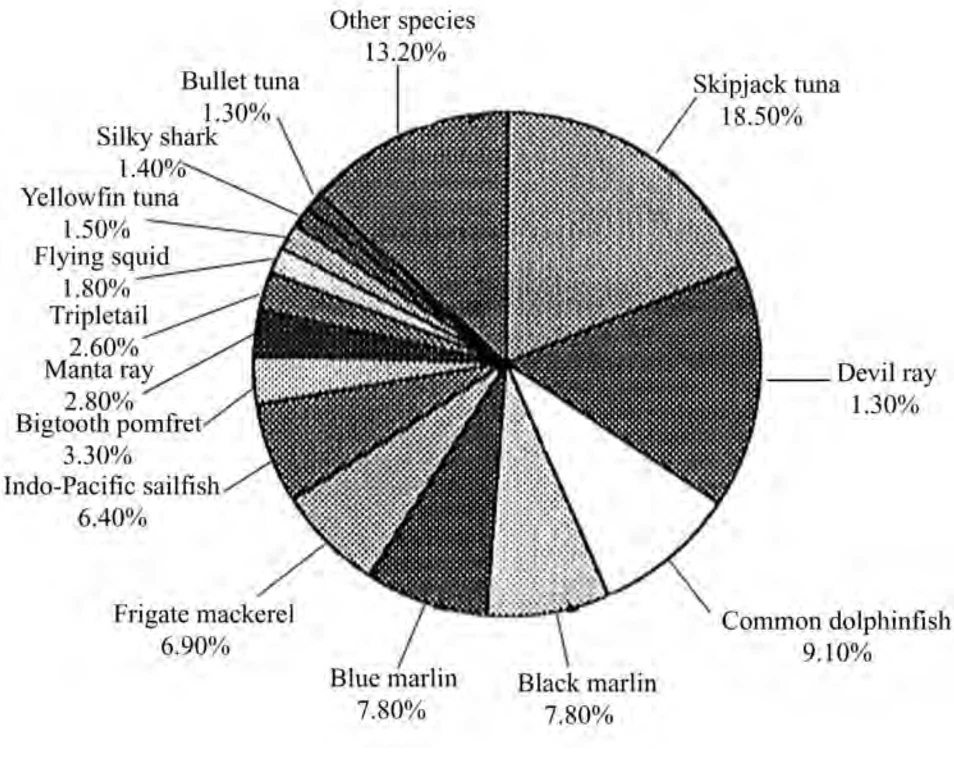

Fig. 4. Catch rate of major species caught by gillnet in 1996.

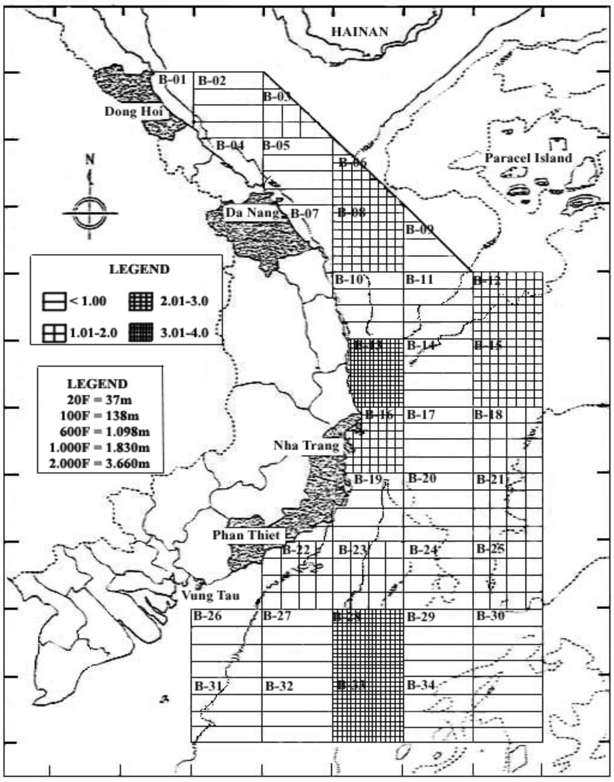

Fig. 5. Distribution of CPUE (kg/tan) in S-W monsoon.

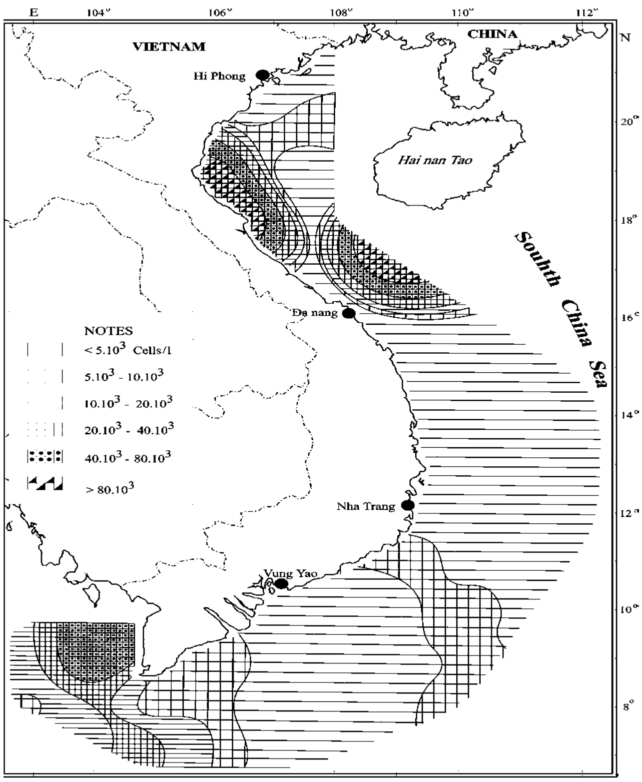

Fig. 6. Distribution of CPUE (kg/tan) in N-E monsoon.

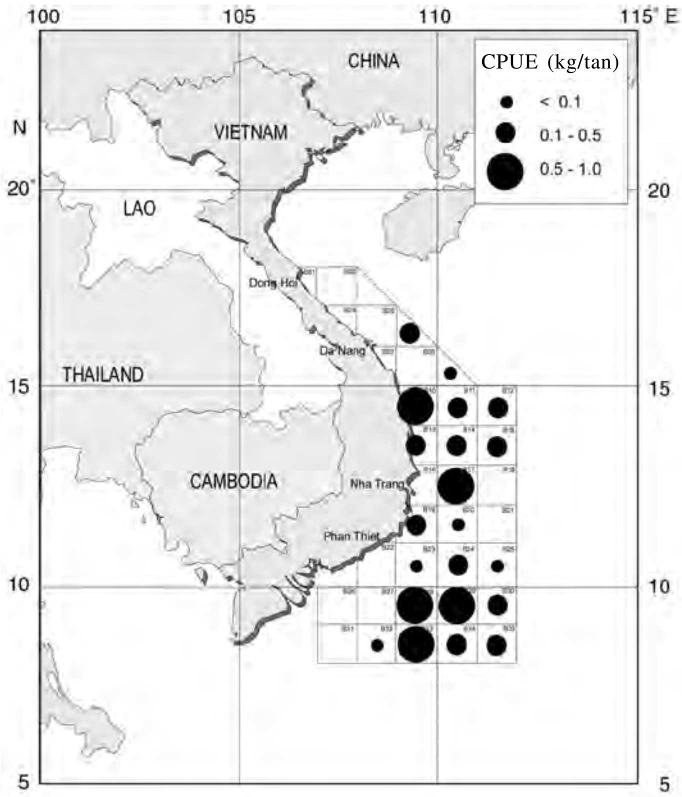

Fig. 7. Distribution of CPUE (kg/tan) of skipjack tuna in S-W monsoon.

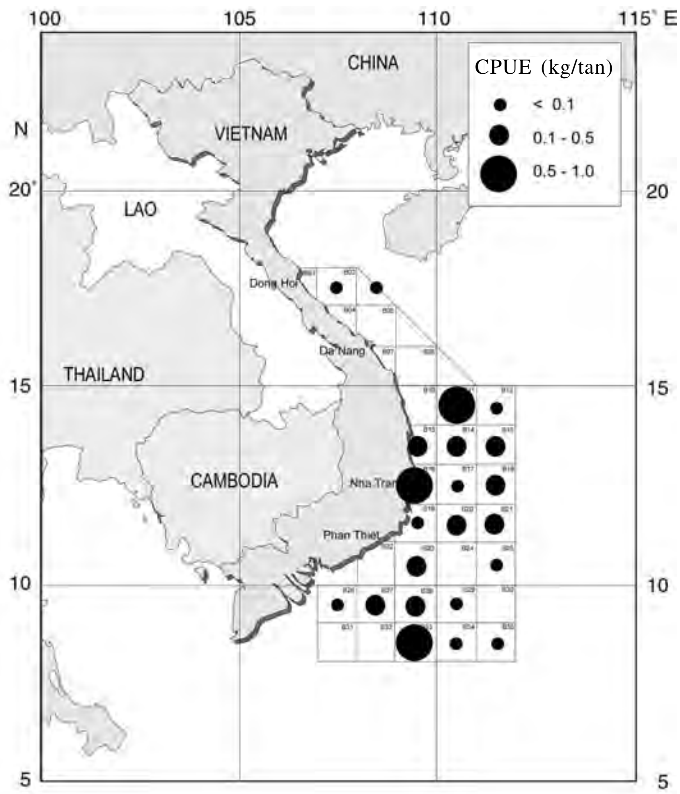

Fig. 8. Distribution of CPUE (kg/tan) of Skipjack tuna in N-E monsoon.

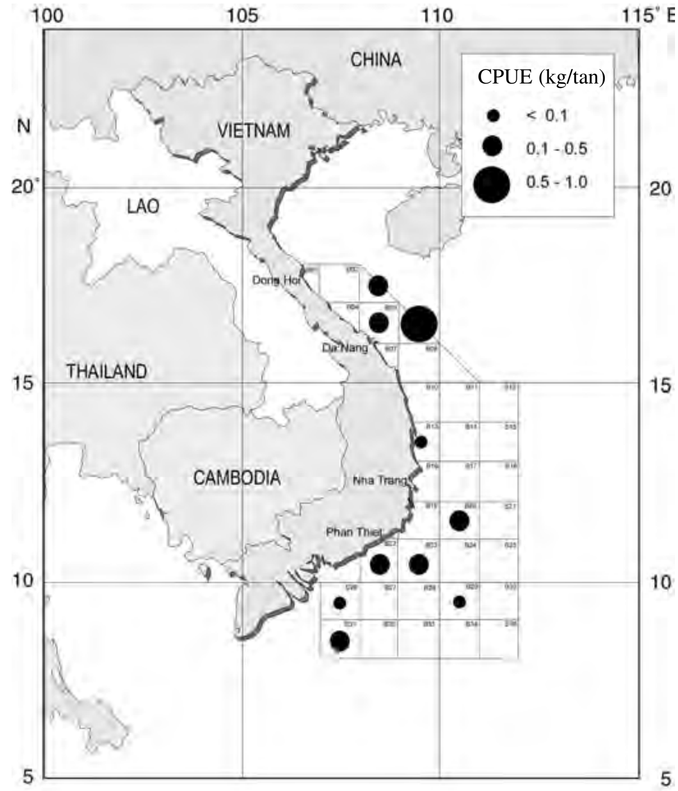

Fig. 9. Distribution of CPUE (kg/tan) of Frigate mackerel in S-W monsoon.

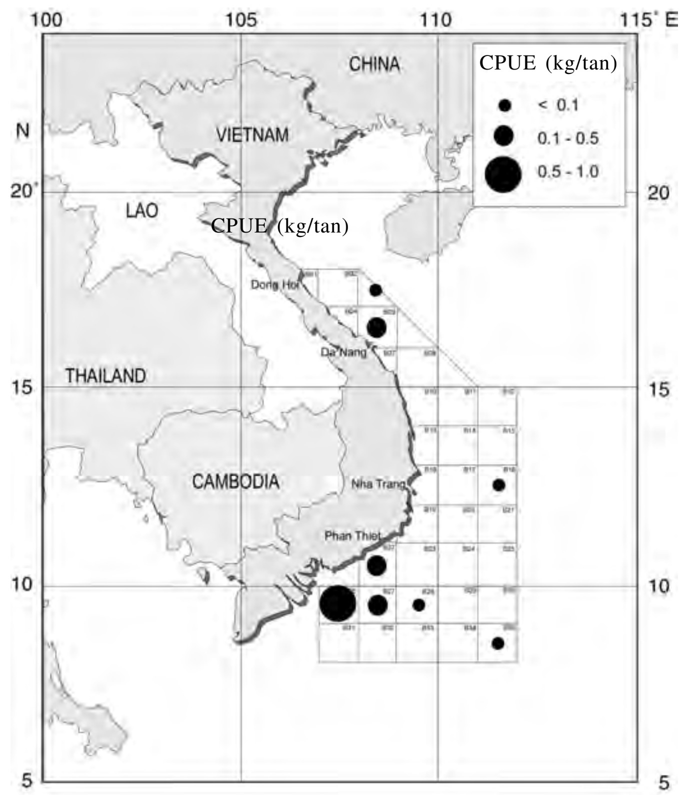

Fig. 10. Distribution of CPUE (kg/tan) of Frigate mackerel in N-E monsoon.

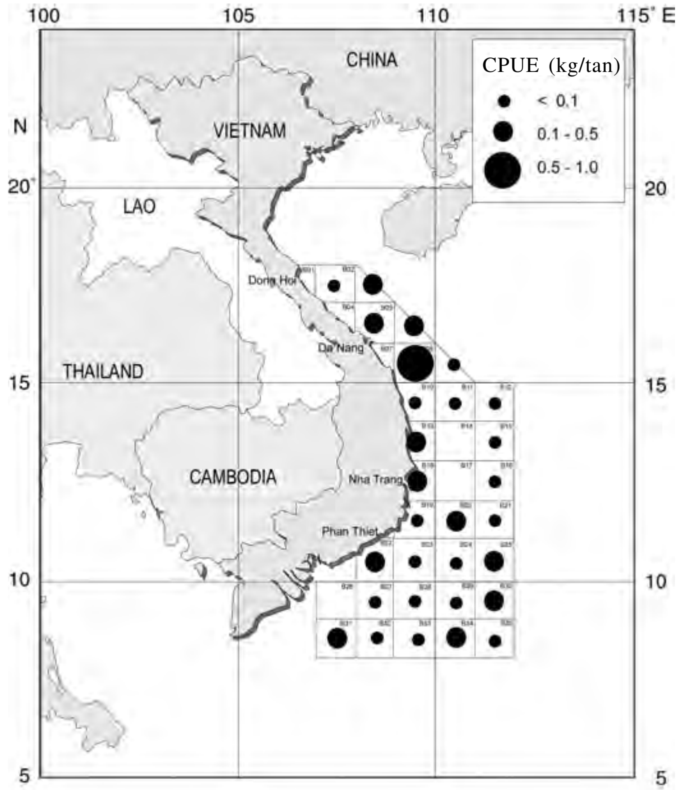

Fig. 11. Distribution of CPUE (kg/tan) of common Dolphinfish in S-W monsoon.

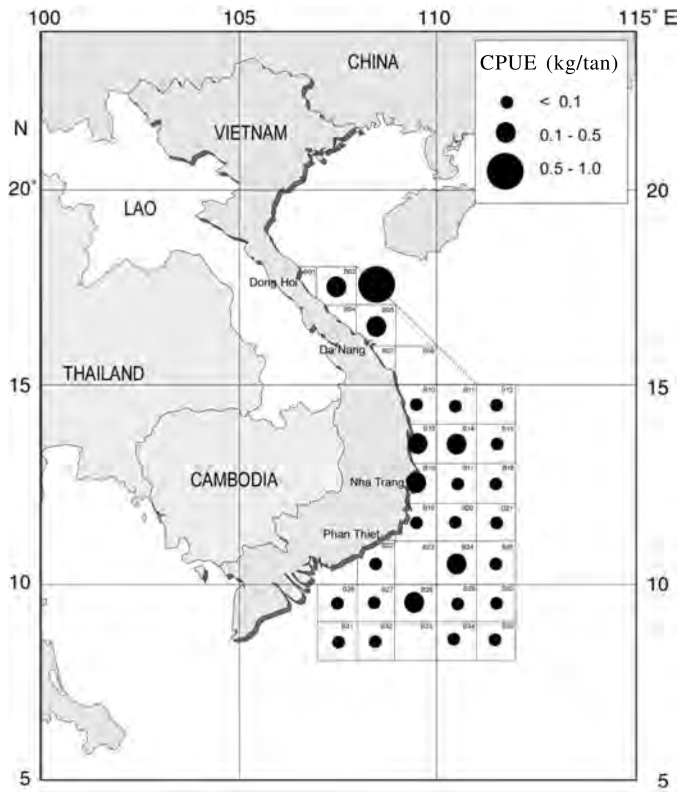

Fig. 12. Distribution of CPUE (kg/tan) of common Dolphinfish in N-E monsoon.

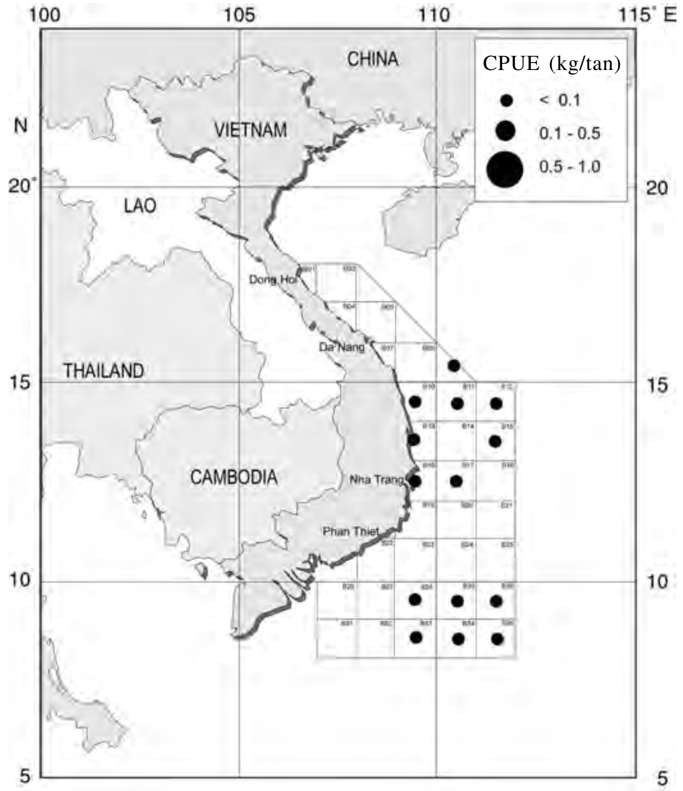

Fig. 13. Distribution of CPUE (kg/tan) of Bigtooth pomfret in S-W monsoon.

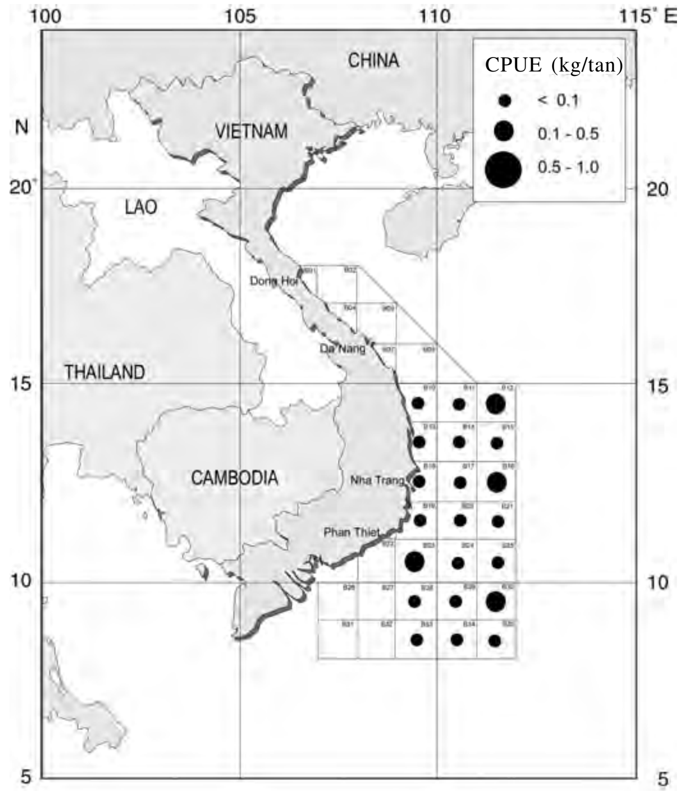

Fig. 14. Distribution of CPUE (kg/tan) of Bigtooth pomfret in N-E monsoon.

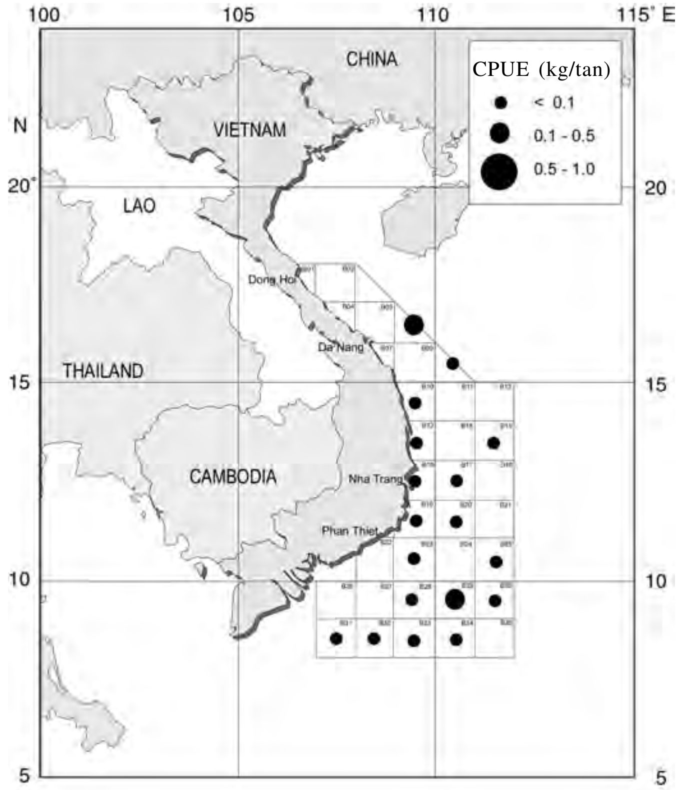

Fig. 15. Distribution of CPUE (kg/tan) of Tripletail in S-W monsoon.

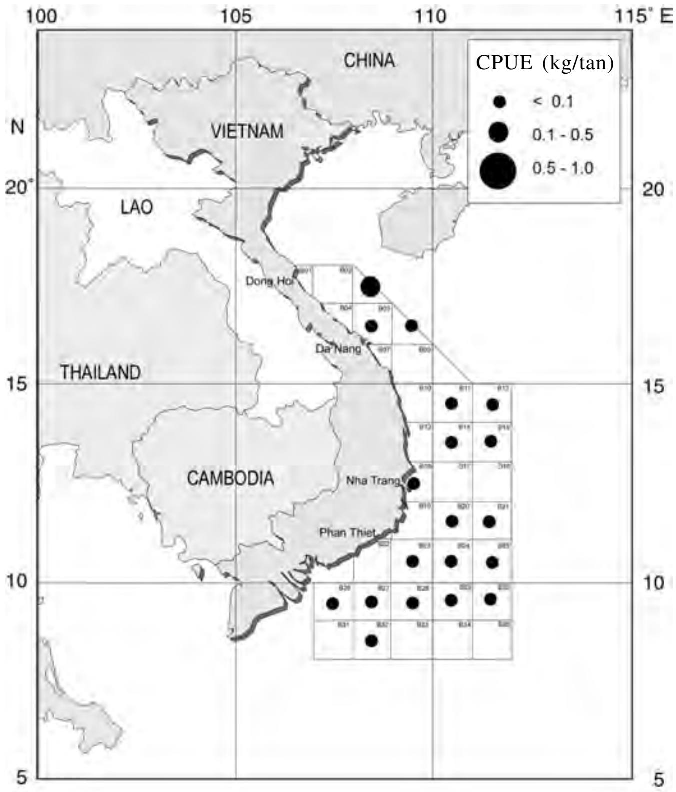

Fig. 16. Distribution of CPUE (kg/tan) of Tripletail in N-E monsoon.

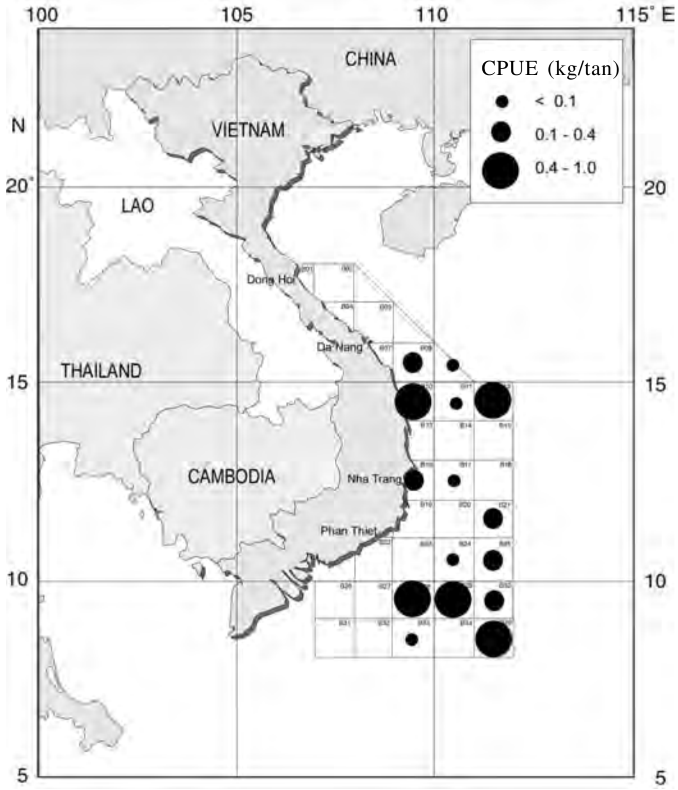

Fig. 17. Distribution of CPUE (kg/tan) of Flying squid in S-W monsoon.

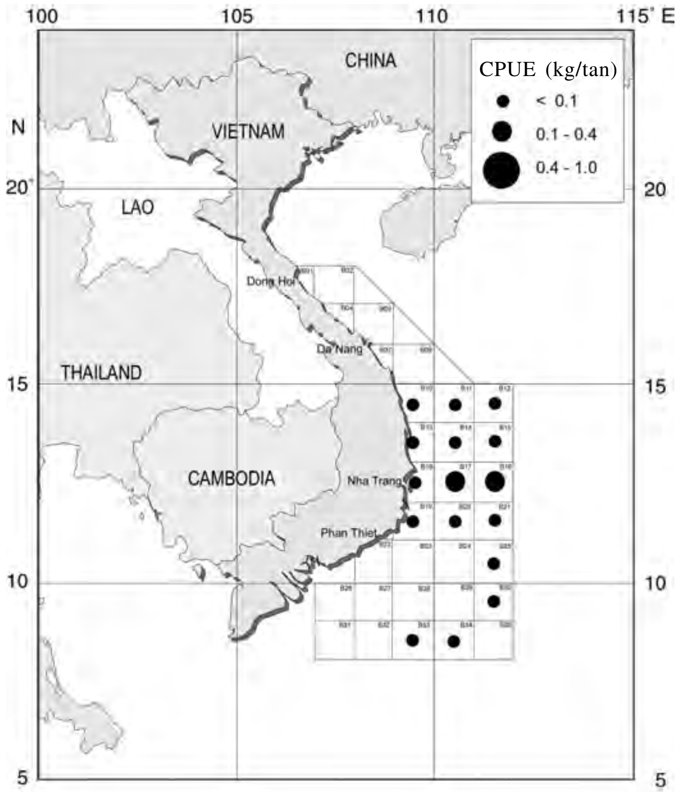

Fig. 18. Distribution of CPUE (kg/tan) of Flying squid in N-E monsoon.

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Tuna Resource Exploration with Tuna Longline in the South China Sea, Area IV : Vietnamese Waters

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ABSTRACT

The survey was designed to be carried out only in the central part of the whole area which was considered as deep sea or oceanic zone. Depth of water is mostly more than 1,000 m deep. The exploration area was covered from latitude 7°-30.0' N to latitude 16°-00.0' N and longitude 110°-00.0' E to longitude 112°-30.1' E covering around 72,000 square miles. Surface temperature varied from 27.4° C to 30.1° C, shallow thermocline layer is still the characteristic of South China Sea fishing ground. It was detached from 15-50 meters depth then water temperature decreased gradually until at the depth of 130-200 m with water temperature around 15.3° C. Three tuna were caught during the survey of M.V.SEAFDEC and many were caught on local fishing boat by both type of fishing gear tuna longline and drift gill net. They are mostly skipjack tuna *Katsuwanus pelamis* (Linnaeus, 1758) and yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) others catch were dolphinfish *Coryphaena hippurus* (Linnaeus 1758), wahoo *Acanthocybium solandri* (Cuvier, 1831), shortfin mako shark *Isurus oxyrinchus* (Rafinesque, 1809), Bigeye thresher shark *Alopias superciliosus* (Lowe, 1839), swordfish *Xiphias gladius* (Linnaeus, 1758), Bigtooth pomfret *Brama orcini* (Cuvier, 1831) and the most abundance was lancetfish *Alepissaurus borealis* (Gill, 1874). Tuna resource was found more abundance in the middle part of the survey area than the upper and lower. Their swimming layer was around 50 m to 90 m depth.

Key words : Thermocline layer, Optimum temperature, tuna longline, drift gill net, swimming layer, distribution, abundance, lancet fish

Introduction

Vietnamese waters presently cover very wide area almost more than 160,000 square miles including Exclusive Economic Zone (EEZ). The waters cover the western part of South China Sea, which is along the longitudinal line of 103°-00.0'E to 112°-30.0'E, and cover wide range of latitude from around 06°-30.0'N to 21°-30.0'N. This geographic location causes to the different fishing ground condition and fisheries resources of Vietnamese waters. Fishing ground conditions of Vietnamese waters could be separated into three different types by geographical characters. Firstly, coastal water in the high latitude fishing ground in Tonkin Bay which is shallow water and seawater temperature is a little bit cooler than the southern area (27°-28°C). Secondly, deep sea waters or oceanic zone in the central part of the area, depth of water is more than 1,000 m deep, the continental slope is very steep along the offshore of Qui Nhon to Nha Trang. And thirdly, shallow water fishing ground in the low latitude area, it is located in the southern part of Vietnam which is effected by Maekong River and the Gulf of Thailand. Sea depth is shallow and warmer than the northern part (29-30 °C). As Vietnam is located in the tropical zone of the world, so their main fisheries resource is not much different from other countries in Southeast Asia. They may have some minor differences in the resource of northern and southern area. However, fisheries resource of Vietnam has more abundance and varied in quantity and species. Fisheries product of Vietnam in 1996 was 1,028,500 metric tons, marine fisheries was the main product total 962,500 metric tons (SEAFDEC-1998). Tuna and tuna-like fishes of Vietnam are composed of frigate tuna *Auxis thazard* (Lacepede, 1800), bullet tuna *Auxis rochei* (Risso, 1810) eastern little tuna or Kawakawa *Euthynnus affinis* (Cantor,1849), longtail tuna *Thunnus tonggol* (Bleeker, 1851) these were found in the coastal waters. And other species of tuna found in the oceanic zone are skipjack tuna *Katsuwonus pelamis* (Linnaeus, 1758), yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) and bigeye tuna *Thunnus obesus* (Lowe, 1839). Coastal tuna and tuna-like fishes were caught by purse seine, drift gill net and trolling line while the oceanic species were less caught by drift gill net and drifting longline. Generally the oceanic species are living in deep waters (oceanic zone) with the depth of water of over 200 m deep. They are usually found in the over 1000 m depth fishing ground. So that the suitable fishing ground of tuna in Vietnamese waters should be the central part which is considered by the depth contour of 1000 m. By geographical chart this area is located at the latitude between 7° N to 16° N and longitude between 110° E to 113°E, it covers about 72,000 square miles. Most of Vietnamese fishing boats are vary small and carried out fishing operation by near shore waters, a small number of bigger vessels are operating in off shore waters for oceanic squid (flying squid) angling (jigging), drift gill net and drifting long line. So it seems to be under utilization of the tuna resources in the waters for Vietnamese fishermen.

Presently there are some Vietnamese fishermen operating drifting longline for tuna and other pelagic species in the off shore waters of Oui Nhon down to Nha Trang Province. Their fishing boats size are about 12-17 m in length and 3-4 m in width, with main engine about 80-150 horsepower. They operate two kind of fishing gears on their vessel, surface gill net for catching flying fish in daytime is purposely for bait supply and drifting longline at nighttime. The catch are skipjack tuna, yellowfin tuna, marlin, swordfish, wahoo, dolphinfish and shark. It is quite very difficult to study on the stock assessment of tuna by using tuna longline fishing gear, because there are so many outside factors play interaction to the operation of this gear. However, the analysis of catch rates (number per hook) is still used as the best measure of effort for stock assessment purpose but it is not appropriate for economic analysis (Polacheck, 1990). South China Sea had been the main fishing ground for Taiwanese tuna longline in the previous times, it was indicated that the catch rate was around 3.4 fish/100 hook for all catches and 2.5 tuna per 100 hooks in the 1950s (Tapiador, 1952). CPUE for tuna in Zulu sea in 1983 was around 0.2 percent (Tiongson, 1983) and the last survey of MV SEAFDEC on the Western Philippines in 1998 was no catch of tuna on that survey, it may be that some fishing technique were not appropriate to that fishing ground.(Dickson, 1998) However, tuna resource in the South China Sea have shown significantly declined in the 1980s (Tiongson, 1993). Small-scale tuna longline and artisanal tuna fishing are still operated in the off shore fishing ground of Philippines and Vietnam by small-scale fisherman of the countries.

Materials and Methods

Tuna longline fishing gear used for this survey are the original gear used on MV SEAFDEC from 1994 with two different types of branchline Multifilament and Monofilament. The gear construction was consisted of 50 m of 7 mm diameter mansen rope for mainline. Two different types of branchline, 31 m of 4 mm diameter polyester rope, sekiyama and wire leader, and 23 m of 1.8 mm diameter nylon monofilament with wire leader. Buoy line was 25 m of 7 mm diameter Mansen rope connected to 300 mm diameter plastic buoy, ball shape. The gear was arranged into a basket which was consisted of 4-

6 branchlines in one basket depend upon fishing condition, mostly 4 branchlines in a basket was used in this survey, total hook numbers in each operation was about 360 hooks. (Fig.1)

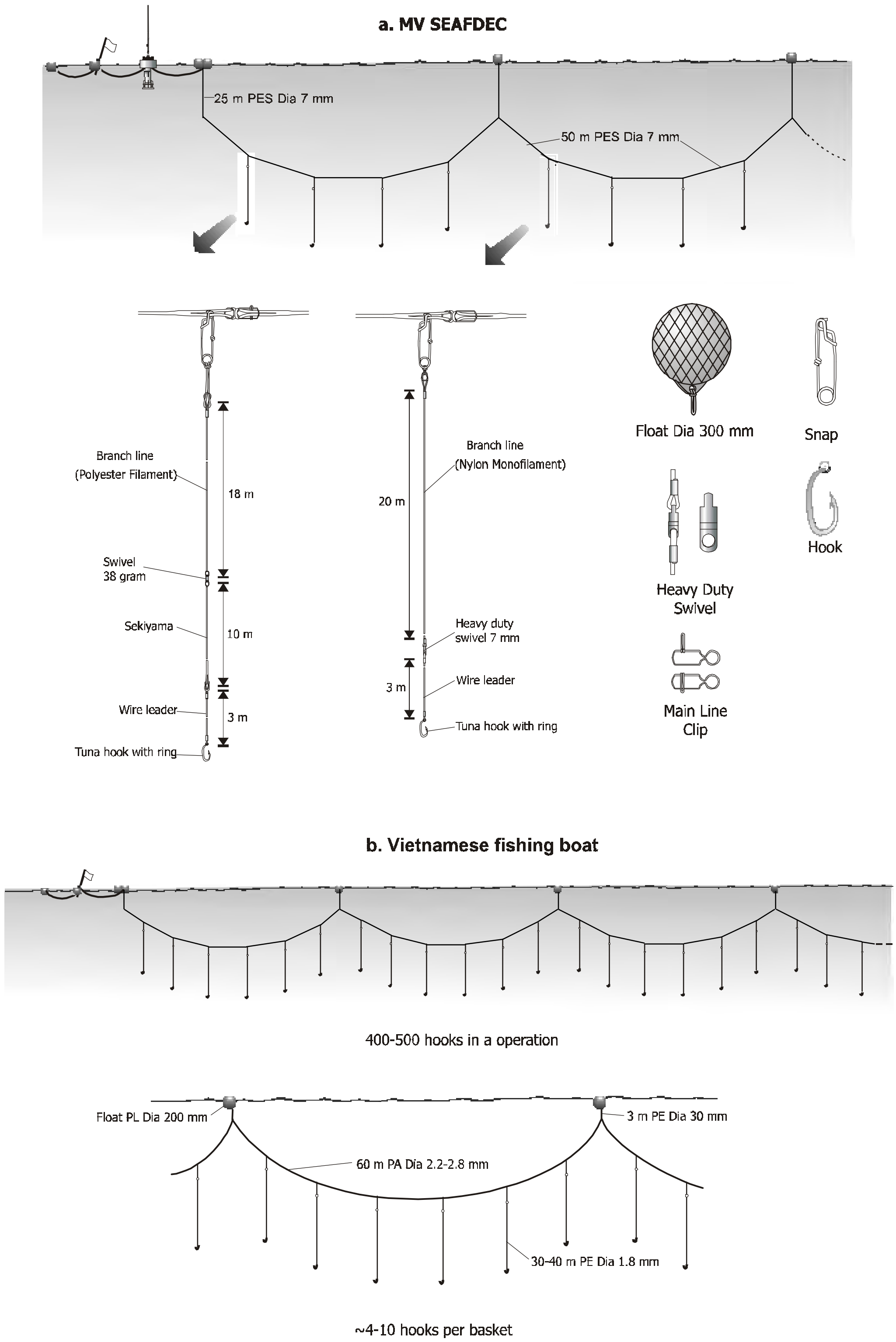

Fig. 1. (a) Fishing gear construction and arrangement of MV SEAFDEC
(b) local fishing boat of Vietnam

Dr. Chu Tien Vinh, Vietnamese fisheries biologist, provided all information and data the local fishing vessels as well as fishing gear installed onboard the local fishing boat accompanying this survey. Local tuna long line fishing gear was consisted of 60 m of 2.2-2.8 mm diameter of nylon monofilament mainline, 30-40 m of 1.8 mm diameter of nylon monofilament branchline, 3 m of 3 mm diameter polyethylene buoy line. The gear was arranged into 6-10 hooks in a basket, total hook numbers in the operation were about 400-500 hooks. The main survey was conducted on MV SEAFDEC together with oceanographic and the others of the collaborative research program, the accompanying survey were carried out on the other two local fishing boats. MV SEAFDEC is a 1,276 gross tonnage tuna purse seine training and research vessel of the Southeast Asian Fisheries Development Center (SEAFDEC), Training Department (TD). The other two local fishing vessels were Vietnamese fishing vessels, 17 m long with 120 Hp of main engine and 19 m long with 330 Hp of main engine, they carried out the survey by drifting longline and drift gill net respectively. The details of drift gill net fishing gear were not been informed but the catch was appeared in the background of this paper. (Catch data provided by Dr. Chu Tien Vinh)

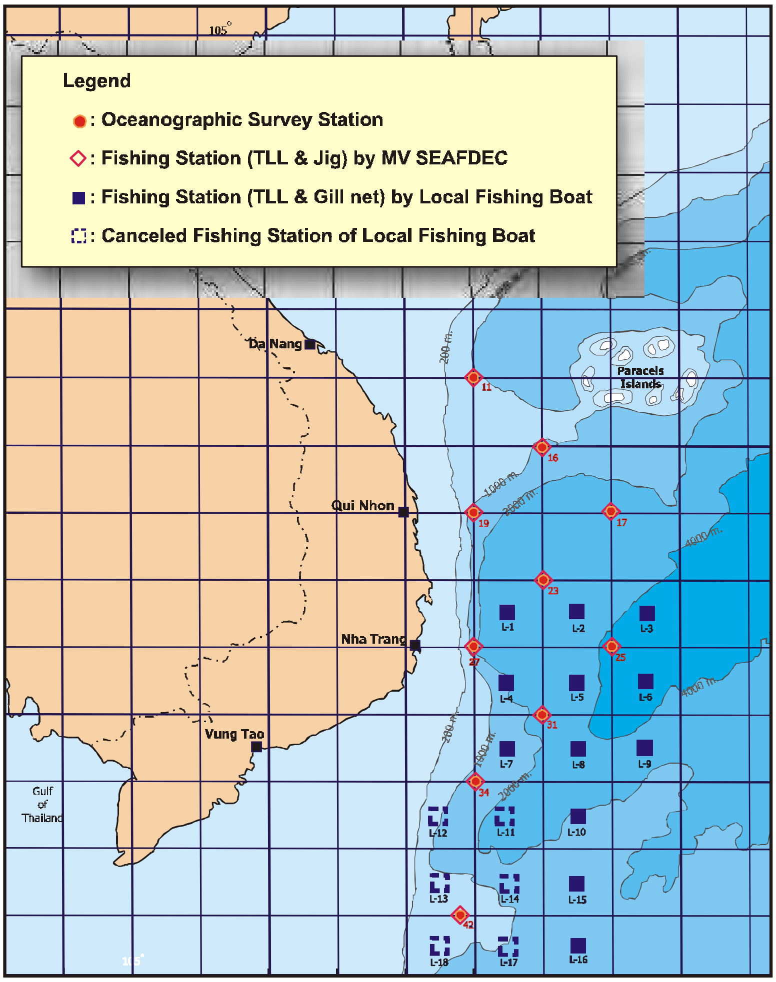

Fig. 2. Fishing survey station during the cruise by MV SEAFDEC and local fishing boat.

Ten fishing survey stations were planned along the stations of Oceanographic survey, they were designed mostly beyond the depth contour of 1,000 m deep, these for MV SEAFDEC. The designed of 18 accompanying survey stations by local fishing boats were distributed among the ten stations of

MV SEAFDEC with around 45 miles interval. However, the fishing survey had been conducted in 12 stations and the rest of 6 stations in the southern area were cancelled. (Fig.2)

Fishing Operation

Indo-pacific mackerel and Indian mackerel were prepared for bait of tuna longline on MV SEAFDEC while flying fish was used on the local fishing vessel. The first two fishing stations were used for fishing survey and checking the swimming layer of tuna at the same time. So fishing gear arrangements of the first two fishing operation on MV SEAFDEC were 6 and 5 branchlines in one basket. Depth of hooks layer were 134-155 m and 70-110 m deep, there was no tuna catch at that time. Then the gear arrangement of 4 branchlines was used for the remained 8 fishing survey stations, they were designed to operate in the two different periods of time, daytime and nighttime, four by four stations. In order to check water temperature at hooks layer, two set of depth meter and temperature meter recorder (RMD&RMT) were fixed at the lowest branchline of the basket number 20 and 60 of the line (total 85 baskets). Daytime operation was carried out from 0500 hrs. to 1500 hrs. While nighttime operation was conducted from 1800 hrs. until 0600 hrs. of the next day.

Fishing operation on board local fishing vessel was carried out only at nighttime (1500 hrs.-0500 hrs.) during the period of 17-28 May 1999.

Fishing Ground Conditions

Oceanographic data of fishing ground were detached and recorded by ICTD before and after the fishing operation, they were water temperature from surface to 1,000 m, salinity, dissolved oxygen, and transparency. At some station, XBT was operated to check the water temperature profile of fishing ground. Those data were used to identify thermocline layer, and also RMT&RMD device were used to confirm water temperature and depth of hooks layer at the same time of operation. (Table.1) Record of water temperature at hook layer compared to water temperature profile was shown in Fig. 3. Prior to any fishing operation, discussion among researchers had been made on the results which had caused effect to the previous operation as to fishing ground conditions, hooks layer and catch.

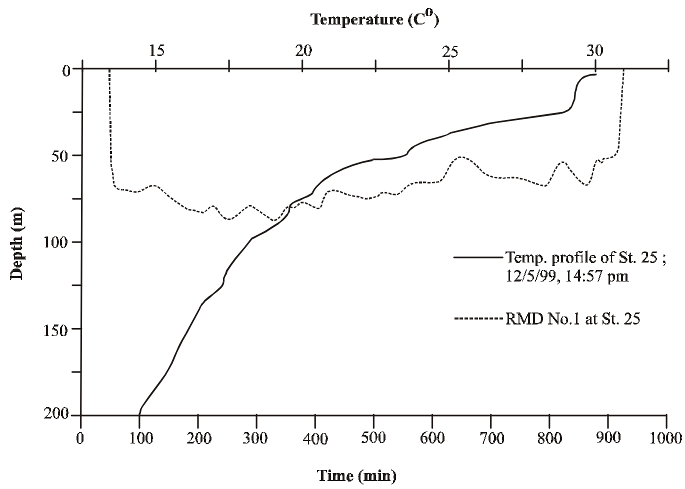

Fig. 3. The respective depth of hooks layer (from RMD) in comparison with the temperature profile of fishing ground from ICTD at Station no. 25.

Results

The tuna survey by tuna longline was carried out by two vessels, MV SEAFDEC and local fishing boat of Vietnam. Twenty-two fishing operations were conducted, 10 operations by MV SEAFDEC and 12 operations by the local one, 3,408 hooks and about 6,000 hooks were set by those two vessels. There were not so many tuna caught, two large sized yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) and one big sized skipjack tuna *Katsuwonus pelamis* (Linnaeus, 1758) were taken by MV SEAFDEC while 55.9 kg of yellowfin tuna and 73.4 kg of skipjack tuna were taken by local fishing vessel. Other catch by MV SEAFDEC were wahoo *Acanthcybium solandri* (Cuvier, 1831), dolphinfish *Coryphaena hippurus* (Linnaeus, 1758), swordfish *Isurus oxyrinchus* (Rafinesque, 1809), bigeye thresher shark *Alopias superciliosus* (Lowe, 1839), Blue shark *Prionace gluca* (Linnaeus, 1758) black ray and lancetfish *Alepissaurus borealis* (Gill, 1874) while other catch of local fishing boat were. Spanish mackerel, Tripletail, dolphinfish, bigtooth pomfrect *Brama orcini* (Cuvier, 1831), shark and others (Table 2 and 3).

There was no difference between the catch by daytime and nighttime of the operation on MV SEAFDEC, even through there was 5 to 6 hours different in the immersion time, 8-9 hours for daytime operation and 14 hours for night time operation. Almost of the operation on board local fishing vessel were conducted at nighttime for 13 hours immersion times.The hook rate for overall of this survey by MV SEAFDEC was 0.88 percent and only 0.09 percent for tuna (yellowfin and skipjack tuna) but it could not be compared with the catch of local fishing boat because the informed data was only available in total weight of the catch. However it was found that there were yellowfin and skipjack tuna distributed in the oceanic zone at the central part down to southeastern part of Vietnamese waters. This could be more clear understood, when it was compared to the catch of drift gill net which had been operated in the area at the same time (see Table 3 and Fig. 4)

Fishing ground condition of the central area of Vietnamese waters was determined station by station of the fishing survey. It was found that the vertical temperature profile of the fishing stations show a mixed layer of about 10 to 50 m deep after that the water temperature starts to decrease gradually. The thermocline layer is evidently not prominent with temperatures of around 16 °C to17 °C and 15 °C to16 °C at 150 and 200 m, respectively. The level of dissolved oxygen in the upper layer (60 m deep) was about 3.22 –3.88 ml/l, salinity levels were 33.89 to 34.44 ppt. at 60 m deep. (Table1) Base on RMT and RMD data which was recorded at fishing station number 25, 74 kg yellowfin tuna was caught with one blue shark *Prionace glauca* (Linneaus,) one wahoo and three lancetfish. Depth of hooks layer was recorded at 50-80 m deep with the water temperature at 20.5 °C to 23.5° C and depth of sea was over 4,000 m. (Fig. 3) It was similar to the hooks layer of the operation at station number 19 which the result was 56 kg yellowfin tuna, 8.2 kg skipjack tuna, one shortfin mako shark, one dolphinfish, one black ray and one lancetfish. So that according to the information of this survey it could be assumed that the swimming layer of tuna in this area are around 50-90 m deep from the surface.

Table 1. Fishing ground condition of the survey station.

Station No	Location		Sea Depth(m)	Surface temperature (°C)	Transparency (m)	Water quality at 60 m. depth		Thermocline layer				Hook layer			
								Upper		Lower		Monofilament		Multifilament	
	Latitude	Longitude				Salinity (ppt)	DO(ml/l)	Depth(m)	Temp(°C)	Depth(m)	Temp(°C)	Depth(m)	Temp(°C)	Depth(m)	Temp(°C)
11	15°55.0 N	111°20.8 E	847	27.4	29	34.28	4.14	51	26.4	165	16.7	135-145	17.0-18.5	145-155	17.0-18.0
16	14°55.1 N	111°02.7 E	1230	28.6	36	34.05	4.12	40	27.3	140	16.0	100-110	18.0-20.0	70-110	19.0-21.0
17	13°56.9 N	112°01.2 E	2100	29.2	38	33.89	3.83	15	28.8	130	17.3	55-65	15.0-26.0	60-85	23.0-26.0
19	14°00.0 N	109°59.8 E	653	27.9	27	34.44	3.82	30	27.5	110	19.6	55-90	21.0-23.0	55-75	23.0-24.0
23	13°05.0 N	110°58.8 E	2703	29.3	33	34.16	3.69	15	28.8	130	17.2	55-65	*	50-65	24.0-25.0
25	12°02.5 N	112°02.4 E	4117	29.7	30	34.44	3.31	20	29.2	110	17.6	50-75	20.0-22.0	55-80	20.0-23.0
27	11°58.2 N	109°59.7 E	1734	28.3	31	34.39	3.62	15	28.0	200	15.3	50-75	23.0-24.0	55-65	23.0-24.5
31	10°56.0 N	110°59.0 E	2940	28.8	31	34.39	3.77	10	28.7	145	16.4	45-85	21.0-23.0	45-65	22.0-23.0
34	09°55.1 N	109°56.8 E	1614	30.1	33	34.08	3.22	30	29.3	195	15.4	85-90	21.5-23.0	90-110	21.0-22.5
42	07°57.0 N	109°49.5 E	628	29.7	24	34.26	3.70	25	29.4	200	15.8	75-105	22.0-23.0	80-105	20.0-23.0

* RMT was out of order.

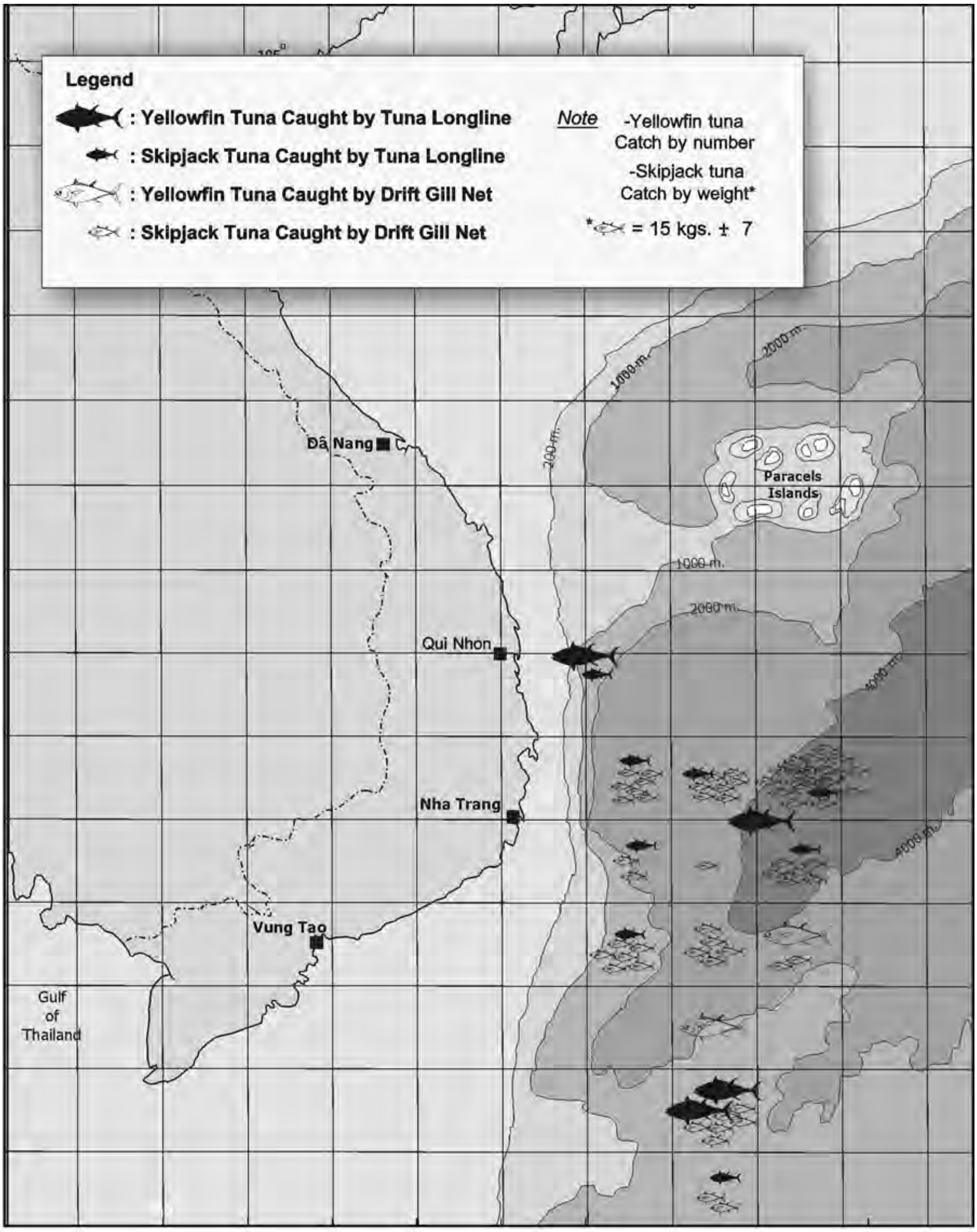

Fig. 4. Result of the survey.

Discussion

The most important factor in tuna longline fishing is determination of the swimming layer (suitable depth) of the target species caught. (Dickson, 2000 refer to Hanamoto, 1974; Nishi, 1990; Boggs, 1992) Dickson, 2000 was also refer to Nagano *et.al.,* 1997 that the comparison between shallow and deep longlines, it was indicated that the albacore, bigeye tuna and lancetfish having catch rate increased with depth while yellowfin, swordfish, mako shark and the blue shark had no clear catch rate trend with depth. Comparing to the deep longline, the shallow longline has also been observed to have higher percentage yellowfin tuna (Suzuki *et.al.*, cited in Nakano *et.al.,*1997 referred by Dickson ,2000) So, at the first two station (St. 11 and St. 16) the gear arrangement of 6 and 5 branchlines in one basket were trial in the fishing operations, depth of the hook was reached at 135-155 m and 70-100 m with the range of water temperature at 17.0-18.5°C and 18.0-21.0°C, respectively. Catch at two stations were only lancetfish, black ray and bigeye tresher shark. It was considered that hook layer (hook depth) was too deep at this fishing ground condition, water was a little bit cooler than the optimum temperature for yellowfin and skipjack tuna, 21.0-24.0°C and 20.0-22.0°C (Laenastu and Rosa, 1963 cited in Stretta, 1991). Then the remained eight fishing survey stations were carried out by four branchlines in a basket arrangement of the fishing gear. Under this fishing condition, hook layer was displayed from 50 m depth to 110 m depth which the water temperature varied from 21.0-26.0°C. Finally, two yellowfin and one skipjack tuna were caught at station number 19 and 25. Therefore, consideration only temperature could not be used as the determinant of CPUE, other environmental parameters has strongly effect too (Andrade and Gracia, 1999). Other parameter such as salinity, dissolved oxygen, relative irradiance (total light) are also effect to tuna distribution, the maneuvering sphere of tuna was located just above the combined layer of thermocline, halocline and oxycline, they corresponded to slightly above or just within the high-turbidity water layer (Morinaga *et.al.***,** 1992). Fishing ground condition of the survey area at 60 m depth was 33.89-34.44 ppt. of salinity, 3.22-4.14 ml/l of dissolved oxygen and 20.0-24.0°C of water temperature, it should be good for yellowfin tuna and skipjack tuna distribution when compare to study of Morinaga *et.al.***,**1992.

However, 340-360 hooks in one operation was too small, the hooks may be not much distributed to the suitable area and layer of tuna. So it has made small size of samples from the survey too. The result from the local fishing boat survey was a little bit better than MV SEAFDEC in total catch, but the data was not clearly identified. By the rough gear construction information, it could believe that their hooks depth were around 30-80 m deep. When their catches were taken into consideration, many spanish mackerel and dolphinfish had been caught in five stations and also one tripletail *Lobotes surinamensis* (Bloch). Those were shallow layer pelagic habitat of the oceanic. Also bait is the one of the important factor of the line fishery, flying fish which is the natural bait in this waters was used on local fishing vessel.

It could be confirmed that there are many tuna and skipjack distribution in the above thermocline layer (50-90 m depth) off the survey waters.

Table 2. Fishing Operation condition and catch on each survey station of MV SEAFDEC.

Station No	Number of gear (basket)		Number of hook per basket	Total hook	Operation time		Hook layer		Type of bait	Catch	
	Mono	Multi			Immersion time (hrs)	Daytime Nightime	Depth(m.)	Temp(^oC)		Species	Weight (kg.)
11	30	30	6	360	8	Daytime	135-155	17.0-18.5	Chub Mackerel	Black ray	6.5
										Bigeye thresher shark	20.0
16	32	32	5	360	8	Daytime	70-110	18.0-21.0	Chub Mackerel	Black ray	5.3
										3 Lancetfish	8.8
17	42	43	4	340	8	Daytime	55-90	23.0-26.0	Chub Mackerel	Shortfin mako shark	85.5
									Flying squid	Wahoo	8.0
19	42	43	4	340	8	Daytime	55-90	21.0-24.0	Chub Mackerel	Yellowfin tuna	56.0
									Flying squid	Dolphinfish	5.0
										Skipijack tuna	8.2
										Black ray	3.6
										Shortfin mako shark	30.0
										Lancetfish	5.6
23	41	43	4	336	9	Daytime	50-65	24.0-25.0	Chub Mackerel	Black ray	5.1
25	42	41	4	332	14	Nightime	50-80	20.0-23.0	Chub Mackerel	Yellowfin tuna	74.4
									Flying squid	Blue shark	70.0
										Wahoo	5.5
										3 Lancetfish	4.3
27	40	43	4	332	9	Daytime	50-70	23.0-24.5	Chub Mackerel	Black ray	6.0
									Flying squid	2 Lancetfish	5.0
31	41	42	4	332	14	Nightime	45-85	21.0-23.0	Chub Mackerel	Blue shark	38.0
34	43	42	4	340	14	Nightime	85-110	21.0-23.0	Chub Mackerel	Snake mackerel	0.4
42	42	42	4	336	14	Nightime	75-105	20.0-23.0	Chub Mackerel	3 Bigeye thresher shark	212.0
										Swordfish	23.5

Table 3. Fishing condition and catch of local fishing boat compare to the catch of drift gill net.

Date	Station No.**	Location		Total hook	Operation time		Type of bait	TLL Catch		Drift Gill Net Catch*	
		Latitude	Longitude		Immersion time (hrs)	Daytime /Nighttime		Species	Weight (kg.)	Species	Weight (kg.)
17/5/99	L-7	10°30.0 N	110°30.0 E	500	13	Nighttime	Flying fish	Shark	59.9	Devil ray	140.9
								Skipjack tuna	9.5	Skipjack tuna	97.2
								Others	3.6	Others	10.6
18/5/99	L-6	11°30.0 N	110°30.0 E	500	13	Nighttime	Flying fish	Dolphinfish	5.3	Skipjack tuna	33.8
								Skipjack tuna	16.0	Wahoo	11.9
										Others	6.2
19/5/99	L-1	12°30.0 N	110°30.0 E	500	13	Nighttime	flying fish	Shark	16.0	Skipjack tuna	102.5
								Skipjack tuna	10.1	Others	10.1
								Tripletail	2.9		
20/5/99	L-2	12°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Skipjack tuna	14.0	Skipjack tuna	115.2
										Black marlin	51.2
										others	16.4
21/5/99	L-3	12°30.0 N	112°30.0 E	500	13	Nighttime	flying fish	Skipjack tuna	14.0	Skipjack tuna	430.7
										Black marlin	110.6
22/5/99	L-4	11°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Skipjack tuna	12.6	Skipjack tuna	88.7
										Black marlin	161.8
										others	10.4
23/5/99	L-5	11°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Spanish macke	7.0	Skipjack tuna	15.2
										Black marlin	66.5
										others	11.3
24/5/99	L-9	10°30.0 N	112°30.0 E	500	13	Nighttime	flying fish	Shark	21	Yellowfin tuna	8.2
								Spanish macke	8.4	Skipjack tuna	31.1
										others	11.7
25/5/99	L-8	10°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Pomfret	0.8	Skipjack tuna	79.1
										others	6.9
26/5/99	L-10	09°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Shark	4.5	Yellowfin tuna	5.5
								Spanish macke	2.0	Spanish mackere	6.9
										Marlin	9.4
										Others	5.8
27/5/99	L-15	08°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Yellowfin tuna	55.9	Skipjack tuna	85.8
								Others	1.7	Black marlin	7
28/5/99	L-16	07°30.0 N	111°30.0 E	500	13	Nighttime	flying fish	Skipjack tuna	6.2	Yellowfin tuna	6.6
								Spanish macke	2.6	Skipjack tuna	36.4
										Others	34.5

* Drift gill net operated by another local fishing boat
** Local fishing boat survey station
*** Information by Dr. Chu Tien Vinh

Acknowledgements

The authors would like to thank Dr. Chu Tien Vinh who provided us the local fishing boat survey information, Dr. Somboon Siriraksophon, for justification of the survey map and Ms. Nathacha Sornvaree, Ms. On-uma Pattamapranee for helping manuscript preparation.

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Fish Taxonomic Studies in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

Work was undertaken on fish taxonomy of marine fish found in Vietnamese waters in order to revise the "Field guide to important commercial marine fishes of the South China Sea". Two field surveys were carried out at 9 separate locations from April 23 to May 17, and 2 other locations from September 20-26, 1999. A total of 442 specimens of fish from 107 different families were collected and photographed. Among the 442 specimens, 336 specimens were successfully identified to the species level, 99 specimens to the genus level, and only 7 specimens to the family level. The sampling areas at Qui Nhon, Nha Trang and Phan Thiet provided the most number of samples of 96, 94 and 79 fish, respectively. A total of 348 fish were new candidates for the Field Guide. More field surveys are necessary to cover the rather extensive array of new fish specimens expected to be found in these waters.

Key words : Fish taxonomy, marine fish, Vietnamese waters

Introduction

In 1998, SEAFDEC/ MFRDMD published a book entitled "Field guide to important commercial marine fishes of the South China Sea" which mostly emphasized on fish specimens collected in Malaysian waters (Mansor *et al*., 1998). To enlarge the scope of interest, the Marine Fishery Resources Development and Management Department (MFRDMD) proposed the revision of the Field Guide as part of its three-year program. Since 1998, MFRDMD has instituted fish taxonomic work in Vietnamese waters to seek for fish still unlisted in this book, in collaboration with the Research Institute of Marine Products (RIMP), Vietnam.The marine fisheries of Vietnam are considered as multi-species, multi-gear, small-scale and free-assessed fisheries. The marine fish fauna is diverse in nature, with an estimated number of more than 2000 species belonging to over 700 genera and 200 families (Vinh and Chung, 2000). Most of the fishing efforts are by relatively small vessels of engine capacity less than 60 hp. The major fishing gears operated by these vessels are trawls, purse seines, gillnets, lift nets, long lines and hand lines. This paper reports the important findings obtained in this study.

Materials and Methods

Fish samples, including both commercial and trash, which have not been listed in the Field

Guide, were collected at the main fish landing centers and markets along the coast of Vietnam. To accomplish this work, RIMP provided a vehicle and driver, and assigned a senior researcher as the responsible Vietnamese counterpart. Both researchers from MFRDMD and Vietnam carried out two sampling surveys from Halong City in the north to Rach Gia in the south (Fig. 1). The first survey covered 9 areas, such as Haiphong, Thanh Hoa, Vinh, Danang, Quay Nhon, Nha Trang, Phan Thiet, Vung Tau, and Rach Gia during the period 23rd April - 17th May, 1999 when M/V SEAFDEC was cruising off the coast of Vietnam. The second survey covered Cat Ba, which is in the vicinity of Hai Phong, and Halong City during 20th-26th September, 1999.

Fish were carefully chosen after referring to the Field Guide. If the selected fish was not mentioned in the Field Guide, at least three fish per species were purchased from the fish vendor. The collected fish samples were stored properly in ice-boxes. In the first survey, samples disposal was undertaken in two ways. If the research vessel M/V SEAFDEC was in the vicinity, fish in the ice-boxes were sent directly to be stored in the M/V SEAFDEC cold room, and the measurement, identification and photographing of fish samples were undertaken at the laboratory of MFRDMD. These specimens were later preserved in 10% formaldehyde and kept in the collection room. In cases where M/V SEAFDEC was not available, the measurement, identification and photographing of fish samples were undertaken at the accommodation shelters of the researchers, in which fresh water was readily available, right after sampling.

Fish were identified using FAO species catalogues and taxonomic literatures prepared by Abu Khair and Mohd Azmi (1996), Axelrod *et al.* (1988), Burgess *et al.* (1990), Chin (1998), Dakin (1975), Gloerfelt-Tarp and Kailola (1984), Heemstra and Randall (1993), Last and Stevens (1994), Mansor *et al.* (1996), Mansor *et al.* (1998), Masuda *et al.* (1975), Masuda *et al.* (1984), Masuda and Allen (1987), Min *et al.* (1996) and Satapoomin and Poovachiranon (1997). The ICLARM database CD known as "FishBase 97" was also referred using the facilities available within MFRDMD.

Fig. 1. Map of the coast of Vietnam indicating the main landing centres where sampling was carried out.

Results

A total of 442 specimens of fish from 107 different families were collected and photographed (listed in Table 1). Of these fish, 336 specimens were successfully identified to the species level, 99 specimens to the genus level, and only 7 specimens to the family level. Work is still on-going to identify these fish to the species level. A total of 348 fish specimens were new candidates for the Field Guide (Table 2).

Table 3 shows the numbers of family, genus and species of the fish specimens classified according to the localities. The sampling areas at Qui Nhon, Nha Trang and Phan Thiet provided the most number of samples of 96, 94 and 79 fish, respectively.

Table 1. List of fish specimens sampled at the various landing sites in the study.

No.	Family name	Genus	Species	Length(mm)TL	Locality
1	ACANTHURIDAE	*Acanthurus*	sp. 1	412	Phan Thiet
2		*Acanthurus*	sp. 2	224	Phan Thiet
3		*Naso*	*brevirostris*	350	Qui Nhon
4		*Naso*	*hexacanthus**	500	Phan Thiet
5		*Naso*	*lituratus*	252	Qui Nhon
6		*Naso*	*lituratus*	250	Qui Nhon
7		*Naso*	*Unicornis**	375	Nha Trang
8	AMBASSIDAE	*Ambasis*	*Nalua*	101	Qui Nhon
9	ANTENNARIDAE	*Antennarius*	sp. 1	162	Cat Ba
10		*Antennarius*	*Striatus*	105	Phan Thiet
11	APOGONIDAE	*Apogon*	*Aureus*	150	Qui Nhon
12		*Apogon*	*Doederleini*	85	Qui Nhon
13		*Apogon*	*Ellioti*	101	Qui Nhon
14		*Apogon*	*Kiensis*	98	Phan Thiet
15		*Apogon*	*Kiensis*	90	Phan Thiet
16		*Apogon*	*Quadrifasciatus*	118	Halong Bay
17		*Apogon*	*Quadrifasciatus*	88	Halong Bay
18		*Apogon*	sp. 1	107	Phan Thiet
19		*Apogon*	sp. 2	96	Phan Thiet
20		*Apogon*	*trimaculatus*	148	Qui Nhon
21		*Cheilodipterus*	*macrodon*	140	Qui Nhon
22		*Cheilodipterus*	*macrodon*	169	Qui Nhon
23	ARIIDAE	*Arius*	*maculatus**	105	Vinh
24		*Arius*	*thalassinus**	185	Cat Ba
25	ARIOMMATIDAE	*Ariomma*	*indica**	260	Qui Nhon
26		*Ariomma*	*indica**	205	Qui Nhon
27		*Ariomma*	sp. 1	163	Thanh Hoa
28	ATHERINIDAE	*Atherinomorus*	*ogilbyi*	122	Qui Nhon
29	BALISTIDAE	*Canthidermis*	*maculatus*	300	Danang
30		*Canthidermis*	*maculatus*	160	Qui Nhon
31		*Canthidermis*	*maculatus*	290	Qui Nhon
32	BATRACHOIDIDAE 1			167	Phan Thiet
33	BELONIDAE	*Ablennes*	*hians**	750	Haiphong
34		*Strongylura*	*strongylura*	295	Haiphong
35		*Tylosurus*	*crocodilus crocodilus*	1010	Rach Gia
36	BERYCIDAE	*Centroberyx*	*druzhinini*	265	Danang
37	BLENNIIDAE	*Xiphasia*	*setifer*	420	Nha Trang
38	BOTHIDAE	*Bothus*	*myriaster*	172	Phan Thiet
39		*Bothus ?*	sp. 1	117	Phan Thiet

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
40		*Pseudohombus*	*cinnamoneus*	277	Nha Trang
41		*Pseudohombus*	*lexisquamis*	330	Vinh
42		*Pseudohombus*	*lexisquamis*	280	Vinh
43		*Pseudohombus*	sp. 1	152	Vinh
44		*Pseudohombus*	sp. 2	152	Nha Trang
45		*Pseudohombus*	sp. 3	247	Vinh
46	BRAMIDAE	*Brama*	*japonica*	387	Danang
47	BRANCHIOSTEGIDAE	*Branchiostegus*	*albus*	244	Nha Trang
48		*Branchiostegus*	*argentatus*	307	Danang
49		*Branchiostegus*	sp. 1	160	Cat Ba
50		*Branchiostegus*	sp. 2	230	Haiphong
51	BREGMACEROTIDAE	*Bregmaceros*	*macclellandii*	89	Cat Ba
52	CAESIONIDAE	*Caesio*	*caerulaureus**	225	Nha Trang
53		*Caesio*	*lunaris*	330	Qui Nhon
54		*Caesio*	*pisang*	180	Qui Nhon
55		*Paracaesio*	*xanthurus*	410	Nha Trang
56		*Paracaesio*	*xanthurus*	260	Qui Nhon
57	CALLIONYMIDAE	*Callionymus*	sp. 1	110	Vinh
58		*Callionymus*	sp. 2	235	Qui Nhon
59		*Dactylopus*	*dactylopus*	230	Cat Ba
60		*Dactylopus*	*dactylopus*	141	Cat Ba
61		*Dactylopus*	sp. 1	122	Phan Thiet
62		*Repomucenus*	*richardsonii*	153	Cat Ba
63		*Repomucenus*	sp. 1	66	Haiphong
64		*Repomucenus*	sp. 2	178	Haiphong
65		*Repomucenus*	sp. 3	169	Haiphong
66		*Repomucenus*	sp. 4	415	Haiphong
67		Synchiropus	sp. 1	103	Phan Thiet
68	CARANGIDAE	*Alepes*	*djedaba**	145	Haiphong
69		*Alepes*	sp. 1	100	Vinh
70		*Alepes*	sp. 2	137	Haiphong
71		*Carangoides*	*hedlandensis**	405	Qui Nhon
72		*Carangoides*	*orthogrammus*	260	Qui Nhon
73		*Caranx*	*sexfasciatus**	450	Danang
74		*Caranx*	*tille**	233	Danang
75		*Decapterus*	*maruadsi**	390	Danang
76		*Decapterus*	*maruadsi**	210	Haiphong
77		*Decapterus*	*russelli**	345	Danang
78		*Elagatis*	*bipinnulata**	295	Qui Nhon
79		*Scomberoides*	tol*	147	Haiphong
80		*Scomberoides*	*tala**	490	Danang
81		*Seriolina*	*nigrofasciata**	148	Halong Bay
82		*Trachinotus*	*baillonii*	390	Nha Trang
83		*Trachinotus*	*baillonii*	233	Qui Nhon
84		*Trachinotus*	*baillonii*	232	Qui Nhon
85		*Trachurus*	*japonicus*	186	Haiphong
86		*Uraspis*	*helvola**	295	Danang
87		*Uraspis*	*helvola**	270	Qui Nhon
88	CARCHARHINIDAE	*Carcharhinus*	*sealei*	610	Haiphong
89		*Carcharhinus*	sp. 1	310	Haiphong
90		*Carcharhinus*	sp. 2	440	Rach Gia

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
91	CENTROPOMIDAE	*Lates*	*japonicus*	366	Qui Nhon
92		*Psammoperca*	*waigiensis**	238	Danang
93	CEPOLIDAE	*Acanthocepola*	*limbata*	250	Phan Thiet
94	CHAETODONTIDAE	*Chaetodon*	*guentheri*	116	Qui Nhon
95		*Chaetodon*	*wiebeli*	124	Haiphong
96		*Chaetodon*	*wiebeli*	198	Nha Trang
97		*Chaetodon*	*xanthurus*	130	Nha Trang
98		*Heniochus*	sp. 1	270	Qui Nhon
99		*Heniochus*	sp. 2	300	Qui Nhon
100	CHAUNACIDAE	*Chaunax*	sp. 1	150	Qui Nhon
101	CLUPEIDAE	*Amblygaster*	sp. 1	135	Haiphong
102		*Dussumieria*	*acuta (F)*	140	Phan Thiet
103		*Dussumieria*	*acuta (M)*	148	Haiphong
104		*Dussumieria*	*elopsoides*	195	Haiphong
105		*Ilisha*	*elongata*	260	Haiphong
106		*Nematolosa*	*come*	170	Haiphong
107		*Nematolosa*	*come*	177	Halong Bay
108		*Nematolosa*	*come*	183	Qui Nhon
109		*Nematolosa*	sp. 1	220	Vinh
110		*Sardinella*	*gibbosa**	130	Haiphong
111		*Sardinella*	*melanura*	167	Haiphong
112		*Sardinella*	*melanura*	145	Vinh
113		*Sardinella*	*zunasi*	135	Vinh
114	CONGIOPODIDAE	*Amblyapistus*	sp. 1	120	Phan Thiet
115		*Erisphex*	*potti*	83	Qui Nhon
116		*Hypodytes*	*rubripinnis*	75	Nha Trang
117		*Hypodytes*	*rubripinnis*	89	Phan Thiet
118	CONGRIDAE	*Gnathopis*	*nystromi nystromi*	130	Cat Ba
119	CORYPHENIDAE	*Coryphaena*	*equiselis*	412	Danang
120	CYNOGLOSSIDAE	*Cynoglossus*	*arel*	180	Qui Nhon
121		*Cynoglossus*	*bilineata*	145	Nha Trang
122		*Cynoglossus*	*bilineata*	218	Thanh Hoa
123		*Cynoglossus*	*interuptus*	110	Nha Trang
124		*Cynoglossus*	*interuptus*	95	Nha Trang
125		*Cynoglossus*	*interuptus*	90	Vinh
126		*Cynoglossus*	*interuptus (yg)*	107	Danang
127		*Cynoglossus*	*robustus*	350	Nha Trang
128		*Cynoglossus*	*robustus*	460	Qui Nhon
129		*Cynoglossus*	sp. 1	144	Phan Thiet
130		*Cynoglossus*	sp. 2	213	Rach Gia
131		*Cynoglossus*	sp. 3	250	Phan Thiet
132		*Paraplagusia*	*bilineata*	118	Danang
133		*Paraplagusia*	*bilineata*	120	Nha Trang
134	DACTYLOPTERIDAE	*Dactyloptena*	*orientalis*	360	Qui Nhon
135		*Dactyloptena*	sp. 1	185	Qui Nhon
136	DASYATIDAE	*Dasyatis*	*annotatus*	230	Vinh
137		*Dasyatis*	*violacea*	500	Qui Nhon
138		*Gymnura*	sp. 1	226	Vinh
139		*Taeniura*	*lymma*	280	Vinh
140	DREPANIDAE	*Drepane*	*puntata*	260	Danang
141		*Drepane*	*puntata*	455	Thanh Hoa

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
142	DROSOMATIDAE	*Konorisus*	*punctatus*	185	Haiphong
143	ELEOTRIDIDAE	*Bostrichthys*	*sinensis*	110	Qui Nhon
144	ELOPIDAE	*Elops*	*machnata*	167	Nha Trang
145	ENGRAULIDAE	*Coilia*	*macrograthus*	165	Haiphong
146		*Stolephorus*	*tri**	100	Haiphong
147		*Stolephorus*	*tri**	100	Vinh
148		*Thryssa*	*dussumieri*	113	Vinh
149		*Thryssa*	*hamiltonii**	128	Haiphong
150		*Thryssa*	*setirostris*	180	Haiphong
151		*Thryssa*	*setirostris*	160	Vinh
152	EXOCOETIDAE	*Cypselurus*	*hiraii*	233	Danang
153		*Cypselurus*	*poecilopterus*	344	Danang
154		*Cypselurus*	*poecilopterus*	353	Danang
155		*Cypselurus*	*poecilopterus*	240	Danang
156	FISTULARIDAE	*Fristularia*	*commersonii*	910	Danang
157	GEMPYLIDAE	*Ruvettus*	*pretiosus*	340	Qui Nhon
158	GOBIIDAE	*Acentrogobius*	*audax*	119	Halong Bay
159		*Brachyamblyopus*	*coecus*	128	Thanh Hoa
160		*Istigobius*	sp. 1	164	Phan Thiet
161		*Boleophthalmus*	*pectinirostris*	117	Qui Nhon
162	GOBIIDAE 1			112	Haiphong
163	GRAMMISTIDAE	*Diploprion*	*bifasciatus*	146	Nha Trang
164	HAEMULIDAE	*Hapalogenys*	*kishinouyei*	228	Danang
165		*Parapristipoma*	*trilineatum*	435	Nha Trang
166		*Parapristipoma*	*trilineatum*	176	Nha Trang
167		*Parapristipoma*	*trilineatum*	177	Nha Trang
168		*Plectorhynchus*	*cinctus*	136	Phan Thiet
169		*Plectorhynchus*	*diagrammus*	199	Nha Trang
170		*Plectorhynchus*	*diagrammus*	300	Qui Nhon
171		*Plectorhynchus*	*pictus*	445	Danang
172		*Plectorhynchus*	*pictus*	152	Phan Thiet
173		*Plectorhynchus*	*polytaenia*	98	Phan Thiet
174		*Plectorhynchus*	sp. 1	145	Phan Thiet
175		*Pomadasys*	sp. 1	160	Nha Trang
176	HARPADONTIDAE	*Harpadon*	*nehereus**	270	Haiphong
177	HEMIRAMPHIDAE	*Hemiramphus*	*far**	338	Nha Trang
178	HOLOCENTRIDAE	*Myripristis*	*melanosticta**	255	Phan Thiet
179		*Ostichthys*	*hypsipterygion*	300	Qui Nhon
180		*Ostichthys*	*hypsipterygion (yg)*	135	Qui Nhon
181		*Sargocentron*	*rubrum**	146	Danang
182	KYPHOSIDAE	*Kyphosus*	*cinerascens**	310	Qui Nhon
183		*Kyphosus*	*cinerascens**	200	Qui Nhon
184	LABRIDAE	*Bodianus*	*oxyeephalus*	340	Nha Trang
185		*Cheilinus*	*chlorurus**	244	Qui Nhon
186		*Cheilinus*	*trilobatus**	198	Qui Nhon
187		*Choerodon*	*azurio*	180	Halong Bay
188		*Coris*	*gaimard*	252	Qui Nhon
189		*Halichoeres*	*bicolor*	134	Halong Bay
190		*Halichoeres*	*bicolor*	132	Halong Bay
191		*Halichoeres*	*bicolor*	143	Phan Thiet
192		*Halichoeres*	*nigrescens*	133	Phan Thiet

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
193		*Hemigymnus*	*melapterus**	355	Danang
194		*Hemigymnus*	*melapterus**	300	Phan Thiet
195		*Xyrichthys*	*aneitensis*	135	Phan Thiet
196		*Xyrichthys*	*dea*	227	Haiphong
197		*Xyrichthys*	*dea*	204	Haiphong
198		*Xyrichthys*	*dea*	232	Qui Nhon
199		*Xyrichthys*	*pavo*	192	Haiphong
200		*Xyrichthys*	*pavo*	182	Qui Nhon
201		*Xyrichthys*	sp. 1	90	Phan Thiet
202		*Xyrichthys*	sp. 2	148	Phan Thiet
203		*Xyrichthys*	sp. 3	265	Danang
204		*Xyrichthys*	*sp. 4*	175	Haiphong
205		*Xyrichthys*	*verreus*	148	Qui Nhon
206		*Halichoeres*	sp. 1	157	Halong Bay
207		*Halichoeres*	sp. 2	92	Phan Thiet
208	LABRIDAE 1			182	Phan Thiet
209	LACTARIIDAE	*Lactarius*	*lactarius**	224	Nha Trang
210	LEIOGNATHIDAE	*Leiognathus*	*elongatus*	113	Phan Thiet
211		*Leiognathus*	*nuchalis*	110	Vinh
212		*Leiognathus*	*rivulatus*	90	Phan Thiet
213		*Leiognathus*	*rivulatus*	110	Phan Thiet
214		*Leiognathus*	*ruconius*	87	Vinh
215	LETHRINIDAE	*Gnathodentex*	*aureolineatus**	232	Qui Nhon
216		*Gymnocranius*	*affinis*	240	Nha Trang
217		*Lethrinus*	*haematopturus*	270	Danang
218		*Lethrinus*	*mahsena*	185	Nha Trang
219		*Lethrinus*	*miniatus*	320	Nha Trang
220		*Lethrinus*	*ornatus**	304	Nha Trang
221		*Lethrinus*	*reticulatus*	414	Danang
222		*Lethrinus*	*xanthochilus*	560	Nha Trang
223	LOBOTIDAE	*Lobotes*	*surinamensis**	285	Danang
224	LOPHIIDAE	*Lophiomus*	*setigerus*	315	Qui Nhon
225		*Lophiomus*	sp. 1	230	Phan Thiet
226	LUTJANIDAE	*Aphareus*	*furcatus*	210	Qui Nhon
227		*Aphareus*	*rutilans**	320	Nha Trang
228		*Aprion*	*virescens**	385	Qui Nhon
229		*Lutjanus*	*fulviflamma**	145	Nha Trang
230		*Lutjanus*	*gibbus**	490	Nha Trang
231		*Lutjanus*	*johni**	390	Danang
232		*Lutjanus*	*johni**	165	Qui Nhon
233		*Lutjanus*	*lutjanus**	180	Nha Trang
234		*Lutjanus*	*malabaricus**	190	Haiphong
235		*Lutjanus*	sp. 1	420	Danang
236		*Pinjalo*	*lewisi**	670	Phan Thiet
237		*Symphorus*	*nematophorus**	293	Danang
238		*Symphorus*	*nematophorus**	248	Nha Trang
239	MEGALOPIDAE	*Megalops*	*cyprinoides**	540	Danang
240	MONACANTHIDAE	*Cantherhines*	*dumerilli*	245	Qui Nhon
241		*Cantherhines*	*fronticinctus*	240	Qui Nhon
242		*Monacanthus*	*chinensis*	135	Qui Nhon
243	MONOCENTRIDAE	*Monocentris*	*japonica*	145	Qui Nhon

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
244	MONODACHTYLIDAE	*Monodachtylus*	*argenteus*	210	Qui Nhon
245	MUGILIDAE	*Liza*	*affinis*	165	Thanh Hoa
246		*Liza*	*vaigiensis*	157	Qui Nhon
247		*Valamugil*	*seheli*	198	Nha Trang
248	MULLIDAE	*Mulloidichthys*	*flavolineatus*	308	Nha Trang
249		*Parupeneus*	*barberinus*	295	Nha Trang
250		*Parupeneus*	*cyclostomus**	393	Nha Trang
251		*Parupeneus*	*heptacanthus*	248	Nha Trang
252		*Parupeneus*	*pleurospilus**	135	Phan Thiet
253		*Parupeneus*	sp. 1	285	Nha Trang
254		*Parupeneus*	*trifasciatus*	250	Nha Trang
255		*Parupeneus*	*trifasciatus*	115	Qui Nhon
256		*Upeneus*	*bensasi*	125	Qui Nhon
257	MURAENESOCIDAE	*Muraenesox*	*cinereus*	350	Nha Trang
258		*Muraenesox*	sp. 1	300	Nha Trang
259	MURAENIDAE	*Gymnothorax*	*fimbriata*	370	Nha Trang
260		*Gymnothorax*	*fimbriata*	660	Nha Trang
261		*Gymnothorax*	*reticularisus*	510	Danang
262		*Gymnothorax*	*reticularisus (yg)*	230	Nha Trang
263		*Gymnothorax*	sp. 1	562	Phan Thiet
264		*Gymnothorax*	sp. 2	347	Phan Thiet
265		*Gymnothorax*	sp. 3	610	Nha Trang
266		*Strophidon*	*ui ?*	1100	Nha Trang
267	MYLIOBATIDAE	*Aetomylaeus*	sp. 1	144	Phan Thiet
268	NEMIPTERIDAE	*Nemipterus*	*bathybius**	260	Nha Trang
269		*Nemipterus*	*japonicus**	240	Haiphong
270		*Nemipterus*	*japonicus**	280	Haiphong
271		*Nemipterus*	*marginatus**	170	Qui Nhon
272		*Nemipterus*	*marginatus**	135	Vinh
273		*Nemipterus*	*thosaporni*	185	Cat Ba
274		*Nemipterus*	*virgatus*	350	Nha Trang
275		*Nemipterus*	*virgatus*	240	Qui Nhon
276		*Scolopsis*	*ciliatus*	196	Nha Trang
277		*Scolopsis*	*eriomma*	322	Nha Trang
278		*Scolopsis*	*monogramma**	345	Nha Trang
279		*Scolopsis*	*taeniopterus**	225	Haiphong
280	OGCOCEPHALIDAE	*Halieutaea*	*fumosa*	95	Qui Nhon
281	OPHICHTHIDAE	*Pisoodonophis*	sp. 1	980	Danang
282	OPHIDIIDAE	*Sirembo*	*imberbis*	137	Phan Thiet
283		*Sirembo*	sp. 1	164	Cat Ba
284	OPISTOGNATHIDAE	*Opistognathus*	sp. 1	141	Phan Thiet
285	ORECTOLOBIDAE	*Chiloscyllium*	*punctatum**	315	Phan Thiet
286		*Chiloscyllium*	sp. 1	480	Phan Thiet
287	OSTRACIONTIDAE	*Lactoria*	sp. 1	62	Phan Thiet
288	OSTRCIIDAE	*Ostracion*	sp. 1	227	Nha Trang
289	PEMPHERIDAE	*Pempheris*	sp. 1	152	Nha Trang
290	PINGUIPEDIDAE	*Parapercis*	*filamentosa*	122	Phan Thiet
291		*Parapercis*	*filamentosa*	150	Phan Thiet
292		*Parapercis*	*snyderi*	90	Halong Bay
293		*Parapercis*	sp. 1	222	Phan Thiet
294		*Parapercis*	sp. 2	140	Cat Ba

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
295	PLATYCEPHALIDAE	*Elatis*	*ransonneti*	172	Qui Nhon
296		*Platycephalus*	sp. 1	475	Haiphong
297		*Platycephalus*	sp. 2	145	Haiphong
298		*Platycephalus*	sp. 3	150	Phan Thiet
299		*Rogadius*	*asper*	150	Phan Thiet
300	PLEURONECTIDAE	*Pleuronectes*	sp. 1	275	Vinh
301	PLOTOSIDAE	*Plotosus*	*lineatus**	225	Vinh
302	POLYNEMIDAE	*Polydactylus*	sp. 1	260	Rach Gia
303	POMACANTHIDAE	*Apolemichthys*	*trimaculatus*	220	Phan Thiet
304		*Pomacanthus*	*imperator*	330	Phan Thiet
305		*Pomacanthus*	*semicirculatus*	292	Phan Thiet
306		*Pomacanthus*	sp. 1	210	Phan Thiet
307	POMACENTRIDAE	*Abudefduf*	*septemfasciatus*	155	Nha Trang
308		*Abudefduf*	sp. 1	114	Cat Ba
309		*Abudefduf*	*vaigiensis*	138	Qui Nhon
310		*Chromis*	*fumea*	125	Qui Nhon
311		*Pristotis*	*jerdoni*	118	Haiphong
312	POMACENTRIDAE 1			156	Phan Thiet
313	POMACENTRIDAE 2			76	Phan Thiet
314	POMACENTRIDAE 3			157	Qui Nhon
315	PRIACANTHIDAE	*Priacanthus*	*cruentatus*	250	Phan Thiet
316		*Priacanthus*	*hamrur**	380	Danang
317		*Priacanthus*	sp. 1	350	Danang
318		*Priacanthus*	sp. 2	255	Nha Trang
319		*Pristigenys*	*niphonia*	190	Qui Nhon
320		*Pristigenys*	*niphonia*	155	Qui Nhon
321	RAJIDAE	*Raja*	*boesemani (M)*	230	Haiphong
322	RHINOBATIDAE	*Rhinobatus*	*schlegelic*	500	Nha Trang
323	RHYACICHTHYIDAE	*Rhyncopelatus*	*oxyrhynchus*	117	Vinh
324	SCARIDAE	*Cetoscarus*	*bicolor*	470	Danang
325		*Scarus*	*dimidiatus*	170	Qui Nhon
326		*Scarus*	*psittacus**	218	Qui Nhon
327		*Scarus*	*psittacus**	240	Qui Nhon
328		*Scarus*	*rubroviolaceus**	325	Qui Nhon
329		*Scarus*	*rubroviolaceus**	245	Qui Nhon
330		*Scarus*	*rubroviolaceus**	230	Qui Nhon
331		*Scarus*	*sordidus**	255	Qui Nhon
332		*Scarus*	*sordidus**	225	Qui Nhon
333	SCATOPHAGIDAE	*Scatophagus*	*argus*	165	Danang
334		*Scatophagus*	*argus*	103	Vinh
335	SCIAENIDAE	*Johnius*	*coitor*	135	Danang
336		*Nibea*	*albiflora*	337	Danang
337	SCOMBRIDAE	*Acanthocybium*	*solandri*	575	Qui Nhon
338		*Euthynnus*	*affinis*	500	Vinh
339		*Grammatorcynus*	*billineatus*	410	Nha Trang
340		*Katsuwonus*	*pelamis**	642	Qui Nhon
341		*Scomberomorus*	*commerson**	200	Halong Bay
342		*Scomberomorus*	*guttatus**	550	Qui Nhon
343		*Scomberomorus*	sp. 1	203	Vinh
344		*Thunnus*	*albacares*	580	Qui Nhon
345	SCORPAENIDAE	*Pterois*	sp. 1	315	Qui Nhon

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
346		*Scorpaenopsis*	*diabolus*	205	Halong Bay
347		*Scorpaenopsis*	*diabolus*	217	Nha Trang
348		*Apistus*	*carinatus*	132	Haiphong
349		*Apistus*	*carinatus*	132	Haiphong
350		*Apistus*	*carinatus*	112	Phan Thiet
351		*Apistus*	*carinatus*	162	Phan Thiet
352		*Minous*	sp. 1	98	Cat Ba
353		*Minous*	sp. 2	99	Cat Ba
354	SCORPAENIDAE 1			192	Qui Nhon
355	SCYLIORHINIDAE	*Cephalosylium*	*umbratile*	414	Qui Nhon
356	SERRANIDAE	*Cephalopholis*	*boenack**	123	Phan Thiet
357		*Cephalopholis*	*sonnerati**	437	Nha Trang
358		*Cephalopholis*	*sonnerati**	390	Nha Trang
359		*Cephalopholis*	sp. 1	175	Nha Trang
360		*Epinephelus*	*amblycephalus*	280	Nha Trang
361		*Epinephelus*	*areolatus*	147	Nha Trang
362		*Epinephelus*	*awoara*	348	Danang
363		*Epinephelus*	*awoara*	385	Danang
364		*Epinephelus*	*bleekeri**	640	Nha Trang
365		*Epinephelus*	*coioides**	180	Phan Thiet
366		*Epinephelus*	*diacanthus*	175	Nha Trang
367		*Epinephelus*	*fasciatus**	300	Nha Trang
368		*Epinephelus*	*melanostigma*	250	Nha Trang
369		*Epinephelus*	*polylepis*	620	Nha Trang
370		*Epinephelus*	*quoyanus**	236	Qui Nhon
371		*Epinephelus*	*radiatus*	392	Nha Trang
372		*Epinephelus*	*trimaculatus*	340	Danang
373		*Epinephelus*	*tukula*	587	Nha Trang
374		*Plectropomus*	*aerolatus*	473	Nha Trang
375		*Plectropomus*	*leopardus**	600	Nha Trang
376		*Plectropomus*	*leopardus**	450	Nha Trang
377		*Plectropomus*	*oligacantus*	486	Nha Trang
378		*Trisotropis*	sp. 1	315	Qui Nhon
379		*Variola*	*louti*	595	Nha Trang
380	SIGANIDAE	*Siganus*	*canaliculatus**	123	Cat Ba
381		*Siganus*	*canaliculatus**	108	Cat Ba
382		*Siganus*	*canaliculatus**	145	Nha Trang
383		*Siganus*	*canaliculatus**	145	Vinh
384		*Siganus*	*chrysospilos*	375	Phan Thiet
385		*Siganus*	*corallinus**	273	Phan Thiet
386		*Siganus*	*javus**	154	Nha Trang
387		*Siganus*	sp. 1	270	Nha Trang
388		*Siganus*	sp. 2	180	Nha Trang
389	SILLAGINIDAE	*Sillago*	*parvisquamis*	166	Haiphong
390		*Sillago*	*sihama**	330	Haiphong
391	SOLEIDAE	*Euryglossa*	*orientalis*	150	Haiphong
392		*Euryglossa*	*orientalis*	105	Vinh
393		*Heteromycteris*	sp. 1	96	Nha Trang
394		*Pardachirus*	*pavoninus*	195	Haiphong
395		*Solea*	*ovata*	100	Nha Trang
396		*Zebrias*	*zebra*	140	Thanh Hoa

Table 1. (Continued).

No.	Family name	Genus	Species	Length(mm)TL	Locality
397	SPARIDAE	*Acanthopagrus*	*latus*	267	Qui Nhon
398		*Acanthopagrus*	sp. 1	367	Danang
399		*Acanthopagrus*	sp. 2	183	Nha Trang
400		*Acanthopagrus*	sp. 3	273	Nha Trang
401		*Argyrops*	*bleekeri*	460	Nha Trang
402		*Argyrops*	sp. 1	470	Nha Trang
403		*Dentex*	*tumifrons*	400	Danang
404		*Dentex*	*tumifrons*	282	Danang
405		*Pagrus*	sp. 1	530	Nha Trang
406		*Pagrus*	sp. 2	550	Nha Trang
407	SPHYRAENIDAE	*Sphyraena*	*obtusatta**	205	Haiphong
408	SQUALIDAE	*Isistius*	*brasiliensis*	438	Qui Nhon
409	STROMATEIDAE	*Pampus*	*chinensis**	339	Nha Trang
410	SYNGNATHIDAE	*Hippocampus*	*kuda*	96	Phan Thiet
411		*Hippocampus*	sp. 1	96	Phan Thiet
412		*Hippocampus*	sp. 2	101	Phan Thiet
413		*Hippocampus*	sp. 3	92	Phan Thiet
414		*Hippocampus*	sp. 4	99	Phan Thiet
415		*Syngnathoides*	*biaculeatus*	189	Haiphong
416	SYNODONTIDAE	*Synodus*	sp. 1	175	Phan Thiet
417	TAENIODIDAE	*Taenioides*	*cirratus*	217	Thanh Hoa
418		*Taenioides*	sp. 1	187	Danang
419		*Taenioides*	sp. 2	170	Thanh Hoa
420		*Taenioides*	sp. 3	223	Thanh Hoa
421	TETRAODONTIDAE	*Arothron*	sp. 1	120	Phan Thiet
422		*Arothron*	sp. 2	82	Vinh
423		*Lagocephalus*	*gloveri*	145	Vinh
424	THERAPONIDAE	*Rhyncopelatus*	*oxyrhynchus*	120	Vinh
425		*Therapon*	*jarbua**	340	Danang
426		*Therapon*	*jarbua**	185	Haiphong
427	TORPEDINIDAE	*Narcine*	*timlei*	250	Cat Ba
428		*Narcine*	*timlei*	287	Phan Thiet
429		*Torpedo*	*marnoratus*	120	Phan Thiet
430		*Torpedo*	sp. 1	142	Phan Thiet
431		*Torpedo*	sp. 2	360	Phan Thiet
432	TRICHONOTIDAE	*Trichonotus*	sp. 1	200	Phan Thiet
433	TRIGLIDAE	*Lepidotrigla*	*abyssalis*	168	Qui Nhon
434		*Lepidotrigla*	*hime*	121	Cat Ba
435		*Satyrichthys*	*rieffeli*	290	Nha Trang
436		*Satyrichthys*	*rieffeli*	320	Nha Trang
437	URANOSCOPIDAE	*Ichthyocampus*	*lebeck*	340	Danang
438		*Uranoscopus*	*bicinctus*	147	Phan Thiet
439		*Uranoscopus*	*cognatus*	212	Phan Thiet
440		*Uranoscopus*	sp. 1	193	Qui Nhon
441	ZANCLIDAE	*Zanclus*	*canescens*	167	Qui Nhon
442	ZEIDAE	*Zeus*	*faber*	340	Qui Nhon

* Indicates fish that is already listed in the Field Guide book

Table 2. The number of new fish specimens still unlisted in the Field Guide according to the localities they were obtained.

	Halong City	Cat Ba	Haiphong	Thanh Hoa	Vinh	Danang	Qui Nhon	Nha Trang	Phan Thiet	Vung Tau	Rach Gia
No. of Family	6	11	18	7	15	19	45	32	32	0	4
No. of Genus	7	13	25	7	20	27	55	43	39	0	4
No. of Species	8	14	32	9	25	30	65	67	62	0	4

Table 3. Number of families, genera and species of fish specimens sorted according to the localities they were obtained (for all fish specimens).

	Halong City	Cat Ba	Haiphong	Thanh Hoa	Vinh	Danang	Qui Nhon	Nha Trang	Phan Thiet	Vung Tau	Rach Gia
No. of Family	8	13	23	7	19	29	48	37	36	0	4
No. of Genus	9	15	34	7	25	38	65	51	46	0	4
No. of Species	10	16	47	9	30	45	82	87	71	0	4

Discussion

Fish assemblage observed in the southern parts of Vietnam, such as Vung Tau and Rach Gia, was nearly similar to the one found in Malaysian coastal waters. Because most of the fish species here have been covered by Mansor *et al.* (1998), few samples were necessary. On the other hand, the large variety of fish specimens, which are still unlisted in the Field Guide, was observed at Qui Nhon, Nha Trang and Phan Thiet, and these specimens were collected. The reason for this large variety is probably related to the narrow continental shelf available in these waters.

Two distinct seasons are known to prevail in Northern Vietnam. From November to April, the northern part of Vietnam experiences a relatively cold and humid winter. This is precipitated by invading polar air currents that sweep into Vietnam from Siberia and China, often bringing temperatures down to as low as 0 °C in the mountainous regions of the area. Summer, from May to October, is characterized by higher temperatures, heavy rain and often typhoons. Under such a diverse condition, different types of fish species are perhaps available in this part, especially in the waters of Halong Bay in the Gulf of Tonkin.

Although two sampling activities have been carried out, more sampling efforts are still needed to focus on the Northern and Central areas, to cover the extensive array of new fish specimens expected to be found in Vietnamese waters.

MFRDMD and RIMP have successfully undertaken this study to examine some part of the full taxonomy of fishes found in Vietnamese waters. However, due to the constraints in the SEAFDEC funding, such works are often interrupted and possibly take some considerable time to complete.

Acknowledgements

The authors wish to express their gratitude to the Chief of SEAFDEC MFRDMD for his encouragement in carrying out the study, and to Mr. Nik Nasarudin, Mr. Wan Mohd Jamel and all the supporting staff of the Department in providing assistance in the collection or analysis of the fish specimens. Special appreciation is due to RIMP for their kind assistance in the sampling process, and especially to Mr. Doan Van Du who accompanied our team in the sampling process.

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Species Composition, Abundance and Biomass Distribution of Zoobenthos in Vietnamese Waters

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ABSTRACT

The benthic invertebrate (zoobenthos) fauna in Vietnamese seawaters was surveyed in April - May, 1999. Zoobenthos specimen were sampled by Smith-McIntyre grab on 38 stations and 180 species were recorded and composed of 5 major groups: Polychaeta, Crustacea, Mollusca, Echinodermata and others.The total of density and biomass zoobenthos in Vietnamese seawaters was 156.7 ind/m^2 and 5943.0 mg/m^2 respectively. Polychaeta and Mollusca were groups with the highest abundance in every cases considered. The remaining groups of zoobenthos such as Crustacea and Echinodermata which were lower in abundance but higher in biomass.

There was a remarkable variation of zoobenthos both in species composition and density with the depth, substrate and spatial distribution. Abundance was higher in some subjects considered such as: in depth of 0 - 60m or in types of sandy components or in the Tonkin gulf and the Southeast regions. All diversity indices shown that water quantity in Vietnamese sea offshore in survey time was just satisfactory and good.

Key words: zoobenthos species, composition, abundance, distribution, diversity, Vietnamese waters

Introduction

Benthic fauna in the Vietnamese seawaters was being surveyed because it is an important components of every marine ecosystems, such as littoral, mangrove, seagrass, coral reef, subtidal ones etc. Benthic organisms are considered a major food item for the bottom feeders like demersal fish. Moreover many of them are important commercial value in exploiting, culturing, for example, the prawn, crabs, cockles. Collaborative survey team of China-Vietnam, 1962; [Chung *et al.*, (1971)]; [Gurjanova E.F. (1972)]; [Trong. (1996)].

In addition, benthic communities are also considered as biological indicators for assessing marine water quality because the organisms are mostly sessile and affected by factors causing environment pollution [Trong *et al.*, (1998)].

Therefore, a study on benthic fauna in general and benthic invertebrates in particular may be used as an important information to contribute to assess and manage fishery and environment in the Vietnamese sea waters.

Under the collaborative framework of the project on Marine Fishery Resource in the South China Sea, an integrated survey cruise was carried out in Vietnamese seawater - area IV on 30 April - 29 May, 1999 by M.V. SEAFDEC. A collection of benthic invertebrates was a part of the biological oceanographic data of this survey.

This report presents some results on distribution of fauna composition, abundance, biomass and diversity of marine benthic invertebrates (hereinafter called Zoobenthos) at this area.

Materials and Methods

Sampling

Sampling areas and time

The survey areas are along coastal waters from the North to the South of Vietnam from Latitude 21°00.0' - 09°00.1' N to Longitude 107°55.0' - 104°30.5' E. A total of 58 stations of the project were set up but only on 38 stations were sampled zoobenthos. In the rest 20 stations it was too deep or it's substrates too hard to sample [Fig. 1].

The cruise was carried out on board M.V. SEAFDEC from 29 April to 29 May, 1999. Among these stations, 7 stations (1 - 7) belong to Northern sea region (Tonkin gulf), 9 stations (8 - 29) belong to Central sea and 17 stations (38 - 53) belong to South east sea region and the rests (St. 54 - 58) belong to Southwest sea region [Fig. 1].

Sampling methods

On almost stations, three random samples of bottom sediment were collected by Smith-McIntyre grab with its area coverage 0.05m^2 but only 2 stations (43, 46) could collect 2 samples on each because some physical factors (wave, wind and current) that were so strong which caused more difficult for sampling. The sediment was wash through a set of 4 sieves (2.0, 1.0, 0.5 and 0.1 mm in meshes) with the smallest one lies under the rest. Benthic animals were picked up and fixed in 10% buffer solution in seawater on board (according to Puget sound water quality Authority - 1997). Then they were preserved again in 70% ethyl alcohol in the laboratory.

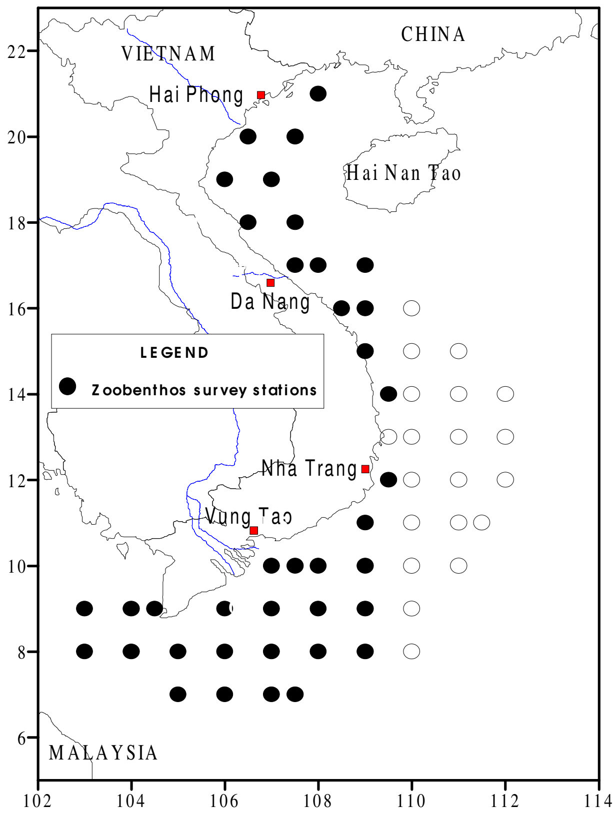

Fig. 1. Map showing survey stations on zoobenthos in area IV.

Identifying

(a) In the laboratory benthic animals were sorted out in major taxonomic groups, such as Polychaeta, Crustacea, Mollusca, Echinodermata and other groups (which composed of Coelenterata, worms). They were identified to the species level as well as possible and counted separately for each taxa. Specimens were weighed on an electronic balance "Satorius - Germany" with accuracy of 0.1 mg. Quantity unit of every taxa was calculated equivalent number of individuals or mg per m^2 of substrate (bottom).

(b) Documents

Some major documents were used for identifying groups of organisms as follow:

- For Polychaeta: [P. Fauvel (1953)], [M. Imajima and O. Hartman (1964)], [J. Day (1967)], [Wu Baoling *et al*. (1986)].
- For Crustacea: [FAO species catalogues (1991)] - Lobsters; [T. Kakai (1976)] - Crabs; [Dai Ai-yun (1991)] - crabs, [K.K. Tiwari (1963)] - Shrimp, etc.
- For Mollusca: [R.T. Abbott *et al*. (1990)] - Mollusca in general; [Tchang -Te *et al.* (1960,1964)] - Gastropoda; [Kevin L. Lamprell & John M. Healy (1998)] - Scaphopoda.
- For Echinodermata: [Tchang Phang Dzoanh *et al.* (1964)], [Walter K. Fisher (1922)]; [R. Koeler (1922)], etc.

Analysis method

Some diversity indices have been used:

(a) The Shannon - wiener index (H') (1949):

$$H' = -\sum_{i=1}^{S} pi(\log_2 pi) \quad \text{or} \quad = -\sum \frac{ni}{N}(\log_2 \frac{ni}{N})$$

Where: pi is equivalent with $\frac{ni}{N}$

ni : number of individuals in the i^{th} species

N : total number of individuals

(b) Eveness index (Pielou, 1996)

$$E = \frac{H'}{\log 2S}$$

Where: H' measured Shannon - wiener diversity

S : total number of species

E : eveness

(c) Margalef's species richness index

$$D = \frac{S-1}{\log eN}$$

Where: D : richness index

S : total number of species

N : total number of individuals

Results

Some major environmental parameters

The deep of sampling area

The measured deep of survey areas was from 22m (station 38) to 4140m (station 25) but the depth of sampling stations on zoobenthos was only from 22m (station 38) to 156m (station 35). There were 18 stations from 22m to 30m in depth, 10 stations from 31 to 60m and only 4 stations from 61 - 90 m, 3 stations from 91 to 120m and 3 station from 120 - 160m in depth [Table 1 and 8, Fig. 1]. Depth of the survey area was grouped in Table 1.

Table 1. The depth of the survey area.

Group of depth (m)	Stations	N o. of station
0- 30	1,2,3,4,7,14,37,38,46,47,48,49,50,51,53,54,57,58	18
31- 60	5,8,9,13,29,36,39,45,52,56	10
61 - 90	6,35,44,55,	4
91 - 120	10, 12,28,	3
121 - 160	20,40,43,	3

Sediment characteristics

Sediment characteristics in the survey area were described in details [Table 2]

- Fine mud (9 stations), mud mixed shell (6 stations), muddy sand (3 stations), mud mixed detritus (1 station) and sand (13 stations), sand mixed shell (3 stations), sandy mud (2 stations), sandy stone (1 station).

- But in general, there were two types of major sediments which covered the survey areas were: muddy and sandy.

Table 2. The substrate characteristics in surveyed sea bed of survey area.

Major types of substrates	Types of common substrates in detail	No. of station
	Fine mud	3,6,9,13,35,52,54,55,58
	Mud & detritus	57
Muddy	Mud & Shell	1,4,5,7,8,56
	Sandy mud	10,20
	Muddy sand	12,14,28,53
	Sand	2,29,39,40,44,45,46,47,48,49,50,51
Sandy	Sandy- stone	43
	Sand & Shell	36,37,38

Salinity of the survey area.

All survey stations were of high depth area and far from coastal waters so they were in high salinity area of seawaters. The salinity of bottom water layer ranged from about 32.0% to about 34.5% in general the salinity of the survey area was rather high.

Species composition and its structure

About 180 benthic invertebrate species and 72 families, 130 genera, belonging to 5 main groups: Polychaeta, Mollusca, Crustacea and Echinodermata and others (Coelenterata, worms) were recorded from analyzing results at 38 stations of Vietnamese seawaters. Among them, species number of Polychaeta was the highest with 78 species and occupied 43.4% of total species, then to Mollusca - 49 species, 27.2 %; Echinodermata -26 species, 13.5 %; Crustaceans - 23 species, 12.8% and the other with 4 species, 2.2% [Table 3, 4]. Among 72 families, some families have higher species such as *Eunicidae* (Polychaeta) with the highest - 20 species and then to two *Maldanidae* (Polychaeta) and *Dentaliidae* (Mollusca) with 10 species for each. 28 families with 2- 7 species, 41 families with only 1 species [Table 3, Fig. 2].

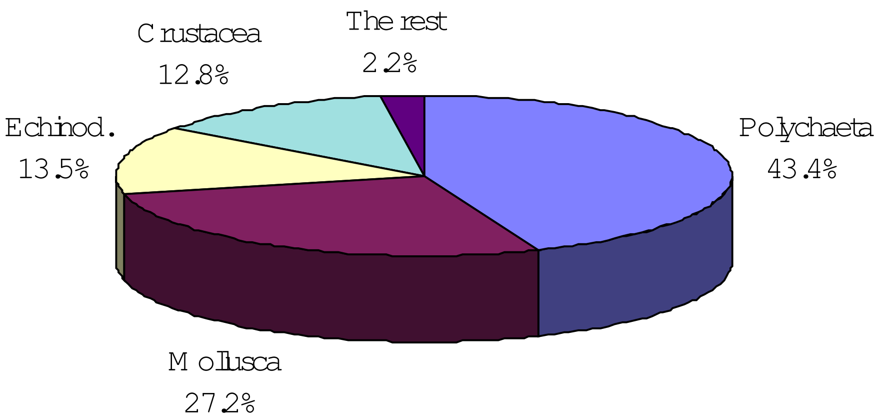

Fig. 2. Relative abundance of zoobenthos in survey area of Vietnamese waters.

Table 3. The checklist and distribution of zoobenthos on survey areas in Vietnamese Waters, Area IV (April - May, 1999).

No	Scientific name	Stations	Notes
	Polychaeta		
	1. Nephthydidae		
1	*Nephthys polybranchia*	10, 38, 46, 50	
2	*N. inermis*	54	
3	*Nephthys* sp.1	1	
	2. Ophellidae		
4	*Armandia lanceolata*	2	
5	*Ammotrypane aulogaster*	38, 51	
	3. Capitellidae		
6	*Capitellethus* sp.	7, 20, 35, 50	
7	*Dasybranchus* sp.	9, 38, 50	
8	*Notomastus* sp.	38	
9	*Heteromastides* sp.	36, 51, 53	
10	*Branchiocapitella* sp.	4	
11	*Pulliella sp.*	50	
12	*Axiothella australis*	14	
	4. Terebellidae	37, 53	
13	*Polymnia nebulosa*	1	
14	*Terebellides stroemi*	1, 37, 51, 57	
15	*Terebellidae gen* spp.	1,	
	5. Eunicidae	45, 49, 53	
16	*Eunice gracilis*	52	
17	*E. coccinea*	28	

Table 3. (Continued).

No	Scientific name	Stations	Notes
18	*Eunice* sp.	3, 7, 8, 45	
19	*Onuphis holobranchiata*	2, 38, 43	
20	*O. eremita*	35	
21	*O. dibranchiata*	36	
22	*Onuphinae* sp.	29	
23	*Drilonereis filum*	1, 52	
24	*Lumbriconereis notocirrata*	2, 52	
25	*Lumbriconereis* sp.	54	
26	*L. impatiens*	8, 36, 46, 57	
27	*L. latreilli*	7, 47	
28	*L. simplex*	4	
29	*L. heteropoda*	53	
30	*M. stragulum*	6	
31	*M. fallax*	53	
32	*Marphysa* sp.1	2	
33	*Hyalinoecia tubicola*	29	
34	*Arabella* sp.1	56	
35	*Diopatra neapolitana*	57	
	6. Cirratulidae	52	
36	*Cirratulus filiformis*	20, 52	
37	*Tharyx filibranchia*	52	
38	*Th . multifilis*	5, 54	
	7. Chaetopteridae	50, 53, 55	
39	*Phyllochaetopterus* sp.	5, 35, 38, 39, 47, 53	
	8. Spionidae	37	
40	*Prionospio pinnata*	1, 2, 45, 50	
41	*P. krusadensis*	14,	
42	*Prionospio* sp.	35, 54	
43	*Nerine cirratulus*	1, 2, 14, 53	
44	*Nerine* sp.	9, 29, 35, 37, 50, 57	
45	*Scolelepis indica*	1	
46	*Laonice* sp.	38, 49	
	9. Glyceridae		
47	*Goniada emerita*	28, 53	
48	*Glycera longipinnis*	49, 50	
49	*G. alba*	14, 38	
50	*G. rouxii*	6	
	10. Ariciidae		
51	*Aricia cuvieri*	50	
52	*Nainereis laevigata*	13	
53	*Haploscoloplos* sp.1	49	
54	*Scoloplos kerguliensis*	10	
55	*S. marsupialis*	57	
	11. Maldanidae	5, 40, 52, 53	
56	*Euclymene lumbricoides*	50	
57	*Axiothella obockensis*	29, 38	
58	*Asychis* sp.1	2, 52	
59	*Maldane sarsi*	50	
60	*C. (Euclymene) annandalei*	6, 7,	
61	*Petaloproctus* sp.	20, 40	
62	*Clymenella* sp.1	52	
63	*Clymene (Euclymene) insecta*	7, 20	
64	*Clymene (Euclymene)* sp.	38, 52, 53	
65	*Maldanidae gen* spp.	14, 29, 35, 38, 54	

Table 3. (Continued).

No	Scientific name	Stations	Notes
	12. Aphroditidae	14	
66	*Eunoe pallida*	9	
67	*Polyodontes melanonotus*	9, 50	
	13. Amphinomidae		
68	*Pseudeurythoe paucibranchiata*	2	
69	*Chloeia rosea*	5, 43	
	14. Sternaspidae		
70	*Sternaspis scutata*	20, 36, 56, 57	
	15. Ampharetidae		
71	*Melina* sp.	20	
72	*Ampharetidae gen* spp.	35	
	16. Nereidae		
73	*Leptonereis* sp.	4	
74	*Tylonereis* sp.	5	
	17. Chloraemidae		
75	*Brada talehsapensis*	57	
	18. Heterospionidae		
76	*Heterospio sinica*	20	
	19. Owenidae		
77	*Owenia fusiformis*	49	
78	Polychaeta nonidentifyed	13, 40, 44, 46, 48, 57	
	Crustacea		
	20. Ocypodidae		
79	*Macrophthalmus* sp.1	58	
	21. Penaeidae		
80	*Metapenaeus* sp.	38	
	22. Alpheidae		
81	*Alpheus malabaricus*	38	
82	*Alpheus* sp.	7, 35	
83	*Synalpheus* sp.	12	
84	23. Palaemonidae	35	
	24. Upogebiidae		
85	*Upogebia* sp.1	1, 3, 4	
	25. Nephropidae		
86	*Nephropsis* sp.	2	
	26. Callianassidae		
87	*Callianassa* sp.1	5, 8, 9, 28, 29, 37, 47, 48, 50, 51, 53, 57, 58	
	27. Scyllaridae		
88	*Ibacus* sp.1	2, 46, 47	
	28. Galatheidae		
89	*Galathea* sp.	36	
	29. Goneplacidae		
90	*Camatopsis* sp.1	4	
91	*Carcinoplax* sp.1	39	
92	*Typhlocarcinus nudus*	50	
93	*Xenophthalmodes* sp.	48, 52	
	30. Pinnotheridae		
94	*Neoxenophthalmus obscurus*	54	
95	*Pinnotheres* sp.	1	
	31. Pandalidae		
96	*Pandalus* sp.	50	
97	Amphipoda	2, 4, 36, 37, 45, 47, 49, 53	
98	Isopoda	2, 28	

Table 3. (Continued).

No	Scientific name	Stations	Notes
99	Mysidacea	2, 5	
100	Other non-identified	47	
101	Entosnostraca	53	
	Mollusca		
	Scaphopoda	1, 6, 43	
	32. Dentaliidae	6	
102	*Dentalium aprinum*	4, 5, 20, 10, 28, 36, 37, 39, 44, 45, 47, 48, 50, 52	
103	*D. thetidis*	14	
104	*D. octangulatum*	36	
105	*D. elephantinum*	39, 50	
106	*D. hexagonum*	7, 8, 20, 28, 52, 53, 56, 58	
107	*Dentalium (D.) katowense*	51	
108	*D. bisexangulatum*	46	
109	*Dentalium* sp.	6, 10, 37, 50, 51	
110	*Graptaeme acutissimum*	58	
111	*G. aciculum*	56	
	33. Gadilidae		
112	*Gadila spretus*	4, 5, 29, 35	
113	*Deschides* sp.	39	
114	*Polyschides andersoni*	45	
115	*P. gibbosus*	12, 14, 28, 49, 57	
116	*P. prionotus*	20	
117	*Polyschides* sp.	5, 8, 40, 52	
	34. Laevidentaliidae		
118	*Laevidentalium lumbricatum*	36, 39, 40, 58	
119	*L. jaffaensis*	37	
120	*L. largierescens*	37	
121	*L. longitrorsum*	10, 37, 39, 47, 52, 55, 56	
122	*L. erectatum*	12, 38, 40, 51, 52, 53, 55, 58	
123	*Laevidentalium* sp.	36, 37, 38, 39, 40, 45, 46, 47, 48, 50, 56	
	35. Pulsellidae		
124	*Compresidens platyceras*	10, 20, 40, 52, 53, 56	
	36. Omnigliptidae		
125	*Omniglypta cerine*	47	
	Gastropoda		
	37. Pyramidellidae		
126	*Pyramidella* sp.	3	
	38.Bullidae		
127	*Atys cylindricus*	29	
	39. Turritellidae		
128	*Turritella bacillum*	36	
129	*Turritella terebra*	36, 45, 46, 47	
130	*Turritella* sp.	45, 50, 51, 53	
	40. Turridae		
131	*Turricula javana*	14	
132	*Turris* sp.	12	
	41. Terebridae		
133	*Hastula* sp.	13	
134	*Terebra funiculata*	45, 46	
	42. Conidae		
135	*Conus* sp.	43	
	43. Cancellariidae		
136	*Cancellaria* sp.	2	

Table 3. (Continued).

No	Scientific name	Stations	Notes
	44. Architectonidae		
137	*Heliacus* sp.	47, 53	
	45. Volutidae		
138	*Fulgoraria daviesi*	4	
	46. Acteonidae		
139	*Otopleura auriscati*	1	
	47. Naticidae		
140	*Polinices* sp.	2	
	48. Epitonidae		
141	*Amaea decussata*	49	
	49. Olividae		
142	*Ancilla* sp.	6	
	50. Cavoliniidae (Pteropoda)		
143	*Cavolinia tridentata*	12	
144	*C. uncinata*	7, 12	
	Bivalvia		
	51. Solenidae		
145	*Solen* sp.	36	
	52. Solecurtidae		
146	*Sinovacula* sp.	54	
	53. Glycymerididae		
147	*Glycymeris reevei*	51	
148	*Glycymeris sp.*	51	
	54. Veneridae		
149	*Dosinia* sp.	38	
	55. Donacidae		
150	*Donax* sp.	44	
	Echinodermata	6, 8, 20	
	56. Ophiactidae		
151	*Ophiactis savignyi*	1	
	57. Amphiuridae		
152	*Amphioplus praestans*	1, 48	
153	*A. retictus*	43	
154	*A. depressus*	49	
155	*Amphipholis kochii*	58	
156	*Amphiura* sp.	35, 38	
	58. Ophiolepididae		
157	*Ophioplocus japonicus*	5, 51	
	59. Ophiotrichidae		
158	*Macrophriothrix longipeda*	5	
159	*Ophiothrix striolata*	44	
	60. Ophiothrichidae		
160	*Ophiomusium altum*	51	
	61. Ophiocomidae		
161	*Ophiarthrum pictum*	9, 12	
162	62. Ophiuroidae (only legs)	39, 43, 48, 51	
	63. Trichasteridae		
163	*Asteronyx loveni*	39	
	64. Fibulariidae		
164	*Fibularia acuta*	2	
	65. Temnopleuriudae		
165	*Temnopleurus* sp.	36	
	66. Loveniidae		
166	*Lovenia trifolis*	38, 58	

Table 3. (Continued).

No	Scientific name	Stations	Notes
	67. Clypeasteridae		
167	*Clypeaster reticulatus*	44	
168	*Cl. virescens*	47	
	68. Laganidae		
169	*Laganum depressum*	46	
170	69. Echinometridae	5	
	Holothuroidea		
	70. Synaptidae		
171	*Potankya asymetrica*	1	
	71. Phyllophoridae		
172	*Actinocucumis typicus*	6, 56	
173	*Phyllophorus* sp.	56	
174	*Phyllophorus* sp. ef fragilis	36	
	72. Holothuriidae	14, 56	
175	*Actinopyga echinites*	36, 51	
	73. Molpadiidae		
176	*Molpadia* sp.	51	
	Coelenterata		
177	*Hydrozoa*	39	
178	Echiuroidea	7, 28, 51, 58	
179	Plathelminthes	5, 35, 36, 49, 51, 54	
180	Nematoda	35	

The structure of the species composition is correspondent with previous studies, it showed that, the Molluscean and Polychaeta play major role in the structure of zoobenthos species composition [Chung N. V., 1994]; [Trong P.D. *et al*. (1998)]. Some species were composed of *Nephthys polybranchia, Capitellethus* sp.*, Terebellides stroemi, Lumbriconereis impatiens, Prionospio pinnata, Nerine* sp.*, Phyllochaetopterus* sp. *(Polychaeta*); *Callianasa* sp. (*Crustacea*); *Dentalium* sp.*, Laevidentalium* sp.*, Gadila spretus, Polyschides gibbosus, Compresidens platyceras, Turritella* sp. *(Mollusca)*, with high occurrence in the survey area.

Distribution and abundance of zoobenthos

Distribution of species composition

The spatial distribution

Distribution of species composition on stations of the survey was very different. There were 4 stations (3, 4, 13, 55) which were of few species and changed from 2 species (station 3) to 5 species (station 44). Besides, on the 17 stations (1-2,14-20, 35, 36, 38, 39, 46, 47, 50, 51, 52, 53, 56, 57, 58) with higher number of species and changed from 9 to19 species/ station [Table 4].

The average index of species number on the whole of survey stations is 9.1 species per station [Table 4]. Besides from Table 4 also shown that:

- In the Tonkin Gulf, there were 7 stations (with 58 species) which had rather high average index of species number with 10.0 species/ station, so they were under the average index and changed from 2 to 16 species/ station
- In the Central sea, there were 9 stations (50 species) which had the lowest average index of species number with only 7.0 species/ station, and changed from 2 to 14 species/ station.
- In the Southeast sea, there were 17 stations (114 species) which had the highest average index of species number with 11.9 species/ station and varied from 5 to 19 species/ station.

- In the South west, there were 5 stations (35 species) which had low in this average index with 7.4 species/ station.

In general, average index of species number reached the highest in the Southeast and the lowest in the Central Sea.

Table 4. Species distribution on survey areas of Vietnamese waters.

Survey areas	Station	Species No.
Tonkin gulf (58 species)	1	14
	2	16
	3	2
	4	9
	5	14
	7	8
	6	7
Central sea (50 species)	8	6
	9	6
	10	6
	12	7
	13	3
	14	9
	20	11
	28	8
	29	7
	35	12
South - East (114 species)	36	17`
	37	9
	38	19
South - East (114 species)	39	11
	40	6
	43	6
	44	5
	45	8
	46	9
	47	12
	48	7
	49	8
	50	18
	51	15
	52	15
	53	15
South - west (35 species)	54	7
	55	3
	56	9
	57	9
	58	9
Average species index		**9.10**

Variation in species composition with depth

It was shown in Table 5. that:

- Species numbers on the 28 survey stations in depth of 0 - 60 m changed from 2 to 19 species/ station. Average index was 9.91 species/ station and reached the highest. Among them, 9 stations with higher in species number composed of: stations number 1(14 sps), 2 (13 sps.), 36 (14 sps.), 38 (19 sps.), 47 (10 sps.), 50 (18 sps.), 51 (14 sps.), 52,53 (15 sps.). Only station number 3 with the lowest species number (2 sps.).

- Species number on the 7 survey stations in depth of 61 - 90 m changed from 3 species (St. 55) to 10 species / St. (St. 39), average index of species reached only 6.7 species/station and was the lowest. Four stations with rather high in species number composed of stations number 45(8 sps), 39 (10 sps.).

- Species number on 3 stations in depth of 91 - 120m changed from 6 species (station 10) to 7 species (stations 12, 28) which had average index of 6.6 was the lowest as it was in depth group of 61 - 90m.

- On 4 survey stations in depth over 120 m, species numbers changed from 6 to 13 species/ station. It's order after that of station group in depth of 0 - 60m, average index was 9.0 species/ station and stood in second.

Table 5. Distribution of species number with depth in April-May,1999.(unit : species number/station).

Survey areas	Stations	Depth			
		<60 m	61 - 90m	91- 120m	121- 160m
	1	14			
Tonkin gulf	2	13			
	3	2			
	4	8			
	5	6			
	6		6		
	7	7			
	8	6			
	9		6		
Central sea	10			6	
	12			7	
	13	3			
	14	9			
	20				11
	28			8	
	29		7		
	35				13
	36	14			
	37	8			
	38	19			
	39		10		
	40				6
	43				6
	44		5		
	45		8		
	46	9			
Southeast	47	10			
	48	7			
	49	8			
	50	18			
	51	14			
	52	15			
	53	15			
	54	6			
	55		3		
Southwest	56	9			
	57	9			
	58	9			
Average species index		**9.91**	**6.7**	**6.6**	**9.0**

Distribution of species composition on the type of substrate

In general, from two types of major substrates which could be divided into 8 types substrate in detail such as fine mud, mud & detritus, mud & shell, sandy mud, muddy sand, sand, sandy stone, sand & shell [Table 2]. On every type there was different distribution of zoobenthos [Table 6].

- On the fine mud: On these stations, species number changed from 2 to 15 species/ station and average 6.7 species/ station. There were 3 stations with the high species number such as station 35 (10 sps.), 52 (15 sps.), 58 (9 sps.) and 2 stations with the low species number such as station 3 (2 sps.), 13 (3sps.).

- On the mud and shell: On these stations, the species number changed from 6 to 14 species/ station and average index 8.8 species/ station. There were 3 stations with the high species number such as station 1 (14 sps.), 5 (9 sps.), 56 (9 sps.) and 2 stations with the low species number such as station 7 (7 sps.), 8 (6 sps.).

- On the sandy mud: On these stations, the species number changed from 6 species (St. 10) to 11 species (St. 20)

- On the muddy sand: On these stations, the species number changed from 6 to 15 species/ station and average was 9.3 species/ station. There were only one station 53 with high species number (15 sps.) and the rest 2 stations with low species number such as station 12 (7 sps.), 28 (6 sps.).

- On the sand: On these stations, the species number varied from 5 to 18 species/ station and average species index was 9.6 species/ station. There were 4 stations with high species number such as station 39 (10 sps.), 47 (10 sps.), 50 (18 sps.), 51 (14), and 5 stations with low species number such as station 40 (6 sps.), 44 (5 sps.), 45 (8 sps.), 48 (7 sps.), 47 (8 sps.).

- On the sand and shell: On these stations, the species number changed from 8 to 19 species/ station and average of species index was 13.7 species/ station and only one station 38 with the highest species number (19 sps.) and the rest 2 stations with 14 species (St. 36) and 8 species (St. 37).

The survey results demonstrated that average of species number was the highest with 13.7 sps. /station on the substrate of sand and shell, the lowest on the fine mud (6.7 sps./station).

Relative abundance of zoobenthos

Species distribution of zoobenthos in the regions of the survey area were much irregular. There were 58 species in the Tonkin Gulf (occupied 32.2% of total species), 50 species in the Central sea (27.8%), 114 species in the Southeast (63.3%) and only 35 species in the Southwest (19.4%) [Table 7].

Relative abundance

Besides distribution species number in every stations on each region lead to different abundance of each taxonomic group. However the priority order on relative abundance of these groups was not changed.

Table 7 also shows that, in every regions, Polychaeta always occurred the most amount of species with 40% (in the south-west) to 54% (in the central). Mollusca having amount of species less than that of Polychaeta and this group abundance ranged from 20.7% (in Tonkin gulf) to 34% (in Central). The third position on abundance belongs to Crustacea in Tonkin gulf and Central or to Echinodermata in South-east and South-west [Table 7, Fig. 3].

Quantitative characteristics of benthic fauna and it's distribution

Common characteristics

Analyzing results on benthic fauna quantity were presented on table 9 and table 10, from these tables we can see that the priority order of quantity indices between groups as follows: Mollusca has the highest values with 66.9 inds./m^2 then to Polychaeta, Crustacea, Echinodermata and others with the lowest value of 9.6 inds./m^2 in density but in biomass these orders are changed, Echinodermata was the highest value with 2769.4 mg/m^2, then to Mollusca, Crustacea, Polychaeta and the lowest value was in Others with of 35.5mg/m^2. Density of zoobenthos reached the highest at station 2 with 399 ind/m^2 and the lowest at station 3 with only 13.2 ind/m^2. Biomass reached the highest at station 1 with 22766.4 mg/ m^2 and the lowest at station 13 with 106.5 mg/m^2. Quantity average of the whole area were 156.7 ind. and 5970.3 mg per m^2. [Table 8, 9]. There were two reasons contributing to largeness of abundance and biomass of zoobenthos. Firstly, regular distribution of organisms in the area. This matter importantly affected to their abundance, for example, Mollusca and Polychaeta having high occurrence with 94.7

and 97.4% respectively so this groups having also high density. [Table 3, 8, 9]. Secondly, individual's weight of organisms, almost species of Crustacea and Mollusca having heavy shell or some Holothurioms (Echinodermata) having bigger body measurement.

Table 6. Number species distribution on the types of substrates(number species/station) April-May, 1999.

Region	Stations	FM	M&D	M& Sh	SM	MS	S	SS	S & Sh
	1			14					
	2						13		
Tonkin gulf	3	2							
	4			8					
	5			9					
	6	6							
	7			7					
	8			6					
	9	6							
	10				6				
Central Sea	12					7			
	13	3							
	14					9			
	20				11				
	28					6			
	29						7		
	35	10							
	36								14
	37								8
	38								19
	39						10		
	40						6		
	43							6	
Southeast	44						5		
	45						8		
	46						9		
	47						10		
	48						7		
	49						8		
	50						18		
	51						14		
	52	15							
	53					15			
	54	6							
	55	3							
	58	9							
Southwest	57		9						
	56			9					
		6.66	**-**	**8.83**	**8.5**	**9.25**	**9.58**	**-**	**13.66**

Notes: FM: fine mud; M&D: mud &detritus; M&Sh: mud&shell; SM: sandy mud; MS: muddy sand; S:sand; SS: Sand stones; S&Sh: sand&shell.

Table 7. Distribution of Zoobenthos species number between regions in Vietnamese waters.

Group \ Region	Tonkin Gulf	Central sea	Southeast	Southwest
Polychaeta	28/48.3*	27/54.0	46/40.3	14/40.0
Crustacea	10/17.2	3/6.0	14/12.2	3/8.6
Mollusca	12/20.7	17/34.0	33/29.0	10/28.6
Echinodermata	8/13.8	2/4.0	17/15.0	6/17.1
Others	0	1/2.0	4/3.5	2/5.7
Total species	**58/100.0**	**50/100.0**	**114/100.0**	**35/100.0**

[*] : density/percent [28 (ind./m^2 /48.3%]

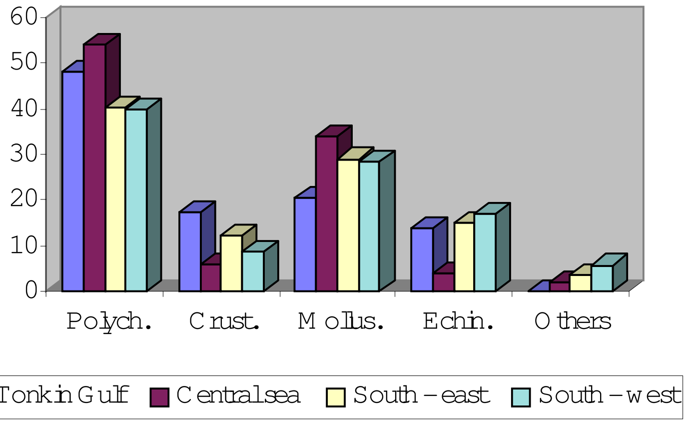

Fig. 3. Relative abundance of zoobenthos between seawaters regions of Vietnam in April- May,1999.

Table 8. Quantitative distribution of zoobenthos in the Vietnamese waters, AreaIV (April-May,1999). Where: Density/Biomass: Inds./(mg/m^2).

Station	Depth (m)	Polychaeta	Crustacea	Mollusca	Echinodermata	Others	Total
1	34	86.2/ 366.6	93.2/ 21366.6	6.6/ 133.3	19.8/ 988.9	0	205.8/ 22766.4
2	29	72.8/ 452.9	39.7/ 1419.8	19.9/ 233.3	266.6/ 5266.6	0	399.0/ 7372.6
3	28	6.6/ 66.6	0	6.6/ 333.3	0	0	13.2/ 399.9
4	26,5	33.2/ 233.3	46.5/ 739.9	93.2/ 4133.2	0	0	172.9/ 5106.4
5	58	39.6/ 486.3	13.2/ 66.6	166.6/ 2833.2	39.8/ 2133.3	0	259.2/ 5519.4
6	80	19.8/ 46.5	0	19.9/ 133.3	19.9/ 399.9	0	59.6/ 579.7
7	40	26.4/ 1239.8	6.6/ 66.6	86.6/ 1200.0	0	6.6/ 66.6	126.2/ 2573.0
8	45	13.2/ 72.2	6.6/ 66.6	19.9/ 366.6	6.6/ 66.6	0	46.3/ 572.0
9	75	26.4/ 866.4	6.6/ 33.3	0	33.3/ 8266.6	0	66.3/ 9166.3
10	107	13.2/ 866.6	0	42.1/ 1066.5	0	0	55.3/ 1933.1
12	105	0	6.6/ 33.3	146.4/ 2133.2	6.6/ 2533.3	0	159.6/ 4699.8
13	42	13.2/ 39.9	0	6.6/ 66.6	0	0	19.8/ 106.5
14	36	46.3/ 453.0	0	39.9/ 699.9	6.6/ 133.3	0	92.8/ 1286.2

Table 8. (Continued).

Station	Depth(m)	Polychaeta	Crustacea	Mollusca	Echinodermata	Others	Total
20	143	46.2/ 513.0	0	53,2/ 766.6	6.6/ 66.6	0	106.0/ 1346.2
28	110	13.2/ 1006.6	13.2/ 99.9	39.9/ 733.2	0	6.6/ 6.6	72.9/ 1846.3
29	72	39.8/ 186.5	13.3/ 100.0	139.9/ 2599.9	0	0	193.0/ 2886.4
35	156	66.2/ 66.2	13.2/ 133.2	6.6/ 200.0	13.3/ 666.6	26.6/ 79.9	125.9/ 1145.9
36	45,5	26.4/ 679.8	13.2/ 46.6	233.0/ 9633.1	19.8/ 9533.3	6.6/ 6.6	299.0/ 19899.4
37	32	13.2/ 73.2	26.6/ 46.6	79.7/ 3266.4	0	0	119.5/ 3386.2
38	22	93.2/ 359.7	13.2/ 339.9	26.5/ 399.9	33.2/ 13133.2	0	166.1/ 14232.7
39	62	6.6/ 6.6	6.6/ 66.6	193.0/ 3199.8	13.2/ 333.3	6.6/ 66.6	226.0/ 3672.9
40	129	13.2/ 13.2	0	59.7/ 766.5	0	0	72.9/ 779.7
43	147	20/ 550	0	20/ 450	20/ 600	0	60/ 1600
44	79	6.6/ 6.6	0	13.2/ 266.6	13.2/ 1200.0	0	33.0/ 1473.2
45	61	13.2/ 66.6	6.6/ 6.6	306.4/ 9233.2	0	0	326.2/ 9306.6
46	51	30.0/ 30.0	10.0/ 1500.0	110.0/ 4050.0	10.0/ 3300.0	0	160.0/ 8880.0
47	42	13.2/ 39.9	73.1/ 173.1	73.1/ 2133.1	26.6/ 6866.6	0	186.0/ 9212.7
48	33	6.6/ 33.3	13.2/ 39.9	13.2/ 366.6	13.2/ 199.9	0	46.2/ 639.7
49	20	33.1/ 146.4	6.6/ 6.6	19.9/ 466.6	6.6/ 100.0	6.6/ 6.6	72.8/ 726.2
50	33	73.3/ 806.1	13.2/ 1066.6	59.6/ 1133.2	0	0	146.1/ 2005.9
51	44	19.8/ 106.5	13.3/ 33.3	33.6/ 699.9	39.7/ 2533.3	13.2/ 73.2	119.6/ 3446.2
52	51	52.8/ 172.9	6.6/ 33.3	73.1/ 1266.4	0	0	132.5/ 1472.8
53	34	6.6/ 86.7	33.2/ 139.9	66.6/ 1366.5	0	0	106.4/ 1593.1
54	26	39.7/ 126.4	6.6/ 333.3	6.6/ 1000.0	0	6.6/ 6.6	59.5/ 1466.3
55	70	6.6/ 6.6	0	39.9/ 600.0	0	0	46.5/ 606.6
56	57	13.2/ 466.6	0	59.7/ 1299.8	19.9/ 1666.6	0	91.8/ 3433.0
57	34	83.3/ 4046.4	6.6/ 66.6	6.6/ 333.3	0	0	96.5/ 4446.3
58	23,5	0	13.2/ 1333.3	86.4/ 1133.2	13.2/ 1533.3	6.6/ 6.6	119.4/ 4006.4

Polychaeta

Polychaeta was rather high density with 31.5 inds/m^2 and stood at the second position after that of Mollusca but its biomass was the lowest with only 410.7 mg/m^2 when comparing with four main taxonomic groups [Table 9]. Quantity averages per station of Polychaeta reached the highest with 93.2

ind/m^2 at station 38 and with 4046.4 mg/m^2 at station 57 but the lowest with 6.6 ind/m^2 at stations 3, 39, 44, 53, 55 and with 6.6 mg/m^2 at stations 39, 44, 55 [Table 8]. Some families which had high occurrence such as *Eunicidae* with 34 times per 24 stations, *Maldanidae* - 25 times per 18 stations, *Capitellidae* - 14 time per 10 stations, *Spionidae* - 21 times per 14 stations, play an important role in quantitative composition of this group [Table 3].

Table 9. Quantitative average value of benthic fauna.

Group	Polych.	Crustacea	Mollusca	Echinod.	Others	Total
Density	31.5	19.3	66.9	29.4	9.6	156.7
Percent (%)	20.1	12.3	42.7	18.8	6.1	100.0
Biomass	410.7	1087.3	1640.4	2796.4	35.5	5943.3
Percent (%)	6.9	18.3	27.6	46.6	0.6	100.0

Crustacea

Crustacea was the lowest density with 19.3 inds/m^2 but its biomass was the third position with 1087.3 mg/m^2 after that of Echinodermata and Mollusca groups [Table 9]. Quantity average per station of Crustacea reached the highest with 93.2 ind and 21366.6 mg/ m^2 at same station 1 but the lowest with 6.6 ind/m^2 at stations 5, 7, 8, 9, 12, 39, 45, 49, 52, 54, 57 and with 6.6 mg/m^2 at station 45. [Table 8]. Only two species with high occurrences were *Callianassa* sp.1 (13 times) and *Amphipoda* (8 times) and they played main role in quantitative composition of this group [Table 3].

Mollusca

Mollusca was high quantity both in density and biomass. Density of this group was the highest with 66.9 inds/m^2 , its biomass was 1640.4 mg/ m^2 which was at the second position after that of Echinodermata group [Table 9]. Quantity average of Mollusca per station reached the highest with 306.4 ind. at station 45, with 9633.1 mg/m^2 at station 36 but the lowest with 6.6 ind/ m^2 at stations 1, 3, 13, 35, 54, 57 and with 66.6 mg/m^2 at station 13 [Table 8]. Remarkable contribution to quantitative composition of this group are families of *Scaphopoda*, such as *Dentalidae* (36 times of occurrence per 27 stations), *Laevidentalidae* - 32 times of occurrence per 18 stations and *Galididae* - 16 times per 15 stations. Among them some species composing of *Dentalium aprinum, Laevidentalium sp* were rather high occurrences with 14 times and 11 times for each separately [Table 3].

Echinodermata

Echinodermata was rather low density with 29.4 inds/m^2 and was at the third position after that of Polychaeta, Mollusca but was the highest biomass (2769.4 mg/m^2) in zoobenthos [Table 9]. Quantity average per station of this group reached the highest with 266.6 ind. at station 2 and with 9533.3 mg/ m^2 at station 36 but the lowest with 6.6 ind. at stations 8, 12, 20, 49 and with 66.6 mg/m^2 at stations 8, 20 [Table 8]. Echinodermata distributes in the area very thin, almost of species appeared only one time and only one family *Amphiuridae* with 15 species having 7 times of occurrences. Almost organisms of Echinodermata are of small measurement but some of them were more large, for example the presence of *Ophiarthrum pictum* in stations 9, 12 or of *Clypeaster virescens* in stations 47 contributed to raise biomass of Echinodermata in these stations unusually [Table 3, 8].

Distribution of abundance

Distribution of abundance with depth

The highest density of zoobenthos was occurred at water depth of 31 - 60m.with 141.7 ind/m^2 . At the depth of 0 - 30m and 61 - 90 m, density of zoobenthos was almost same largeness with 133.4 and 134.7 ind/m^2 then density decreased to the lowest value at the depth of over 120 m (79.7 ind/m^2). We can see that when the depth raised, common density of the fauna was decreased gradually. This trend occurred at almost taxonomic groups with various levels. Except three groups Crustacea, Echinodermata and others which were same decreasing trend in density mentioned, Mollusca and Polychaeta appeared a contract trend. Density of Polychaeta decreased gradually at the depth of 0 - 30m to 91 - 120m but it raised at the depth of over 120 m. Density of Mollusca raised rapidly at the depth of 0 - 30m to 31 - 60m but it was decreased at the depth of 131 - 160m. [Fig. 4].

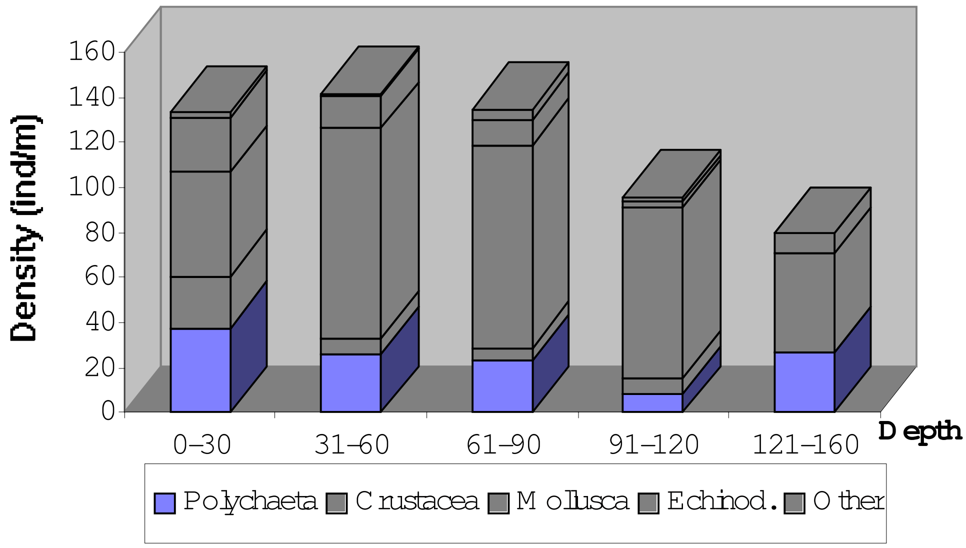

Fig. 4. Distribution of total density of zoobenthos fauna with water depth.

Variation in abundance with sediment

Substrate characteristics and its distribution in the survey area is mentioned above in details. Even distribution of benthic species is accounted. And of course, distribution of their abundance varies too from station to station and from type of sediment to type of it. Surveyed results show that, characteristics of sediment in the area is compounded and complicated one. The compound property is mixture of various sediments such as mud or sand, mud with shell, mud with detritus or sand with shell and sand with stone. The complicated property is the patch distribution of sediment, for example, sandy type could be seen in Tonkin Gulf (station 2) or in Central sea (stations 28, 29) and in South east sea, etc.

So in order to see more clearly different distribution of abundance of zoobenthos which depends on types of sediment, we grouped substrates into main groups and calculated results of abundance on each type of sediment as follows [Table 10].

Table 10 shows that, abundance of zoobenthos in fine mud was the lowest with average of 83.7 ind./m^2 but in sandy mud or muddy sand and in sand, abundance was higher with 138.1 and 210 ind./m^2 respectively.

Table 10. Distribution of zoobenthos abundance on main groups of sediment.

Group of sediment	**Fine mud**				**Mud mixed shell**			**Sandy mud, muddy sand**		**Sand**		
Sea region	1	2	3	4	1	2	4	2	3	1	2	3
Abundance in each group	26.4	43.0	129.2	80.5	176.6	46.3	91.8	103.4	172.8	399.0	133.0	97.6
Average	72.3				105.0			138.1		210.0		

Notes*:* 1: Tonkin Gulf with stations : 1 - 7
2: Central sea " : 8 - 29
3: South-east sea " :35 - 53
4: South west sea " : 54 - 58

Change of abundance between regions

Zoobenthos abundance differently varied from the North region to the South one. The highest abundance occurred in the North region (Tonkin Gulf) with 176.5 inds./m^2 then to the Southeast with 114.1 inds./m^2 and the lowest abundance occurred in the Southwest region with only 82.9 inds./m^2 [Table 11, Fig. 5].

Among benthic groups, Mollusca and Polychaeta always have higher abundance than that of the rest group [Table 11]. From Fig. 4. we can see that, Northern and Southeast was two regions which were rather high in zoobenthos abundance.

Table 11. Distribution of abundance between regions of Vietnamese waters.

Sea region	**Polych.**	**Crust.**	**Moll.**	**Echin..**	**Others**	**Total**
North (Tonkin Gulf)	40.7	28.5	57.0	49.4	0.9	176.5
Percent (%)	23.1	16.1	32.3	28.0	0.5	100.0
Central	23.5	5.1	54.2	6.6	0.7	90.1
Percent (%)	26.0	5.7	60.2	7.3	0.8	100.0
Southeast	29.1	14.6	81.6	12.3	3.5	141.1
Percent (%)	20.6	10.3	57.9	57.9	2.5	100.0
Southwest	28.6	5.3	39.8	6.6	2.6	82.9
Percent (%)	34.5	6.4	48.0	7.96	3.4	100.0

Diversity of zoobenthos in the survey area

As same as analysis on distribution of species composition and abundance of zoobenthos among regions of the Vietnamese sea, diversity indices of zoobenthos varied very differently among four sea regions [Table 12].

Table 12 shows that, diversity indices in the South-east region were the highest with 3.1465 in H' index, 2.2082 in richness and 0.9145 in eveness; then to Tonkin Gulf with 2.5972, 1.7092 and 0.8606 respectively and the Southwest region with 2.5267, 1.4823 and 0.8945 respectively. In the Central sea region, these indices were the lowest with 2.2075, 1.3647 and 0.8272 respectively.

Table 12. Diversity indices in Vietnamese seawaters in April - May, 1999.

Diversity indices	Tonkin Gulf	Central sea	Southeast	Southwest
H' index	2.5972	2.2075	3.1465	2.5267
Richness	1.7092	1.3647	2.2082	1.4823
Eveness	0.8606	0.8272	0.9145	0.8945

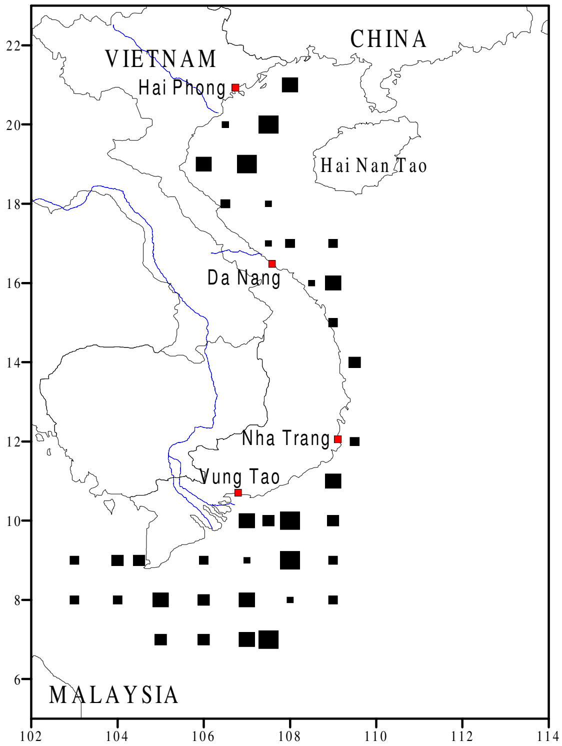

Fig. 5. The abundance of zoobenthos in the Vietnamese waters.

Discussion

It could be about 180 recorded invertebrate species did not reflect sufficiently richness and abundance of macrobenthic fauna of Vietnamese sea area. This is only a part of picture on species composition and its distribution in the offshore of Vietnam. In fact, only respective soft bottom community of a narrow area of the Northwest of Tonkin gulf called Hai Phong - Quang Ninh sea were recorded about 465 macrobenthic species (zoobenthos). While Tonkin gulf fauna is considered poorer than the south-east fauna [Chung N.V. (1994)].

However the recent surveyed results on zoobenthos permitted assess biological environmental status of the Vietnamese sea.

Firstly, it was affirmed that the structure of a soft bottom community composed of 4 major group (Polychaeta, Crustacea, Mollusca, Echinodermata). When this structure is changed it is question to environmental changes.

It is clear that, coastal zone of Vietnam runs from North to South with about 3260 km. Along this coastal line has four main river mouth systems. Among them Mekong river system in the Southeast is the largest then to Red river system. Every year this river system discharge into the sea hundreds or even thousands of alluvium soil accompanying with rich nutrient substances. It may be one of the principal reasons causing different richness and abundance of zoobenthos among sea regions of Vietnam.

Analyzing results shown that the South-east region which was the richest species number (occupied 63.3% total fauna species) but abundance and biomass stood after Tonkin gulf region while species composition of Tonkin gulf was poorer and stood right way after that of Southeast and occupied of 32.2% total species. In general these two regions were higher both in species composition and abundance than those in the rest two regions.

Among major zoobenthos groups of soft bottom communities of the survey area, Polychaeta and Mollusca were always the most superior in abundance. Polychaeta was richer than Mollusca in species composition but poorer than Mollusca in density and biomass. This situation occupied both in the whole survey area in general and in every sea regions in particular.

In near-shore areas which located in the depths below 60m, zoobenthos concentrates more distribution. In these depths about 140 species (80% total species number) were recorded and their density reached the highest. It can see that near shore areas are strongly affected by environmental pollution so here considered the most sensitive places.

On the sea bed, especially on sandy component and muddy mixed shell which was more suitable for adaptable distribution of zoobenthos. So on these bottom areas abundance of zoobenthos was higher than that on other substrates especially on fine mud.

When comparing between abundance recorded in this survey with the previous results on same regions more changes in density of zoobenthos were seen. For example, density of zoobenthos among four regions such as Tonkin gulf, Central, Southeast and Southwest used to reach 103, 52, 193 and 257 ind/m^2 respectively [Canh N.T. (1996)] but recent survey results were about 178, 90, 141 and 83 ind/m^2 respectively. It is clear that there were more changes relating to environment issues in the whole of survey area. This matter is suitable completely with diversity indices recently calculated, that is abundance of zoobenthos in central sea region is always lower than that in other regions.

Conclusion

About 180 benthic invertebrate species (Zoobenthos) of 130 genera, 72 families belonging to 5 major groups were found out from specimen sampled on 38 survey stations in Vietnamese seawaters. Among zoobenthos groups, Polychaeta was the most abundance with 78 species, occupied 43.4% of total species, then to Mollusca - 49 species, 27.2%, Echinodermata - 26 species, 13.5 %; Crustaceans - 23 species, 12.8% and the others (Coelenterata, worms) - 4 species, 2.2%.

Quantity average of zoobenthos varied strongly among taxonomic groups or among regions and related to types of substrate or to water depth.

The superiority of species composition in general leads to their superiority of abundance in every landscape or in the sea regions. Especially, superiority of Polychaeta and Mollusca both in species composition and abundance can be seen in benthic fauna or in the sea regions.

So their variations were expressed in diversity indices. And it is very useful for us to use zoobenthos to assess sea water quality.

Acknowledgments

This study was supported by SEAFDEC's interdepartmental collaborative research program. The authors would like to thank all staff on board of M.V. SEAFDEC for sampling. We also thank

RIMP's leadership especially Dr. Son Dao Manh on behalf of executive officials of Vietnam side in project program for his helping in our implementation.

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Composition, Abundance and Distribution of Zooplankton in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

The samples of 58 stations in Vietnamese Waters were collected by M.V.SEAFDEC on 21 April - 5 June 1999. Thirty-seven groups of zooplankton were found in this study. Copepoda was the most abundance followed by Chaetognatha and Ostracoda. Biomass varied from 0.21-7.29 ml/m^3 (average 1.03 ± 1.22 ml/m^3). Station 56 has the highest biomass. Abundance varied from 99-2,365 ind/m^3 (average 580±527 ind/m^3). Station 58 has the highest abundance due to high number of Chaetognatha, polychaete, *Lucifer* spp., Thecosomes and Echinodermata larvae. Whereas Station 19 has the lowest abundance. Cephalopod paralarvae were concentrated. They were classsified into 15 genera belonging to 11 families: *Sepia* sp., *Inioteuthis* sp, *Loligo* spp., *Enoploteuthis* sp., *Abralia* sp., *Watasenia* sp., *Onychoteuthis* sp., *Ctenopteryx sicula, Nototodarus* sp., *Sthenoteuthis oualaniensis*, *Thysanoteuthis rhombus* , *Liocranchia* sp., *Teuthowenia* sp., *Octopus defilippi*, *Octopus* Type A, *Octopus* Type B, *Octopus* Type C and *Tremoctopus* sp. *Sthenoteuthis oualaniensis* found to be most abundance followed by *Octopus* Type B and *Enoploteuthis*. *Sthenoteuthis oualaniensis* found mostly in the middle part of Vietnamese waters especially in the oceanic zone.

Key words: zooplankton, abundance, biomass, Vietnamese Waters, cephalopod paralarvae

Introduction

Marine zooplankton plays a key role in the food chains of the sea as they transfer energy from phytoplankton to higher trophic levels. Numerous studies have shown that small zooplankton (e.g. copepods, tintinnids, cladocerans, larval molluscs) are important component of larval fish food [Hould & Lovdal (1982), [Balbontin *et al.* (1986)], [Anderson (1994)]. Hence, variation in the availability of these organisms has been hypothesized to be related to the larval survival and the subsequent recruitment to the adult population of marine fishes [Cushing (1975)].

Marine plankton of Vietnamese waters was investigated since the beginning of 19 the century [Shirota (1966) referred to Rose, 1926)]. Many papers reported about composition, distribution and classification of plankton in Vietnam [Hamon (1956), [Shirota (1966)] and [Alvarino (1967)]. Some studied on the relationship between amount of zooplankton and feeding rate of fish [Shirota (1967a)] or zooplankton and environment [Shirota (1967b)]. The purpose of the present investigation is to describe the zooplankton community in Vietnamese Waters and provide an estimation of abundance, composition, biomass and their distribution. Besides, cephalopod paralarvae will be concentrated.

Materials and Methods

The samples of 58 stations in Vietnamese Waters were collected by M.V.SEAFDEC on 21

April - 5 June 1999 (Table 1 & Fig. 1). Plankton was collected using 0.33 mm mesh net attached to 60 cm diameter bongo frames. A flowmeter was attached within the aperture of the net to measure the amount of water filtered. At each station a 30 minutes oblique tow of the bongo net was made while the ship cruises at 2 knots. The depth of the haul was 5-7 meters above the sea bottom for the station that the depth was less than 100 meters and 100 meters for the station that the depth was over 105 meters. The samples were preserved in 10 % buffer formalin-seawater immediately. In the laboratory, the displacement volume of total zooplankton was measured after large gelatinous zooplankton had been removed. The samples were subsampled with Falsom Plankton Splitter and then count to taxon. Data on biomass and abundance were standardized per cubic metre. Cephalopod paralarvae were sorted out and identified to species level. The classification of cephalopod paralarvae was based on Kubodera and Okutani (1981), Okutani (1966 and 1968), Okutani and Mc Gowan (1969), Sweeney *et al* (1992), Tsuchiya *et al* (1991), Yamamoto and Okutani (1975) and Young and Harman (1985).

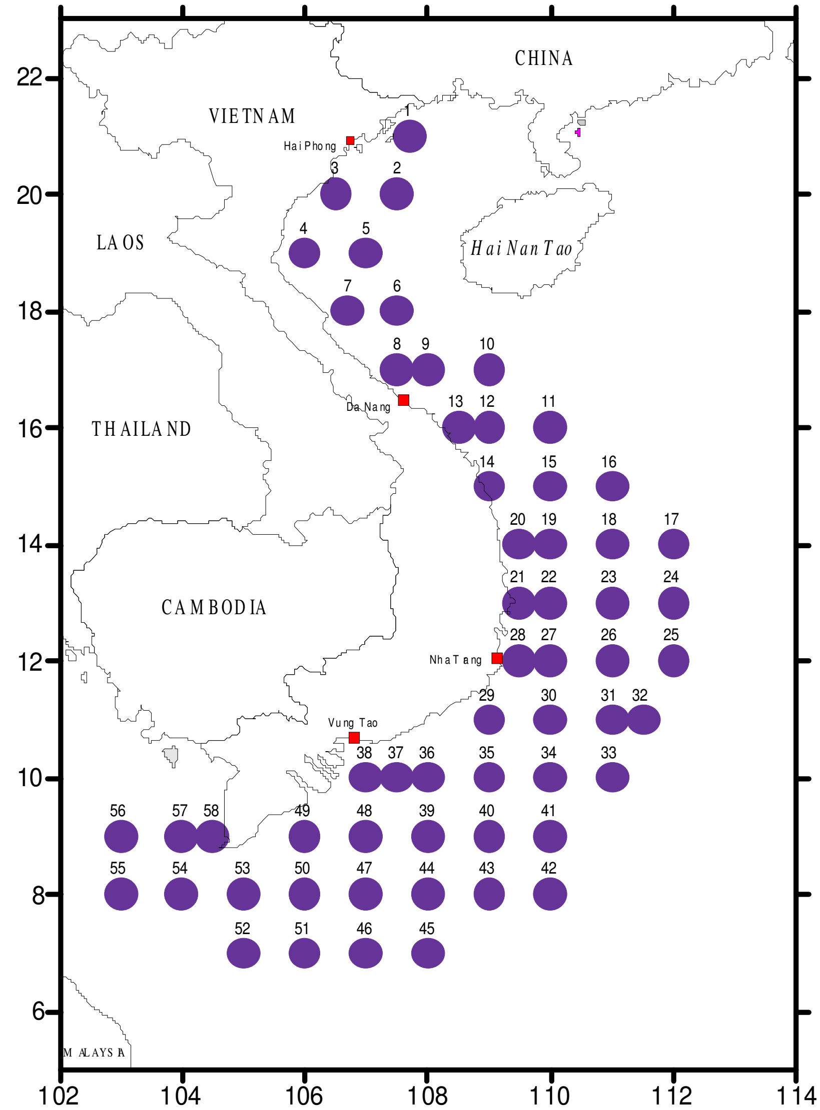

Fig. 1. Location of sampling stations.

Table 1. Information of all survey stations in the Vietnamese waters.

St.	Date	Time	Water Depth	St.	Date	Time	Water Depth
1	30/4/99	0536-0556	34	30	18/5/99	0529-0559	645
2	30/4/99	1121-1148	27	31	18/5/99	1328-1358	2790
3	30/4/99	1812-1838	28	32	19/5/99	1158-1228	4267
4	1/5/99	0001-0029	27	33	22/5/99	1400-1430	3370
5	1/5/99	0655-0725	58	34	21/5/99	1158-1228	1589
6	1/5/99	1323-1352	80	35	21/5/99	0534-0607	155
7	1/5/99	1936-2006	38	36	20/5/99	2027-2057	45
8	2/5/99	0211-0241	45	37	20/5/99	1614-1644	31
9	2/5/99	0613-0643	73	38	20/5/99	1152-1222	21
10	2/5/99	1333-1403	107	39	23/5/99	1241-1320	62
11	3/5/99	0552-0620	847	40	23/5/99	0515-0535	133
12	3/5/99	2129-2158	104	41	22/5/99	2147-2217	1856
13	4/5/99	0157-0225	40	42	25/5/99	1520-1550	647
14	6/5/99	0505-0532	35	43	25/5/99	0824-0854	147
15	6/5/99	1153-1223	463	44	25/5/99	0033-0103	78
16	7/5/99	0540-0610	1220	45	26/5/99	2021-2051	61
17	8/5/99	0550-0620	2200	46	27/5/99	0056-0026	56
18	8/5/99	2140-2210	1481	47	24/5/99	1714-1744	42
19	9/5/99	0618-0648	642	48	23/5/99	1950-2020	33
20	10/5/99	0604-0634	140	49	24/5/99	0300-0329	20
21	10/5/99	1137-1207	133	50	24/5/99	1010-1040	32
22	10/5/99	1605-1635	1997	51	27/5/99	0840-0909	44
23	11/5/99	0538-0608	2697	52	27/5/99	1546-1616	51
24	12/5/99	0836-0906	3335	53	27/5/99	2254-2324	34
25	12/5/99	1425-1455	4150	54	28/5/99	0631-0701	25
26	13/5/99	1407-1437	2880	55	28/5/99	1335-1405	70
27	14/5/99	0515-0545	1737	56	28/5/99	1915-1945	56
28	14/5/99	1811-1839	110	57	29/5/99	0553-0623	34
29	17/5/99	1621-1651	72	58	29/5/99	1001-1030	23

Results

Biomass and abundance of zooplankton

Biomass and abundance of total zooplankton were shown in Table 2 and 3. Biomass varied frim 0.21-7.29 ml/m^3 (average 1.03±1.22 ml/m^3). Station 56 has the highest biomass. Abundance varied from 99-2365 no/m^3 (average 580±527 ind/m^3). Station 58 has the highest abundance due to high number of Chaetognatha, polychaete, *Lucifer* spp. Thecosomes and Echinodermata larvae. While Station 19 has the lowest abundance.

Thirty-seven groups belonging to 11 phylum of zooplankton were found in this study. Copepods were the most abundance and found at all stations, comprising 46.1 % of the zooplankton population. The following groups were Chaetognatha and Ostracoda, comprising 7.6% and 7.1% of total zooplankton respectively. Mollusca formed 12.9 % of total zooplankton population. Veliger of Bivalvia was 43.7% of mollusc group. Gastropoda, including veliger, Heteropod, Thecosomata, Gymnosomata and Nudibranchia, were 35.3 % of mollusc group. Cephalopod paralarvae forming only <0.1 % of total zooplankton population and found to be common in this area. Fish egg and larvae, shrimp larvae and stomatopod larvae were also found to be very common and comprising 0.8 %, 2.4 % and 0.2 % of zooplankton respectively. Ctenophora, Gymnosomata, nudibranchia, phyllosoma larvae, pyrosomata, amphioxus and platyhelminthes found to be rare and comprising <0.1 % of zooplankton population in this study area. The total number and percentage of major groups of zooplankton were shown in Table 4. The average abundance and frequency of occurrence of zooplankton were shown in Table 5 and 6.

Table 2. Biomass of zooplankton (ml./m^3) in Vietnamese waters.

Station	biomass	Station	biomass	Station	biomass	Station	biomass
1	0.94	16	0.66	31	0.49	46	0.38
2	0.47	17	0.30	32	0.47	47	1.61
3	0.48	18	0.34	33	0.68	48	0.82
4	0.70	19	0.21	34	0.49	49	3.21
5	1.07	20	0.44	35	0.6	50	0.46
6	0.97	21	0.39	36	1.63	51	1.54
7	1.22	22	0.44	37	1.47	52	1.07
8	1.82	23	0.38	38	0.47	53	1.05
9	1.95	24	0.38	39	0.96	54	0.68
10	0.72	25	0.58	40	0.53	55	0.86
11	0.37	26	0.40	41	0.99	56	7.29
12	1.21	27	0.47	42	0.93	57	5.96
13	1.70	28	0.40	43	0.31	58	2.43
14	0.94	29	0.56	44	0.78		
15	0.41	30	0.56	45	0.29		

Table 3. Total abundance of zooplankton (ind/m^3) inVietnamese waters.

Station	abundance	Station	abundance	Station	abundance	Station	abundance
1	1,833	16	210	31	195	46	235
2	512	17	154	32	207	47	382
3	381	18	122	33	280	48	635
4	712	19	99	34	217	49	2,207
5	656	20	283	35	365	50	340
6	550	21	352	36	265	51	744
7	895	22	141	37	1,240	52	512
8	1,004	23	202	38	1,194	53	899
9	1,456	24	196	39	788	54	447
10	479	25	312	40	324	55	421
11	186	26	229	41	475	56	1,793
12	284	27	234	42	416	57	1,991
13	1,218	28	199	43	203	58	2,365
14	577	29	246	44	438		
15	269	30	330	45	131		

Table 4. Total number and percentages of major groups of zooplankton in Vietnamese waters at 58 stations.

Taxon	Total	Percentage within group	Overall percentage
I. Coelenterata	919.9	-	2.7
A. Medusae	95.5	10.4	0.3
B. Siphonophora	824.4	89.6	2.4
II. Ctenophora	7.3	-	<0.1
III. Mollusca	4350.2		12.9
A. Bivalvia - veliger	1900.6	43.7	5.7
B. Gastropoda			
1. Veliger	1534.5	35.3	4.6
2. Heteropod	148.9	3.4	0.4
3. Thecosomata	751.5	17.3	2.2
4. Gymnosomata	5.8	0.1	<0.1
5. Nudibranchia	0.2	<0.1	<0.1
C. Cephalopoda - paralarvae	8.6	0.2	<0.1
IV. Arthropoda	22262.2	-	66.2
A. Cladocera	1027.2	4.6	3.1
B. Ostracoda	2385.6	10.7	7.1
C. Copepoda	15740.9	70.7	46.1
D. Cirripedia,larvae	102.2	0.5	0.3
E. Amphipoda, Isopoda, Cumacea	190.9	0.9	0.6
F. Decapoda	2407.3	10.8	7.2
1. Lucifer spp.	1170.1	5.3	3.5
2. Brachyuran	315.6	1.4	0.9
3. Caridea and Penaeidae larvae	801.8	3.6	2.4
4. Phyllosoma larvae	3.3	<0.1	<0.1
5. Anomuran	116.5	0.5	0.3
G. Stomatopod larvae	63.0	0.3	0.2
H. Mysidacea	55.1	0.2	0.2
I. Euphausiacea	290.0	1.3	0.9
VI. Chaetognatha	2569.4	-	7.6
VII. Chrodata	1947.6	-	5.8
A. Thaliacea	1159.6	59.5	3.4
B. Larvacea - *Oikopleura* spp.	508.2	26.1	1.5
C. Pyrosomata	2.6	0.1	<0.1
D. Amphioxus	0.6	<0.1	<0.1
E. Fish egg and larvae	276.6	14.2	0.8
VIII. Invertebrate larvae (Cyphonautes, Actinotroch, polychaet larvae, brachiopod, echinodermata)	1557.2	-	4.6
IX. Other (platyhelminthes)	2.4	-	<0.1
Grand total	33615.9	-	100

Table 5. Taxonomic list of zooplankton found in Vietnamese waters.
The average abundance of zooplankton : + + + = > 10 ind/m^3
+ + = 6- 10 ind/m^3
+ = 0-5 ind/m^3

Taxon	Abundance	Taxon	Abundance
Medusae	+	Shrimp larvae	+++
Siphonophora	+++	Phyllosoma larvae	+
Ctenophora	+	Anomura larvae	+
Platyhelminthes	+	Stomatopoda larvae	+
Cyphonautes,larvae	+	Bivalve larvae	+++
Actinotrocha,larvae	+	Gastropod larvae	+++
Chaetognatha	+++	Heteropoda	+
Polychaeta	+	Naked Pteropod	+
Cladocera	+++	Shelled Pteropoda	+++
Ostracoda	+++	Nudibranchia	+
Copepoda,larvae	+++	Cephalopod larvae	+
Cirripedia,larvae	+	Echinodermata larvae	+++
Amphipoda	+	Thaliacea	+++
Isopoda	+	Larvacea	++
Mysidacea	+	Pyrosomata	+
Cumacea	+	Amphioxus larvae	+
Euphausiacea	+	Brachiopoda larvae	+
Lucifer spp.	+++	Fish eggs	+
Brachyura larvae	++	Fish larvae	+

Table 6. Taxonomic list of zooplankton found in Vietnamese waters.
Frequency of occurrence : R = Rare, C=Common, VC =Very Common

Taxon	Frequency	Taxon	Frequency
Medusae	VC	Shrimp larvae	VC
Siphonophora	VC	Phyllosoma larvae	R
Ctenophora	R	Anomura larvae	VC
Platyhelminthes	R	Stomatopoda larvae	VC
Cyphonautes,larvae	C	Bivalve larvae	VC
Actinotrocha,larvae	R	Gastropod larvae	VC
Chaetognatha	VC	Heteropoda	VC
Polychaeta	VC	Naked Pteropod	C
Cladocera	VC	Shelled Pteropoda	VC
Ostracoda	VC	Nudibranchia	R
Copepoda,larvae	VC	Cephalopod larvae	C
Cirripedia,larvae	VC	Echinodermata larvae	VC
Amphipoda	VC	Thaliacea	VC
Isopoda	R	Larvacea	VC
Mysidacea	VC	Pyrosomata	C
Cumacea	R	Amphioxus larvae	R
Euphausiacea	VC	Brachiopoda larvae	R
Lucifer spp.	VC	Fish eggs	VC
Brachyura larvae	VC	Fish larvae	VC

At the neritic zone, it showed high biomass and abundance of total zooplankton as well as many groups such as bivalve larvae, gastropod larvae, fish eggs, *Lucifer* spp., medusae, stomatopod larvae, brachyura larvae, shrimp larvae, thecosomata. Some groups have high number at oceanic zone such as Cephalopod paralarvae, Oikopleura, Pyrosomata, and Amphioxus. (Appendix A)

If we separated Vietnamese waters into three part, the upper part (from Hi Phong to Da Nang), the middle part (from Da Nang to Vung Tao) and the lower part (below Vung Tao). The upper part and the lower part showed the highest biomass and abundance of total zooplankton. Most of zooplankton showed the same trend except Amphioxus, Platyhelminthes and Pyrosomata.

The abundance of cephalopod paralarvae

Cephalopod paralarvae were concentrated. They were classified into 15 genera from 11 families. The list of the classification of cephalopod paralarvae was shown in Appendix B. *Sthenoteuthis oualaniensis* found to be most abundance (294 ind/1000m^3) followed by *Octopus* Type B (236 ind/1000m^3) and *Enoploteuthis* (169 ind/1000m^3). *Sthenoteuthis oualaniensis* found mostly in the middle part of Vietnamese waters especially in the oceanic zone. Number of cephalopod paralarvae was shown in Appendix C.

Discussion

The biomass and abundance of zooplankton in Vietnamese waters in this investigation was higher than in the Gulf of Thailand and the east coast of Peninsular Malaysia and Sabah, Sarawak and Brunei Darussalam waters in the same period [Jivaluk (1999[1], 1999[2])]. At the upper part and the lower part of Vietnamese waters where the water depth was less than 200 meters (neritic zone), high biomass and abundance were found. This result coincided with Santhankumari (1991) who found the standing stock was relatively high in the neritic zone of the west coast of India. Fallahi (1993) also found the decreasing of plankton abundance from the littoral zone to pelagic zone in the southern part of Caspian Sea. It was concluded that the upper part and the lower part of Vietnamese waters are more productive than the middle part in this study. Especially in the area below Vung Tao (Station 58) where is a Mekong Delta. The water run off brings a lot of nutrient to the sea and make high productivity in that area. This is true also in the Gulf of Thailand whereas Sudara and Udomkit (1984) found that the major factor influencing the distribution of zooplankton seems to be the amount of nutrients available.

There are many other abiotic and biotic factors which influencing on zooplankton abundance. Temiyavanich (1984) noted that zooplankton abundance had significant correlation to the phytoplankton. Santhankumari (1991) observed standing stock of zooplankton in West Coast of India and found that maximum zooplankton production was noticed with the low temperature and low DO during post-monsoon season. Besides, salinity also affected the zooplankton community structure. Ranta and Vuorinen (1990) concluded that in the Seili area, northern Balti Sea, long-term salinity fluctuation coincided with changes in the meso-plankton community. Difference species and species group correlated differently with the salinity change.

Copepods were the main contributors in the present observation followed by Chaetognatha and Ostracoda. This also holds true for the most zooplankton communities sampled in the world ocean [Wimpenny (1966) and [Omori and Ikeda (1976)]. Hould & Lovdal (1982) shown that copepods are important component of larval fish food. Not only copepod, other small zooplankton (e.g. tintinnids, cladocerans, eggs and larval stages of crustaceans, larval molluscas and unicellular organisms) were also important for fish larvae as well [Nagasawa (1993)] and [Anderson (1994)]. Besides, Barange (1989) concluded that the highest abundance of fish larvae were found between the surface and the thermocline - coinciding with denser concentrations of zooplankton biomass. But in this investigation found no clear relation between fish larvae and the amount of copepod. Same evidence was found by Sameoto(1972). He found no significant correlation between biomass of copepods and the estimated abundance of herring larvae.

Shirota (1966) investigated marine plankton of South Vietnam. He found 763 species of 13 phylum of marine zooplankton. In this study found thirty-seven groups belonging to 11 phylum. Although species composition was not studied. Geographical diversity gradients obtained in this study, based on the groups at the primary sorting level, will serve to give an idea of geographical distributions of animal communities.

Numerous studies point out that zooplankton was affected on fisheries. Jakob *et.al.* (1981) noted that the peak periods in the zooplankton biomass were found to coincide with the peak seasons of pelagic fisheries. Suseelan et al. (1985) found that pelagic fish catch, consisting mostly of anchovies and lesser sardines, showed clear peaks, closely following the primary and secondary peaks of zooplankton. Krisshnapillai (1981) also found that the fish catch/hour was maximum in October which was the most productive month of the zooplankton. In this investigation, we studied only once a year. If we study every month and collect the fish catch/ hour at the same area, we might see some relation between fish catch and zooplankton biomass.

The investigation on cephalopod paralarvae showed that 15 genera belonging to 11 families were found. Some were economic species, found in neretic and oceanic area such as *Sepia* sp., *Loligo* spp. and *Sthenoteuthis oualaniensis*. Some genera occurred only oceanic area such as *Abralia* sp., *Watasenia* sp., *Onychoteuthis* sp., *Ctenopteryx sicula, Nototodarus* sp., *Thysanoteuthis rhombus*?, *Liocranchia* sp., and *Teuthowenia* sp., Duc (1997) reported new data on the cephalopod fauna of Vietnam Sea. He found 69 species of cephalopod belonging to 24 genera, 14 families, 3 orders. Some genera of this investigation were not found in the list of Duc (1997) may be because of the ecology of cephalopod paralarvae itself. They may float over the ocean by the current. Most of deep-sea cephalopod paralarvae act as pelagic zooplankton and swim near surface. After getting older they will stay in the deeper water. Another possible thing is that the way to collect deep-sea samples may not suitable so the adult specimens were never been found.

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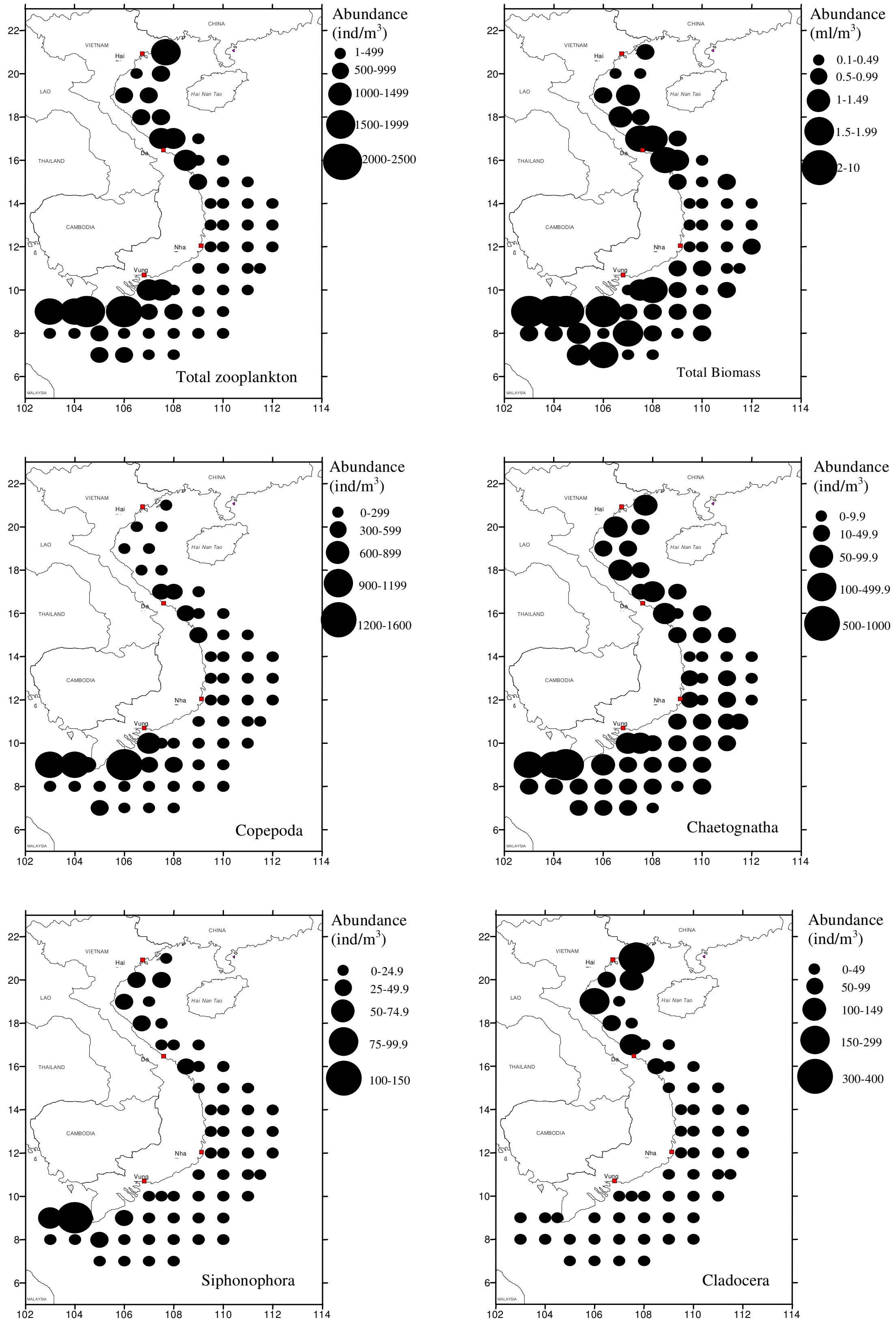
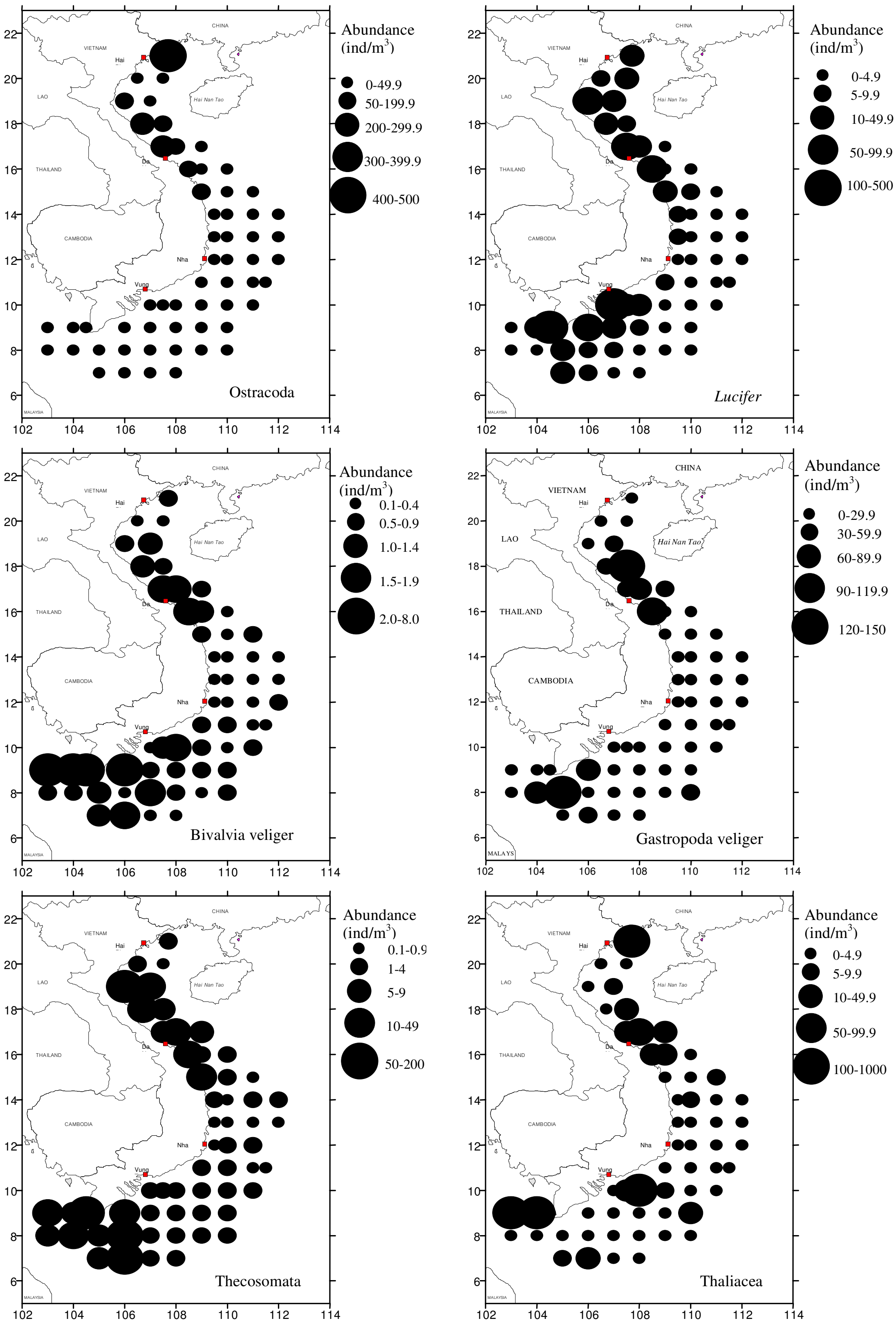
Appendix A1

Distribution and abundance of total zooplankton, total biomass, Copepod, Chaetognatha, Siphonophora and Cladocera of Vietnamese waters from 21 April - 5 June 1999.



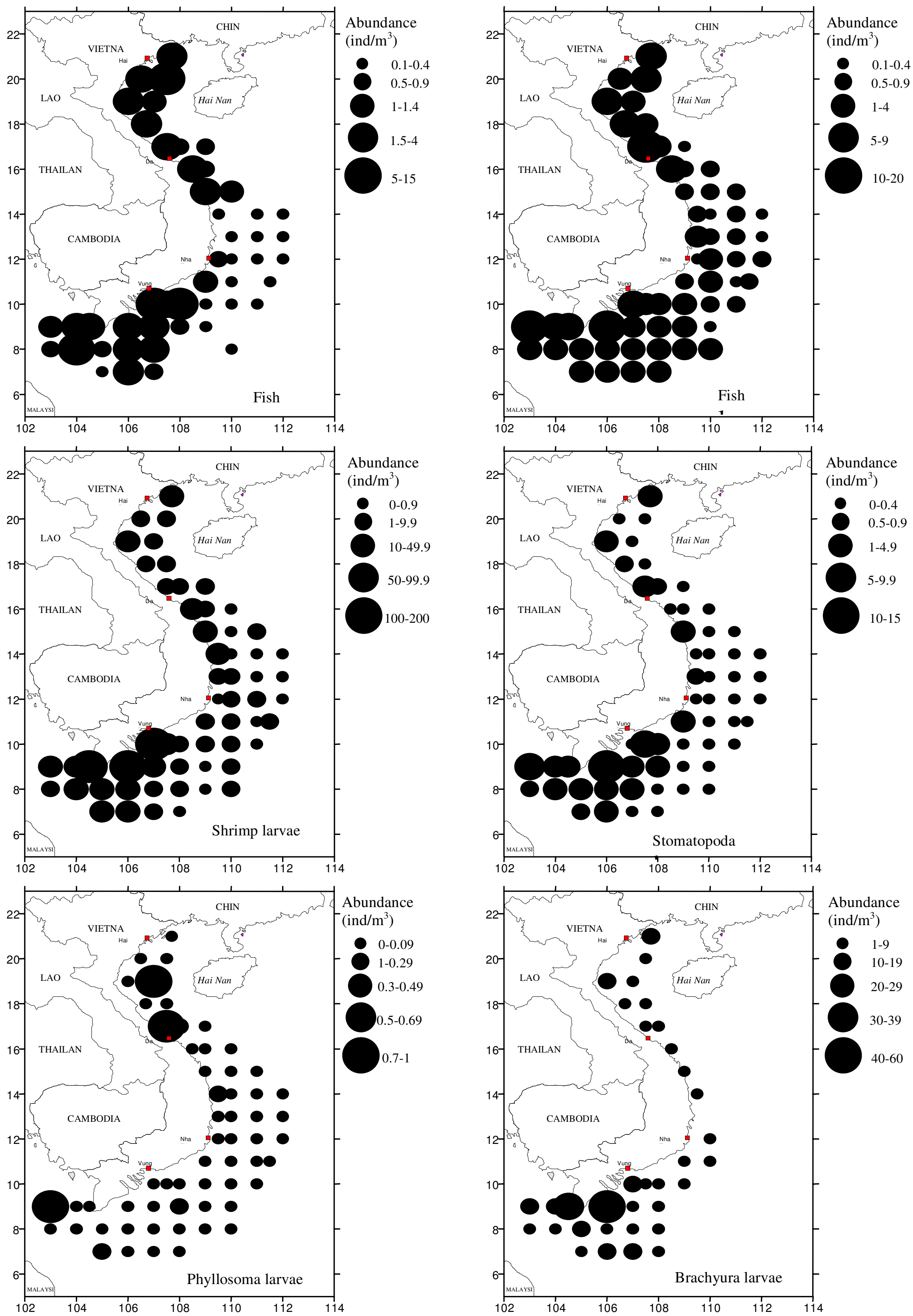
Appendix A2

Distribution and abundance of Ostracoda, *Lucifer* spp.Bivalvia veliger, Gastropoda veliger, Thecosomata and Thaliacea of Vietnamese waters from 21 April-5 June 1999.



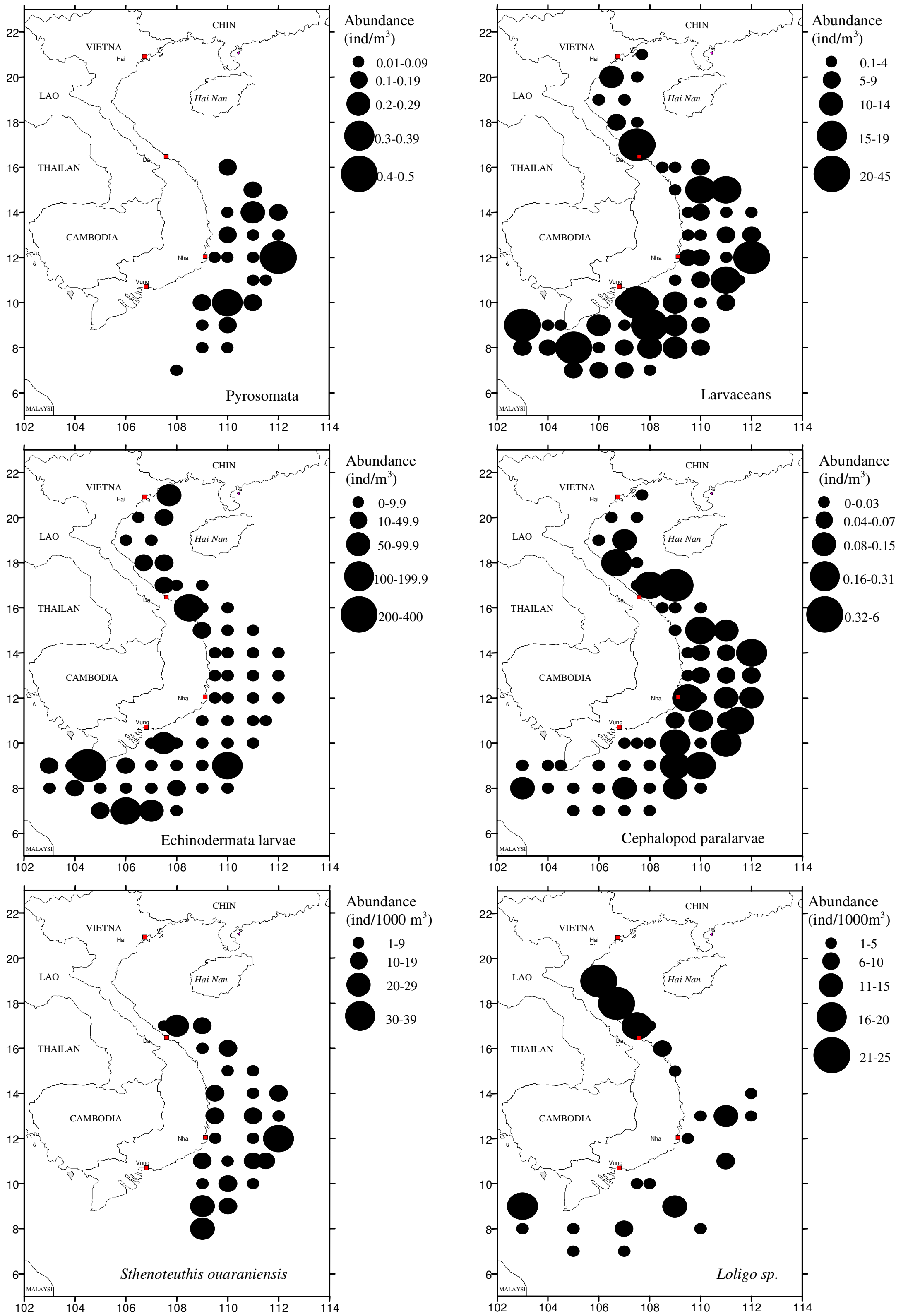
Appendix A3

Distribution and abundance of fish egg, fish larvae, shrimp larvae, Stomatopoda larvae, Phyllosoma larvae and Brachyura larvae of Vietnamese waters from 21 April-5 June 1999.



Appendix A4

Distribution and abundance of Pyrosomata, Larvaceans,Echinodermata larvae, Cephalopod paralarvae, *Sthenoteuthis ouaraniensis* and *Loligo* sp. of Vietnamese waters from 21 April -5 June 1999.



Appendix B

Cephalopoda paralarvae species list

Class Cephalopoda cuvier, 1798

Subclass Coleoida Bather, 1888

Superorder Decebrachia Stolley, 1919

Order Sepiida Naef, 1916

Family Sepiidae Keferstein, 1866

Sepia sp. Linnaeus, 1758

Order Sepiolida (non sensu Fioroni, 1981)

Family Sepiolidae Leach, 1817

Subfamily Sepiolinae Leach, 1817

Inioteuthis sp. Verril, 1881

Order Teuthida Naef, 1916

Suborder Myobsida Orbigny, 1845

Family Loliginidae Steenstrup, 1861

Subfamily Loligininae Naef, 1921

Loligo spp. Schneider, 1784

Suborder Oegopsida Orbigny, 1845

Family Enoploteuthidae Pfeffer, 1900

Enoploteuthis sp.Orbigny, 1839

Abralia sp. Gray, 1849

Watasenia sp. Ishikawa, 1913

Family Onychoteuthidae Gray, 1849

Onychoteuthis sp. Lichtenstein, 1818

Family Ctnopterygidae Grimpe, 1922

Ctenopteryx sicula AppellÖf, 1899

Family Ommastrephidae Steenstrup, 1857

Subfamily Todarodinae Adam, 1960

Nototodarus sp. Pfeffer, 1912

Subfamily Ommastrephinae Steenstrup, 1857

Sthenoteuthis oualaniensis Lesson, 1830

Family Thysanoteuthis

Thysanoteuthis rhombus Troschel, 1857

Family Cranchiidae Prosch, 1849

Subfamily Cranchiinae Prosch, 1849

Liocranchia sp. Pfeffer, 1884

Subfamily Taoniinae Pfeffer, 1912

Teuthowenia sp. Chun, 1910

Superorder Octobrachia Fioroni, 1981

Order Octopoda Leach, 1818

Family Octopus Cuvier, 1797

Octopus defilippi Verany, 1851

Octopus Type A

Octopus Type B

Octopus Type C

Family Tremoctopodidae Tryron, 1879

Tremoctopus sp. Delle Chiaje, 1830

Appendix C

Number of Cephalopod paralarvae per 1000 m^3 at 58 stations of Vietnamese Waters during 21 April -5 June 1999.

	Stations														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Sepia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inioteuthis sp.	0	0	0	0	0	0	0	0	2	2	0	4	2	0	0
Loligo spp.	0	0	0	22	0	0	21	20	2	0	0	0	7	5	0
Enoploteuthis sp.	0	0	0	0	0	9	0	0	0	0	14	0	0	0	22
Abralia sp.	0	0	0	0	0	0	0	0	18	0	7	0	0	0	0
Watasenia sp.	0	0	0	0	0	0	0	0	0	7	0	0	0	0	13
Onychoteuthis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Ctenopteryx sicula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nototodarus sp.	0	0	0	0	0	0	0	0	10	0	5	0	0	0	0
Sthenoteuthis oualaniensis	0	0	0	0	0	0	0	5	28	11	14	4	0	0	6
Thysanoteuthis rhombus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liocranchia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Teuthowenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus defilippi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus Type A	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
Octopus Type B	4	0	0	0	0	0	0	5	6	7	5	4	0	0	41
Octopus Type C	0	0	0	0	0	0	0	0	2	2	0	2	0	0	2
Tremooctopus sp.	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
unknown	0	0	0	0	0	0	0	0	2	0	0	4	0	0	6
Total	4	0	0	22	0	9	24	29	71	31	44	21	10	5	97

	Stations														
	16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Sepia sp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Inioteuthis sp.	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Loligo spp.	0	4	0	0	0	0	2	12	2	0	0	0	2	0	0
Enoploteuthis sp.	6	0	0	0	0	0	0	0	2	11	57	6	0	0	0
Abralia sp.	0	0	0	2	0	0	0	0	8	0	0	0	0	0	0
Watasenia sp.	0	2	2	7	0	0	5	2	4	0	12	0	2	0	0
Onychoteuthis sp.	12	22	0	0	9	0	2	6	10	11	6	0	2	0	4
Ctenopteryx sicula	21	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Nototodarus sp.	0	5	0	0	0	0	0	4	0	6	0	0	0	2	0
Sthenoteuthis oualaniensis	3	14	2	0	12	13	0	10	8	31	6	0	5	11	2
Thysanoteuthis rhombus	0	5	0	0	0	0	0	2	0	3	0	0	0	0	0
Liocranchia sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Teuthowenia sp.	0	0	0	0	0	0	0	6	0	3	0	0	0	0	0
Octopus defilippi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus Type A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus Type B	0	2	8	0	12	4	0	0	2	0	0	2	2	2	2
Octopus Type C	0	0	0	0	0	0	2	0	0	0	3	0	0	0	2
Tremooctopus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unknown	0	2	0	0	0	0	0	4	4	0	3	0	0	4	0
Total	41	58	13	12	33	17	11	52	39	65	87	8	15	20	13

Appendix C (Continued).

	Stations														
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Sepia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inioteuthis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loligo spp.	8	0	0	0	0	3	4	0	0	12	0	3	0	0	0
Enoploteuthis sp.	0	0	0	12	6	0	0	0	0	9	0	0	7	0	0
Abralia sp.	0	3	5	5	2	0	0	0	0	7	0	3	0	0	0
Watasenia sp.	8	3	11	0	0	0	0	0	0	0	0	8	0	0	0
Onychoteuthis sp.	0	0	8	0	0	0	0	0	0	7	7	0	2	0	0
Ctenopteryx sicula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nototodarus sp.	8	0	0	0	0	0	0	0	0	5	2	0	0	0	0
Sthenoteuthis oualaniensis	15	10	5	12	8	0	0	0	0	26	12	0	20	0	0
Thysanoteuthis rhombus	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0
Liocranchia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Teuthowenia sp.	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
Octopus defilippi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus Type A	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Octopus Type B	0	0	0	0	4	0	0	3	9	2	0	0	0	19	2
Octopus Type C	0	0	0	0	2	0	0	0	0	0	0	0	0	7	0
Tremooctopus sp.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
unknown	15	3	13	2	0	0	0	0	0	5	0	0	0	4	0
Total	53	20	53	31	26	3	4	3	9	76	22	13	32	30	5

	Stations													
	46	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**total**
Sepia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Inioteuthis sp.	0	0	0	0	0	3	0	0	0	0	0	0	0	17
Loligo spp.	3	10	0	0	0	0	2	3	0	2	18	0	0	165
Enoploteuthis sp.	0	0	0	0	0	0	0	0	0	8	0	0	0	169
Abralia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	60
Watasenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	86
Onychoteuthis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	116
Ctenopteryx sicula	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Nototodarus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	47
Sthenoteuthis oualaniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	294
Thysanoteuthis rhombus	0	0	0	0	0	0	0	0	0	0	0	0	0	16
Liocranchia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Teuthowenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	19
Octopus defilippi	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus Type A	0	0	0	0	0	0	0	3	0	0	11	0	5	28
Octopus Type B	6	0	6	0	0	5	11	8	13	4	11	25	0	236
Octopus Type C	3	0	0	0	0	0	4	0	0	4	4	0	0	40
Tremooctopus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	4
unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	72
Total	12	10	6	0	0	8	18	13	13	19	43	25	5	1400

Composition, Abundance and Distribution of Fish Eggs and Larvae in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

This report is based on the data of fish eggs and larvae samples which were collected at the 58 stations of the Vietnamese waters, it covered from latitude 7^0 - 21^0 N and longitude 103^0 - 112^0 E. The cruise was carried out from April 30 to May 29, 1999 by M/V SEAFDEC. The Standard larvae net and Bongo net were used for the surface and oblique sampling respectively and 14,507 fish eggs and 18,919 fish larvae were caught. The specimens have been identified, which comprise of 78 families, 94 genera, 94 species of fish eggs and larvae observed from this cruise. The most abundant fish eggs and larvae during the survey were *Engraulidae*, accounted for 8.5% total of eggs and 23.8% total of larvae. The species composition was observed to be very abundant. In each station, at least 6 families and the highest 30 families were collected during the survey. The abundance of ichthyoplankton is rather relatively high, the distribution occurred mainly in the areas of along the coastal, near estuaries and around the islands. The abundance of fish eggs concentrated higher than fish larvae. The density of distribution of fish eggs and larvae in the North sea waters concentrated the most abundant of all and of the Central sea waters was the least abundant of all. Some of families of which fish eggs and larvae have dominated which were presented.

Key words: Ichthyoplankton, Southern China Sea, Tonkin Gulf

Introduction

Studying on fish eggs and larvae (FE - FL) is to identify spawning period and ground of fishes, especially the economical fish species, to serve for fisheries. Simultaneously, study on the growth grounds of concentration and the periods of occurrence of FL that is scientific basis for resources conservation and development of fry source for brackish water aquaculture in the coastal areas. On the other hand, the study materials on FE - FL have importantly contributed to the stock assessment of target fishes. Therefor, study on FE - FL has been carried out in many countries of the world such as Soviet Union, China, Japan, Indonesia, Philippines, India, etc.

In Vietnam, up to now the problem of study on FE - FL has been always mentioned in the program of generally marine research. Many documents have been published not only inside also outside and still the documents haven't been published yet.

The most significantly is the collaborative survey program in the Tonkin Gulf between Vietnam and China (1959 - 1965); and Vietnam - Soviet Union (1960 - 1961). The scientific documents have been published as: On spawning of *Scombridae* [Gorbunova, (1965)]; The FE - FL of *Beloniformes* [Kovalevskaja, (1965)]; Morphology and classification of Flatfishes larvae (*Pleuronectiformes)* [Pertzeva-Ostroumova, (1965)]; The FE - FL of *Synodontidae* and *Theraponidae* [Zviagina, (1965)]; Morphology of *Schindleria praematuna* species [Nguyen Huu Phung, (1971)]. The Institute of Marine Products under the Ministry of Fisheries:

- During 1962 - 1965, carried out the survey of FE - FL in the West coast of the Tonkin Gulf and the report of the survey the entitled: "The season and distribution of FE - FL", which was made by Nguyen Huu Phung, (1973).

- During 1974 - 1975, carried out the survey of FE - FL in the estuary area of Hai Phong rivers (4 surveys for 4 seasons) and the report was made by Do Van Nguyen, (1976).

- During 1975 - 1976, carried out the survey of FE - FL in the coastal waters from Mong Cai (Quang Ninh province) to Cua Sot (Ha Tinh province) (12 surveys for 12 months) and the report was made by Do Van Nguyen, (1977).

- During 1978 - 1980, carried out the program of general survey of study on FE- FL in the sea waters from Nghia Binh province to Minh Hai province (12 surveys cruises) and the report was made by Do Van Nguyen, (1981).

Nha Trang Institute of Oceanography, at present is under the National Center for Sciences and Technology:

- During 1971 - 1972, carried out the survey of FE - FL in the coastal areas of Quang Ninh - Hai Phong provinces (11 cruise surveys) and reports were made by Nguyen Manh Long, Nguyen Huu Phung, Dao Tat Kim, Nguyen Van Be (1977). The reports of taxonomic study on FE - FL of *Clupeiformes*, of *Salangidae*, of *Elopiformes*, of *Mene maculata*; of *Stolephorus*; and of *Synodontidae* were published by Nguyen Huu Phung (1973, 1974, 1976, 1978, 1980). The reports of morphology of *Bregmaceros atripinnis* Tickel, were published, by Dao Tat Kim (1974).

- During 1978 - 1980, carried out the surveys of FE - FL in the sea waters of Thuan Hai - Minh Hai provinces on R/V NCB No.03. The reports of these surveys were made by Nguyen Huu Phung, Hoang Phi, Bui The Phiet (1981) and the report of FE - FL in the estuary areas of the Mekong river was published in 1982. Hoang Phi with the report of the embryo development of *Synodontidae* in Nha Trang sea waters (1980). The reports of FE - FL of sea milk fish (*Chanos chanos* Forskal) living in Van Phong - Ben Goi bay, Nha Trang were published by Nguyen Duy Phuong, Dao Xuan Loc, Pham Thi My, Nguyen Thi Le (1980).

Generally, comparing the results of FE - FL survey in Vietnamese waters, the results of surveys conducted in the Tonkin Gulf more detail and comprehensive than in other sea waters.

With agreement of Vietnamese Government, the Collaborative Research Program among the SEAFDEC member countries has carried out the cruise surveys to collect necessary data and information and to manage the resources of marine fishes and protect the environment of the Vietnamese waters. The surveys were covered from latitude $7^{0}00'$ - $21^{0}00'$ N, longitude $103^{0}00'$ - $112^{0}00'$ E. Study on FE - FL is one of subject that has mentioned in this cruise survey.

Materials and Methods

Materials

The materials used for making this report, mainly based on the data and specimens were collected during the cruise of joint survey in the Vietnamese waters on board of M/V SEAFDEC from April 30th to May 29th 1999. Total number of FE - FL was 14,507 and 18,919, respectively [Table 1].

Methods

Chart of research stations and study sub- areas.

- Research stations were illustrated by quadrangles, the minimum interval between each station is 30 knots and maximum 60 knots.

- There is a line, which passes through 109^{0}30' E, divided the survey area into 3 sub- areas:
Area I: The North
Area II: The Center
Area III: The South.

The research stations were situated in the area I and III with the main depth below 100 m (except 5 stations with the depth from 104 to 155 m). The stations in the area II had very great depth (about 95% of the stations with over 500 m); The stations no.25 and 32 had the depth over 4000 m [Fig.1].

Sampling and preservation.

At each research station, 2 types of net were used to collect samples as follows:

- Standard larvae net: 1,300 mm in diameter with a mesh size is 500 micron, using to collect samples at the water layer from 1 to 0 m (surface water layer : SWL).

- Bongo net: 600 mm in diameter with mesh size 500 micron at the net mouth part and 330 micron at the cod end was employed for the oblique haul and for sampling at the water layer from the depth 6 - 7 m near bottom to surface (in the stations with the depth below 106 m) or from 100 m to surface (in the stations with the depth over 107 m). (Oblique haul water layer : OHWL).

For both Standard larvae and Bongo net, a flow meter was attached to the mouth part of the each net to determine the volume of water which passed. The sampling time was about 20 - 30 minutes with the towing speed at 1.5 - 2.0 knots. Collected specimens were kept in plastic bottles with capacity from 500 to 1000 ml, and preserved in 4 - 7% formaline solution immediately after each haul and these specimens were analyzed and readjusted by Vietnamese researchers in the laboratories of the Research Institute of Marine Products.

Data identification and readjustment

- Before sorting, FE - FL were separated from plankton and debris. Normally, in each sample bottle, FE - FL were selected and checked two times by two researchers to prevent the number being lost.

- Number of FE - FL at each station as well as each family level have been identified and calculated in the same volume of sea water was 1000 m^3 (individual / 1000 m^3 sea waters = IN. / 1000 m^3 S.W.).

- FE - FL were observed to classify and done by using the stereo microscope. This device was attached with a camera in order to take the typical samples of FE - FL.

- Using the descriptions and classification keys, which were given in list of references to identify names of fishes, FE - FL that haven't been identified were preserved for future identification.

- A list of species composition was drawn up in order of alphabet to look up them easily.

- Readjusting data and making the report based on the general principles of research procedure on FE - FL of the model survey in 1978.

Results

Composition and abundance of FE - FL.

Collected samples of FE - FL in this survey cruise have been classified partly to species and genus and the most of them have been only classified to family levels. Table 2 shows a list of identified 78 families, 90 genera and 94 species, which occupied 22.66% total of FE and 99.35% of FL, were identified. Besides, 77.34% of FE and 0.65% of FL haven't been unidentified yet.

Table 1. Position and operating conditions of FE-FL sampling during between April 30 to May 29 1999 in the Vietnamese waters by M/V SEAFDEC.

St. No.	Date	Time		Position		Depth (m)	Volume of water passed net (m^3)		Number of samples were collected (Individuals)			
									Standard		Bongo	
		Start	Finish	Lat.(N)	Long.(E)		S.	B.	FE	FL	FE	FL
01	30/4/99	05.36	05.56	21°00'0	107°55'0	34(28)	1483	271	314	416	507	678
02	30/4/99	11.21	11.48	20°00'1	107°29'9	28(21)	2381	394	116	17	4607	651
03	30/4/99	18.12	18.38	19°59'9	106°29'3	28(20)	2515	394	0	9	856	173
04	01/5/99	00.01	00.28	19°00'2	105°59'5	26.5(20)	1916	374	81	329	867	1810
05	01/5/99	06.55	07.25	19°00'0	107°00'7	58(50)	2474	443	44	8	104	429
06	01/5/99	13.23	13.52	17°59'8	107°29'7	80(72)	1710	344	8	9	73	82
07	01/5/99	19.36	20.06	17°59'8	106°39'9	40(30)	2373	415	1	98	979	653
08	02/5/99	02.11	02.41	17°00'0	107°29'9	45(38)	1926	401	412	13	405	3619
09	02/5/99	06.13	06.43	16°35'0	108°00'6	75(65)	2712	485	38	30	8	234
10	02/5/99	13.33	14.03	17°00'3	109°00'1	107(100)	2048	409	10	7	51	147
11	03/5/99	05.52	06.20	16°01'4	109°58'5	847(100)	1873	426	149	11	34	63
12	03/5/99	21.29	21.58	16°00'4	108°59'9	104(96)	1950	477	32	13	44	168
13	04/5/99	01.57	02.25	16°00'6	108°30'6	42(32)	1516	433	7	212	709	1116
14	06/5/99	05.05	05.32	14°59'7	109°00'6	36(28)	2844	422	135	1	33	69
15	06/5/99	11.53	12.23	15°04'4	110°00'3	426(100)	2276	453	53	1	2	40
16	07/5/99	05.40	06.10	15°02'5	110°58'8	1230(100)	2179	325	37	10	6	58
17	08/5/99	05.50	06.20	14°06'5	111°56'5	2100(100)	3189	563	39	27	8	68
18	08/5/99	21.40	22.10	14°00'1	111°00'0	2200(100)	2390	461	0	13	5	55
19	09/5/99	06.18	06.48	14°10'7	109°58'9	653(100)	1820	392	24	14	2	59
20	10/5/99	06.04	06.34	13°59'9	109°29'1	143(100)	1964	343	6	13	8	102
21	10/5/99	11.37	12.07	13°00'2	109°30'0	134(100)	2064	469	5	3	3	276
22	10/5/99	16.05	16.35	12°59'7	109°59'2	1910(100)	2338	537	20	4	3	32
23	11/5/99	05.38	06.08	12°55'3	111°00'3	2697(100)	2156	489	20	6	2	37
24	12/5/99	08.36	09.06	13°00'0	111°59'5	3332(100)	2285	491	16	1	0	66
25	12/5/99	14.25	14.55	12°00'1	111°59'5	4117(100)	2186	343	26	4	2	39
26	13/5/99	14.07	14.37	12°00'2	111°00'0	2889(100)	2055	324	105	52	3	44
27	14/5/99	05.15	15.45	11°46'2	109°56'1	1734(100)	2373	467	25	88	2	30
28	14/5/99	18.11	18.39	11°59'0	109°25'1	110(100)	1742	381	9	33	15	128
29	17/5/99	16.21	16.51	11°00'2	108°59'9	72(62)	2522	342	237	60	56	98
30	18/5/99	05.29	05.59	11°00'0	110°00'7	648(100)	2396	450	26	32	32	99
31	18/5/99	13.28	13.58	10°59'7	111°01'0	2940(100)	1641	253	24	2	4	26
32	19/5/99	11.58	12.28	10°59'7	111°30'0	389(100)	1678	290	34	2	3	42
33	22/5/99	14.00	14.30	09°59'9	111°00'1	3385(100)	2181	358	11	15	4	32
34	21/5/99	11.58	12.28	09°59'9	111°00'3	1614(100)	2505	415	79	15	5	11
35	21/5/99	05.34	06.07	09°59'7	109°10'7	156(100)	2994	498	39	12	36	144
36	20/5/99	20.27	20.57	10°00'2	108°00'7	45.5(38)	2007	297	52	49	462	249
37	20/5/99	16.14	16.44	09°59'6	107°29'6	32(23)	2012	309	11	2	63	47
38	20/5/99	11.52	12.22	10°00'4	106°59'2	22(12)	1442	346	35	30	604	157
39	23/5/99	12.41	13.20	08°59'8	107°59'9	62(52)	1947	323	16	6	19	71
40	23/5/99	05.15	05.35	09°00'2	108°59'5	129(100)	2083	416	52	9	13	69
41	22/5/99	21.47	22.17	09°00'7	110°00'0	1967(100)	1860	392	6	11	1	40
42	26/5/99	15.20	15.50	08°01'2	109°49'9	628(100)	2015	398	30	408	1	93
43	25/5/99	08.24	05.54	08°00'1	109°00'4	147(100)	2499	399	35	12	33	183
44	25/5/99	00.33	01.03	07°59'7	108°00'6	79(71)	1491	350	36	47	26	203
45	26/5/99	20.21	20.51	06°59'7	107°30'5	61(52)	1804	399	11	31	26	166
46	27/5/99	00.56	01.26	06°59'9	107°00'4	51(44)	1656	314	3	39	94	156
47	24/5/99	17.14	17.44	07°59'6	107°00'4	42(35)	2203	409	4	1	129	162
48	23/5/99	19.50	20.20	08°59'9	106°59'6	33(25)	2035	359	3	33	38	246
49	24/5/99	03.00	03.29	09°00'3	106°00'5	20(12)	1667	251	5	339	53	283
50	24/5/99	10.10	10.40	08°00'0	106°00'0	33(25)	2334	403	162	98	224	548
51	27/5/99	08.40	09.09	06°59'9	105°59'9	44(36)	1956	400	37	22	83	117
52	27/5/99	15.46	16.16	06°59'4	104°59'6	51(43)	2311	439	17	49	21	56
53	27/5/99	22.54	23.24	07°59'7	105°00'7	34(26)	2031	364	2	269	21	377
54	28/5/99	06.31	07.01	07°59'7	104°00'2	26(17)	623	242	163	51	115	135
55	28/5/99	13.35	14.05	07°59'6	103°00'3	70(62)	2452	470	17	19	68	615
56	28/5/99	19.15	19.45	08°59'6	102°59'7	57(49)	1732	262	17	39	20	231
57	29/5/99	05.53	06.23	09°00'4	104°00'0	34(27)	846	80	6	75	12	46
58	29/5/99	10.01	10.30	09°00'1	104°30'5	23(15)	1944	165	0	22	1	50
Total:										3241	11605	15678

Note : In depth column, number in parenthes were depth to collect samples for Bongo net.

Table 2. Composition and total numbers of FE-FL were collected in the off-shore of Vietnam during between April 30 to May 29/1999 by M/V SEAFDEC.

Scientific name	English name	Number of FE-FL (Individuals)		% of total		Occurring in the net	
		FE	FL	FE	FL	B	S
1. Acanthuridae.	**Surgeom fishes**		**2**		**0.011**	**+**	**+**
2. Ambassidae.	**Perchletfishes**		**5**		**0.026**		**+**
Ambassis gymnocephalus Lac.	Bald glassy		5		0.026		+
3. Ammodytidae	**Sandlances**		**12**		**0.063**	**+**	**+**
4. Antennaridae	**Frog fishes**		**2**		**0.011**		**+**
Antennarius hispidus (Bl.-Schn.)	Shaggy angler		2		0.011		+
5. Apogonidae	**Cordinal fishes**		**144**		**0.761**	**+**	**+**
6. Atherinidae	**Silver sides**		**40**		**0.211**	**+**	**+**
7. Balistidae	**Trigger fishes**		**1**		**0.005**	**+**	
Abalistes stellaris (Bl.-Schn.)	Starry Trigger fish		1		0.005	+	
8. Belonidae	**Neetle fishes**		**9**		**0.048**		**+**
Tylosurus menanotus (Bleeker)	Blackfin needle fish		2		0.011		+
Tylosurua	Needle fish		1		0.005		+
9. Bothidae	**Lefleye flounders**		**245**		**1.295**	**+**	**+**
Arnoglossus elongatus Weber	Scald fish		20		0.106	+	
Arnoglossus	Scald fish		114		0.602	+	
Crossorhombus azureus Alcock	Bluespotted flounder		21		0.111	+	+
Crossorhombus			15		0.079	+	+
Psettina hananensis (Wu-Tang)			31		0.158	+	
P. iijimai (Jordan-Stark)			22		0.116	+	+
Psettina			6		0.032	+	+
Pseudorhombus	Flounder		17		0.090	+	+
10. Bregmacerostidae	**Codlets**		**913**		**4.826**	**+**	**+**
Bregmaceros atlanticus Goode	Atlantic cod		237		1.252	+	+
B. atripinnis Tickell	Blackfin cod		41		0.217	+	
B. macclellandi Thompson			635		3.356	+	
11. Brotulidae	**Brotulas**		**20**		**0.106**	**+**	**+**
Sirembo macmoratum (G.-Bcan)			1		0.011	+	
Sirembo			6		0.032	+	+
12. Callionymidae	**Dragonets**		**181**		**0.957**	**+**	**+**
Callionymus	Dragonet		22		0.116	+	+
13. Carangidae	**Carangids**		**1055**		**5.578**		**+**
Caranx	Jack		12		0.063	+	+
Carangoides	Cavalla		35		0.185	+	
Decapterus	Round scad		101		0.534		+
Naucrates ductor (Linnea)	Trevally		5		0.026	+	+
Selar crumenophthalmus (Bloch)	Big eye scad		91		0.481	+	+
Seriola	Trevally		5		0.026	+	
14. Carapidae	**Pearl fishes**		**2**		**0.011**	**+**	
15. Centrolophidae	**Black suffs**		**7**		**0.037**	**+**	**+**
Psenopsis anomala (Tem.-Schl.)	Wart perch		7		0.037	+	+
16. Champsodontidae	**Gaper**		**72**		**0.381**	**+**	**+**
Champsodon capensis Regan	Gaper		47		0.248	+	+
Ch. snyderi Franz	Gaper		25		0.132	+	+
17. Chauliodontidae.	**Viper fishes**	**5**	**2**	**0.034**	**0.011**	**+**	**+**
Chaulioddus sloani (Bl.-Schn.)	Viper fish	5	2	0.034	0.011	+	+
18. Chirocentridae.	**Wolfherrings**	**2**	**24**	**0.014**	**0.127**	**+**	**+**
Chirocentrus dorab Forskal	Dorab wolf herring	2	24	0.014	0.127	+	+

Table 2. (Continued).

Scientific name	English name	Number of FE-FL (Individuals)		% of total		Occurring in the net	
		FE	FL	FE	FL	B	S
19. Chlophthalmidae.	**Barracudas**		**2**		**0.011**	**+**	
Chlorophthalmus mento Garmen	Green eye		2		0.011	+	
20. Clupeidae.	**Sardines**	**300**	**787**	**2.068**	**4.160**	**+**	**+**
*Etrumeus mieropus (*Schl.)	Pacific round herring	119		0.820		+	+
Ilisha elongata (Bennett)	Chinese herring	13		0.090		+	
21. Congridae.	**Conger - eels**		**49**		**0.259**	**+**	**+**
22. Coryphaenidae.	**Dolphin fishes**		**3**		**0.016**		**+**
23. Cynoglossidae.	**Tongue soles**	**125**	**183**	**0.862**	**0.967**	**+**	**+**
Arelia bilineata (Lacepede)	Tongue sole		28		0.148	+	+
Symphurus orientalis (Bleeker)	Tongue sole		15		0.079	+	
Cynoglossus	Tongue sole		136		0.719	+	+
24. Dactynopteridae.	**Flying gurnards**		**18**		**0.095**	**+**	**+**
Dactylopterus orientalis (Cuvier)	Oriental flying gurnard		18		0.095	+	+
25. Diodontidae.	**Porcupine fishes**		**3**		**0.016**	**+**	**+**
26. Drepanidae.	**Sickle fishes**		**14**		**0.074**		**+**
27. Engraulidae	**Anchovies**	**1233**	**4504**	**8.499**	**23.81**	**+**	**+**
Stolephorus commersonii Lac.	Long jawed anchovy	22		0.152		+	+
S. heterolobus Ruppell	Short head anchovy	4		0.027		+	
S. zollengeri Bleeker	Buccaneen anchovy	1206		8.313		+	+
Stolephorus	Anchovy	1	4491	0.007	23.74	+	+
Thrissa	Thrissa		13		0.069	+	
28. Exocoetidae.	**Flying fishes**	**798**	**207**	**5.500**	**1.094**	**+**	**+**
Cheilopogon katoptron Bleeker	Yellow bandflying fish	441	52	3.040	0.275	+	+
Exocoetus volitan Linnea	Tropical two-wing	11		0.076		+	
Exocoetus	Flying fish	2	1	0.014	0.015	+	+
Hyrundichthys oxyocephalus(Bl)	Bong flying fish		38		0.200	+	
Hyrundichthys	Flying fish		17		0.090	+	+
Oxyporhamphus meristocytis P.		61	4	0.420	0.021	+	+
O. micropterus		183	58	1.261	0.306	+	+
Parexocoetus mento (Cuv.-Val.)	African sailfin flying	5	36	0.034	0.190	+	+
29. Fistularidae.	**Cornet fishes**	**34**	**10**	**0.234**	**0.053**	**+**	**+**
Fistularia petimba Lacepede	Red cornet fish	34	10		0.053	+	+
30. Gempylidae	**Snake mackerels**		**65**	**0.234**	**0.344**	**+**	**+**
Gempylus	Snake mackerel		56	0.234	0.296	+	+
Promethichthys prometheus(Cuv)			5		0.032	+	
Lepidocybium flavobrumneum	Escolar		4		0.021		+
31. Gerridae.	**Silver biddies**		**1**		**0.005**		**+**
Gerres filametosus Cuvier	Whipfin morra		0.005		0.005		+
32. Gobiidae.	**Gobies**		**3173**		**16.77**	**+**	**+**
33. Gonostomatidae.	**Gonostobid**		**59**		**0.312**	**+**	
Cyclothone			35		0.185	+	
Vinciguerria			3		0.016	+	
Maurolicus			6		0.032		
34. Hemirhamphidae.	**Half beak fishes**		**1**		**0.005**		**+**
Hemirhamphus geogri(Cuv-Val)	Half beak fish		1		0.005	+	+
35. Istiophoridae.	**Sail fishes**		**4**		**0.021**	**+**	
36. Labridae.	**Wrasses**		**107**		**0.566**	**+**	
37. Lactaridae.	**Falsetrevallies**		**3**		**0.016**	**+**	
Lactarius lactarius (Bl.-Schn.)	Falsetrevally		3		0.016	+	

Table 2. (Continued).

Scientific name	English name	Number of FE-FL (Individuals)		% of total		Occurring in the net	
		FE	FL	FE	FL	B	S
38. Leioglathidae	**Slipmount fishes**		**1778**		**9.398**	**+**	**+**
Gazza minutta (Bloch)	Toothelpony fish		262		1.385	+	
Leiognathus elogatus (Gunther)	Sleuderpony fish		29		0.153	+	+
Leiognathus	Pony fish		120		0.634	+	
39. Lethrinidae.	**Emperors**		**2**		**0.011**	**+**	
40. Lophiidae.	**Anglers**		**2**		**0.011**	**+**	**+**
Lophius setigerus Vahh	Black mounth angler		2		0.011	+	+
41. Lutjanidae.	**Snapper fishes**		**354**		**1.871**	**+**	
Lutjanus erythropterus Bloch	Red snapper		48		0.254	+	+
42. Melanotomatidae.	**Scaleles dragon.**		**7**		**0.037**	**+**	
Bathophilus			3		0.016	+	+
Eutomias			3		0.016	+	+
43. Menidae.	**Moon fishes**		**15**		**0.079**	**+**	**+**
Mene maculata (Bl.-Schn.)	Moon fish		15		0.079	+	+
44. Monacanthidae.	**Leather- Jackets**		**107**		**0.566**	**+**	**+**
Alutera monoceros (Obeck)	Unicorn file fish		17		0.090	+	
Monacanthus	File fish		1		0.005	+	
Stephanolepis japonicus (Til.)	File fish		89		0.470	+	
45. Mugillidae.	**Mullet fishes**		**51**		**0.270**	**+**	**+**
46. Mullidae.	**Goat fishes**		**1333**		**7.046**	**+**	**+**
Upeneus bensasi (Tem.-Schl.)	Bensasi goat fish		396		2.093	+	+
Upeneus	Goat fish		352		1.861	+	+
47. Muraenidae.	**Moray**		**6**		**0.032**	**+**	**+**
Gymnothorax	Moray		4		0.021		+
48. Muraenesotidae.	**Conger ells**	**4**	**11**	**0.028**	**0.060**	**+**	
49. Myctophidae.	**Lantern fishes**		**489**		**2.585**	**+**	**+**
*Diaphus mollis (*Taning)			32		0.169	+	
Diogenichthys atlanticus (Tan.)			22		0.116	+	
D. parnugus Bolin			140		0.740	+	
Benthosema surbobitane (Gil.)			11		0.060	+	
B. filulata (Gil.-Cramer)			6		0.032	+	
Benthosema.			5		0.026	+	
Centrabranchus andreae(Lutken)			1		0.005	+	
Ceratoscopelus maderensis(Low.)			31		0.164	+	
C. warmingi (Lutken)			64		0.338	+	
Hygophum hygomi (Lutken)			60		0.317	+	+
H. proximum Becker			16		0.085	+	+
H. reinhardti (Lutken)			1		0.005	+	
Myctophum asperum Rich.			13		0.069	+	
M. nitidulum Garman			20		0.106	+	
M. spinosum (Stein.)			5		0.026	+	
M. pristilepis (Gil.-Cramer)			3		0.016	+	
Myctophum			19		0.100	+	+
Symbolophorus boops (Rich.)			2		0.011	+	
S. evermanni (Gilbert)			10		0.053	+	
Symbolophorus			7		0.037	+	
50. Nemichthyidae.	**Threed eels**		**41**		**0.217**	**+**	
51. Nemipteridae.	**Threadfinbream**		**441**		**2.331**	**+**	**+**
52. Oncocephalidae.	**Bat fishes**		**1**		**0.005**	**+**	
Haliteua stellata Vahh	Starry hard fish		1		0.005	+	

Table 2. (Continued).

Scientific name	English name	Number of FE-FL (Individuals)		% of total		Occurring in the net	
		FE	FL	FE	FL	B	S
53. Ophichthyidae.	**Snake eels**	**197**	**5**	**1.365**	**0.026**	**+**	**+**
54. Paralipididae.	**Barracudinas**		**5**		**0.026**	**+**	
Lestidiops fascifium (Perr)	Barracudina		5		0.026	+	
55. Platicephalidae.	**Flatheadfishes**		**5**		**0.026**	**+**	
56. Pleuronectidae.	**Right eye flounders**	**3**	**19**	**0.021**	**0.100**	**+**	**+**
Brachypleura novaezeelandi(G.)	Largescale flounder		2		0.011	+	
Samaris cristatus Gray	Grayscrested		17		0.090	+	+
57. Pomacentridae.	**Damsel fishes**		**12**		**0.063**	**+**	**+**
58. Pomadasyidae.	**Grunters**		**82**		**0.433**	**+**	**+**
59. Priacanthidae.	**Big eye fishes**		**206**		**1.089**	**+**	**+**
60. Psettodidae.	**Sping turbot**		**3**		**0.016**	**+**	
Psettoides erumei (Bl.-Schn.)	Arrewtoothed		3		0.016	+	
61. Scorpaenidae.	**Scorpion fishes**	**74**	**153**	**0.510**	**0.809**	**+**	**+**
62. Scopelosauridae.			**5**		**0.026**	**+**	
63. Sciaenidae.	**Drums**		**137**		**0.724**	**+**	**+**
64. Scombridae.	**Mackerel fishes**		**603**		**3.187**	**+**	**+**
Acanthucybium solandri (Cuv.)	Wahoo		9		0.047	+	+
Scomberomorus guttatusBl.-Schl	Indo-pacific mackerel		91		0.481	+	+
S. commersonii (Lacepede)	Talang queen fish		60		0.317	+	+
Scomberomorus	Spanish mackerel		9		0.047	+	
Sarda orientalis (Tem.-Schl.)	Bonito		5		0.026	+	
Scomber japonicus (Houttuyn)	Cub mackerel		6		0.032	+	
Rastrelliger kanagurta (Cuv.)	Indian mackerel		145		0.766	+	
Rastrelliger	Mackerels		65		0.344	+	+
Auxis thazard (Lacepede)	Frigate tuna		7		0.037	+	
Euthynnus affinis (Cantor)	Easten litte tuna		124		0.655	+	
Katsuwonus pelamis (Linnea)	Skipjack tuna		41		0.217	+	+
Thunnus albacares (Bennett)	Yellow fin tuna		18		0.095	+	+
Th. obesus (Lowe)	Big eye tuna		16		0.085	+	+
Th. tongol (Bleeker)	Longtail tuna		6		0.032	+	+
Thunnus	Tuna		1		0.005	+	
65. Scaridae.	**Parrot fishes**		**59**		**0.312**	**+**	
66. Serranidae.	**Grouper fishes**		**186**		**0.983**	**+**	**+**
Epinephelus tauvina Forskal	Greasy grouper		35		0.185	+	+
Epinephelus	Grouper		43		0.227	+	+
Cephalopholis	Rosk cods		2		0.011	+	
67. Siganidae.	**Rabbit fishes**		**1**		**0.005**	**+**	**+**
68. Soleidae.	**Sole fishes**	**4**	**25**	**0.028**	**0.132**	**+**	**+**
Zebrias zebra (Bloch)	Zebra sole		22		0.116	+	
69. Sphyraenidae.	**Barracudas**		**175**		**0.925**	**+**	**+**
70. Syngnathidae.	**Sea horse fishes**		**9**		**0.048**	**+**	**+**
Hippocampus hixtris Kaup	Sea horse		7		0.037	+	+
Syngnathus drajong Bleeker	Pipe fish		2		0.011	+	
71. Schindleridae.	**Schindler fishes**		**14**		**0.074**	**+**	**+**
Schindleria praematuna Schl.			14		0.074	+	+
72. Synodontidae.	**Lizard fishes**	**348**	**159**	**2.392**	**0.841**	**+**	**+**
Saurida elongata (Tem.-Schl.)	Slender lizard fish	88	28	0.606	0.148	+	
S. tumbil (Bloch)	Greater lizard fish	5	20	0.034	0.106	+	
S. undosquamis (Richardson)	Brushtooch lizard	48	33	0.331	0.174	+	+
Synodus hoshinosis Tanaka	Lizard fish		6		0.032	+	
S. wariegatus Lacepede	Redl lizard fish	9	10	0.062	0.053	+	+
Trachinocephalus myops Forster	Snake fish	197	62	1.358	0.328	+	+

Table 2. (Continued).

Scientific name	English name	Number of FE-FL (Individuals)		% of total		Occurring in the net	
		FE	FL	FE	FL	B	S
73. Stomiastidae.	**Scaly dragom**		**2**		**0.011**		**+**
74. Tetrodontidae.	**Puffers**		**153**		**0.808**	**+**	**+**
Fugu	Puffer		7		0.037	+	+
Lagocephagus	Puffer		68		0.359	+	
75. Teraponidae.	**Theraponids**		**103**		**0.544**	**+**	**+**
Terapon theraps (Cuv.-Val.)	Largescaled theropon		56		0.296	+	+
76. Trichiuridae.	**Hairtails**	**159**	**82**	**1.096**	**0.433**	**+**	**+**
Trichiurus	Hairtail		82		0.433	+	+
77. Triglidae.	**Gurrads**		**26**		**0.137**	**+**	**+**
78. Uranoscopidae.	**Stargazers**		**1**		**0.005**	**+**	
Unidentified.		**11219**	**1221**	**77.34**	**0.645**		
Total		**14507**	**18919**	**100.0**	**100.0**		

Table2 showed that:

For FE : 22.66% of total FE samples was identified, belonging to 14 families, of which *Engraulidae* accounted for the highest number of total FE samples(8.50%), followed by *Exocoetidae*(5.50%); *Synodontidae*(2.40%); *Clupeidae*(2.07%); *Ophichthyidae*(1.3%); *Trichiuridae* and *Cynoglossidae*(0.86%).

For FL : There were 4504 individuals of FL of *Engraulidae* obtained in this survey cruise, accounted for 23.81% total of FL. And the following FL were *Gobiidae* (16.77%); *Leiognathidae* (9.49%); *Mullidae* (7.05%); *Carangidae* (5.59%); *Bregmacerostidae* (4.83%); *Clupeidae* (4.16%); *Scombridae* (3.19%); *Myctophidae* (2.60%); *Nemipteridae* (2.33%); *Lutjanidae* (1.87%); *Bothidae* (1.39%); *Priacanthidae* and *Tetrodontidae, Exocoetidae* (1.09%); *Serranidae* (0.98%); *Cynoglossidae* (0.97%); *Sphyraenidae* (0.92%); *Synodontidae* (0.84%); *Apogonidae* (0.76%); *Scorpaenidae* (0.81%); and *Sciaenidae* (0.72%). Only 22 families had number of FL that occupied 91.97% total of collected samples.

Table 2 also presented the difference of composition of families, genera and species in the SWL and OHWL. There were about over 50% number of families, genera and species occurring in the both water layers. The rest occurred in the either SWL or OHWL. These differences were shown in Table 3.

At each station, the composition of collected family, genus, species was very abundant, at least there were 6 and the highest 30 families appeared [Table. 4].

Table 4 showed that the survey cruise was conducted in peak of spawning season of fishes in Vietnamese sea waters, so that the abundance of number of family, genus, and species could be observed at all the research stations.

Based on the habit at conditions, 78 families were identified, belonging to 4 large ecological groups, namely:

- Pelagic fishes group, consists of 16 families such as: *Ambassidae; Atherinidae; Beloniidae; Centrolophidae; Carangidae; Chirocentridae; Clupeidae; Coryphaenidae; Engraunidae; Exocoetidae; Fistularidae; Hemirhamphidae; Istiophoridae; Menidae; Scombridae; Sphyraenidae* which accounted for 39.37% of total FL.

- Coral fishes group, consists of 13 families such as: *Balistidae; Carapidae; Diodontidae;*

Congridae; Muraenidae; Nemichthyidae; Labridae; Monacanthidae; Pomacentridae; Serranidae; Scaridae; Syngnathidae; Tetrodontidae which accounted for 3.88% of total FL

- Mesodemersal fishes group, consisted of 20 families such as: *Acanthuridae; Apogonidae; Dactylopteridae; Drepanidae; Gempylidae; Gerridae; Leiognathidae; Lethrinidae; Lutjanidae; Mugillidae; Mullidae; Nemipteridae; Priacanthidae; Pomadasyidae; Lactaridae; Sciaenidae; Siganidae; Synodontidae; Teraponidae; Trichiuridae* which accounted for 26.30% of total FL.

- Demersal fishes group, consisted of 29 families such as: *Ammodytidae; Antennaridae; Bothidae; Bregmacerostidae; Brotulidae; Callionymidae; Champsodontidae; Chauliodontidae; Chlophthalmidae; Cynoglossidae; Gobiidae; Gonostomatidae; Lophiidae; Melanotomatidae; Muraenesotidae; Myctophidae; Oncocephalidae;Ophichthyidae;Paralipididae; Platycephalidae; Pleuronectidae; Psettoididae; Scorpaenidae; Scopelosauridae; Soleidae; Schindleridae; Stomiastidae; Triglidae; Uranoscopidae* which accounted for 29.80% of total FL

In general, this division is only relatively, because some of fishes called pelagic fish, some time they go down to near bottom layer as some species belonging to the *Carangidae* or some of demersal fishes go down to live in the coral reef areas, etc. This occurrence is called the vertical migration or the change of ecological area. However, there is a relative concept of division to compare among them. By this division, the pelagic fish group comprised only 16 families, but its number of collected FL wassurvey area and survey period had been in a peak of spawning season of almost pelagic fishes, especially the species belonged to *Engraulidae,Clupeidae,Carangidae,Scombridae, Exocoetidae*, Mesodemersal and demensal fish families with the number of collected FL were approximately, accounted for 26.30% and 29.80% for each group. The coral reef fish group had the smallest number of FL, occupied only 3.88% total FL.

Distribution of FE-FL

The general trend of distribution of FE-FL in the Vietnamese sea waters in the survey period was concentrated along the coastal line and around islands or near the estuaries of the big rivers. FE usually concentrated with high density, FL distributed scattering, only some areas concentrated with high density. The density of FE-FL distribution in the North and South sea waters concentrated higher than in the Central sea waters.

The density of FE-FL distribution in the North sea water concentrated higher than in the South sea waters. For example, in the Northern sea waters, the density of FE-FL was high (over 1000 IN/ 1000 m^3 S.W), which occurred in the 4 main areas such as: around Bach Long Vi island; along the coastal line from Co To to Long Chau islands; along the coastal line from Ba Lat to Thuan An estuary; and the coastal area near Hoi An estuary.

The distribution density of FE which was 11700 FE / 1000 m^3 SW occurred in the area around Bach Long Vi island and of FL which was 9000 IN/1000m^3 SW occurred in the coastal areas from Con Co island to the Thuan An estuary.

The density of FE-FL distributed scattering in the South sea waters, the concentration of this area was not higher than the North sea waters. The density of FE-FL concentrated highly (over1000 IN./1000 m^3 S.W.), occurred in the sea waters: for FE from Southwest of Phu Quy island to Mekong estuaries, for FL from Mekong estuaries to the Southwest of Con Son island and from along the coastal line to the South of study area..

In the Central sea waters the distribution of FE-FL concentrated lower than other sea waters. The area having the highest density, obtained 500 IN. /1000 m^3 S.W. is in the area from Quy Nhon to Nha Trang [Fig.2 & 3].

Comparing with the density of FE-FL in the SWL and OHWL showed that: For SWL, the distribution density of FE-FL was not very abundant, the highest number of FE-FL obtained only 262 FE and 281 FL/1000 m^3 S.W. In the OHWL, the distribution density of FE-FL was always more abundant than the SWL (higher than 44 times and 32 time to the distribution density of FE-FL, respectively). [Fig. 2, 3, 4 and 5].

The distribution density of FE-FL of some dominated fish families were presented in the Table 5 and 6.

Table 3. Difference of composition of families, genera and species in the SWL and OHWL.

	Number of family, genus and species occurred in the		
	Both SWL & OHWL	Only SWL	Only OHWL
Family	49	9	20
Genus	47	6	37
Species	45	4	46

Table 4. Number of family, genus, species was collected in each survey station.

Station No	Number of			Station No	Number of		
	Family	Genus	Species		Family	Genus	Species
01	20	11	9	30	28	19	13
02	16	7	5	31	13	14	13
03	17	8	3	32	17	24	20
04	15	16	14	33	12	12	10
05	28	15	13	34	6	10	10
06	20	11	8	35	28	23	18
07	28	21	13	36	26	18	16
08	26	25	17	37	14	12	9
09	30	18	12	38	19	9	8
10	26	15	11	39	22	20	18
11	17	14	11	40	18	18	20
12	28	21	14	41	13	13	11
13	24	16	9	42	23	27	20
14	15	7	4	43	22	21	16
15	9	10	9	44	29	22	18
16	18	18	16	45	25	18	19
17	21	17	15	46	17	12	9
18	16	18	10	47	13	7	7
19	19	17	12	48	20	8	6
20	22	12	11	49	23	15	9
21	18	17	9	50	23	14	14
22	22	19	13	51	19	14	11
23	12	11	9	52	17	14	9
24	13	13	12	53	25	13	9
25	12	15	13	54	24	10	8
26	23	27	19	55	25	13	11
27	16	16	14	56	25	13	9
28	20	11	6	57	15	9	9
29	27	14	12	58	14	7	4

Table 5. Mean abundance of the FL (Number under 1000 m^3 sea waters volume) and frequency occurred of some main families in survey sub-areas.

Order	Family	Number / 1000 m^3 S.W.			Frequency (%)		
		North	Central	South	North	Central	South
01	*Apogonidae*	2	5	11	23.08	27.27	69.56
02	*Bothidae*	22	2	13	69.23	54.54	82.61
03	*Bregmacerostidae*	24	14	66	76.92	63.64	69.56
04	*Callionymidae*	14	1	8	64.23	40.91	52.17
05	*Carangidae*	95	4	44	92.31	31.82	100.0
06	*Champsodontidae*	8	2	1	61.54	31.82	39.13
07	*Clupeidae*	37	very few	19	46.15	4.54	30.43
08	*Cynoglossidae*	22	1	6	92.31	22.72	47.83
09	*Engraulidae*	732	6	30	92.31	72.72	73.91
10	*Exocoetidae*	8	1	1	30.77	18.18	8.69
11	*Gempylidae*	9	1	very few	23.08	31.82	8.69
12	*Gobiidae*	227	37	173	100.0	72.72	100.0
13	*Labridae*	2	2	10	15.38	40.91	52.17
14	*Leiognathidae*	258	2	37	92.31	22.72	91.30
15	*Lutjanidae*	29	3	6	61.54	27.27	56.52
16	*Monacanthidae*	1	0	15	7.69	0	56.52
17	*Mullidae*	93	2	12	92.31	22.72	78.26
18	*Myctophidae*	4	42	9	23.08	95.45	30.43
19	*Nemipteridae*	59	2	4	92.31	13.64	21.74
20	*Pomadasyidae*	14	1	very few	61.54	13.64	8.69
21	*Priacanthidae*	14	1	8	38.46	36.36	52.17
22	*Scorpaenidae*	14	1	5	84.62	27.27	43.48
23	*Sciaenidae*	16	very few	5	30.77	9.09	34.78
24	*Scombridae*	67	6	17	84.62	68.18	69.56
25	*Serranidae*	3	1	13	61.54	27.27	73.91
26	*Sphyraenidae*	20	2	5	61.54	40.91	43.48
27	*Synodontidae*	13	2	7	76.92	31.82	43.48
28	*Tetrodontidae*	16	4	4	53.85	54.54	34.78
29	*Teraponidae*	2	1	7	15.38	9.09	26.09
30	*Trichiuridae*	2	-	8	23.08	-	21.74

Table 6. Mean abundance of the FE (Number under 1000 m^3 sea waters volume) and frequency occurred of some main families in survey sub-areas.

Order	Family	Number / 1000 m^3 S.W.			Frequency (%)		
		North	Central	South	North	Central	South
1	*Clupeidae*	4	1	12	23.08	13.64	13.04
2	*Engraulidae*	218	0	31	46.15	0	21.74
3	*Exocoetidae*	3	12	3	30.76	86.36	39.13
4	*Cynoglossidae*	0	0	16	0	0	17.39
5	*Synodontidae*	22	0	26	53.85	0	73.91
6	*Ophichthyidae*	5	very few	2	46.15	9.09	30.43
7	*Trichiuridae*	13	very few	3	46.15	9.09	30.43

These tables showed that:

For FE:

In the North sea waters, the highest average density of FE was *Engraulidae,* which occupied 218 FE/1000m^3 S.W. The following families was *Synodontidae* (22 FE), *Trichiuridae* (13 FE). But they just only appeared in 50% of study stations.

In the Central sea waters, *Exocoetidae* had the highest average density of FE of all, it occupied only 12 FE/1000m^3 S.W, the frequency of observation was 30.76%.

In the South sea waters, *Engraulidae* had the highest average density of FE of all, 31 FE/1000m^3 S.W, but the frequency of appearance occupied only 21.79%. The following families as *Synodontidae* 12 FE, frequency 73.91%, *Cynoglossidae* 16 FE and frequency 17.39%, *Clupeidae* 12 FE and frequency 13.04%.

For FL:

In the North sea waters, *Engraulidae* had the highest average density of FL of all, it obtained 732 FL/1000 m^3 S.W and the number of stations that collected samples of this family occupied 92.31%. The following families as *Leiognathidae* (288 FL and 92.31%), *Gobiidae* (226 FL and 100.0%), *Carangidae* (95 FL and 92.71%), *Mullidae* (59 FL and 92.31%), *Scombridae* (67 FL and 84.62%), *Nemipteridae* (59 FL and 95.45%).

In the Central sea waters, *Myctophidae* had the highest average density of FL of all, it obtained 42 FL/1000m^3 S.W and the frequency was 95.45%. The following families as *Gobiidae, Bregmacerostidae, Scombridae* (37, 14, 6 FL and 72.72%, 63.64%, 68.18%, respectively).

In the South sea waters, *Gobiidae* had the highest average density of FL of all, it obtained 173 FL/1000 m^3 S.W. The following families as *Bregmacerostidae* (66 FL and 69.56%), *Carangidae* (49 FL and 100.0%), *Leiognathidae* (37 FL and 91.30%), *Engraulidae* (30 FL and 73.19%), *Clupeidae* (9 FL and 30.43%), *Serranidae* (13 FL and 73.91 %), etc.

FE-FL of some dominant fish families

Engraulidae

In the coastal pelagic fishery of Vietnam, some species of Anchovy family (*Engraulidae*) have high economic value. Presently, there are about 33 species belonging to 6 genera of Anchovy family [MoF(1996)]. In this survey, 1,233 FE and 4,504 FL of Anchovy family were collected, which accounted for 8.5% of total collected FE and 23.82% of total FL of all species, this is the highest number of not only FE but also FL of collected fish species. We initially identified FE of 3 species *Stolephorus commersonii*; *Stolephorus heterolobus; Stolephorus zollengeri* and FL of *Stolephorus* and *Thrissa* [Table 2].

Diagnostic features

FE of Anchovy have elongated elliptical shape, size ranged from 0.8 to 1.8 mm x 0,5 to 0.8 mm. Egg membrane is smooth and transparent except for *Stolephorus commersonii* has a small knob in one side. Egg of Anchovy has yolk-sphere with turtle-shell shaped. Egg of two species *Stolephorus commersonii* and *Stolephorus zollengeri* have no oil globule in yolk; or there is only one oil globule in yolk, such as egg of *Stolephorus heterolobus* (egg size is bigger 1.5 - 1.8mm x 0.6-0.7mm) and another species (egg size's smaller 1.1-1.3mm x 0.6-0.7mm)[Fig. 33].

The FL of Anchovy family are small, long with small head and lower jaw shorter than upper jaw. Body depth before anus is the same. Head and opercle are spineless. All fins have no spine rays, no adipose fin, specific swimming bladder. Anus is in the back half of body. From the tip of snout to anus is about 60% of total body length. Black pigment distribute along with intestinal tube, or on the lower edge of body. Black pigment also scatters on the caudal fin. The number of muscle-segment varies among different genus; *Stolephorus* 26-28 + 16-20, *Thrissa* 29 - 32 + 16 - 22. The character of FL of Anchovy family to distinguish from Herring fish family is the beginning place of anal fin base that is usually equal or before the end place of dorsal fin base in horizontal straight of body. The number of muscle-segment after anus is often a lot (16-20).

The FE-FL distribute widely in the survey area. The occurrence frequency is 77.59%.The high concentration occurred only in the North and sparse in the Central (maximum 19 IN/1000m^3 S.W.).

In the Northern waters: the FE distribute with high density from 500 – 791 FE/ /1000m^3 S.W in 2 regions: From Southwest of Bach Long Vy island to the coastal line between Long Chau island and Ba Lat estuary, and the out side area of Cu Lao Cham island. The density of FL is repeatedly with density of FE but trend to appear in the area along coastal line to South , particular in the Southeast of Con Co island to Thuan An mouth, the density of FL up to 6,663 FL/1000m^3 S.W.

In the South sea area, the FE distribute mainly in the coastal area; from Vung Tau to Dai mouth (624 FE/1000m^3 S.W). The FL scatter all over the survey area. In the Southwest area of Tho Chu island, the density is 210 FL/1000m^3 S.W.[Table 7 & Fig. 6]

Table 7. Mean abundance of the FE-FL(Number under 1000 m^3 sea waters) and frequency occurred of some genus, species of Anchovy family in the survey sub-areas.

Genus, species	North		Central		South	
	Mean density	Frequency (%)	Mean density	Frequency (%)	Mean density	Frequency (%)
Stolephorus	734.0	12.30	5.4	67.27	32.3	69.57
S. heterolobus	0.8	15.38	0	0	0	0
S. zollengeri	182.7	53.85	0	0	31.2	17.39
S. commersori	4.8	15.38	0	0	0	0
Thrissa	0	0	1.4	22.73	0	0

Clupeidae

The species of Herring fish family are also important to the pelagic capture fisheries in Vietnam such as: Lift net with light, gill net for sardine, purse seine ... Now, in the sea of Viet Nam, there are about 56 species belonging to 18 genera of Herring fish family.[MoF (1996)].The collected number of FE-FL samples of Herring family are 300 and 787 ; respectively and accounted for 2.07% and 4.16% of total collected FE-FL.

Diagnostic features

The FE of Herring fish family are spherical with smooth membrane, without cling substances. The diameter of egg ranges from 1.0–2.5 mm. The big eggs have large yolk crack. They are big yolk–spheres, turtle shell shape. Yolk of *Etrumeus micropus* egg do not contain oil globule (diameter of *Etrumeus micropus* egg from 1.23–1.35mm), or one oil globule in yolk of *Ilisha elongata* egg (diameter from 2.1–2.5 mm, diameter of oil globule from 0.35–0.40mm, black pigment appear on oil globule) or egg of some other species have many oil globules such as *Anodontostoma chacunda* [Mito, S. (1960)].

The FL are all tiny, elongated and small head, head and opercle lack of spine. All fins not to be supported by rigid rays. From the tip of snout to the anus is about 80% of total body length. Black pigment appears on intestinal tube. The FL of Herring are the same with the FL of Anchovy fish at first glance. The muscle- segment from 39–62 . The distinguished character from FL of Anchovy is the beginning of anal fin base always after the end of dorsal fin base. The muscle number after the anal is about 6–15 [Fig. 33].

Eggs of Herring fish distribute widely in North and South sea areas. We hardly collected any samples in the Central area, but at the 19th station we collected 5 FL/1000m^3 S.W and at the 20th station 17 FE /1000m^3 S.W.

In the North sea area, the density of FE-FL from 112 to 495 IN/1000m^3 S.W occurred in coastal area from Co To island to Ba Lat estuary.

In the South sea area, the density from 100–179 IN/1000m^3 S.W in area of Me Kong estuaries and from 200-218 IN/1000m^3 S.W in area of Dinh An estuary to Southwest area of Con Son island.[Fig. 7]

Exocoetidae

Flying fish are the most typical pelagic species in the sea area of Viet Nam. There are about 24 species belonging to 7 genera of Flying fish family [MoF(1996)].

In this survey, we collected 798 FE and 207 FL of Flying fish; about 5.5% and 1.09% of total collected FE-FL. We initially classified 6 species of 5 genus [Table 2].

Diagnostic features

Egg of Flying fish is spherical. Diameter of egg ranges from 1.4 – 3.3 mm, it varies from different species. Membrane of egg is transparency, colorless. The egg membrane of *Exocoetus volitan* is smooth, shiny, but egg membrane of *Oxyporhamphus microptesus* and *O. meristocystys* cover with short spines (0.05 – 0.07mm), *Cheilopogon katoptron* with spine knot 0.3 –0.5 mm on the membrane surface, *Parexocoetus mento* membrane with 10 – 12 stings distribute equally on the surface, one of which is bigger and longer . The egg membrane of *Hyrundichthys oxycephalus* has 2 sets of sting in 2 poles, that one is about 15-18 short stings (3cm) and another 8-10 longer ones (6cm).In the development of embryo, the embryo has many black - brown pigment, in radial, or rounded shape on embryo and yolk sac, that is also a character to classify out. The embryo is usually short and big. The pectoral and pelvic fin develop rapidly when the embryo is still in egg.

The FL of Flying fish are often short, big and rather round. The anus located behind body. From the tip of snout to anus is about 70% total body length. Fins develop quickly especially for pectoral and pelvic ones. Black and black-brown distribute all over the body. The lower jaw is longer than the upper one. [Fig.34].

The FE-FL of Flying fish distribute widely in survey area. The maximum is 59 IN/1000 m^3 S.W. The occurrence frequency in Central sea waters is higher than in the North and the South [Table 8 and 9]

Scombridae

The Mackerel fish family is an important economic pelagic family in Viet Nam not only in quantity but also in quality. All of them are pelagic migrants. Now 32 species of 13 genera are recorded in Viet Nam sea area [MoF.(1996)]. There were 603 individuals of Mackerel FL obtained during the cruise with length from 3.0-13.7 mm, about 1.39% of total obtained FL. During the cruise, 74 individuals were collected in the SWL and 529 individuals in the OHWL from 42 stations. The specimens were identified which comprise of 12 species of 9 genera [Table 2].

Diagnostic features

The FL is elongated, flat in two sides, the highest depth of the body is usually near the head. The anus is located in the middle of body. The tail is slender towards the end. Mouth is large, many sharp teeth. The edge of stomach near the tail has many, little, or without radial black pigment, that is the character to identify. There are many muscle-segment arranged closely, it varies from different genera. For example *Scomber* and *Rastrelliger*: 30 – 31; *Scomberomorus*: 49 – 52; *Sarda* : 45; *Acanthucybium*: 64; *Thunnus*: 40 –41; *Euthynnus* and *Auxis*: 38 – 39; *Katsuwonus*: 39 - 40 ...[Fig.35].

The FL distribute widely in the survey area. The density in the North is often higher than the South and the Central. They usually distribute with high density (100 – 182 IN/ 1000 m^3 S.W) from areas of Me - Mat islands to Con Co island and Thuan An mouth. In the South and the Central area, the highest density was recorded only to 100 IN/1000m^3 S.W [Table 10 &11].

Table 8. Mean abundance of the FE-FL(Number under 1000 m^3 sea waters) and frequency occurred of some species of Flying family in the survey sub-areas.

Genus, species	North		Central		South	
	Mean density	Frequency (%)	Mean density	Frequency (%)	Mean density	Frequency (%)
Cheilopogon katoptron	0.9	38.46	4.6	86.36	2.1	43.48
Exocoetus volitan	0	0	0.4	9.09	0.9	13.04
Exocoetus	0	0	0.2	9.09	0	0
Hyrundichthys oxycephephalus	7.5	23.08	0	0	0	0
Hyrundichthys	0.2	7.7	0.3	4.5	0	0
Oxyporhamphus micropterus	0.3	30.77	2.6	77.27	0.8	34.78
Oxy. meristocystis	0.1	7.7	0.6	22.73	0.6	8.69
Parexocoetus mento	0.4	15.38	0.5	27.27	0.2	21.74
Exocoetidae	2.3	15.38	0.7	54.54	0.2	13.04

Table 9. Abundance and distribution FE-FL of some species of Flying fish Exocoetidae in the Vietnamese waters.

Ck: *Cheilopogon katoptron*; **Ev**: *Exocoetus volitan*; **E**: *Exocoetus sp.;* **Ho***: Hyrundichthys oxyocephalus;* **H***: Hyrundichthys sp.;* **Omi***: Oxyporhamphus micropterus;* **Ome***: O. meristocystys;* **Pm***: Parexocoetus mento;* **Exo***: Exocoetidae.*

Species	Ck.	Ev.	E.	Ho.	H.	Omi.	Ome.	Pm.	Exo.
Station	**North**								
1	x			x x		x			
2	x								
3						x			
4				x x					x x
5									
6							x	x	
7				x x				x	
8									
9	x				x	x			
10	x					x			
12	x								x
13									
14									
	Central								
11	x x					x x	x		x
15	x						x		
16	x					x	x		x
17	x					x x	x	x	x
18			x						
19	x					x			x
20			x						
21									
22	x					x			x
23	x					x	x		
24	x					x			
25	x					x			
26	x x					x x		x	x
27	x					x			x
28	x					x			
30	x					x		x	x
31	x					x x			x
32	x	x				x		x	x
33	x								x
34	x x	x				x		x	x
41	x					x			
42	x x				x	x x		x	

Table 9. (Continued).

Species	Ck.	Ev.	E.	Ho.	H.	Omi.	Ome.	Pm.	Exo.
Station No	**South**								
29	x								x
35	x	x				x		x	x
36		x						x	
37									
38									
39	x					x			x
40	x					xx			
43	x					x			
44	x					x			
45	x					x			
46									
47									
48								x	
49									
50								x	
51									
52	x	x				x			
53	x								
54	x								
55						x	x		
56							x	x	
57									
58									

Note: Number of FE-FL /1000 m^3 sea waters.   x: 1-10;   xx: 11-100.

Table 10. Mean abundance of the FL (Number under 1000 m^3 sea waters volume) and frequency occurred of some species of Scombridae in the survey sub-areas.

Species	North		Central		South	
	Mean density	Frequency (%)	Mean density	Frequency (%)	Mean density	Frequency (%)
Acanthucybium solandri	1.2	23.08	0.1	4.54	3.2	43.48
Scomberomorus guttatus	11.7	30.77	0.1	4.54	0.7	8.70
S.commersonii	3.8	15.38	0.4	4.54	0.9	4.35
Scomberomorus spp.	0.4	7.69	0	0	0	0
Sarda orientalis	0	0	0.5	4.54	0	0
Scomber japonicus	0	0	0.6	13.64	0	0
Rastrelliger kanagurta	14.0	30.77	0.1	4.54	6.9	17.39
Rastrelliger spp.	13.5	30.77	0.2	4.54	0.9	4.35
Auxis thazard	0	0	0	0	0.6	8.70
Euthynnus affinis	18.7	15.38	1.2	13.64	2.1	26.08
Katsuwonus pelamis	0	0	1.4	27.27	0.8	17.39
Thunnus albacares	0	0	1.1	31.82	0.3	4.35
Thunnus obesus	1.9	7.69	0.1	4.54	0	0
Thunnus tongol	0.4	7.69	0	0	0	0
Thunnus spp.	0.2	7.69	0	0	0	0

Table 11. Abundance and distribution FL of some species of Scombridae in the Vietnamese waters were collected from April 30 to May 29 / 1999.

As: *Acanthucybium solandri*; **Sg**: *Scomberomorus guttatus*; **Sc**: *S. commersonii*; **S:** *Scomberomorus sp.*; **So**: *Sarda orientalis*; **Sj**: *Scomber japonicus*; **Rk**: *Rastrelliger kanagurta*; **R**: *Rastrelliger sp.*; **At**: *Auxis thazard*; **Ea**: *Euthynnus affinis;* **Kp**: *Katsuwonus pelamis;* **Ta**: *Thunnus albacares;* **To**: *Thunnus obesus;* **Tt**: *Thunnus tongol;* **T**: *Thunnus sp.*

Species	As	Sg	Sc	S	So	Sj	Rk	R	At	Ea	Kp	Ta	To	Tt	T
Station	North														
1							xx								
2															
3															
4	x	xx	xx				xx			xxx					
5								xx			x				
6													x		
7		xx						xxx							
8	x	xx					xx			xx					
9														x	
10			xx	x				xx							
12								x					x	x	
13	x	xx					xx								
14															x
	Central														
11	x				xx								x		
15											x	x			
16											xx	x			
17										x	x				
18												x		x	
19												x		x	
20		x	x												
21						x									
22															
23			x			x									
24															
25			xx										x		
26			x							xx			x		
27			x									x			
28															
30										x	x	x			
31											xx	x			
32						x		x			x	x			
33			x									x			
34			x												
41															
42		x					x								
	South														
29										xx					
35				xx								x			
36			x					xx	x						
37															
38		x	x				xx								
39		xx					x				xx				
40			x				x		x		x				
43															
44			x							x	x				
45		x	xx							x	x				
46		x	x												
47															
48		x									x				
49															
50		x								x					
51		x								x					
52								x							
53	x	x													
54		x													
55		xx					xx								
56		x													
57		xx													
58															

Note: Number of FL / 1000 m^3 sea waters. x:1-10; xx: 11-100; xxx: 101-182.

Carangidae

In the Carangids fish family, there were 62 species, belonging of 17 genera recorded [MoF (1996)], of which *Decapterus* is usually caught in high productivity by pelagic fisheries, such as: Purse seine, lift net with light and bottom trawl.

In this cruise, we collected 1055 FL of Carangids fish family, identified 2 species 6 genera, with body length from 2.5 – 12.5 mm, about 5.58% of total FL. During the cruise, 188 individuals were collected in the SWL and 867 individuals in the OHWL, from 42 stations.

Diagnostic features

The FL of Carangids fish are in many shapes, but generally they are elongate, flat in two sides. The highest depth is right after the head. The anus is lied in the second half of body, the head is big, with large mouth, the opercle has two specific spine lines. The pigment distribute in line on two sides with radiate form, black or brown. There are about 24 – 26 muscle-segments. [Fig. 37].

The FL of this family occur mainly along coastal range of the North and widely in the South. The Central is very sparse and in small quantity. The density is from 100 – 500 IN/1000 m^3 S.W in Southwest of CoTo island, Northeast of Mat island, out side area of Cu Lao Cham island and the Dinh An estuary. [Table 12, Fig. 8]

Table 12. Mean abundance of the FL(Number under 1000m^3 sea waters volume) and frequency occurred of some species of Carangidae in the survey sub-area.

Species	North		Centre		South	
	Mean density	Frequency (%)	Mean density	Frequency (%)	Mean density	Frequency (%)
Caranx	0.2	7.69	0	0	0	0
Carangoides	1.5	7.69	0	0	0	0
Decapterus	8.3	30.77	0.1	15.38	0.3	8.69
Naucrates ductor	0.4	7.69	0	0	0.1	8.69
Selar crumenophthalmus	1.6	15.38	0.2	76.92	4.9	34.78
Seriola	0.4	7.69	0	0	0.5	8.69
Carangidae	102.3	92.30	3.5	31.82	45.7	100.0

15% of total bottom caught fishes. [Le Trong Phan (1980)]. There are about 16 species belonging to 8 genera [MoF (1996)].

During the cruise, we collected 348 FE and 159 FL, about 2.39% of total FE and 0.84 of total FL, of which 5 FE and 24 FL were collected in the SWL from 13 stations, 343 FE and 135 FL in the OHWL from 37 stations. We initially classified 6 species of 3 genera. [Table 2].

Diagnostic features

Eggs are spherical, diameter from 1.01 – 1.34 mm. The yolk is identical, no oil globule. There are 2 styles of egg membrane: One is smooth like *Saurida undosquamis, Saurida elongata* and the second is six-vein style, in each tip of a vein has one short spine like egg of *Trachinocephalus myops, Saurida tumbil* and *Synodus variegatus.*

The FL are small, long and large mouth. Anus lied at the near end of the body with long and big intestinal tube. The quantity of pigment is depend on each species or developing stage. The number of muscle segment varies from species: 41-61 [Fig. 36]. The morphological characters is described briefly in Table 13.

Table 13. Diagnostic features of FE-FL of some species of Synodontidae.

Species	Diameter of egg (mm)	Structure of egg membrane	Number of muscle segment	Quantity of pigment at intestinal tube
Trachinocephalus myops	1.07-1.21	six-vein style has spine (0,02mm)	31-33+19-22	4 - 6
Saurida tumbil	1.01-1.11	six-vein style has spine (<0,01mm)	35-36+17-18	3-6 (equally big size)
Saurida undosquamis	1.26-1.34	smooth	26-27+21-22	3 - 6
Saurida elongata	1.26-1.28	smooth	29-30+22-26	1 - 4
Synodus variegatus	1.15-1.26	six-vein style has spine very small	58 - 61	10 - 12
Synodus hoshinosis	_	_	54 - 57	7 - 8

Table 14. Abundance and distribution of FE-FL of some species of Synodontidae in the Vietnamese waters were collected from April 30 to May 29 / 1999.

Tm: *Trachinocephalus myops;* **St**: *Saurida tumbil;* **Su**: *Saurida undosquamis;* **Se**: *Saurida elongata;* **Sv**: *Synodus variegatus;* **Sh**: *Synodus hoshinosis.*

Species	Tm	St	Su	Se	Sv	Sh
Station No	**North**					
1	x x x		x			
2	x x x					
3						
4	x	x x				
5			x x	x		
6			x			
7	x		x x	x		
8	x		x			
9			x x			
10	x x					
12	x					x
13	x x					
14						
	Central					
11						
15						
16						
17						
18						
19						
20					x	
21	x				x	x
22	x					
23						
24						
25	x					
26						
27						
28						
30						
31						
32						
33						
34	x					
41			x			
42	x				x	

Table 14. (Continued).

Species	Tm	St	Su	Se	Sv	Sh
	South					
29	x x					
35	x				x	
36	x x			x x		
37	x x	x			x	
38				x x	x	
39	x			x x		
40	x	x	x	x		
43	x x			x x		
44	x x			x x	x	
45	x			x x	x x	
46	x x x					
47	x x			x x		
48	x					
49	x			x x		
50	x			x		
51	x x			x x		
52	x			x x		
53	x		x	x x		
54						
55	x x			x		
56				x		
57						
58						

Note: Number of FE-FL / 1000 m^3 sea waters. x: 1-10; xx: 11-100; xxx: 101-170.

The distribution of FE-FL occured mainly in two sub-regions of North and South. The Central sub-region is rarely observed. The major species is *Trachinocephalus myops* from 101-170 IN/1000 m^3 S.W from CoTo island to Bach Long Vi island and the beyond end of South sub-region. Saurida elongata, distributed denssity is from 11-100 IN/1000 m^3 S.W widely in South sub-region.[Table 14].

Leiognathidae

18 species of *Leiognathidae* belonging to 2 genera were recored in Vietnamese waters. [MoF (1996)].

Two species *Gazza minutta* and *Leiognathus elongatus* are in small number, the rest are only in family level. [Table 2].

Diagnostic features

FL of *Leiognathidae* family are slender, short with large mouth. The parietal elongate in saw shape, opercle has 2 spine lines. The anus lied in the before half of the body, black pigment distribute closely in under edge of caudal body.

They distribute in coastal area of South and North sub-region with density from 500 – 1750 IN / 1000m^3 S.W. They occur from Co To island and along coastal line to areas of Me-Mat islands; and Southwest area of Con Co island [Fig. 9]

Mullidae

They are the main species in all bottom hauls. In the sea of Vietnam, there are about 24 species belonging to 4 genera [MoF. (1996)]

During the cruise, we obtained 133 FL with length from 2.1 – 18.5mm, about 7.05% of total FL, of which 396 individuals belong to *Upeneus bensasi* and 352 individuals are *Upeneus* , the rest are in family level. We collected 740 individuals in SWL from 34 stations and 593 individuals in OHWL at 35 stations. [Table 2].

Diagnostic features

The FL of this family are small, elongate. Head and opercle have no spine. The anus lied in the before half of the body. The quantity of muscle segment is about 24 (10+14). The big ones have two dorsal fins. The second fin is usually symmetrical to anal fin. The black pigment is in small round dotted line distributed sparsely on under edge of caudal body [Fig. 38]

The FL occur widely in survey area. In the SWL, the occurence frequency is about 56.62 %,in the OHWL it is 60.34%.

The density is high in hte North sub-region with maximum of 201-500 IN/1000 m3 S.W. In the South sub-region the highest is 11-101 IN/10003 S.W.[Fig.10]

Nemipteridae

In the Sea of Vietnam, ther were 33 species of 2 genera recorded [MoF(1996)]. During the cruise, we collected 441 individuals of Nemipteridae,about 2.33 % of total FL, of which 81 individuals were in the SWL at 11 stations and 360 individuals in the OHWL at 30 stations.

The distribution density is high in sub-region of the North and sparse in the South and the Central.[Fig. 11].

Gobiidae

Currently, there were 93 species belonging to 42 genera recorded [MoF(1996)]. However, not many of them are economic value. They distribute widely from the coastal brackish water areas to far islands and deep areas.

During the cruise, we collected 3173 FL with average length from 2.5 to 8.5 mm, about 16.77% of total obtained FL, of which 319 individuals were in the SWL at 20 stations and 2858 individuals in the OHWL at 53 stations. All specimens are identified in family level.

Diagnostic features

The FL of *Gobiidae* are tiny, elongate, small head and mouth. Opercle lack of spine, anus is in the middle of the body, intestinal tube is big and short, big bladder. The dorsal fin is symmetrical to anal one. At the under edge of caudal body, there are clearly some radial pigment. [Fig.39].

The distribution of FL is equally to all over the survey area. The distributed density is in Fig. 12.

Bregmacerostidae

The species of *Bregmacerostidae* are tiny and have not economic value. Up to now, there were 3 species of 1 genus [MoF(1996)].

During the cruise, 913 individuals were obtained, with length from 2.5 to 32.3mm, about 4.83% of total FL, of which *Bregmaceros macclellandi* is the dominant species. We got in the SWL 59 individuals at 17 stations and in the OHWL 593 individuals at 28 stations. *Bregmaceros atlanticus* was collected 3 FL in the SWL at 2 stations and 6 individuals in the OHWL at 1 stations. For *B. atripinnis* 6 FL in the SWL at 1 stations and 41 FL in the OHWL at 2 stations.

Diagnostic features

The FL are usually tiny, long and flat. Mouth is rather large. The tip of head often has one spine elongated to be a small string. The pelvic fin is rather big and the dorsal fin is symmetrical to anal fin, with soft rays. The black dotted or radial pigment cover all over the body. The quantity of muscle segment ranges from 47 – 58. The number of anal fin ray (A), dorsal fin ray (D) and muscle segment (M) varies from different species, e.g. *B. macclellandi* M: 52 – 58, A: 58 – 69 (62-66), D: 57-65 (58-61); *B. atlanticus* M: 54-55, A: 58-69 (62-66), D: 47-56 (50-54). [Fig. 40].

The FL distribute widely in the survey area. However, *B. atripinnis* occur only in open area of Tonkin Gulf. *B. macclellandi* tend to occur in the coastal area. *B. atlanticus* tend to occur in the open sea, deep sea areas [Fig. 13].

Myctophidae

They comprise the species living offshore and deep area. All of them are not economic value. Presently, there were about 4 species belonging to 5 genera, which have been recorded by Tran Dinh (1981). This data is not enough due to their habitat is living in deep sea and offshore areas.

During the cruise, 489 individuals were collected with their length is from 3.1 – 12.6 mm, about 2.59% of total FL. 7 individuals were in the SWL at 4 stations and 482 individuals in the OHWL at 31 stations. Initially, 17 species of 8 genera were classified [Table 2].

Diagnostic features

The FL are in small shape, elongate and flat with large mouth. The head and opercle lacks of spine. The eye is elliptical shape but gradually turn in to oval shape in the development. They have adipose fin after the dorsal fin. The pigment is black or brownish colour, round or radial shape. It distribute in order by rule on the body, which varies from different species. [Fig. 41].

The distribution of FL occurs in Central sub-region, in open sea and deep sea areas. The density is sparse [Table 15].

Lutjanidae

In the sea waters of Viet Nam, presently, there are about 52 species belonging to 14 genera [MoF(1996)].

During the cruise, we collected 354 individuals, about 1.87% of total FL. There were 123 individuals in the SWL at 23 stations and 222 in the OHWL at 29 stations. *Lutjanus erythropterus* were collected in the SWL 2 individuals at 1 station and 80 individuals in the OHWL at 13 stations. The distribution of larvae was shown in Fig.14.

Priacanthidae

There are 9 species belonging to 3 genera of this family in Vietnamese waters, now. [MoF (1996)]. In this survey, we collected 206 specimens, with average length from 3.2 – 10.8 mm, about 1.09% of total FL. There were 62 specimens collected in the SWL at 7 stations and 144 individuals in the OHWL at 25 stations. The density of distribution was shown in Fig.15.

Bothidae

The species of *Bothidae* are bottom associated ones. Their characters are for bottom living. There are about 43 species belonging to 12 genera identified [MoF(1996)].

During the cruise, 245 individuals were collected, with body length range from 3.0 – 18.1 mm, about 1.3% of total FL, of which 11 individuals are in the SWL at 8 stations and 234 individuals in the OHWL at 40 stations.

Diagnostic features

The FL of this family are thin, high and flat towards the dorsal and pelvic. The dorsal is usually from the tip of head to the caudal fin. The anal fin elongate from the end of the anus to near caudal fin. All dorsal and caudal fins have many soft rays. The brown-black radial shape of pigment distribute on the lower and upper edge of the body. The gut is long and can be rolled up in 2 folds.[Fig.42].

The FL are observed widely in all sea areas, but are abundant in coastal areas [Table 16].

Table 15. Abundance and distribution of FL of some species of Myctophidae in the Vietnamese waters were collected from April 30 to May 29 / 1999.

Dia: *Diaphus;* **Dio**: *Diogenichthys;* **Ben**: *Benthosema;* **Cera**: *Ceratoscopelus;* **Hygo**: *Hygophum;* **Myc**: *Myctophum;* **Sym**: *Symbolophorus.*

Species	Dia	Dio.	Ben.	Cera.	Hygo.	Myc.	Sym.
Station No	**North**						
1							
2							
3							
4							
5							
6							
7							
8							
9						x	
10							
12					x x	x	
13						x	
14							
	Central						
11					x x	x	x x
15		x x			x x	x x	
16		x	x x		x x	x x	
17		x x			x x	x	x
18		x x		x x	x x	x	x
19		x x	x	x x	x		
20		x			x		
21				x	x	x	
22		x		x		x	
23		x x	x x	x	x		
24		x x		x	x	x	x x
25		x x	x x		x	x	x
26	x	x	x	x x	x	x	
27		x x	x	x x	x		
28							
30					x		
31		x x		x	x	x x	
32	x	x	x		x	x	x
33	x x	x x		x	x		x
34		x		x			x
41	x x	x x		x	x	x	
42	x	x		x	x	x	
	South						
29	x			x			
35	x	x x		x x	x	x	
36				x			
37							
38							
39	x	x					
40	x	x x			x	x x	
43	x x	x x		x		x	
44	x	x		x x			
45							
46							
47							
48							
49							
50							
51							
52							
53							
54							
55							
56							
57							
58							

Note: Number of FL/1000m^3 sea waters. x: 1-10; xx: 11-100.

Table 16. Abundance and distribution of FL of some species of Bothidae in the Vietnamese waters were collected from April 30 to May 29 / 1999.

Ae: *Arnoglossus elongatus;* **Arno**: *Arnoglossus;* **Ca**: *Crossorhombus azureus;* **Cros**: *Crossorhombus sp.;* **Ph**: *Psettina hananensis;* **Pi**: *Psettina iijimai;* **Pset**: *Psettina;* **Pseu**: *Pseudorhombus.*

Species	Ae.	Arno.	Ca.	Cros.	Ph.	Pi.	Pset.	Pseu.
Station	**North**							
1		x						
2								
3								
4		x x						
5					x			
6							x	
7								
8		x x	x x		x x			x x
9					x			x
10					x			
12		x	x					
13		x x				x		x
14								
	Central							
11								
15				x				
16		x						
17								
18	x							
19	x				x			
20								
21		x						
22		x		x			x	
23		x		x				
24								
25								
26		x						
27		x			x			
28								
30							x	
31								
32					x			
33								
34								
41		x						
42		x						x
	South							
29					x			
35		x						
36		x x	x x		x		x	
37						x		
38								
39		x						
40						x		
43		x				x		
44		x x					x	
45		x				x x		
46	x	x						
47						x		
48				x				
49						x		
50	x x							
51		x						x
52				x				
53		x		x			x	
54		x				x		
55		x x		x				
56		x x					x	
57								
58								

Note: Number of FL /1000 m^3 sea water . x: 1-10; xx: 11-100; xxx: 101-200.

Cynoglossidae

The *Cynoglossidae* fish family comprises of benthods due to their morphological features. 27 species belonging to 4 genera were identified in Vietnamese sea waters. [MoF(1996)].

During the cruise, we collected 125 FE and 183 FL, about 0.86% of total FE and 0.97% of total FL, of which 7 FE at 4 stations and 4 FL at 2 stations were in the SWL, 118 FE at 4 stations and 179 FL at 28 stations were in the OHWL. We initially identified 2 species and 3 genera. The rest are in family level. [Table 2].

Diagnostic features

Eggs of *Cynoglossidae* are spherical, diameter ranges from 0.7 – 0.9 mm. The yolk crack is narrow, yolk contain from 7 – 36 oil globules with diameter from 0.02 – 0.08 mm, In the development of embryo, the embryo and yolk have many black pigment.

The FL are thin. Fins is from tip of head to anus. The dorsal, caudal and anal fins are not clearly divided. The first rays of dorsal fin (usually about 2) are longer than other. The pigment is black or brown in dotted or radial form. [Fig. 43].

The distribution of FL is all over the North and South sub-regions. The density is shown in Fig. 17.

Serranidae

Serranidae comprise of many economic species not only in high productivity but also in quality. Some species of *Serranidae* are the important subjects of marine and brackish water culture such as species of genus *Epinephelus*.

In Vietnamese waters, now there are about 68 species belonging to 17 genera [MoF(1996)].

During the survey, 186 individuals were collected with average length from 2.6 - 18.0 mm. 33 specimens in the SWL at 10 stations and 153 specimens in the OHWL at 31 stations were collected. *Epinephelus tauvina* was collected 1 FL in the SWL and 36 FL in the OHWL at 13 stations.

Diagnostic features

The body of FL of *Serranidae* are robust, oblong-oval to rather elongate, in two sides. The highest depth is right after the head. The anus is lied in the middle of body. The head is big with large mouth, sharp teeth. Opercle has 2 long spine lines. Some species of this fish family, the second spine ray of dorsal fin and the first spine ray of ventral fin are elongated in the growth. These spine rays of *E. tauvina* reach the maximum in length at 30^{th} day then shorten little by little. [Nguyen, D. V. & Son, D. M. (1996)] [Fig. 44].

The density of distribution is shown in Fig.16.

Sphyraenidae

They are the pelagic species, migrating vertically daily. In the sea waters of Viet Nam, there are 10 species of 1 genus [MoF(1996)].

During this cruise, we collected 175 FL, with average length from 3.8 – 6.6 mm. 12 individuals in the SWL at 6 stations and 163 FL in the OHWL at 27 stations were collected.

Diagnostic features

The FL are elongate, big head, large mouth with sharp teeth. Anus is in the behind half of the body. The pigments on the body are black dotted ones, about 26 muscle segments.

The FL distribute widely over the survey area. The density is shown in Fig. 18.

Trichiuridae

In the sea area of Vietnam, there are 6 species belonging to 3 genera [MoF.(1996)].

During this survey, we collected 159 FE and 82 FL, about 1.1% of total FE, and 0.43% of total FL. 66 FE at 2 stations, 6 FL at 3 stations in the SWL and 93 FE at 15 stations, 76 FL at 16 stations in the OHWL were collected.

The distribution of FE-FL occurs mainly in North and South sub-regions. The density iin Fig. 19.

Gempylidae

Now, there are about 8 species belonging to 7 genera of *Gempylidae* have been recorded. [MoF(1996)].

During the cruise, we collected 65 FL, only *Promethichthys prometheus* were collected from both in the SWL and OHWL. The *Lepidocybium flavobrumneum* and genus *Gempylus* were collected only in the OHWL. The distribution of FL occurs in the open area of Tonkin Gulf and the Central sub-region [Fig. 20].

Some other fish families

Some other fish families such as: *Apogonidae, Callionymidae, Labridae, Monacanthidae, Pomadasyidae, Sciaenidae, Scorpaenidae, Teraponidae, Tetrodontidae*, which only collected in small number of FL. They are shown in Table 17.

The distribution and density are in Fig. 21, 22, 23, 24, 25, 26, 27, 28 and 29.

Table 17. Some information on FL of some fish families were collected from April 30 to May 29/ 1999 in the Vietnamese waters by M/V SEAFDEC.

Order	Family	% of total	In the SWL		In the OHWL	
			Quantity of FL	Number of station occur	Quantity of FL	Number of station occur
1	*Apogonidae*	0.76	0	0	144	25
2	*Callionymidae*	0.96	34	7	147	30
3	*Labridae*	0.57	4	2	103	23
4	*Monacanthidae*	0.57	6	3	101	15
5	*Pomadasyidae*	0.43	2	1	80	13
6	*Sciaenidae*	0.72	12	2	125	14
7	*Scorpaenidae*	0.81	20	8	133	27
8	*Teraponidae*	0.54	32	4	71	10
9	*Tetrodontidae*	0.81	4	3	149	27

Discussion.

Species composition.

Up to now, 2085 species, 717 genera, 198 families and 32 orders of marine fishes of Vietnam have been found [MoF(1996)].

Comparing with the above-mentioned number, the species composition which was found through studying on FE-FL in this cruise was very small. However, many fish species belonging to the fish groups of Chondropterian, living near the coastal area, and the estuaries, this collect sampling, they could not be collected. On the other hand, the period of collecting FE-FL lasted within one month, that's why the abundance of number of species composition was not enough because each species spawns by a different season.

Above-mentioned results showed that within one month of collecting specimens of FE -FL, 78 families, 90 genera and 94 species were presented. This result also indicated that there were a lot of species spawned in this period and each research station at least 6 families and the most 30 families were caught.

Over 100 species, belonged to 36 families, have been recorded in the list of economical fishes of Vietnamese waters by the Ministry of Fisheries (1996). Comparing the list of economical fishes of Vietnamese waters with the list of FE-FL have been identified, 32 families are the same. Except some of families as *Polymenidae, Ariidae, Sillagidae, Rachycentridae,* they are fishes groups living near the coastal and estuary areas and not to appear in this survey cruise.

Nguyen Huu Phung (1971) presented a list of 38 families, 27 genera and 43 species during study on FE-FL in the Tonkin Gulf.

Do Van Nguyen (1981) presented a list of 95 families, 90 genera and 85 species during study on FE-FL from Nghia Binh to Minh Hai sea areas.

Comparing result of study work on M/V SEAFDEC with previous authors showed that: A lot of objects living near the coastal areas and at the estuaries were not recorded in this survey cruise, such as families of *Ariidae, Polymenidae, Elopidae, Salangidae,* and genera of *Clupanodon, Setypinna, Coilia, Chanos*, etc. But a lot of the objects living in the off-shore waters, and open sea were recorded in this survey cruise such as families of *Myctophidae, Melanotomatidae, Gonostomatidae, Istiophoridae, Gempylidae*, and some of species belonging to *Exocoetidae*.

Some fishes, which live in the deep sea, haven't been recorded in the list of marine fishes of Vietnam yet, [MoF(1996)], as *Myctophidae, Melanotomatidae*.Tran Dinh (1981) have been recorded 5 genera, 4 species belonging to *Myctophidae*. This number is much less than the present fish species. This is easy to understand, because fish species living in the deep areas have small body and always stay in the deep water layer, therefore some fishing gears can not use to catch them as trawl, gill net, long line, etc. To collect samples of this fishes, the oblique haul in the deep water layer has been used and some families, genera, species, living in the deep sea, have been added in the list of marine fishes of Vietnam by the study on FE-FL.

Comparing on the species composition of this survey cruise with Termvidchakorn's research (1999) and by the same method of sampling in the Western sea waters of Sabah, Sarawak and of Brunei Darussalam, which are opposite the Southern sea waters of Vietnam. This indicated that the structure of composition is relatively similar but it is less than in the number of species composition.

Distribution o f FE-FL.

FE-FL were distributed widely in the study area. General tendency, the density of distribution concentrates in the near the coastal areas and around the islands more abundant than in the offshore water and open sea. For all dominate fishes, the density of distribution of the North and South sea waters normally concentrates higher than of the Central sea waters, except *Myctophidae* and *Exocoetidae* families, density of distribution of both these families concentrate in the Central sea waters more abundant than in the North and South sea waters.

This is suitable with the previous studies in the Western coastal areas of the Tonkin Gulf (1977) and in the Nghia Binh-Minh Hai sea waters (1981) of Do Van Nguyen and the studies in Vietnamese sea waters (1994) of Nguyen Huu Phung. [Fig. 30, 31 and 32].

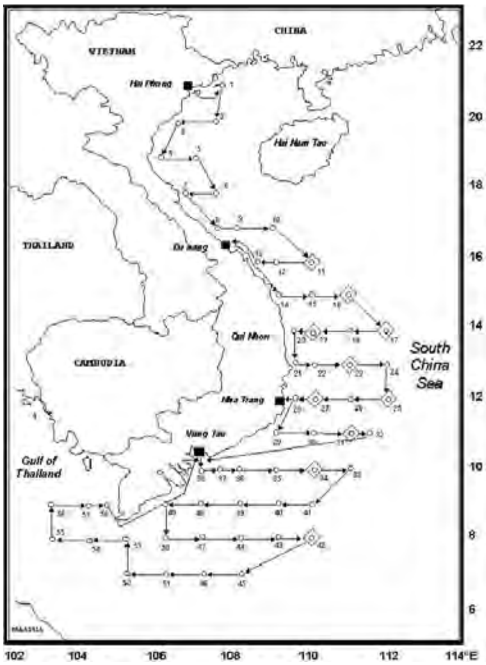

Fig. 1. Location of sampling stations and sub-area.

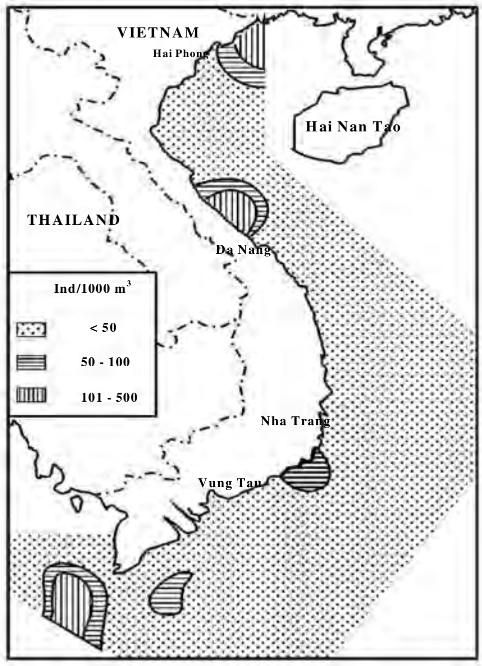

Fig. 2. Abundance and distribution of total fish eggs obtained from the surface haul in Vietnamese waters during April 30 - May 29/1999 by M/V SEAFDEC.

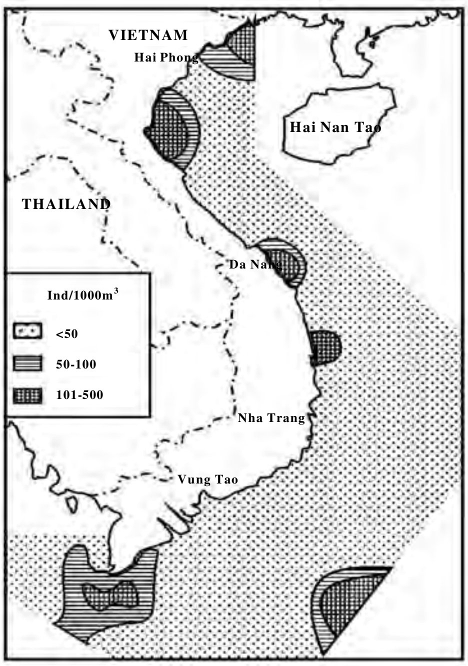

Fig. 3. Abundance and distribution of total fish larvaes obtained from the surface haul in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

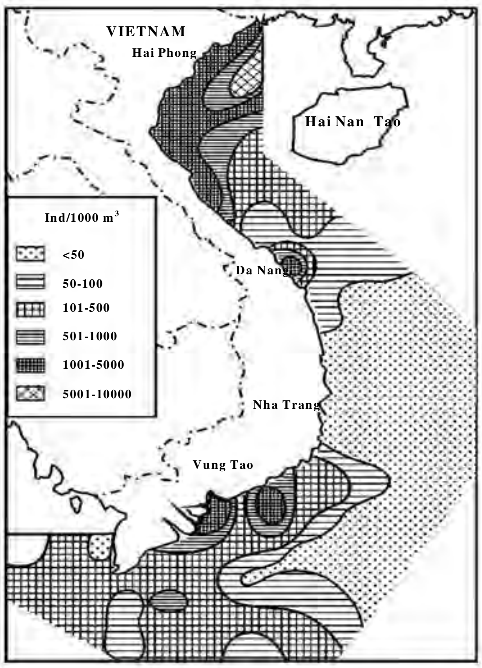

Fig. 4. Abundance and distribution of total fish eggs obtained from the oblique haul in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

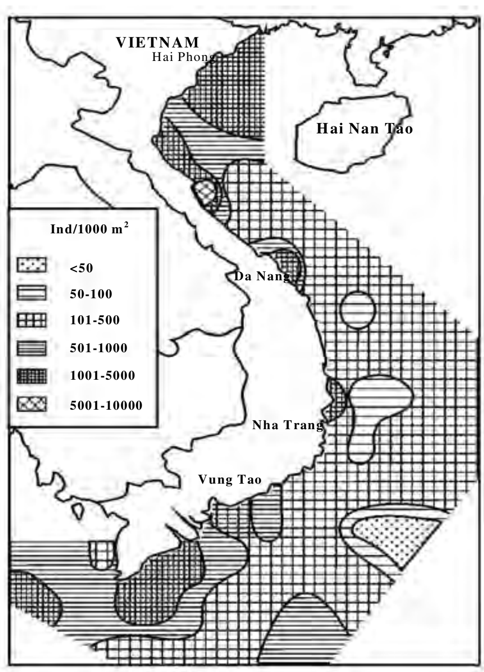

Fig. 5. Abundance and distribution of total fish larvae obtained from the oblique haul in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

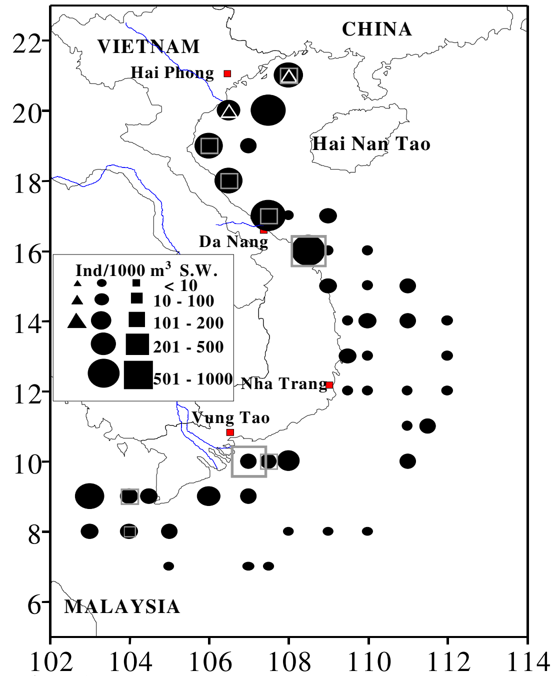

Fig. 6. Abundance and distribution of *Engraulidae* fish eggs and larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

● *Stolephorus* ▲ *S. commersonii*

■ *S. zollengeri*

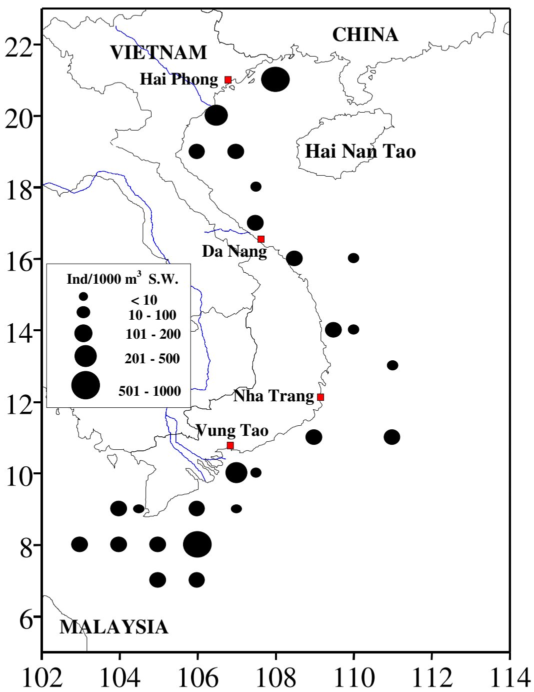

Fig. 7. Abundance and distribution of *Clupeidae* fish eggs and larvae obtained in Vietnam Waters during April 30 - May 29/1999 by M/V SEAFDEC.

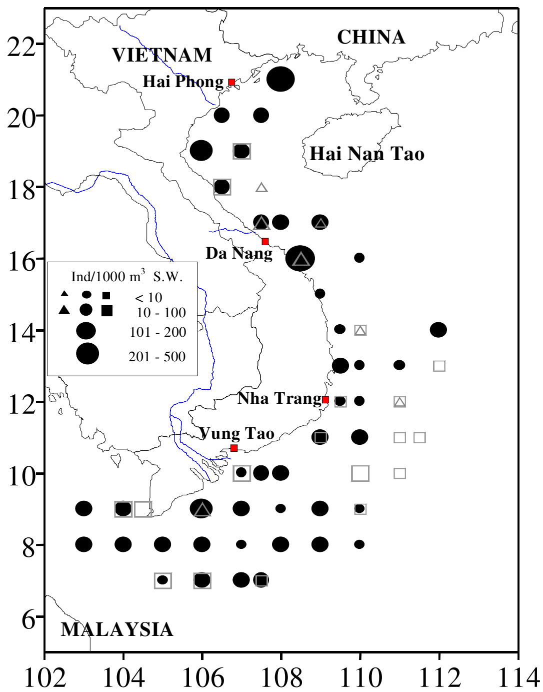

Fig. 8. Abundance and distribution of *Carangidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

● *Carangidae* ▲ *Decapterus*

■ *Selar crumenophthalmus*

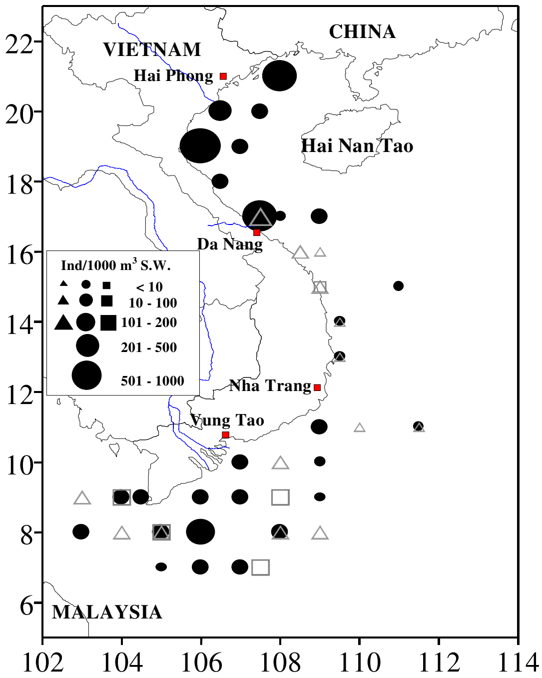

Fig. 9. Abundance and distribution of *Leiognathidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

● *Leiognathus* ▲ *Gazza minutta*

■ *L. elongatus*

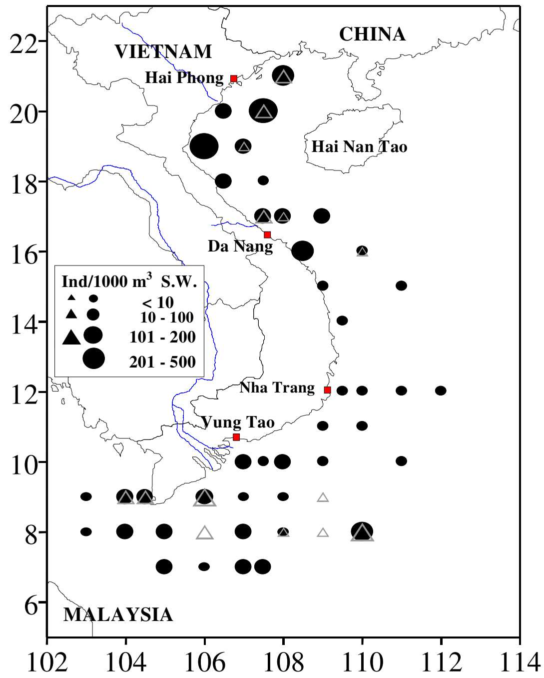

Fig. 10. Abundance and distribution of *Mullidae* fish eggs and larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

● *Mullidae* ▲ *Upeneus bensasi*

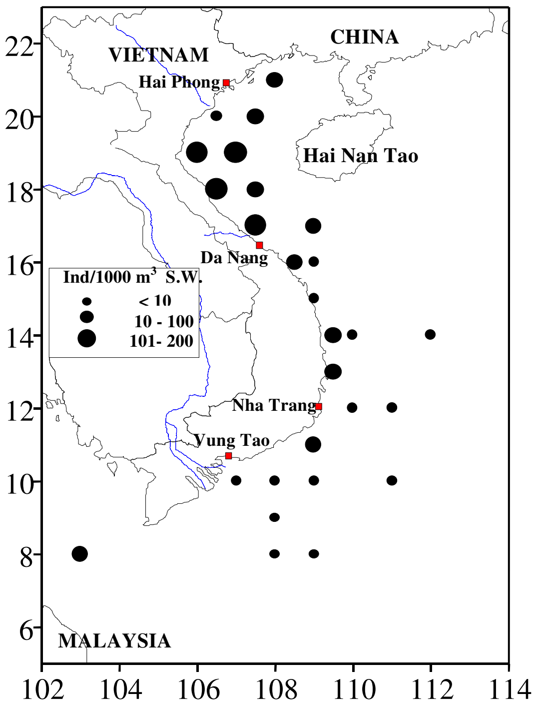

Fig. 11. Abundance and distribution of *Nemipteridae* fish larvae obtained in Vietnamese Waters during April 30-May 29/1999 by M/V SEAFDEC.

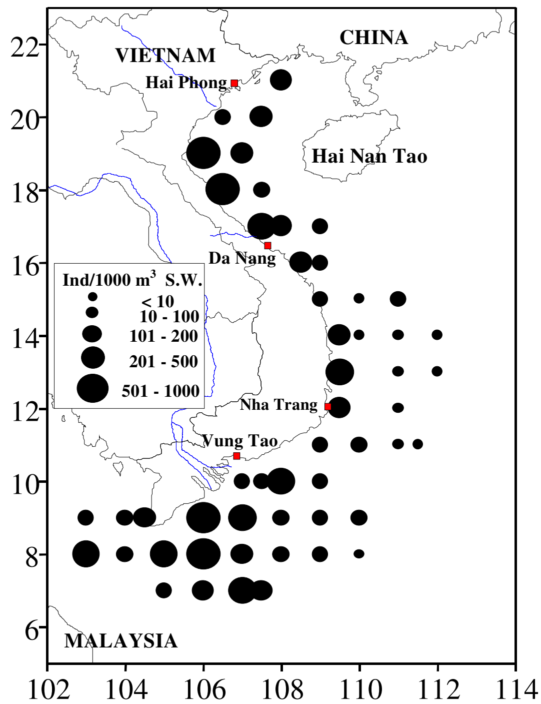

Fig. 12. Abundance and distribution of *Gobiidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

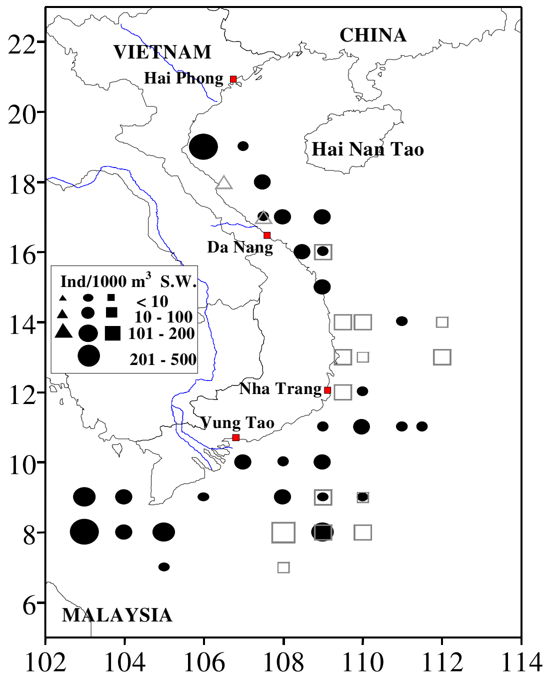

Fig. 13. Abundance and distribution of *Bregmacerostidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999.

● *Bregmaceros macclellandi*
■ *B. atripinnis* ▲ *B. atlanticus*

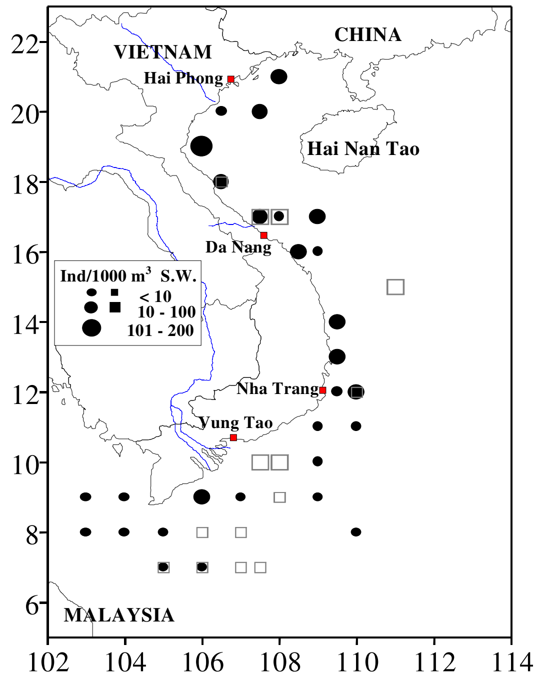

Fig. 14. Abundance and distribution of *Lutianidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999.

● *Lutjanidae* ■ *L. erythropterus*

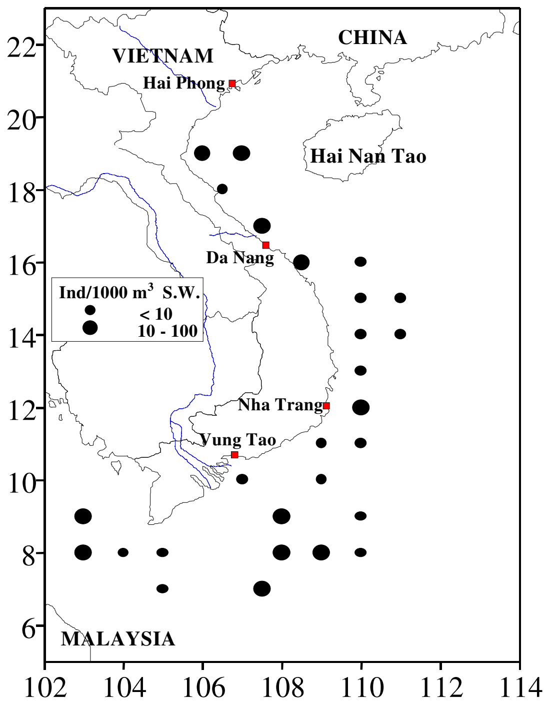

Fig. 15. Abundance and distribution of *Priacanthidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

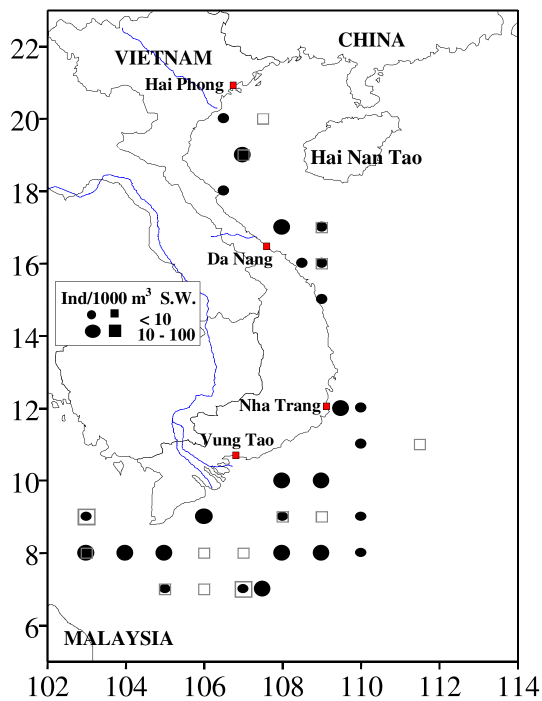

Fig. 16. Abundance and distribution of *Serranidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

● *Seranidae* ■ *Epineplulus taurina*

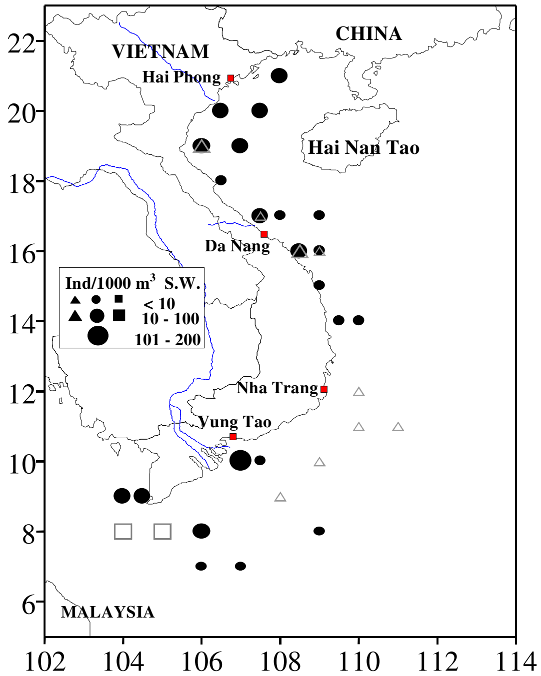

Fig. 17. Abundance and distribution of *Cynoglossidae* fish eggs and larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.
● *Cynoglossidae* ▲ *S. orientalis*
■ *Arelia bilibeata*

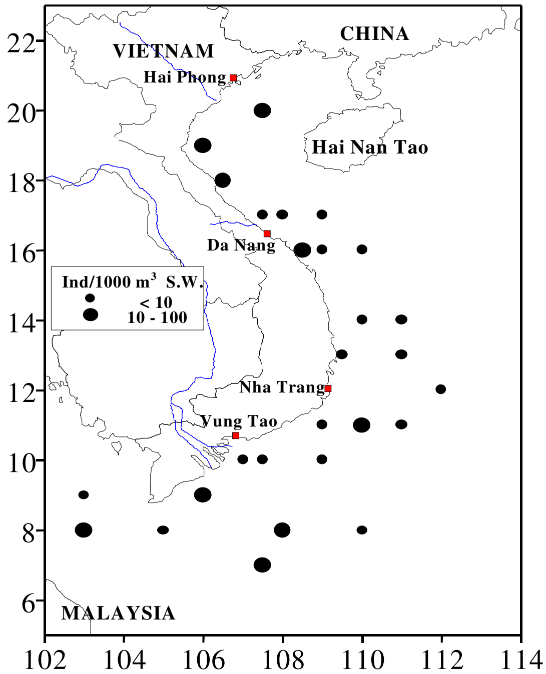

Fig. 18. Abundance and distribution of *Sphyaenidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

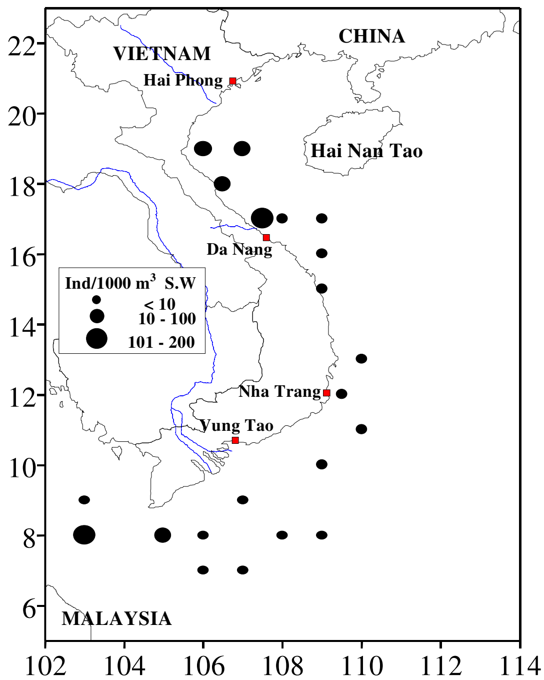

Fig. 19. Abundance and distribution of *Trichiuridae* fish eggs and larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC

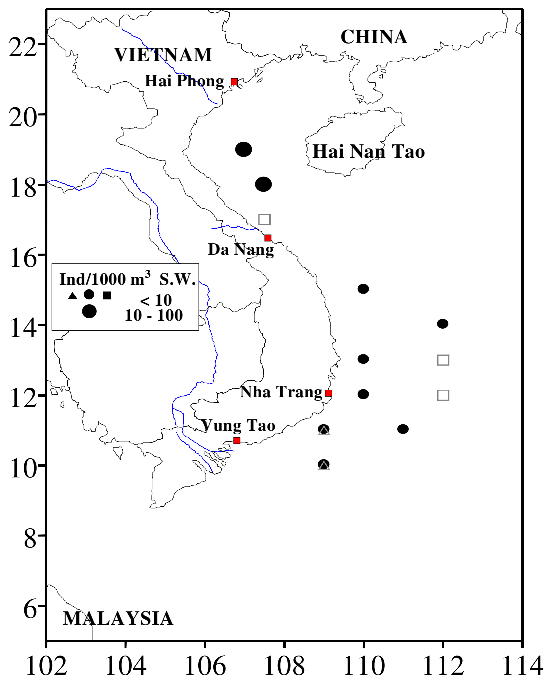

Fig. 20. Abundance and distribution of *Gempylidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.
● *Gempylidae* ▲ *L. flavobrumneum*
■ *Promethichthys prometheus*

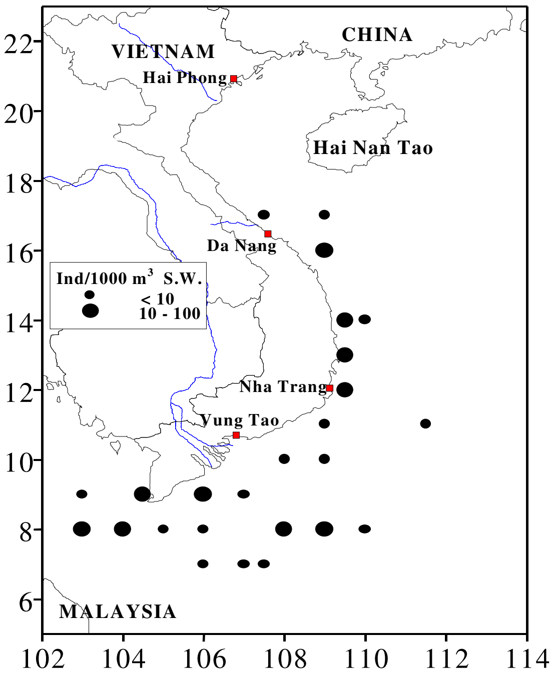

Fig. 21. Abundance and distribution of *Apogonidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

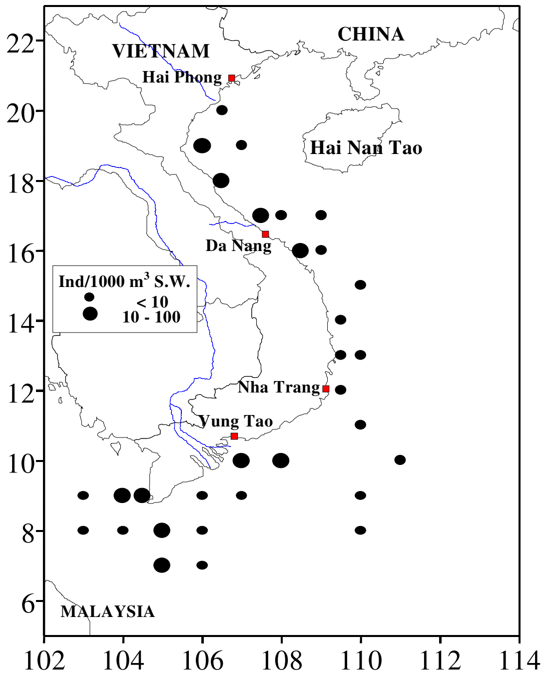

Fig. 22. Abundance and distribution of *Callionymidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

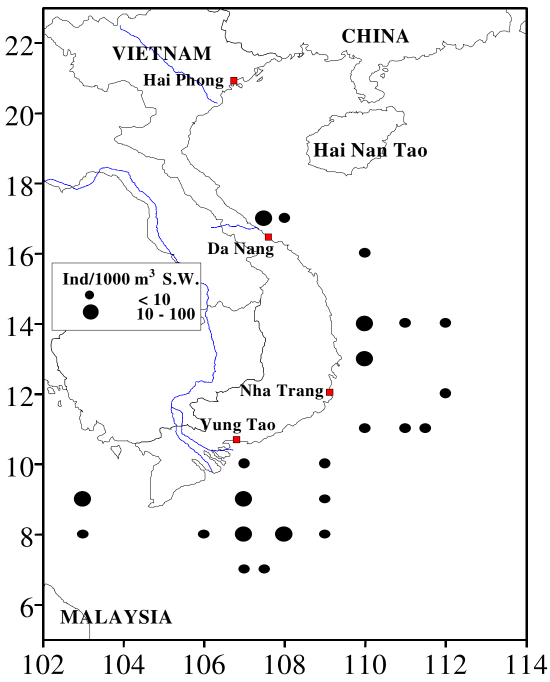

Fig. 23. Abundance and distribution of *Labridae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

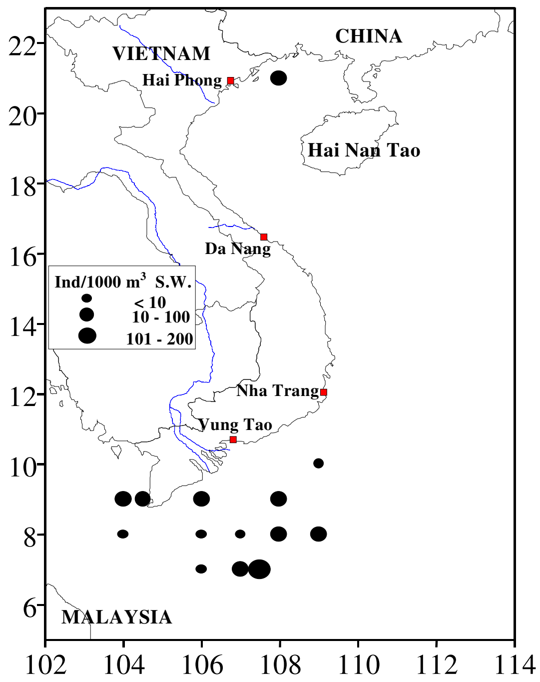

Fig. 24. Abundance and distribution of *Monacanthidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

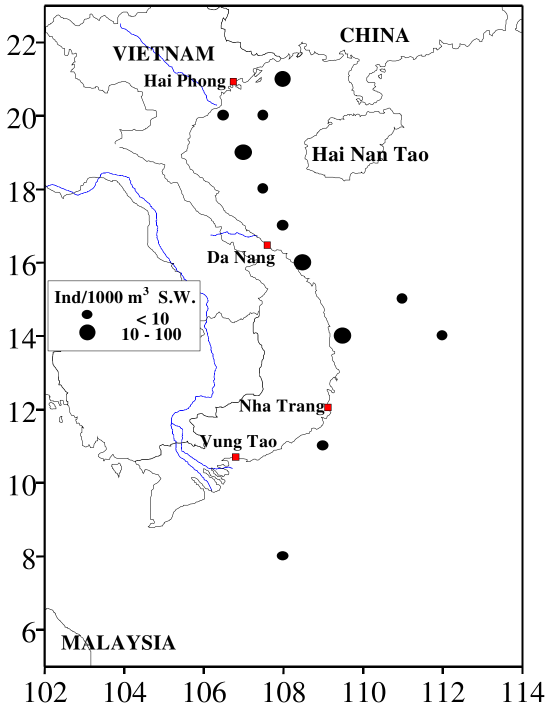

Fig. 25. Abundance and distribution of *Pomadasyidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

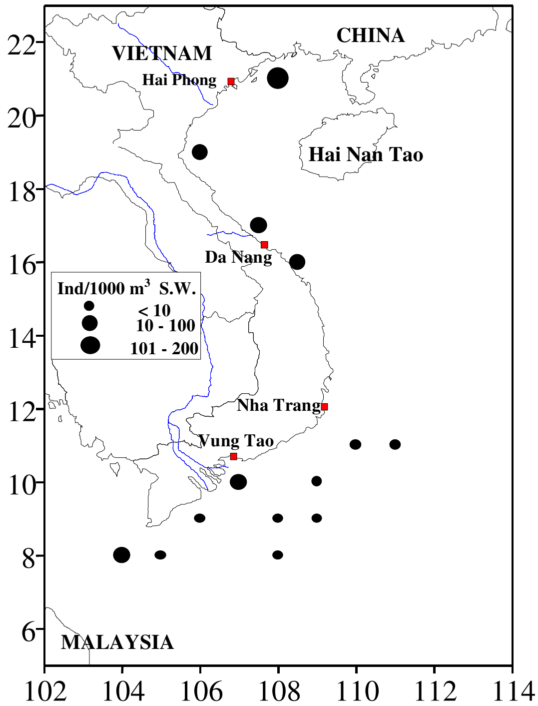

Fig. 26. Abundance and distribution of *Sciaenidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

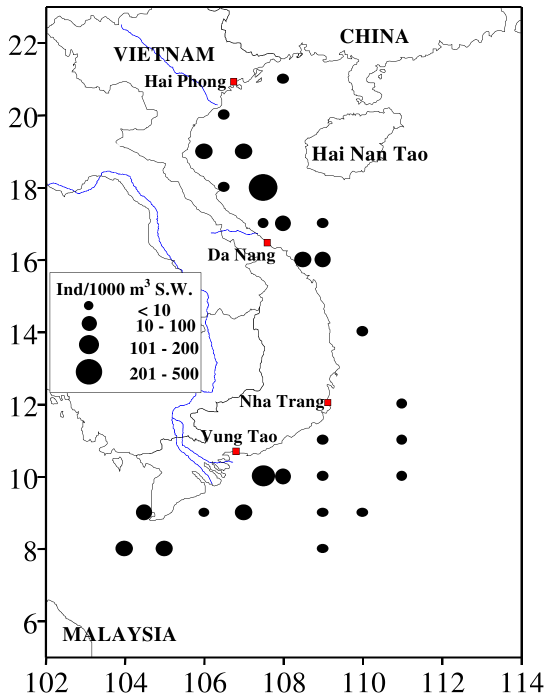

Fig. 27. Abundance and distribution of *Scorpanidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

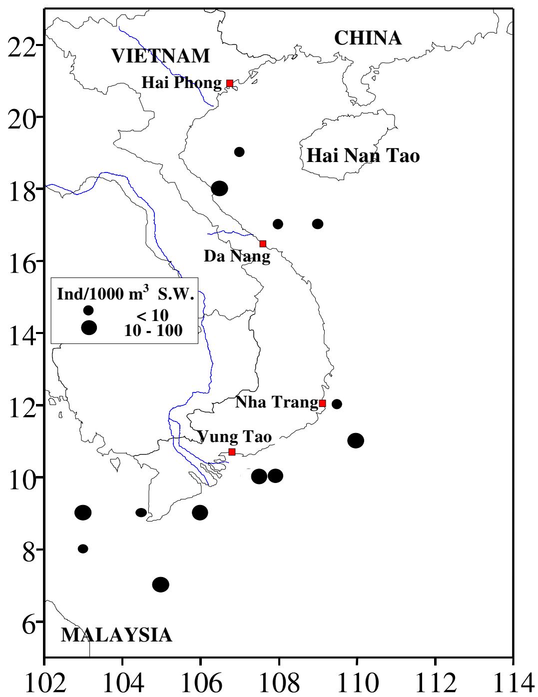

Fig. 28. Abundance and distribution of *Teraponidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

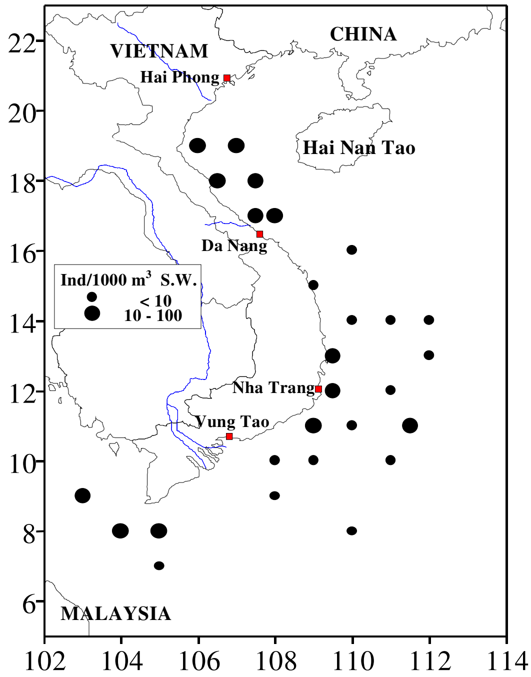

Fig. 29. Abundance and distribution of *Tetrodonidae* fish larvae obtained in Vietnamese Waters during April 30 - May 29/1999 by M/V SEAFDEC.

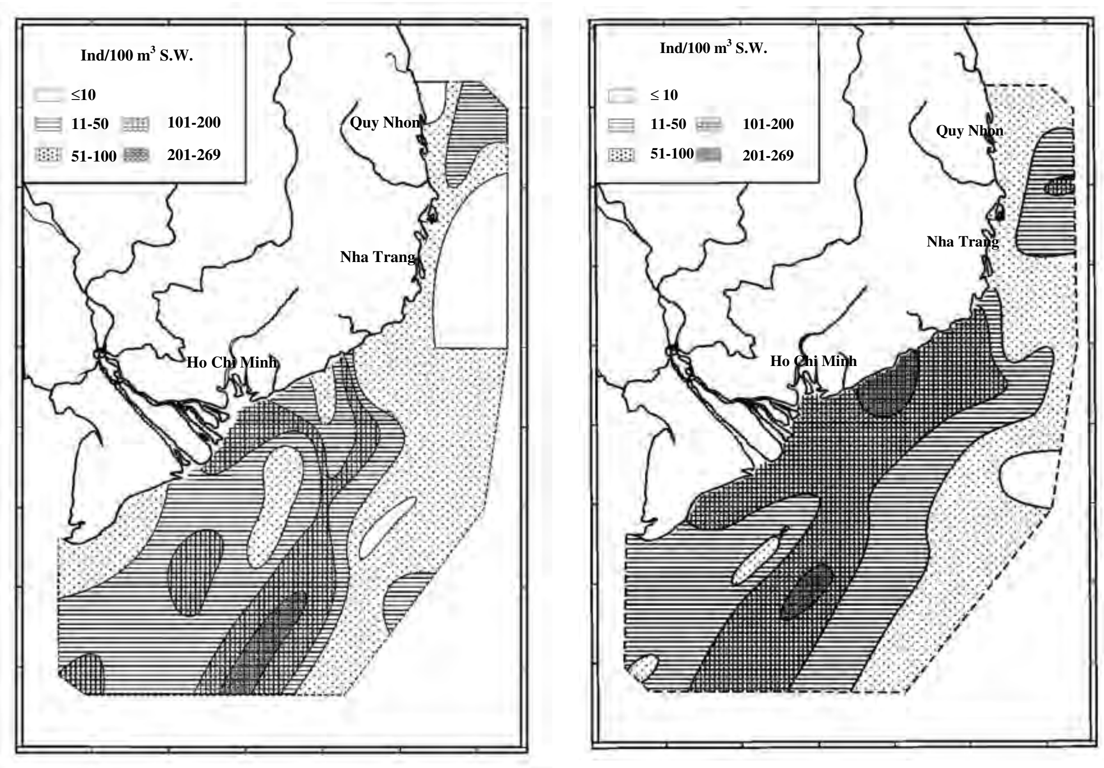

Fig. 30. Abundance and distribution of total fish eggs (a) and larvae (b) obtained during May 1979 in the area from Nghia Binh to Minh Hai provinces (by Do Van Nguyen 1977)

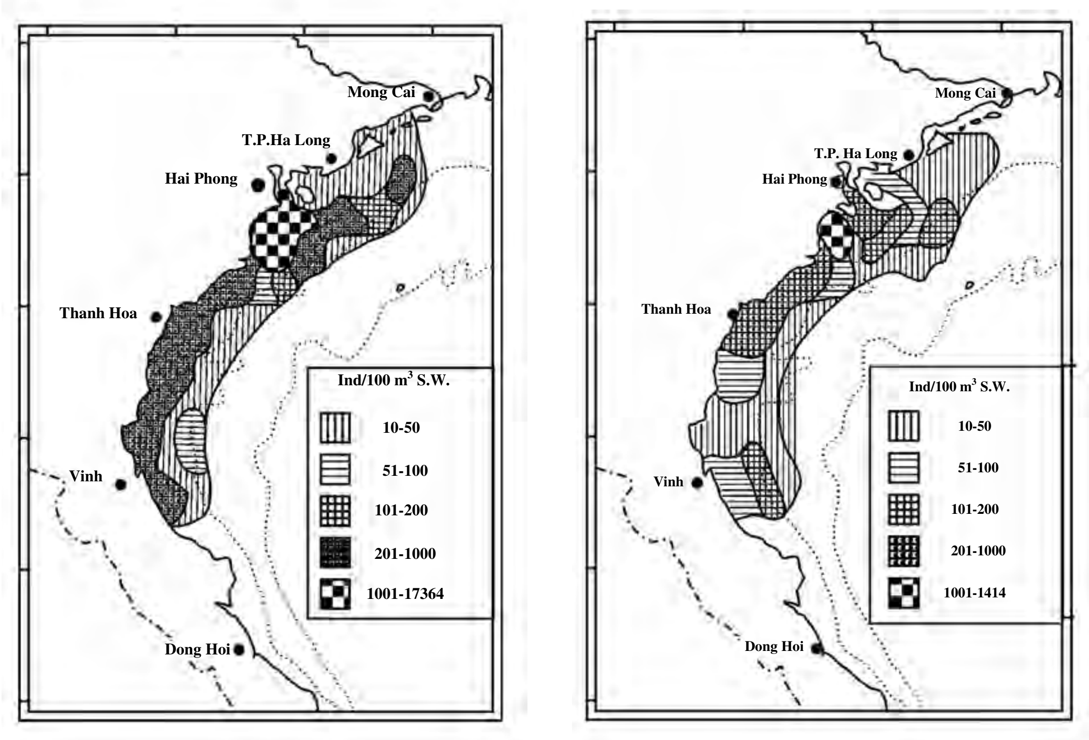

Fig. 31. Abundance and distribution of total fish eggs (a) and larvae (b) obtained during May/1976 in the coastal area from Mong Cai to Cua Sot (by Do Van Nguyen 1977).

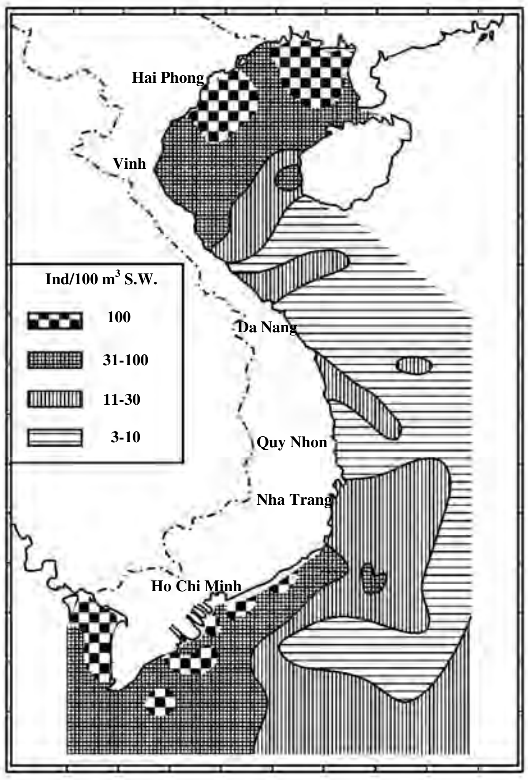

Fig. 32. Mean abundance and distribution of total larvae obtained during 1994 in the Vietnamese Waters (Nguyen Huu Phung 1994).

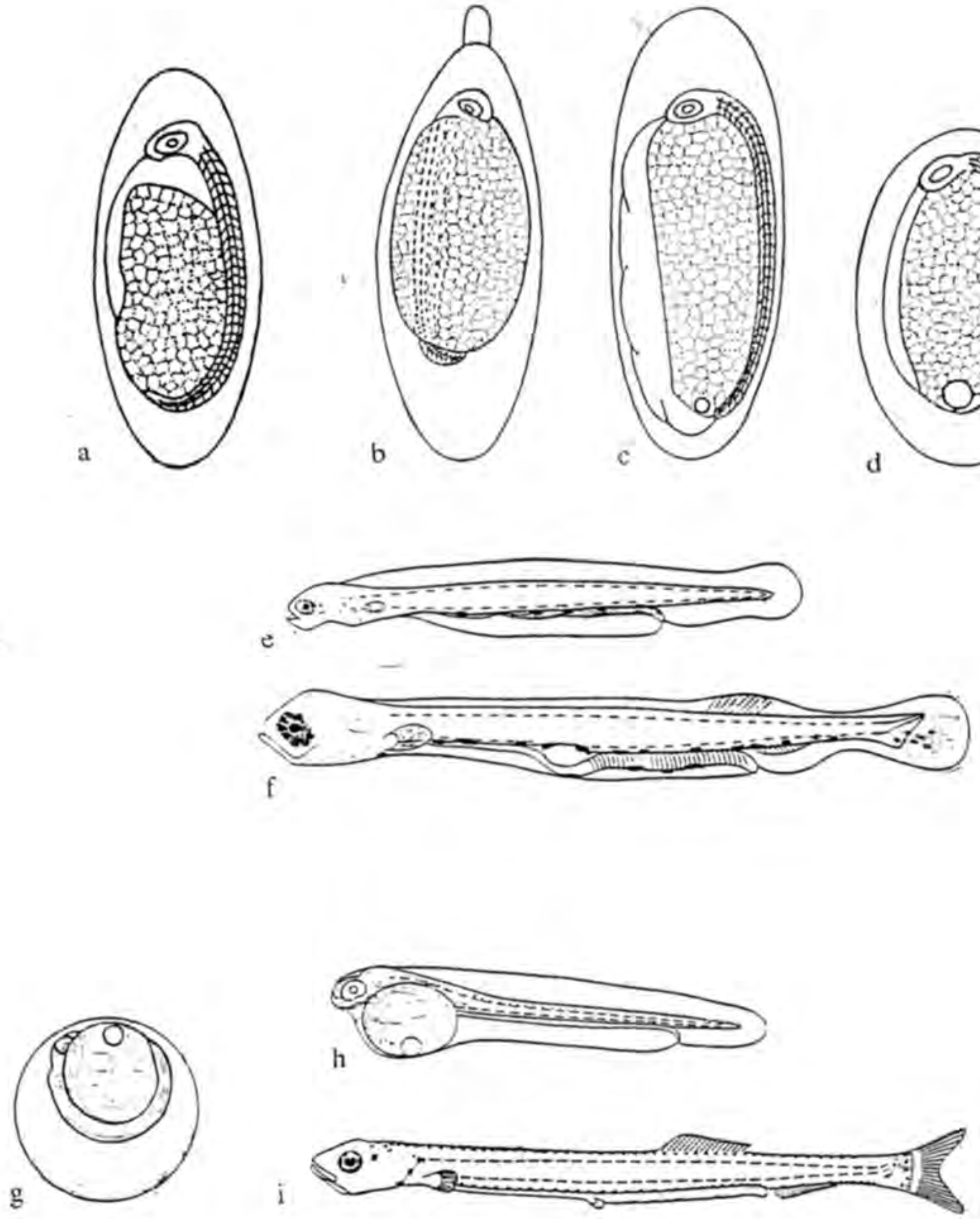

Fig. 33. The fish eggs and larvae of Engraulidae and Clupeidae

a. Egg of *Stolephorus zollengeri* (Blecker)(1.32-0.58 mm).

b. Egg of *S. commersonii* (Lac.)(1.62x0.66 mm)

c. Egg of *S. heterolobus* (Ruppell)(1.58x0.60 mm)

d. Egg of *Stolephorus sp.* (By N.H. Phung)(1.14-0.68 mm)

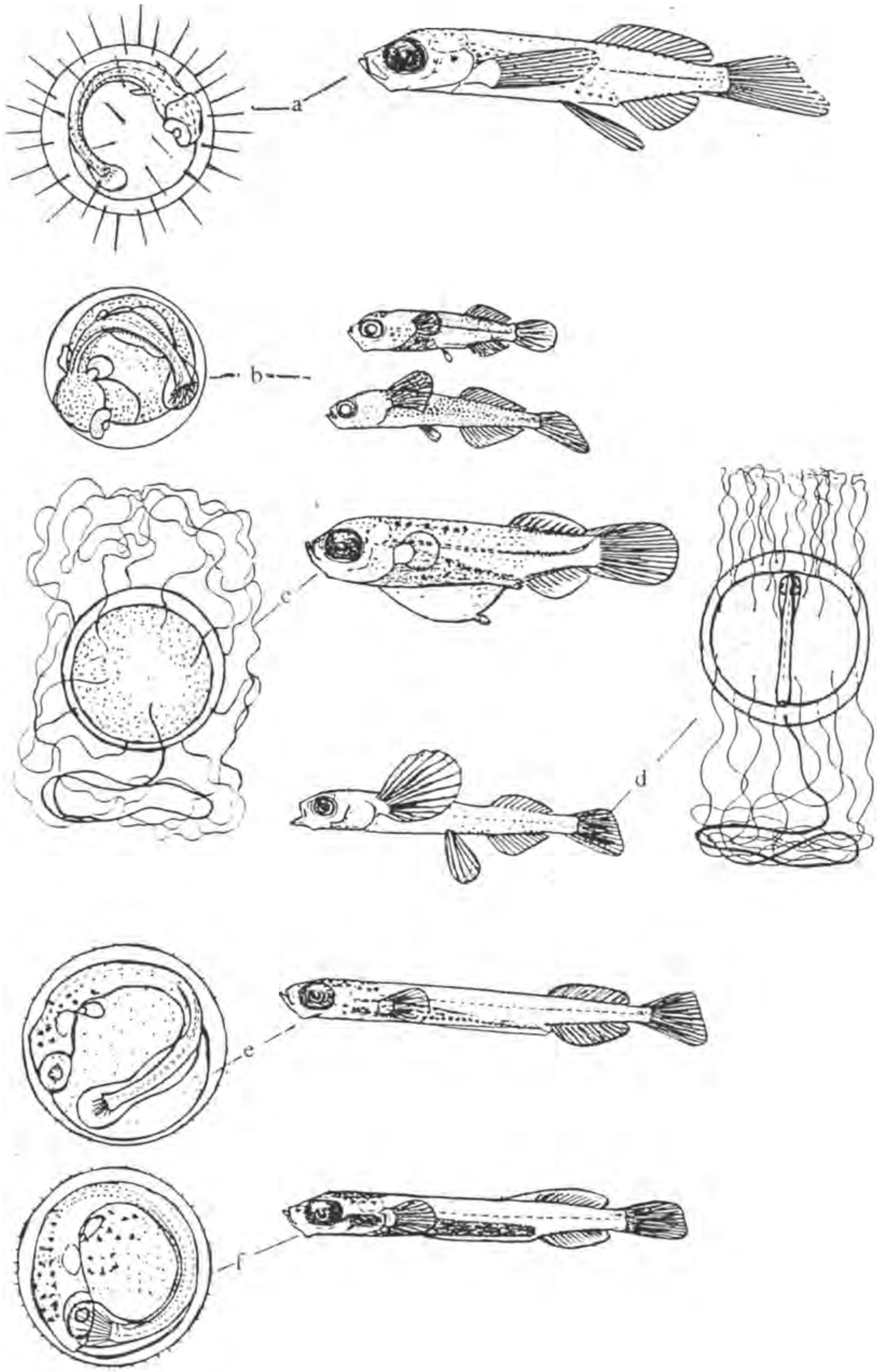

Fig. 34. The fish eggs and larvae of Exocoetidae.
a. *Cheilopogon katoptron*; b. *Exocoetus volitan*; c. *Parexocoetus mento*;
d. *Hyrundichthys oxycephalus*; e. *Oxyporhamphus meristocystis*; f. *O. micropterus*.

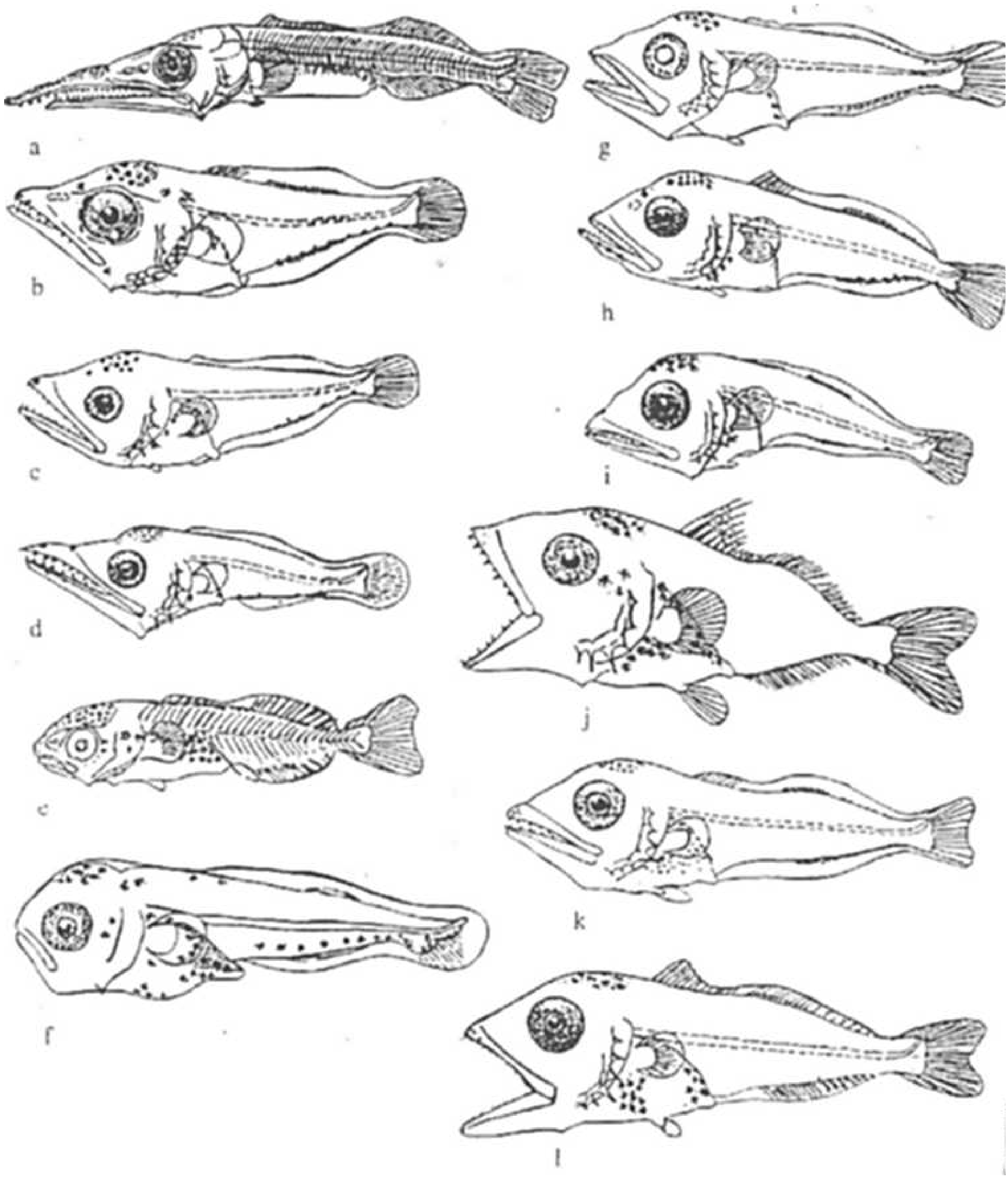

Fig. 35. Some fish larvae of Scombridae.
a. *A. solandri* (7.5 mm); b. *S. guttatus* (5.8 mm); c. *S. commersonii* (5.5 mm); d. *S. Orientalis* (5.5 mm); e. *S. japonicus* (5.4 mm); f. *R. kanagurta* (6.3 mm); g. *A. thazard* (5.7 mm); h. *E. affinis* (6.1 mm); i. *K. pelamis* (5.3 mm); j. *T. albacares* (7.0 mm); k. *T. obesus* (6.1 mm); l. *T. tongol* (7.2 mm)

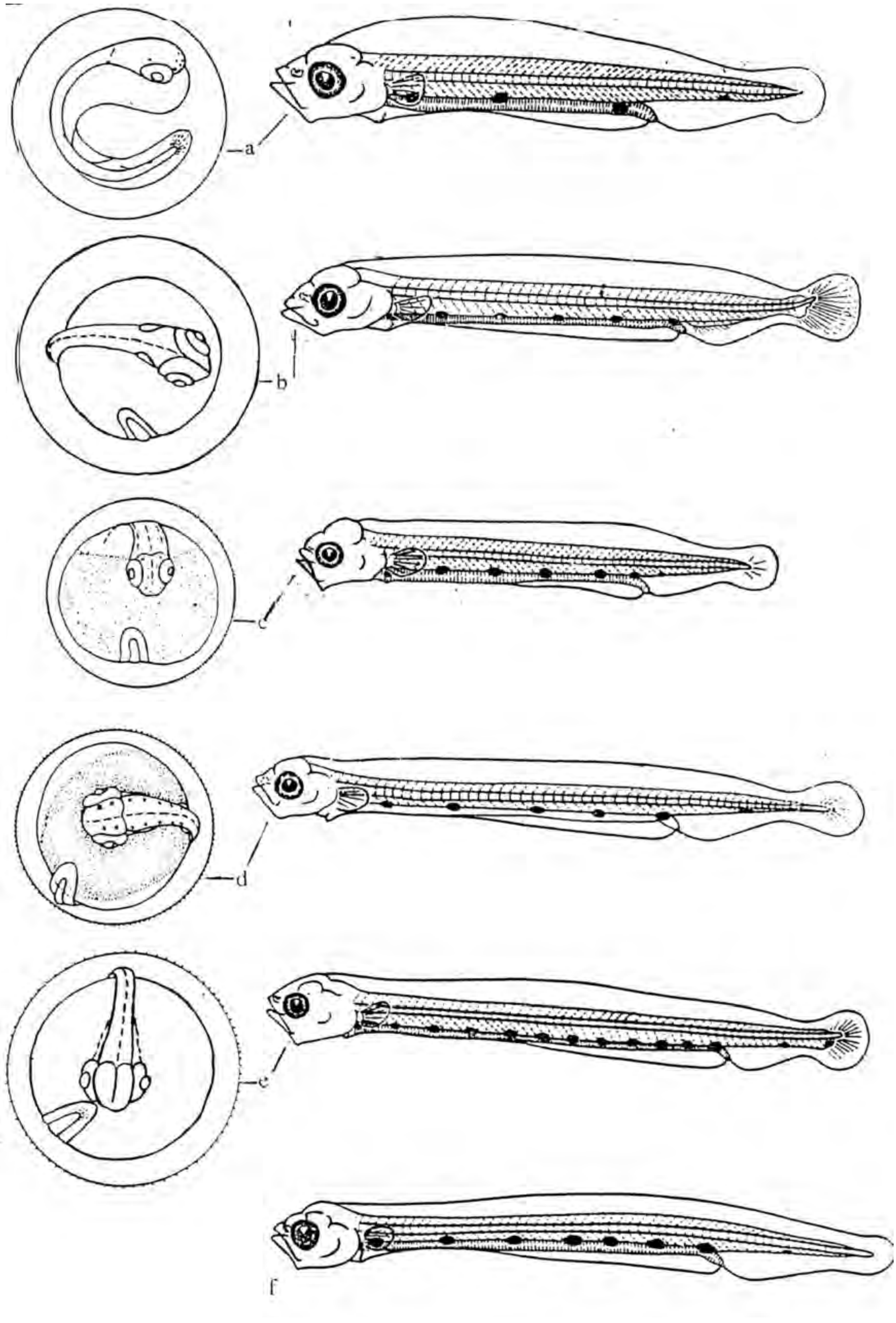

Fig. 36. The fish eggs and larvae of Synodontidae.
a. *Saurida elongata* b. *S. undosquamis*; c. *S. tumbil*; d. *Trachinocephalus myops*; e. *Synodus variegatus*; f. *S. hoshinosis*

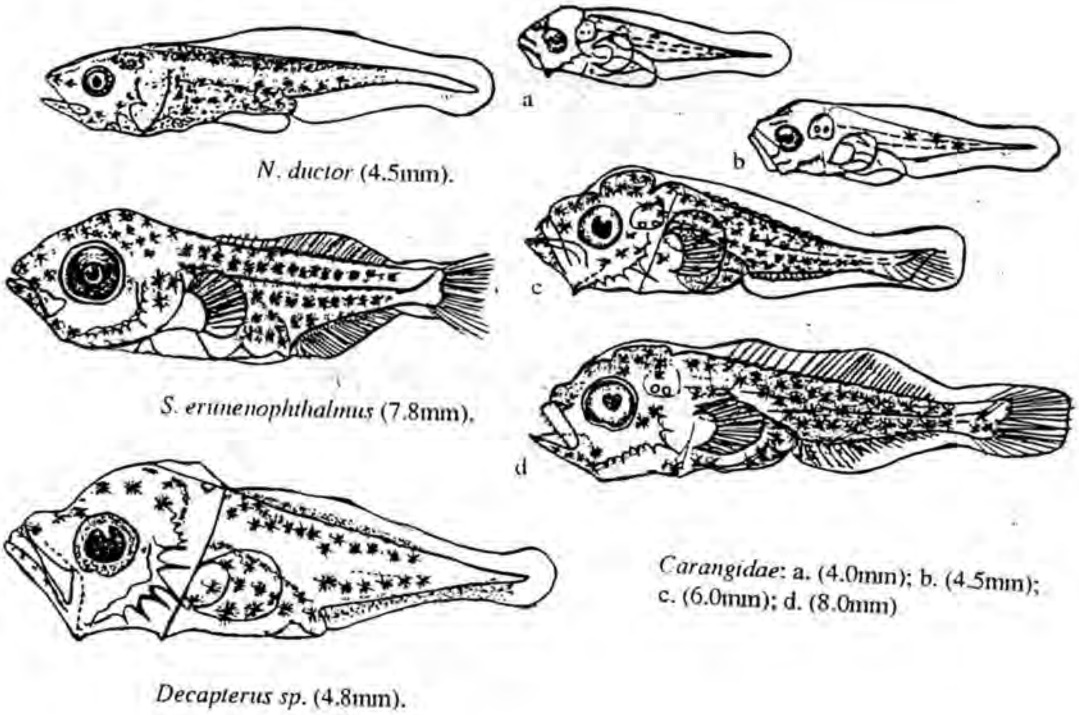

Fig. 37. Some fish larvae of Carangidae.

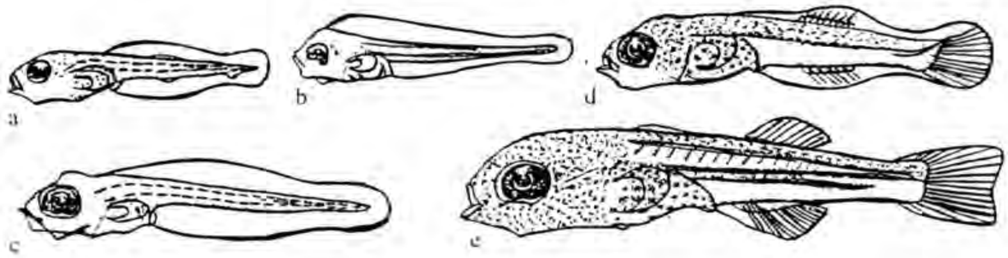

Fig. 38. Some fish larvae of Mullidae.
a. (3.2 mm); b. (3.5 mm); c. 4.0 mm); d. (6.1 mm); e. (10.2 mm)

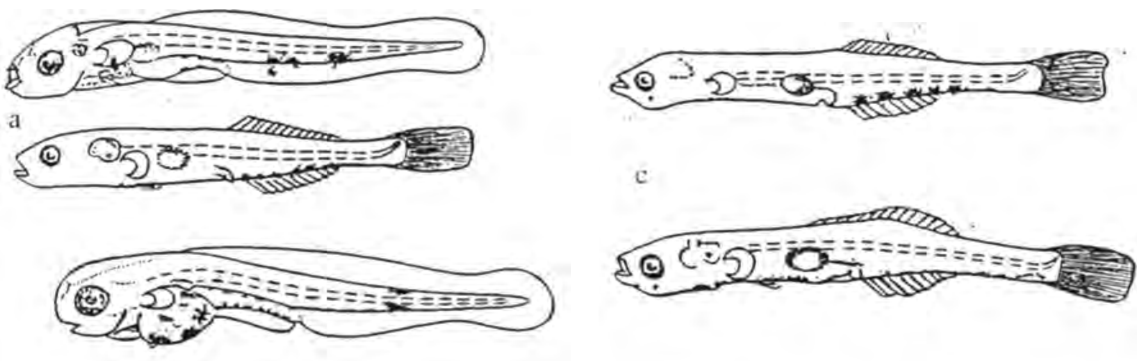

Fig. 39. Some fish larvae of Gobiidae.a. (3.3 mm); b. (5.3 mm); c. (8.0 mm)

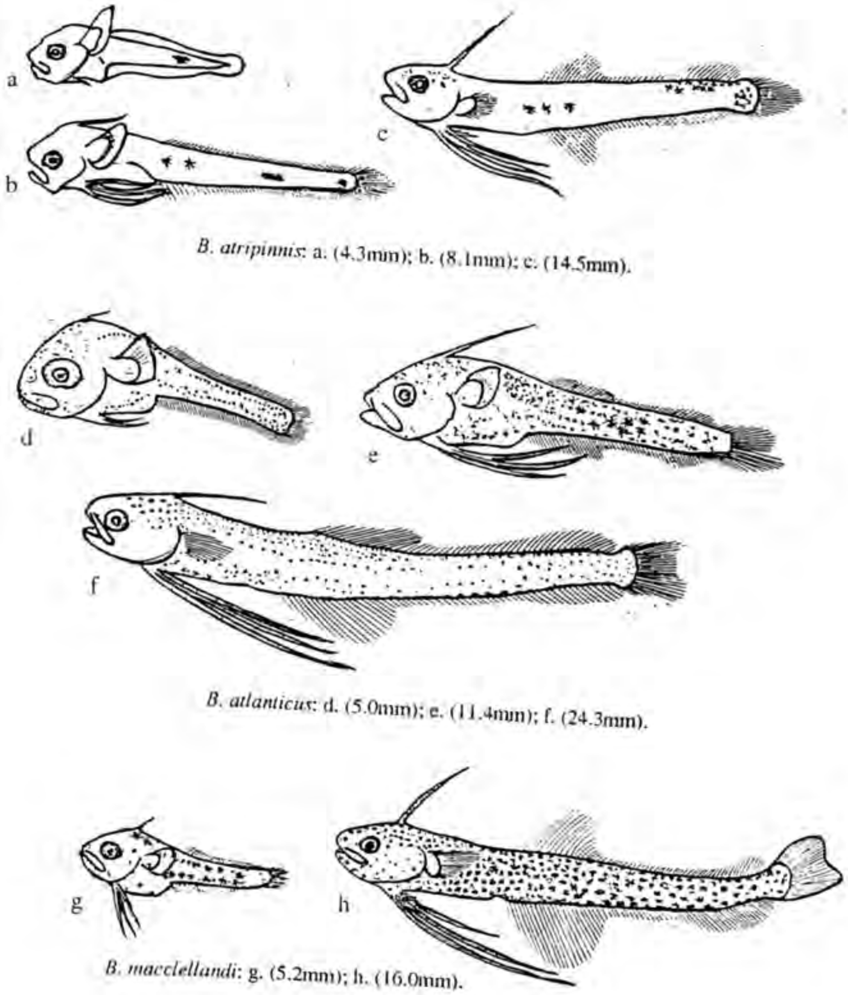

Fig. 40. Some fish larvae of Bregmacerostidae.

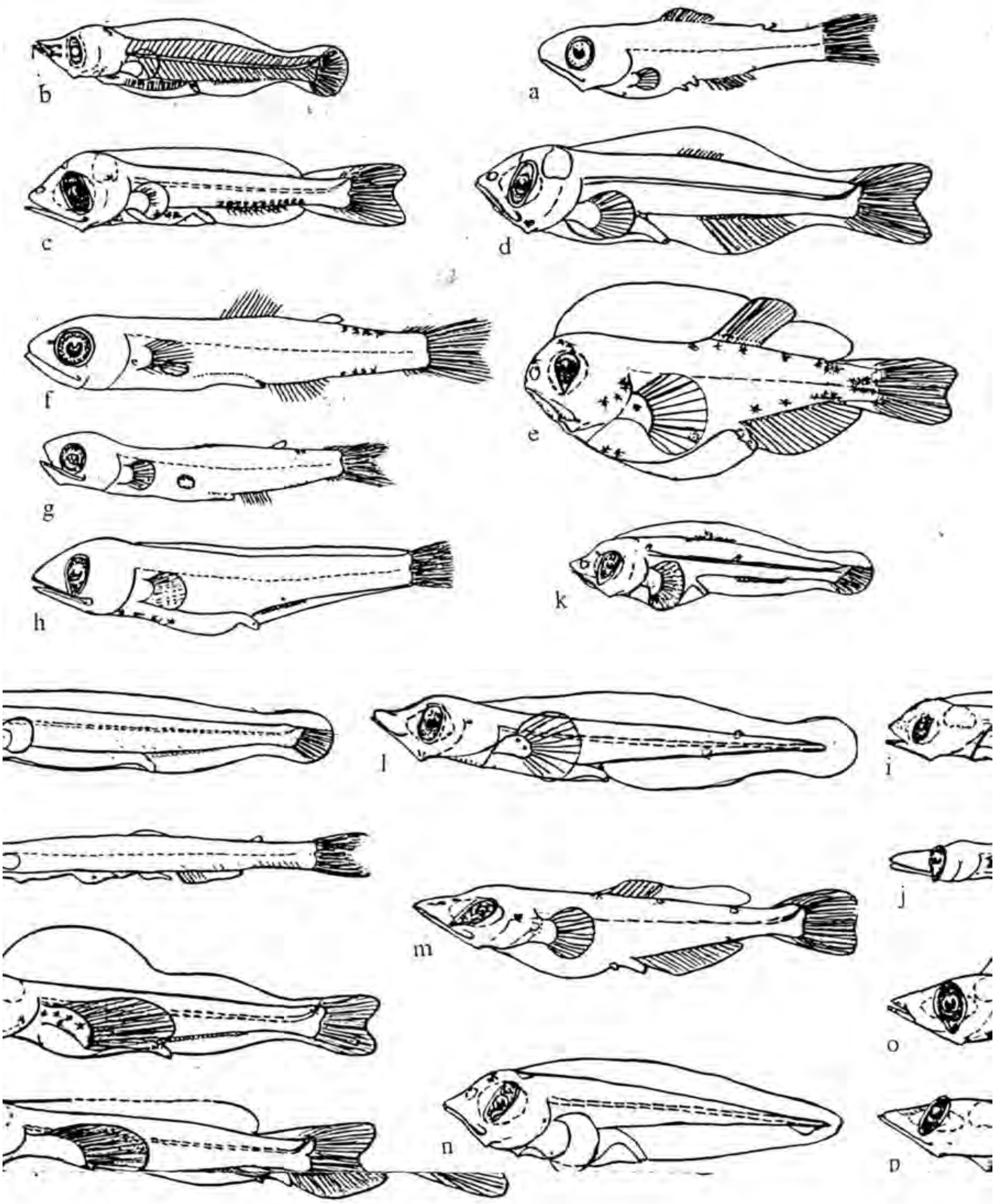

Fig. 41. Some fish larvae of Myctophydae.

a. *D. mollis* (5.1 mm); b. *D. atlanticus* (4.8 mm); c. *D. parnugus* (5.7 mm); d. *B. surbobitale* (6.8 mm); e. *C. andreae* (6.3 mm); f. *C. maderensis* (6.8 mm); g. *C. warmingi* (5.2 mm); h. *H. hygoni* (6.2 mm); i. *H. proximum* (6.5 mm); j. *S. reinhardti* (6.3 mm); k. *M. asperum* (7.3 mm); l. *M. nitidulum* (7.3 mm); m. *M. spinosum* (6.3 mm); n. *M. pristilepis* (5.7 mm); o. *S. boops* (7.3 mm); p. S. evermanni (7.5 mm).

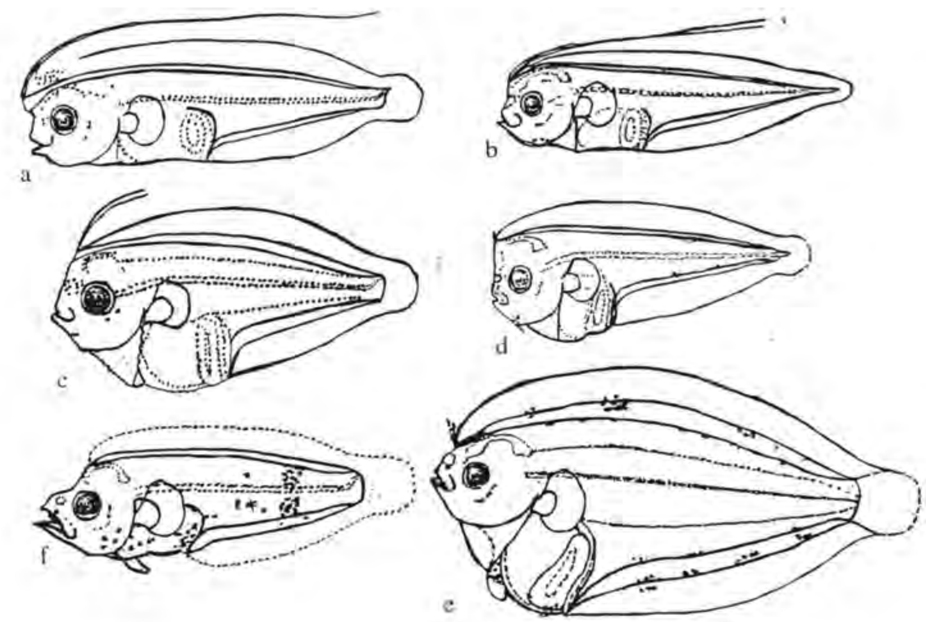

Fig. 42. Some fish larvae of Bothidae.
a. *A. elongatus* (8.3 mm); b. *Aronglossus sp*. (5.3 mm); c. *C. azureus* (6.9 mm);
d. *P. iijimai* (5.0 mm); e. *P. hananensis* (7.8 mm); f. *Psuedorhambus sp*. (8.2 mm).

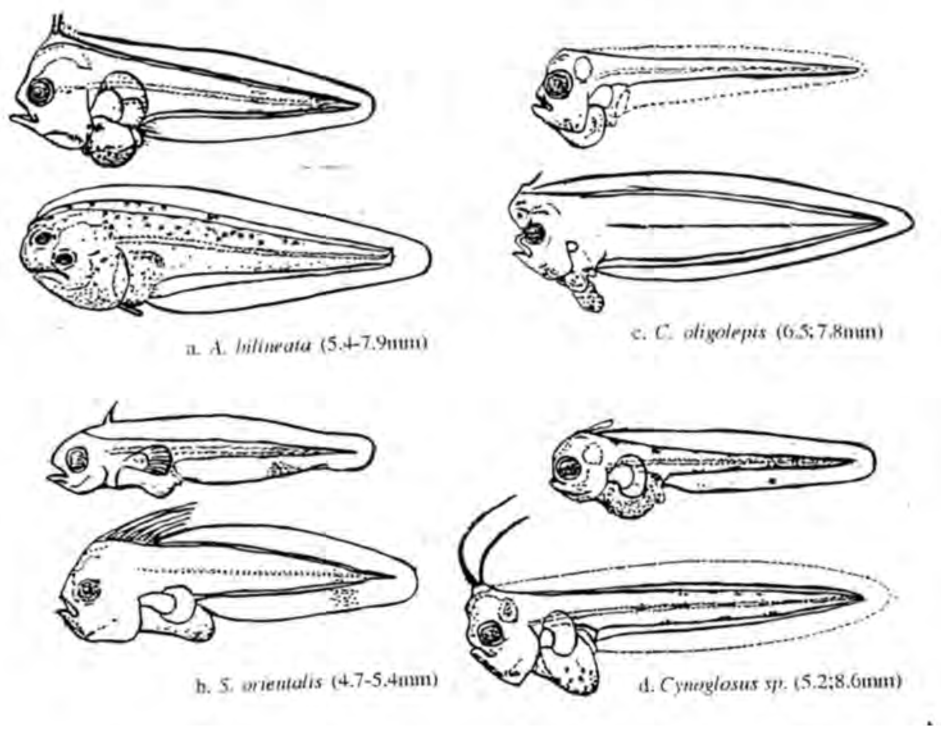

Fig. 43. Some fish larvae of Cynoglossidae.

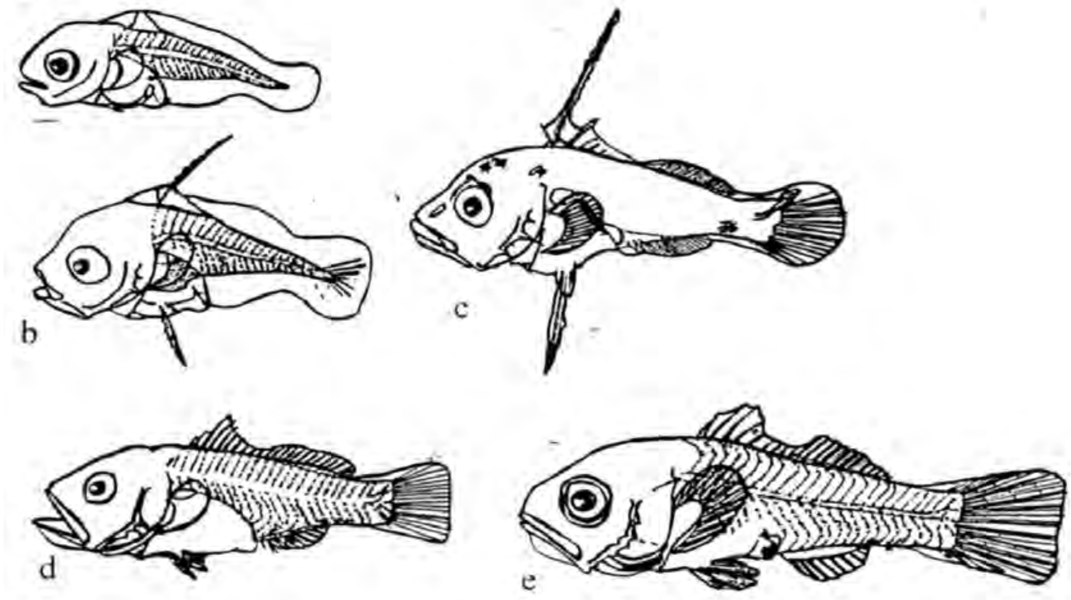

Fig. 44. Some fish larvae of Serranidae.
a. Epinephelus tauvina (2.2 mm); b. (2.6 mm); c. (4.2 mm);
d. Serranidae (4.3 mm); e. (5.6 mm).

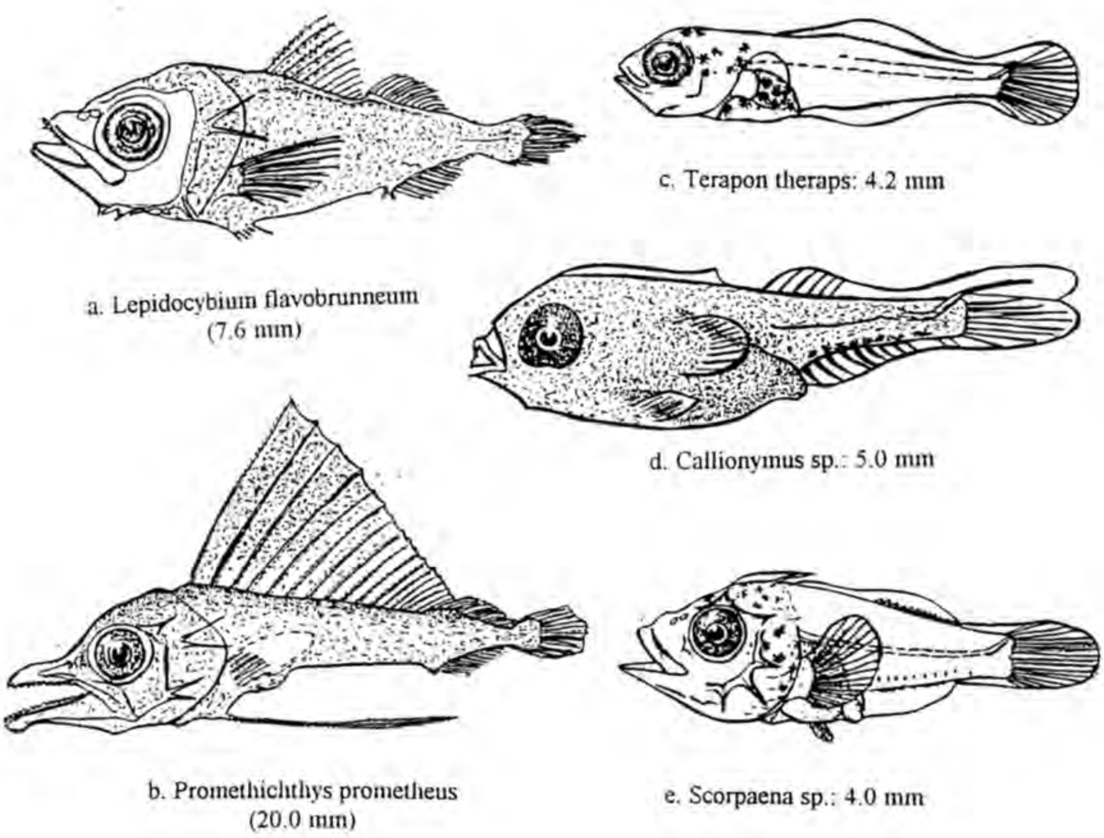

Fig. 45. The larvae of some fish families.
Gemylidae; Teraponidae; Callionymidae; Scorpaenidae.

Conclusions

At first, 78 families, 90 genera and 94 species of FE-FL have been identified, family *Engraulidae* occupied the highest number of all, 85% of total FE and 23.8% of total FL.

During survey species composition which occurred to spawn was very abundant. At each study station, at least 6 families and highest 30 families occurred.

The most abundant fish species, which spawned during survey, was pelagic fishes, obtained 39.37% of total FL.

The density of concentration of FE-FL along the coastal area and around the islands were abundant more than the offshore water and deeper water or open sea.

Comparing between FE and FL, the density and distribution of FE usually concentrated more abundant than of FL.

The density of distribution of FE-FL in the Northern adjacent area is the most abundant of all, follows to the Southern adjacent areas, the Central adjacent area is the least abundant.

Acknowledgements

This research successes by the cooperation of many organizations and people.

I would like to thank Dr. Prof. Bui Dinh Chung for his encouragement, valuable suggestions and reading, correcting the manuscript.

I would like to thank the Secretary General of the Southeast Asian Fisheries Development Center (SEAFDEC) for given the research subject and financial support, allowing me to carry out the research.

I would also like to thank Mrs. Le Kim Oanh for supplying information and materials concerning with the project.

I am also grateful to Dr. Chu Tien Vinh and all staffs of the Research Department of Marine Resources, under the Research Institute of Marine Products (RIMP), who have supported and assisted in these work.

Sincere appreciation is expressed to Captain, crews and scientists on the M.V SEAFDEC for their cooperation at sea.

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Appendix. Geographycal position of some islands, estuaries, and provinces (in order from North to South).

Order	Name	Lattude (N)	Longtude(E)
1	Mong Cai (Quang Ninh)	$21^0 32'$	$107^0 58'$
2	Co To islands	$20^0 58'$	$107^0 45'$
3	Long Chau islands	$20^0 37'$	$107^0 08'$
4	Ba Lat mouth	$20^0 17'$	$106^0 32'$
5	Bach Long Vi island	$20^0 08'$	$107^0 43'$
6	Me island	$19^0 24'$	$105^0 55'$
7	Mat island	$18^0 49'$	$105^0 57'$
8	Cua Sot mouth	$18^0 27'$	$105^0 56'$
9	Con Co island	$17^0 10'$	$107^0 22'$
10	Thuan An mouth	$16^0 33'$	$107^0 38'$
11	Da Nang city	$16^0 03'$	$108^0 11'$
12	Cu Lao Cham island	$15^0 57'$	$108^0 30'$
13	Hoi An mouth	$15^0 54'$	$108^0 22'$
14	Quy Nhon (Nghia Binh)	$13^0 46'$	$109^0 10'$
15	Nha Trang city	$12^0 15'$	$109^0 08'$
16	Phu Quy island	$10^0 34'$	$108^0 51'$
17	Vung Tao city	$10^0 22'$	$107^0 05'$
18	Cua Dai mouth	$10^0 11'$	$106^0 48'$
19	Dinh An mouth	$9^0 33'$	$106^0 17'$
20	Tho Chu island	$9^0 16'$	$103^0 25'$
21	Con Son island	$8^0 46'$	$106^0 41'$
22	Ca Mau (Minh Hai)	$8^0 36'$	$104^0 12'$

Study on Biology of Tuna in the South China Sea, Area IV; Vietnamese Waters

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ABSTRACT

Tuna and tuna-like species are recognized as the most promising target species in off-shore waters of Vietnam. The first studies on biology of tuna were conducted in 1960. To ensure the sustainable exploitation of tuna resources in off-shore waters , studies on biology of tuna are being carried out by the Research Institute of Marine Products.

Materials on biology of tuna were collected on board of research and commercial vessels. Fishing gears were drift gillnets with different mesh-size and longline.

The results of study showed that tuna and tuna-like species are distributed widely in both neritic and oceanic waters of Vietnam. The percentage of Skipjack tuna caught by gillnet in total catch was highest (25.3 %) then followed by Frigate mackerel (8.9) and Bullet tuna (3.4). Yellowfin and Bigeye tunas were dominant in catch by longline.

Biological characteristics of four species of tuna like length frequency distribution, reproduction, feeding, growth and recruitment, mortality rate were described.

The author proposed that the further studies on tuna would be conducted in collaboration among countries bordering the South China Sea.

Key words: Tuna, gillnet, longline, off-shore

Introduction

The appropriate assessment and management of sustainable fisheries requires an understanding of the biological features and distribution of the species on which it is based.

Currently, due to overexploitation of the fisheries resources in coastal waters, problem of management of sustainable coastal fisheries and development of off-shore fisheries became urgent for fisheries sector of Vietnam.

Although the pelagic capture fisheries plays an important role in the development of off-shore fisheries and among pelagic species tuna and tuna-like species were recognized as the most important species in off-shore waters of Vietnam, little studies on their distribution and biology have been conducted.

The first studies on tuna in Vietnam were carried out jointly between Soviet Union and Vietnam in 1960-1961 on board of R/V ONDA and R/V ORLIK which were equipped with purse seine, drift gillnet and long-line. The study scope was mainly in the Tonkin Gulf and partly in the southern parts of the BIEN DONG (the South China Sea).

Some results of studies on distribution and biological characteristics of tuna in coastal waters of Vietnam were reported by [Drudzinhin (1964)], [Bui Dinh Chung (1965),[Tran Don and Nguyen Kiem Son (1978)],[Nguyen Phi Dinh et al. (1971, 1972)], [Chu Tien Vinh and Tran Dinh (1995)], [Vu Huy Thu at al. (1994)] ,[Bui Dinh Chung , Chu Tien Vinh and Nguyen Phi Dinh (1995)], [Nguyen Phi Dinh at al. (1996)].

Tuna species are presently being exploited by Vietnam and other countries in the South East Asian region both in coastal and offshore waters, forming the backbone of their respective pelagic fisheries.

To ensure the sustainable exploitation of these resources in offshore waters of Vietnam, studies on biology and capture fishery aspects of these stocks among other economically important species were carried out by the Research Institute of Marine Products under the Offshore Fishing Program (OFP) of the Ministry of Fisheries of Vietnam and under the technical assistance of JICA, DANIDA and SEAFDEC.

This paper presents results of study on biological features of four tuna and tuna-like species in off-shore waters of Vietnam as the basis for the sustainable exploitation and management of these resources.

Materials and Methods

The materials were collected mainly on board of several vessels operating under different research programs in offshore waters of Vietnam, namely:

· R/V BIEN DONG (1500 Hp) during the implementation of joint Vietnam-Japanese research project on " The marine resources study in Vietnam " which conducted in 1995 - 1997 in offshore parts of the Vietnamese EEZ in an area between Latitude $8^0$00' N to $18^0$00' N and from 40 m in depth to Longitude $112^0$00' E (Fig. 1). And during the implementation of the Collaborative Research Program with SEAFDEC on Marine Fishery Resources in the South China Sea from 01-20/05/1999 in area as shown in Fig. 2. Drift gillnet of 6 mesh-size including 73-mm, 95-mm, 100-mm,123-mm, 150-mm and 160 mm and additionally 48 -mm were used respectively.

· Commercial fishing vessels DONG NAM 01 (1800 Hp) and BV 7603TS (350 Hp). On these vessels , drift gillnet of 100-mm mesh-size was used and on commercial fishing vessel BR 7993 TS (120 Hp), long-line of 300 hooks was used. Those vessels were chartered from the state-owned and private fishing companies during the implementation of the governmental research project called " Survey on fisheries resources for development of offshore fisheries of Vietnam " in 1998- 1999. Study area is shown in [Fig 3].

· M/V SEAFDEC (2800 Hp) during the implementation of the Collaborative Research Program with Vietnam from 21/04-05/06/1999. Long-line and squid jigging were used. Study area is shown in [Fig.4].

In addition, some researchers have been on board of different commercial fishing vessels for collecting materials on tuna biology.

Catch of each haul was classified into species for analysis of catch composition, species composition and catch per unit of effort. The biological data of tuna species caught were obtained by:

Measurement of total and fork length in mm and body weight in g.

Identification of sex and maturity: 6 stages of maturity were recognized on the basis of visual assessed of the gonad and testis. Some matured gonads were collected for determination of fecundity in the laboratory.

Identification of degree of stomach fullness: 5 degrees of fullness were recognized by visual examination. Some stomach were collected for further analysis in the laboratory.

To estimate coefficients a, b of the Length -Weight relationship $W= a.L^b$ by least square regression method. Growth parameters of the von Bertalanffy growth equation $Lt=Lì.[1-exp(K.(t-t_0))]$ and mortality rate (Z, M, F) were estimated by FiSAT (FAO-ICLARM STOSK ASSESSMENT TOOLS) software.

Results

Species composition

98 species belonging to 22 families have been identified, of which 8 tuna and tuna-like species belonged to family *Scombridae*, namely:

- *Auxis rochei* (Risso) — Bullet tuna
- *A. thazard* (Lacepede) — Frigate mackerel
- *Euthynnus affinis* (Cantor) — Eastern little tuna
- *Katsuwonus pelamis* (Linnaeus) — Skipjack tuna
- *Thunnus albacares* (Bonnaterre) — Yellowfin tuna
- *T. obesus* (Lower) — Bigeye tuna
- *T. tonggol* (Bleeker) — Longtail tuna
- *Sarda orientalis* (Temm. et Sch.) — Striped bonito

However, target species of fishing gears used in study and in fishing practices are slightly different. For example, main target species of drift gillnet are Skipjack tuna, Frigate mackerel, Bullet tuna while of long- line are Yellowfin, Bigeye tuna, and Skipjack tuna. For purse seine and lift net Skipjack tuna, Eastern little tuna, Bullet tuna, Longtail tuna are main target species.

Biological characteristics of four species of tuna

Length frequency distribution

Skipjack tuna

Size (Lf) of captured skipjack by gillnet in the Southwest monsoon period (from April-September) ranged 26.4-55.0 cm with the mean length of 45.3 cm [Fig.5a] and in the Northeast monsoon (from October - March) ranged 25.9 - 65.8 cm with the mean length of 49.3 cm [Fig. 6a]. It shows that, in the Northeast monsoon size of caught Skipjack is larger than in the Southwest monsoon.

Due to gear selectivity of gillnet, length of Skipjack tuna being caught is different by mesh-size used. [Fig. 5 b-g] and [Fig. 6 b-f] show the length frequency distribution of Skipjack tuna in Southeast and Northeast monsoon periods respectively.

For the whole year, length of captured Skipjack tuna caught by gillnet of 6 different mesh-size ranged 23.5- 67.5 cm and weight 0.50-8.25 kg respectively, with the mean length of 47.8 cm. Three modes of length frequency distribution were found at 29 cm, 43cm and 55-57cm or at 0.5; 1.75 and 4.25 kg respectively.

Mean length of Skipjack caught by gillnet of 73 -mm mesh-size was 29.3 cm (fish of 1 year group) , of 95mm - 41.9 cm, of 123mm - 42.9 cm (fish of 2 year group) , of 150mm - 55.1 cm and of 160 mm- 56.5cm (fish of 5 year group).

It is noted that, even different mesh-sized gillnet was used, but Skipjack tuna of length group 30.5 -34.5 cm have not been found. It was assumed they might migrate off EEZ of Vietnam to the adjacent seawater of other countries in the region and then coming back to seawater of Vietnam for spawning when they reached 2 years old.

Total length and fork length relationship was :$Lf = 0.9496\ Lt - 1.9423$, $r^2 = 0.9936$ [Fig. 7].

Frigate mackerel

Size of Frigate mackerel caught in the Southwest monsoon period ranged 23.5-43.0 cm with the mean length of 34.5 cm, mode of 39.0 cm [Fig. 8a] and in the Northeast monsoon ranged 26.5-45.0 cm with the mean length of 36.7 cm [Fig.9a].It shows the size caught in Northeast monsoon was a little bit larger than in Northeast monsoon.

For the whole year, Frigate mackerels have length ranged from 23.5 - 45.0 cm and weight ranged 0.1 to 1.9 kg respectively. The mean length of Frigate mackerel captured by gillnet of mesh-size 73mm was 35.3 cm, of 95mm - 40.3 cm, of 123mm- 35.9 cm, of 150mm- 36.9 and of 160 mm- 37.3 cm.

Distribution of length frequency caught by different mesh-size gillnet in the Southwest and Northeast monsoon period is shown in [Fig.8 b-g] and [Fig.9 b-f].

Total length and fork length relationship was : Lf = 0.9372 Lt .+ 3.1655 and r^2 = 0.9856 [Fig. 12].

Bullet tuna

Size of Bullet tuna ranged 19.5 - 30.5 cm in the Southwest monsoon with the mean length of 26.1 cm [Fig.10a] and 14.5- 30.5 cm in the Northeast monsoon with the mean length of 25.6 cm [Fig.11a].

Distribution of length frequency of fish captured by different mesh-size gillnet in Southwest and Northwest monsoon are shown in [Fig.10 b-g] and [Fig. 11 b-f].

For whole year, mean length of Frigate mackerel was 26.1 cm and of those caught by mesh-size of 73 mm was 25.9 cm, 95mm - 26.1cm, 123mm- 25.3, 150mm- 25.2 and 160mm- 25.9.

The total length and fork length relationship was: Lf = 0.9064 Lt +14.017 and r^2 = 0.9192 [Fig. 13].

Yellowfin tuna

Length frequency distribution of Yellowfin tuna caught by gillnet of mesh-size 100mm [Fig. 14] and long-line [Fig. 15] showed that length of yellowfin tuna caught by gillnet ranged 49-90 cm with the mean length of 56.1 cm, and most of them belonging to size group of 49-55 cm while by long-line ranged 50-180 cm with mean length of 98.9 cm.

It showed that Yellowfin of larger size are distributed mainly at the deeper layer than the smaller ones.

Length-weight relationship

Skipjack tuna

Length-weight relationship of both sexes was: $W = 0.0058 \times L^{3..3471}$, $r^2 = 0.9926$ [Fig.16]. Length - weight relationship of Skipjack tuna caught by purse seine from Sarawak waters of Malaysia was $W = 1.494 \times 10^{-6} L^{3.4219}$ [Mansor (1997)] and from Philippines waters was $W = 0.00003267 L^{3.09569}$ [Ronquillo (1963)]

Frigate mackerel

Length-weight relationship of both sexes was: $W = 0.0113 \times L^{3.1547}$, $r^2 = 0.9298$ [Fig. 17]

Bullet tuna

Length-weight relationship of both sexes was: $W = 0.1248. L^{2.3530}$, $r^2 = 0.4058$ [Fig. 18]

Yellowfin tuna

Length-weight relationship of both sexes was: $W = 0.0208 L^{2.9793}$, $r^2 = 0.9860$ [Fig. 19]. In Malaysia waters $W = 8.885 \times 10^{-6} L^{3.1288}$ [Mansor (1997)], and in

Philippines waters W = 0.00002352 $L^{2.84682}$ (for male).

Reproduction

Skipjack tuna

In the Southwest monsoon period , 38.4 % of females having gonads belonged to stage IV (developing stage) and V (spawning stage) and 22 % to stage VI-II, V-III (resting stage) [Fig.20]. The ratio of male and female in this period was 2.18 : 1 . It shown that the main spawning period of Skipjack was in the Southwest monsoon with the peak in April-May.

At the beginning of the Northeast monsoon period (in September-October) , 92.2 % of females of Skipjack were at maturity stage II and III, only 7.8 % still have gonads belonged to IV stage [Fig. 21]. The ratio of male and female in this period was 1: 1.94.

The absolute fecundity for female of 41 cm was about 2 million eggs. Size at first maturity was about 38-43 cm (2 years group).

In Philippines waters the length at first maturity of Skipjack tuna was 42 cm [Ronquillo (1963)].

Frigate mackerel

In the Southwest monsoon, 10.0 % and 16.7 % of females having gonads of IV and VI stage respectively, and 2.2 % of resting stage [Fig.22]. In this period, the ratio of male and female was 1.7: 1. It showed that the spawning season of Frigate mackerel is in this monsoon period with the peak in April-June.

In the Northeast monsoon, only 8.8 % of female having gonads belonged to IV stage, in this time the ratio of male and female was 1.5 : 1 [Fig. 23].

The absolute fecundity of females of 36.5-40.0 cm ranged 129,648- 357,006 eggs. Size at first maturity was about 34 cm.(2 years group).

In Thailand Gulf, the length of first maturity of Frigate mackerel was 31 cm, and fecundity of fish of length 31-39 cm ranged 78.000- 719.900 eggs. [Yesaki (1994)].

Bullet tuna

In the Southwest monsoon, about 30 % of female having gonads belonged to stage IV and V, around 15 % was at resting stage. The ratio of male and female was around 1 : 1 [Fig.24].

In the Northeast monsoon, most of female's gonads were at stage of II and III. [Fig. 25]. The ratio of male and female was 2.7: 1.

The absolute fecundity of females with mean length ranged 25.0 - 26.9 cm varied from 515,010 to 989,066 egg. Size of first maturity was 20 cm (1 year group)

In Thailand Gulf, the length of first maturity of Bullet tuna was 17 cm and fecundity of length group 25-34 cm ranged 52.600-162.800 eggs. [Yesakj (1994)].

Yellowfin tuna

Yellowfin tuna females caught by gillnet in the Southwest monsoon were immature fish with 100 % of maturity stage II, caught in the Northeast monsoon were 100 % of stage III.

On the contrary , Yellowfin tuna caught by long-line in the Southwest monsoon were mature with 16 % of maturity stage IV and 50 % of resting stage. It indicated that spawning season of Yellowfin tuna was in the Southwest monsoon.

According to [Ronqillo (1963)], in Philippines waters the length of first maturity of Yellowfin tuna was 55-67 cm.

Feeding

Skipjack tuna

Degree of fullness of stomach in the Southwest and Northeast monsoon is shown in [Table 1].

In the Northeast monsoon, degree of fullness 3 and 4 comprised 30.3 %, while in the Southeast monsoon only 22.1 %. It indicated that in the spawning period, feeding activity of Skipjack was less than in the post spawning period when fishes had to feed actively in order to recover energy spent during spawning season.

Major species of preys found in stomach of Skipjack were Anchovies, *Caranx spp.*, Indian mackerel *(Rastrelliger kanagurta)*, Scad *(Decapterus spp.),* Squids and Shrimp.

Frigate mackerel

In the Southwest monsoon, stomach fullness of 3 and 4 degree accounted only for 4.88 % while in the Northeast monsoon 18.44 % [Table 2].

Squid and Shrimp were often found in their stomach.

Bullet tuna

Degree of stomach fullness of Bullet tuna is shown in the [Table 3].

Shrimps were most frequently found in stomach of bullet tuna, then followed by Euphausia and Squids.

Yellowfin tuna

Table 4 shows the degree of stomach fullness of Yellowfin tuna by gillnet comparing with tuna caught by long-line in the Southeast monsoon.

It showed that larger Yellowfin tuna caught by long-line were more active in feeding than tuna caught by gillnet.

Unicom leatherjacket (*Aluterus monoceros*), Flying fish, snake mackerel and squid , etc. were found in stomach of Yellowfin tuna.

Growth and recruitment

Skipjack tuna

Parameters of the von Bertalanffy growth equation was estimated as follows:

L_8 = 77.67 cm , K = 0.299 ; t_0 = - 0.510

Standard error (S.E) and Coefficient of Variation (CV) of estimated parameters are shown in [Fig. 26].

Mean fork length of fish of 1 year was 28 cm, 2 years - 42 cm, 3 years- 50cm, 4 years- 58cm and 5 years- 63 cm. It showed that Skipjack grew very fast in the first 2 years before becoming matured and taking part in spawning population.

Skipjack tuna have highest recruitment in November (22.48 %), then followed in December (20.96 %) and January (16.12 %) (Fig. 27).

Growth parameters and length at age of Skipjack tuna in various areas estimated by different Authors are shown in the [Table 5].

Frigate mackerel

Parameters of the von Bertalanffy growth equation was estimated as follows:

L_8 = 49.02 cm, K = 0.426 , t^0 = - 0.867

S.E and CV are shown in [Fig. 28].

Mean length of fish of 1 year was 27 cm, 2 years- 35 cm, 3 years- 39 and 4 years- 43 cm.

The highest percent of recruitment was found in November (20.25 %), then in October (19.26 %) [Fig. 29].

The growth parameter and length at age of Frigate mackerel in various areas were shown in the [Table 6].

Bullet tuna

Estimated mean length of fish of 1 year was 20 cm, 2 year- 27 cm. According to Le Trong Phan (1996), in coastal waters of Central Vietnam, Bullet tuna reached 20.5 cm at 1 year, 27.5 cm at 2 years.

Yellowfin tuna

According to [Wild (1960)] , length at age of Yellowfin in the Eastern Pacific Ocean was as follows: 1 year- 46 cm, 2 years- 84cm, 3 years- 111 cm, 4 years- 131 cm and 5 years- 146 cm.

Mortality rate

Skipjack tuna

Total mortality rate (Z) was estimated to be 0.87, natural mortality M = 0.62 , fishing mortality F = 0.25 and exploitation rate E = 0.29 [Fig.30]. It indicated that , production of Skipjack tuna still can be increased in offshore waters of Vietnam in the future.

Frigate mackerel

Total mortality Z = 1.44 ,natural mortality M = 0.67, fishing mortality F = 0.77 and exploitation rate E = 0.53 [Fig.31].

Discussion

Tuna and tuna-like species are distributed widely in both neritic and oceanic waters of Vietnam. Among them, Skipjack, Yellowfin and Bigeye tunas are highly migratory species and being caught by different fishing gears in offshore waters of Vietnam.

Small size Yellowfin , Bigeye tunas and Skipjack tuna, Frigate mackerel and Bullet tuna were being caught by drift gillnet, purse seine, while larger Yellowfin and Bigeye are captured mainly by long-line.

In catches by gillnet, the percentage of Skipjack tuna was dominant (25.3 %), then followed by Frigate mackerel (8.9 %) and Bullet tuna (3.4 %). On the contrary in catches of long-line Yellowfin and Bigyeye tunas were dominant. Some larger Skipjack were also captured by long-line at depth about 30-40m from surface.

Theoretically, distribution of the oceanic tuna mainly depended on water layer, whereby smaller fish ten to distribute at the upper layer as compared to the larger fish at the deeper layer [Monintja (1998)].

The absence of length group of 30.5-34.5 cm of Skipjack in both neritic and offshore waters of Vietnam indicated on whether their migration from EEZ of Vietnam to adjacent waters or to deeper layer. Fish of this length group was captured by purse seine (80m deep & 10 cm mesh-size) in Sarawak waters of Malaysia [Mansor (1997)]. Therefore determination of movement of Skipjack tuna would be very useful if the tagging method is to be used.

The length frequency distribution of Yellowfin tuna caught by gillnet in offshore waters of Vietnam showed the similarity with the length frequency distribution of Yellowfin caught by purse seine in Sarawak waters of Malaysia. [Kikawa (1973)] suggested that there are two separable migratory groups of Yellofin tuna, one in the western Indian Ocean and other in the Banda-Flores Seas of Indonesia.

The Frigate mackerel are very widely distributed in the continental shelf waters and around the islands in the Southeast Asian waters. They are the seasonal visitors to the coastal waters and usually caught in coastal waters by different fishing gears.

Analysis of maturity stage and fish larvae collected during surveys showed that the Southwest monsoon being a spawning season of most of tuna and tuna-like in offshore waters of Vietnam and April-June were the peak of spawning. [Yamanaka (1990)] reported that the spawning period of Yellowfin off the north Celebes Sea was from April to June and Skipjack are known to breed during the greater part of the year in Philippines waters. [Ronquillo, (1963)].

The coefficients of the length-weight relationship, parameters of the von Bertalanffy growth equation and mortality rates were found different from coastal and offshore populations of tuna studies in Vietnam.The differences were also found between populations inhabiting in offshore waters of Vietnam and other areas.

Skipjack tuna and frigate mackerel in offshore waters of Vietnam have very low natural morality rate.

Tuna and tuna-like species are promising target species for offshore fisheries development in Vietnam. Preliminary findings suggest that offshore waters of Vietnam is an important migratory route for oceanic tuna and they may originate from groups outside the area as indicated by appearance of different size groups during seasons of the year. Therefore further studies on tunas would be conducted in collaboration between countries bordering the South China Sea.

Table 1. Degree of stomach fullness of Skipjack tuna.

Degree of fullness	Fish caught by gillnet (%)	Fish caught by long-line (%)
0	42.86	47.06
1	28.57	0
2	7.14	17.65
3	7.14	11.76
4	7.14	23.53

Table 2. Degree of stomach fullness of Frigate mackerel.

Degree of fullness	Southwest monsoon (%)	Northeast monsoon (%)
0	25.61	64.54
1	61.38	5.67
2	8.13	11.35
3	4.88	17.02
4	0	1.42

Table 3. Degree of stomach fullness of Bullet tuna.

Degree of fullness	Southwest monsoon (%)	Northeast monsoon (%)
0	41.16	40.0
1	41.57	40.0
2	10.61	20.0
3	4.80	0
4	1.77	0

Table 4. Degree of stomach fullness of Yellowfin tuna.

Degree of fullness	Fish caught by gillnet (%)	Fish caught by long-line (%)
0	42.86	47.06
1	28.57	0
2	7.14	17.65
3	7.14	11.76
4	7.14	23.53

Table 5. Growth parameters and length at age of Skipjack tuna.

Areas	Growth parameters			Length at age (cm-year)				Authors
	K	L_8	t_0	1	2	3	4	
North of Japan				26	34	43	54	Aikiwara,1937
Japan				15	45	63	73	Kawasaki,1965
Taiwan	0.302	103.6	-0.016	27	47	62	73	Chi & Yang,1973
Central Pacific	0.550	102.0	-0.02	44	68	83	91	Uchiyama&Struhsaker,1981
Guine Gulf	0.307	86.7	-0.317	29	44	55	64	Chur& Zharov,1983
Coastal waters of Vietnam	0.700	65.0		33	49	57	61	Nguyen Phi Dinh at al.,1996

Table 6. Growth parameters and length at age of Frigate mackerel.

Areas	Growth parameters			Length at age			Authors
	K	L8	t_0	1	2	3	
West of Java	0.70	47.5		24	36	42	Dwiponggo et al.,1986
West coast of Thailand	0.80	47.2		26	37	43	Yesaki, 1994
Sri Lanca	0.54	58.0		25	39	47	Joseph et al.,1986
India	0.49	63.0	-0.270	29	42	50	Silas et al,1985

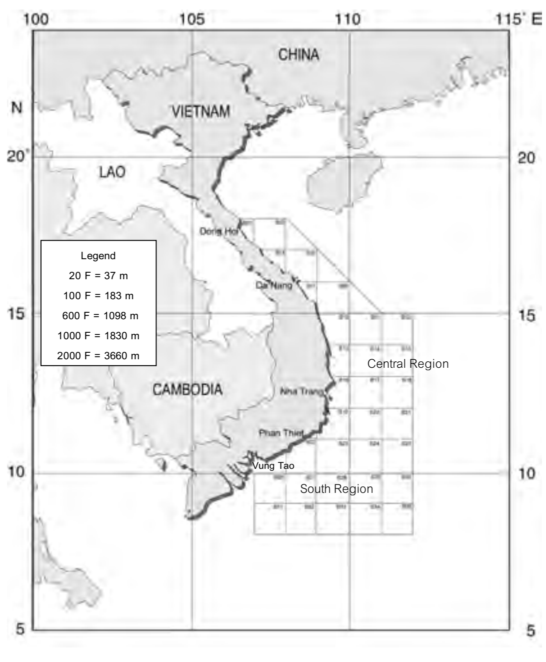


Fig. 1. Study area of R/V BIEN DONG under JICA Project in 1995-1997.

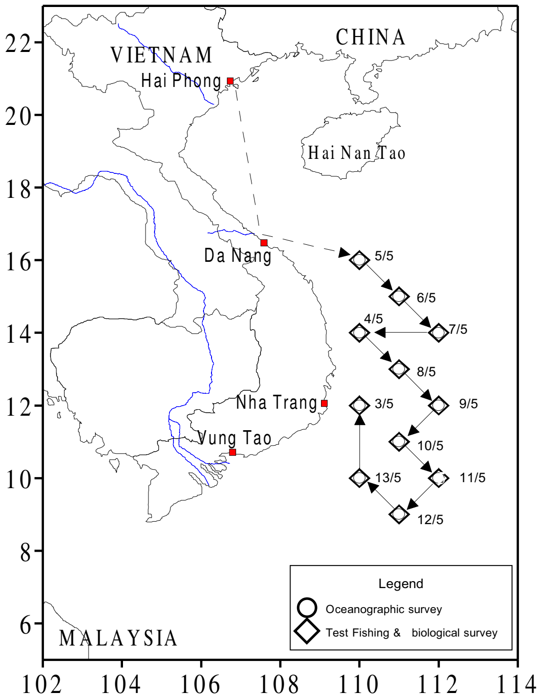


Fig. 2. Study area of R/V BIEN DONG under the collaborative research program with SEAFDEC in May 1999.

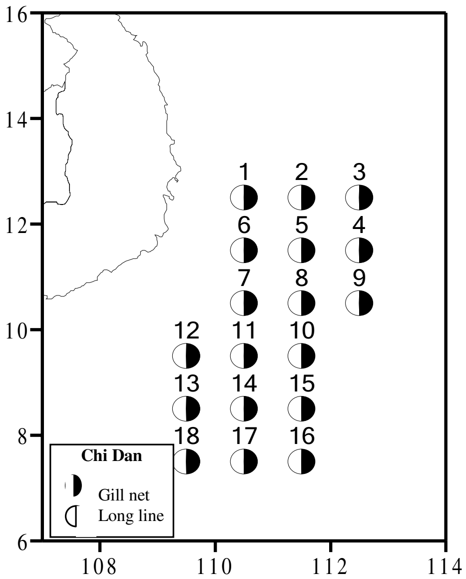


Fig. 3. Study area of F/V DONG NAM, BV 7603 TS and 7993 TS in 1998-1999.

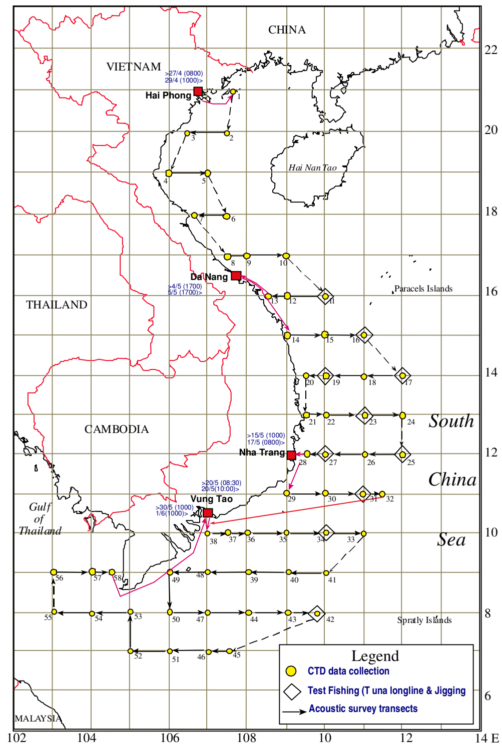


Fig. 4. Study area of M/V SEAFDEC in April-May/1999.

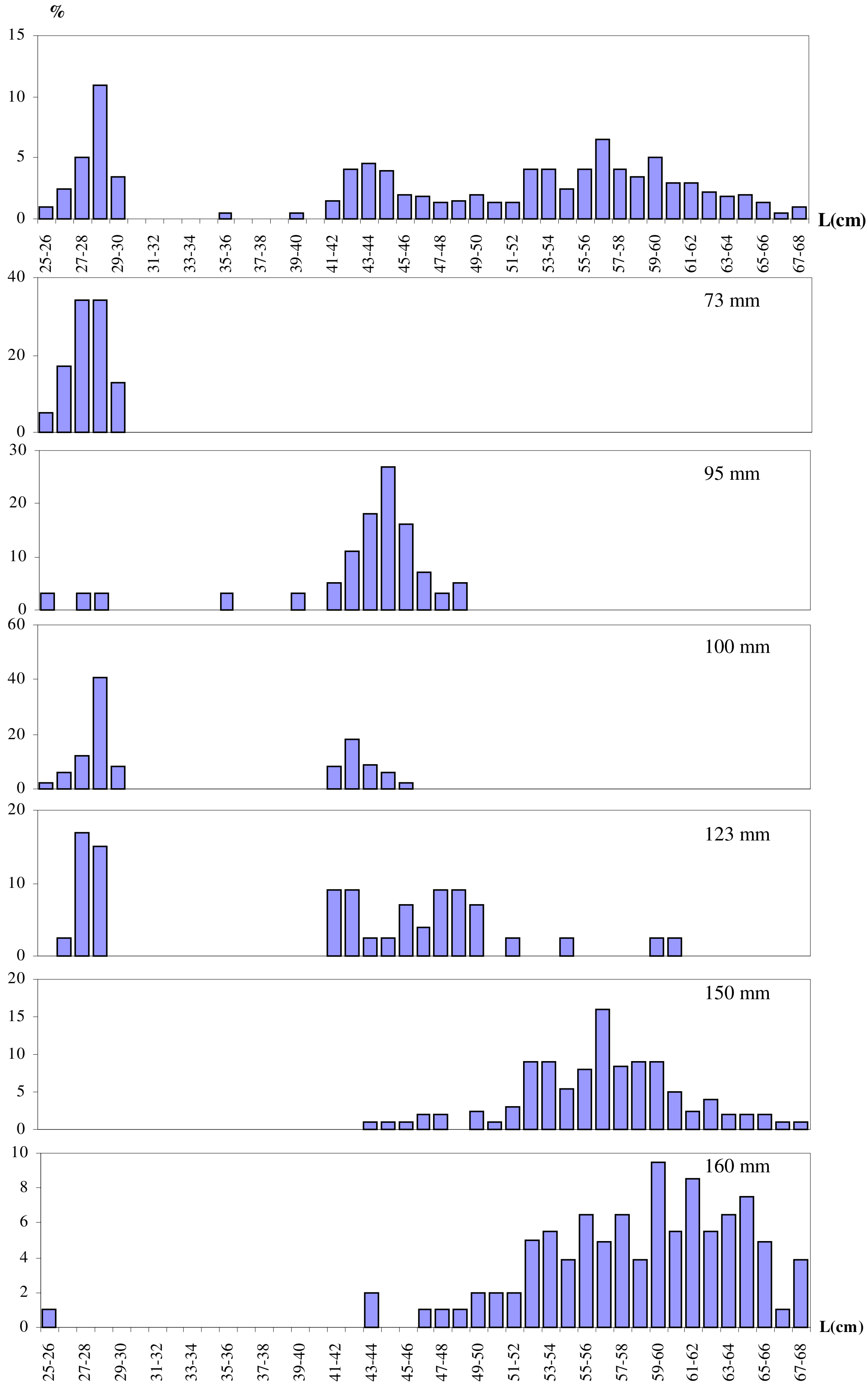


Fig. 5. Length frequency distribution of Skipjack tuna in Southwest monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-100, e-123, f-150 and g-160 mm).

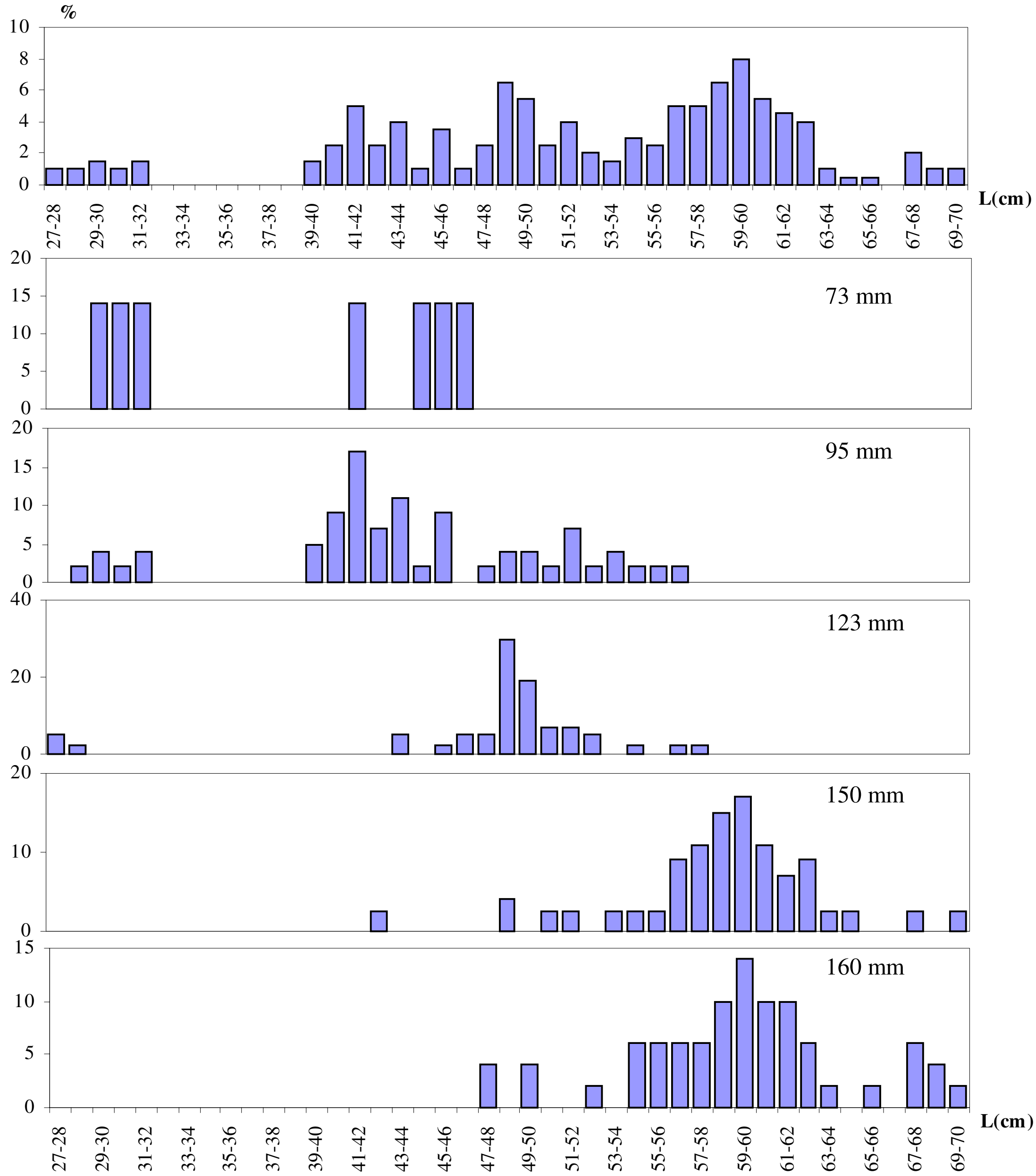


Fig. 6. Length frequency distribution of Skipjack tuna in Northeast monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-123, e-150, f-150 and g-160 mm).

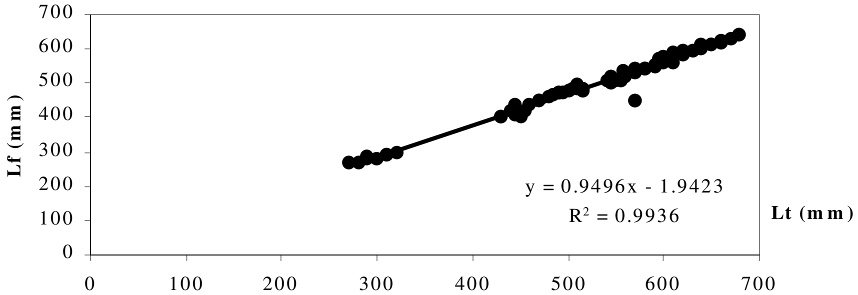


Fig. 7. Relationship between total and fork length of Skipjack tuna.

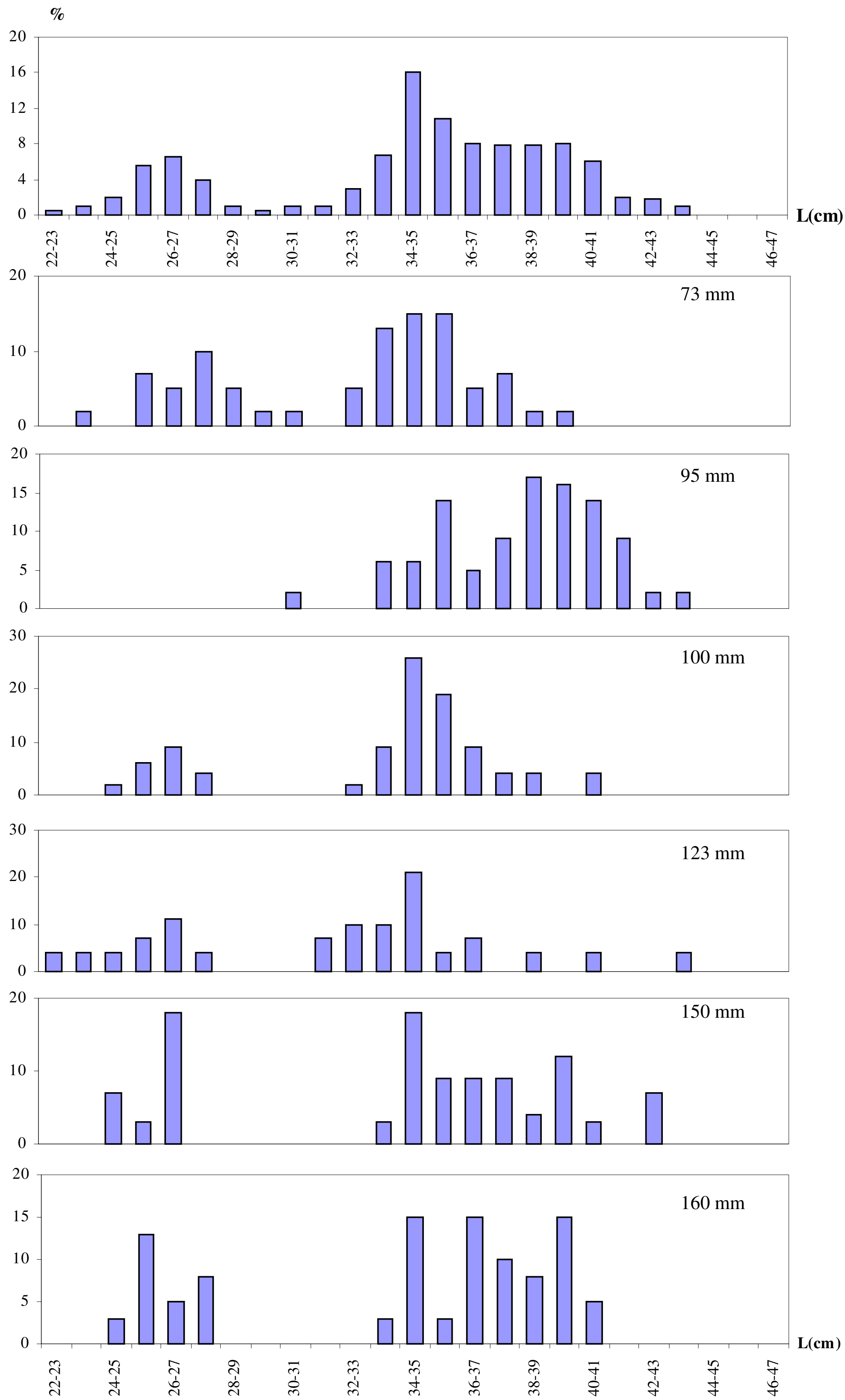


Fig. 8. Length frequency distribution of Frigate mackerel in Southwest monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-100, e-123, f-150 and g-160 mm).

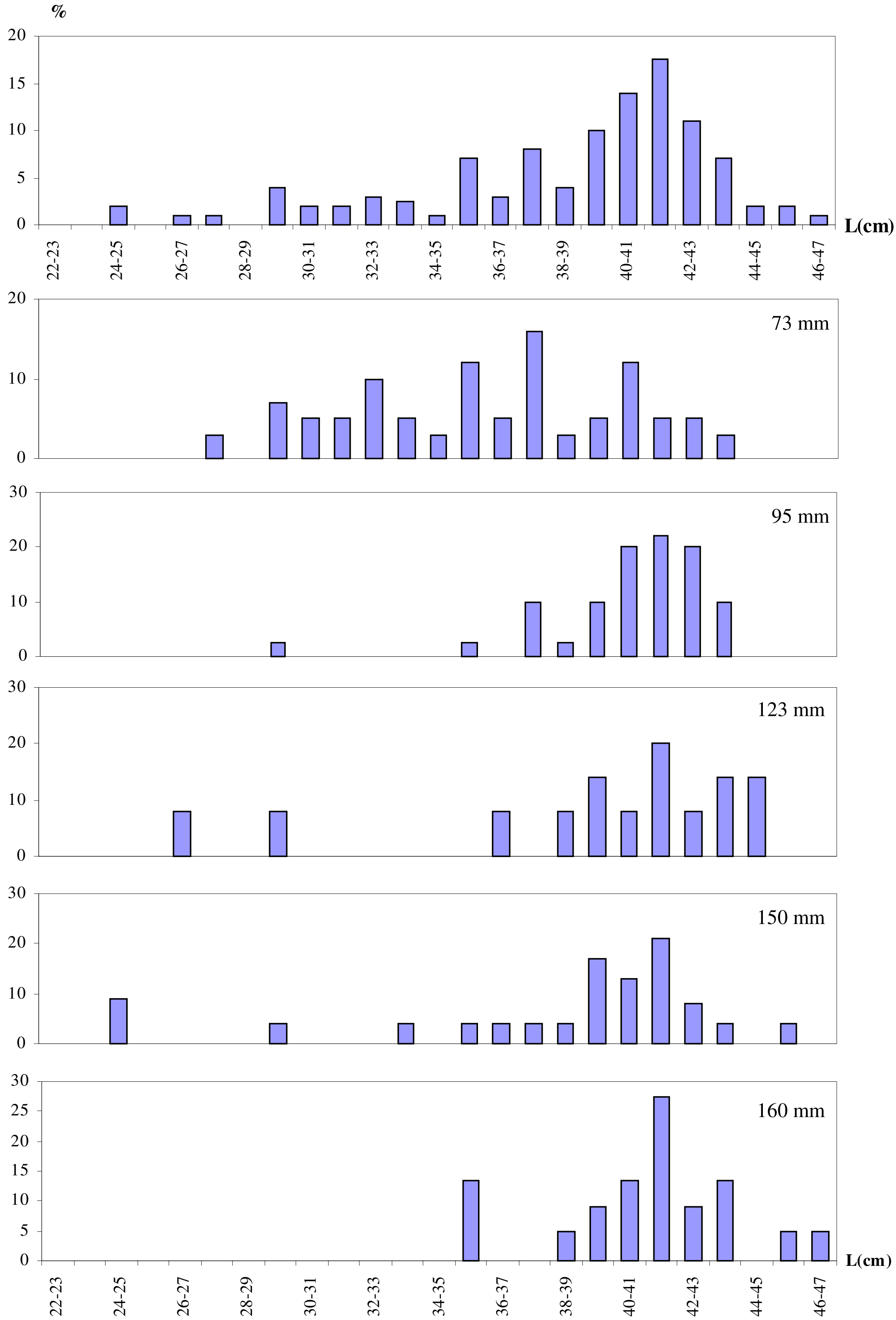


Fig. 9. Length frequency distribution of Frigate mackerel in Northeast monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-123, e-150, f-160 mm).

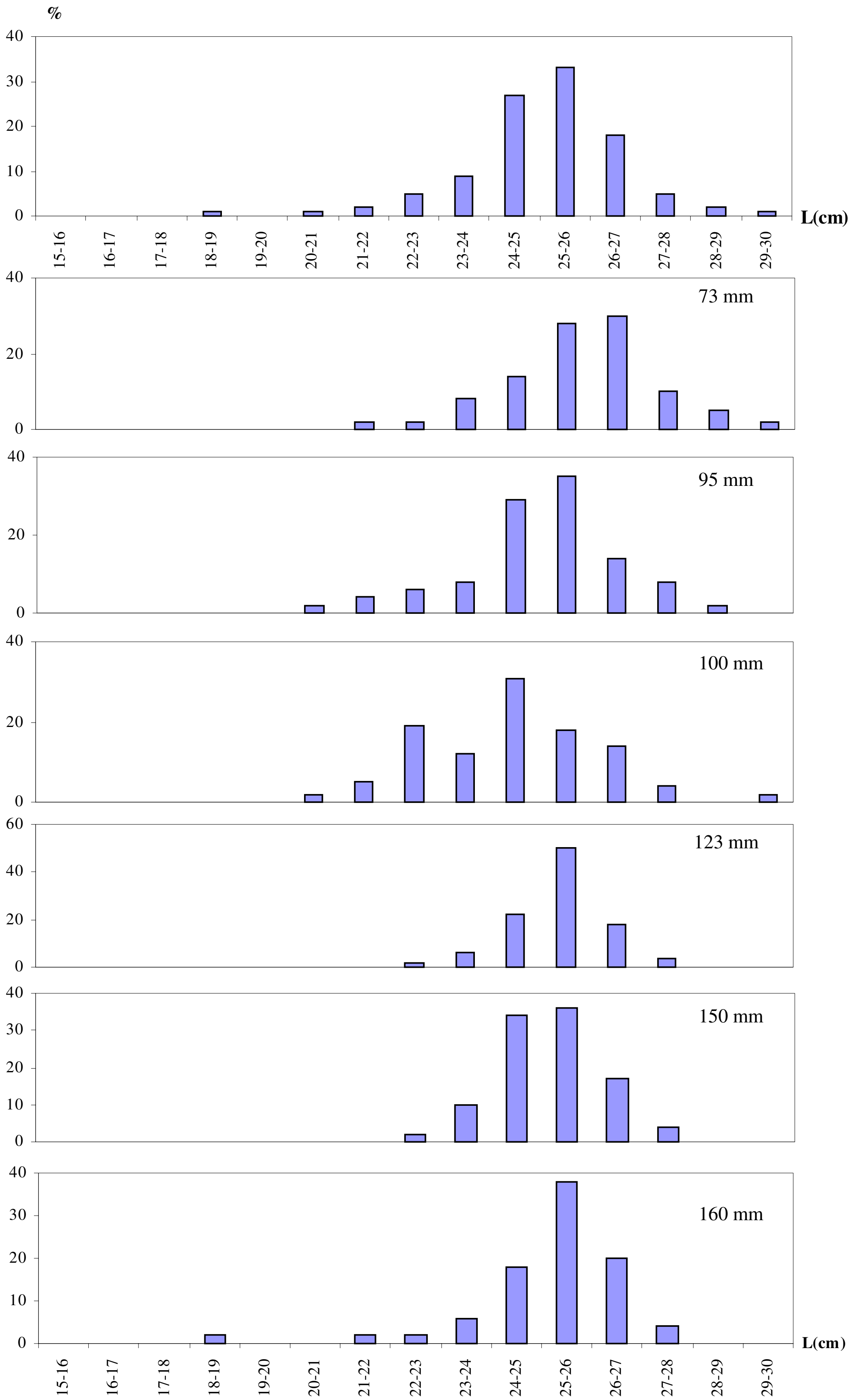


Fig. 10. Length frequency distribution of Bullet tuna in Southwest monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-100, e-123, f-150 and g-160 mm).

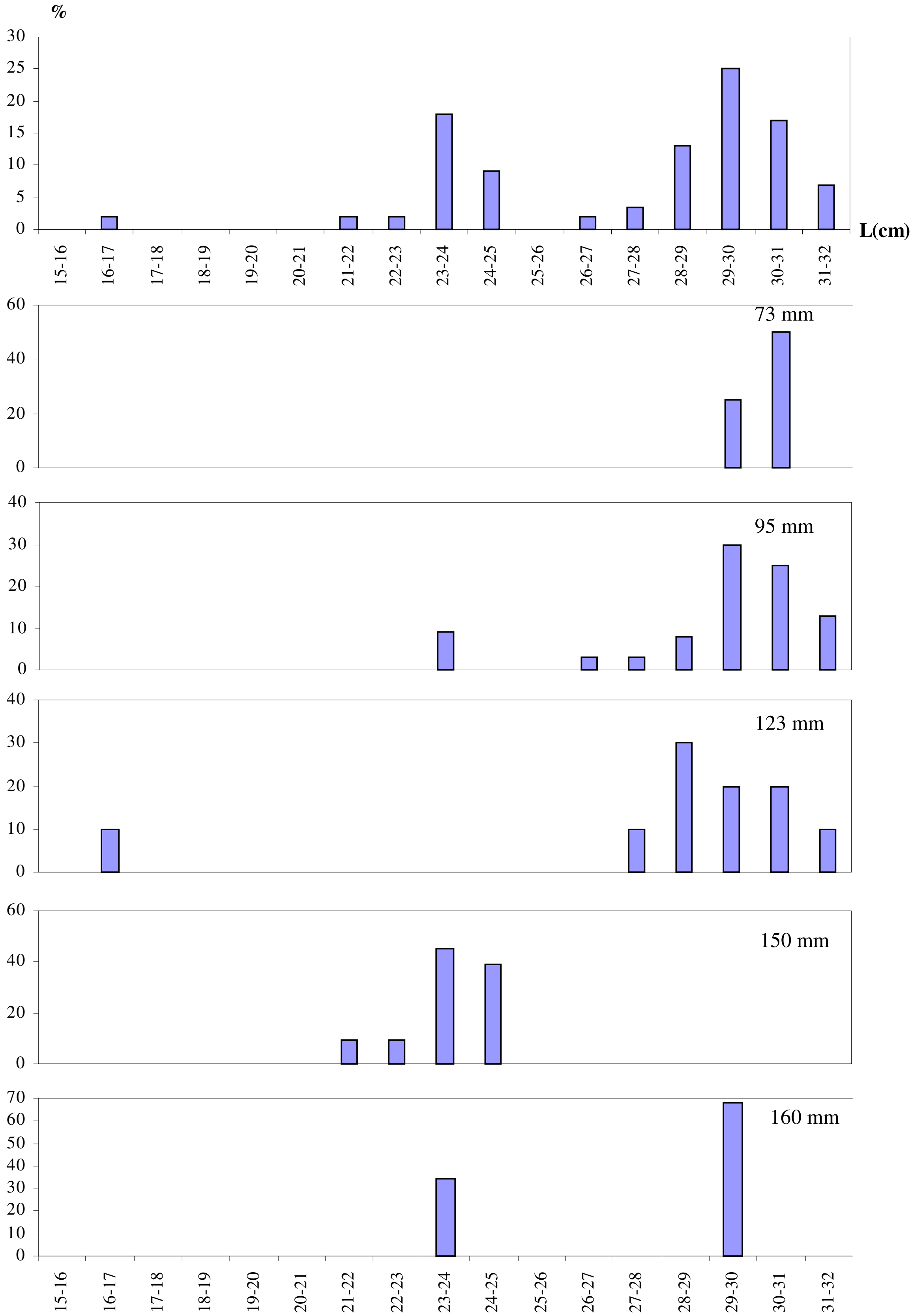


Fig. 11. Length frequency distribution of Bullet tuna in Northeast monsoon (a-whole year, b-mesh size of 73 mm, c-95, d-123, e-150 and f-160 mm).

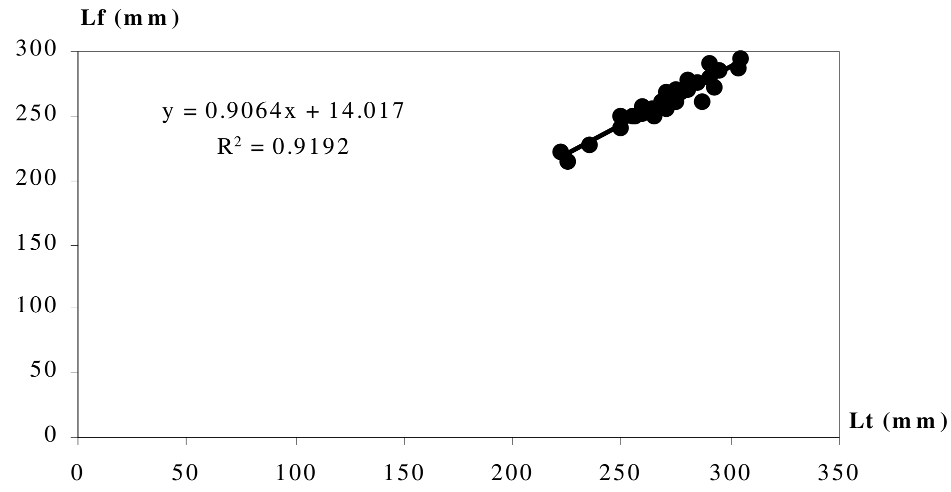


Fig. 12. Relationship between total and fork length of Frigate mackerel.

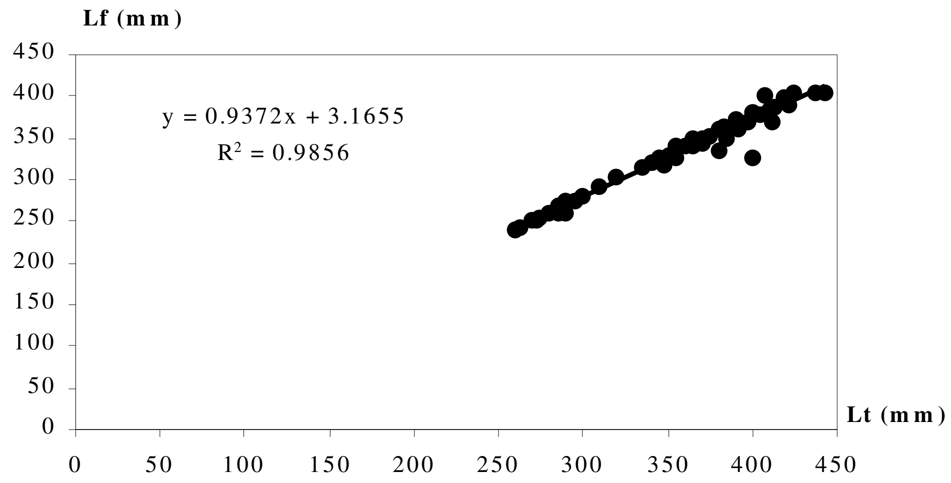


Fig. 13. Relationship between total and fork length of Bullet tuna.

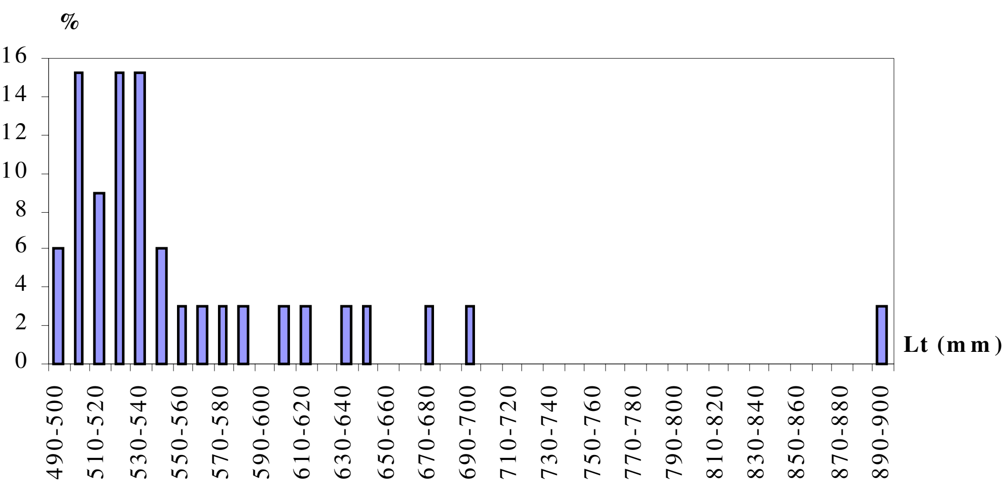


Fig. 14. Length frequency distribution of Yellowfin tuna caught by gillnet.

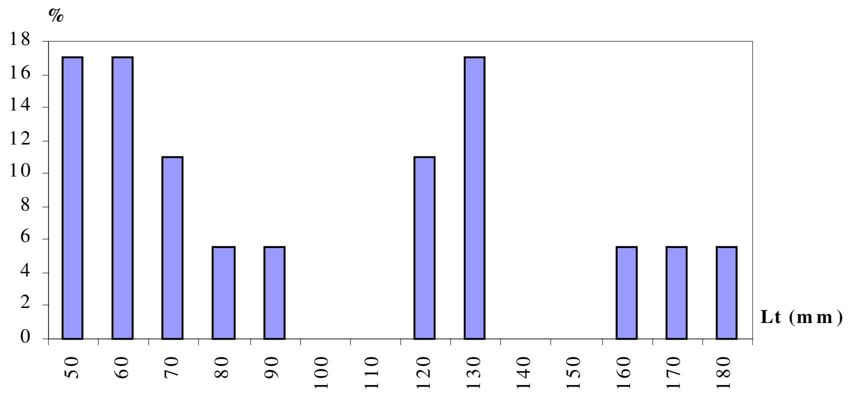


Fig. 15. Length frequency distribution of Yellowfin tuna caught by longline.

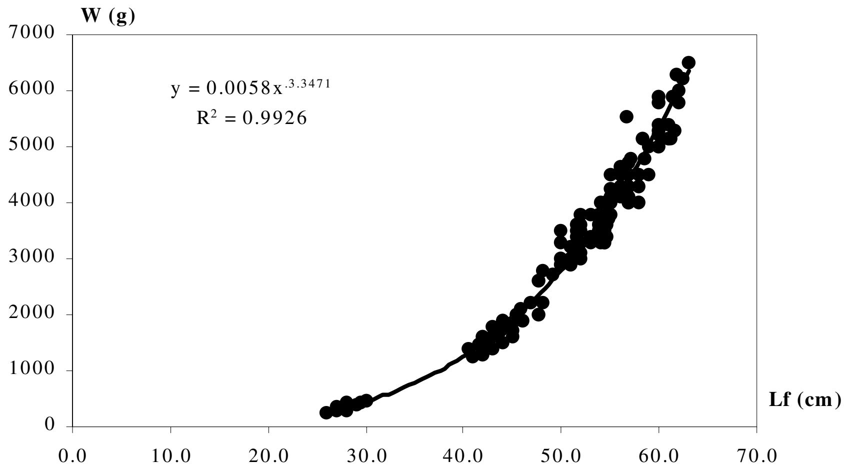


Fig. 16. Length-weight relationship of Skipjack tuna.

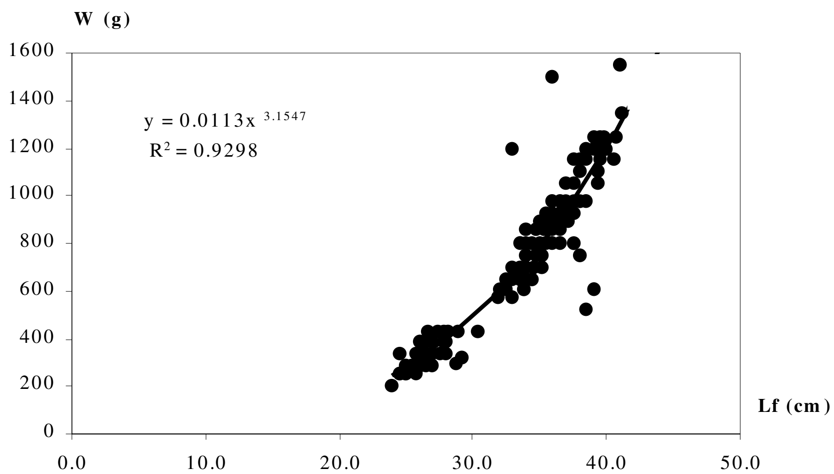


Fig. 17. Length-weight relationship of Frigate mackerel.

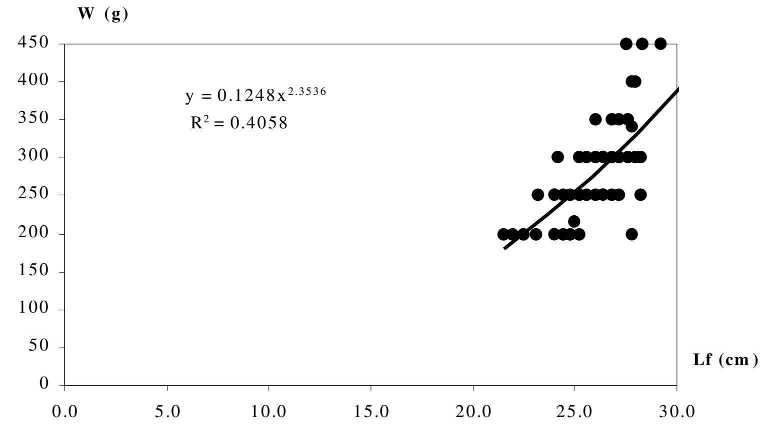


Fig. 18. Length-weight relationship of Bullet tuna.

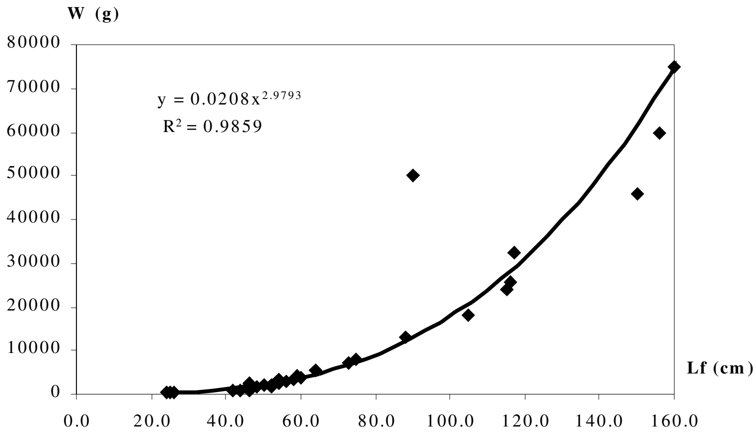


Fig. 19. Length-weight relationship of Yellowfin tuna.

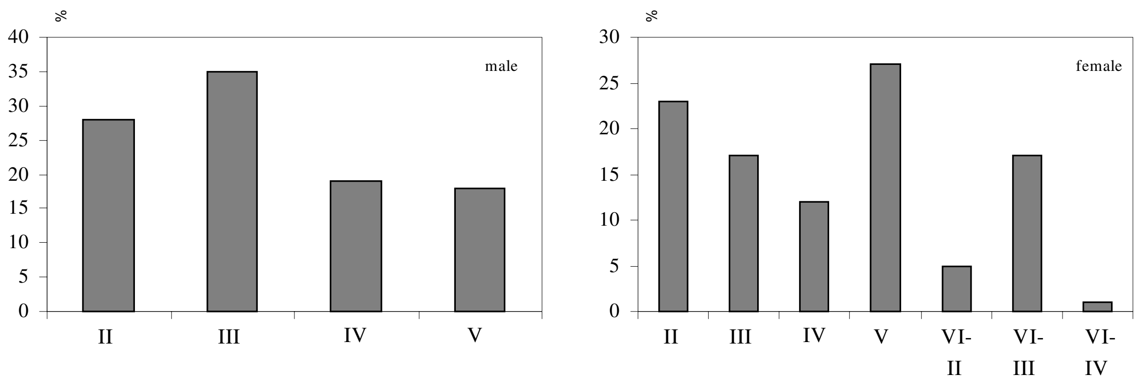


Fig. 20. Maturity stage of Skipjack tuna in Southwest monsoon.

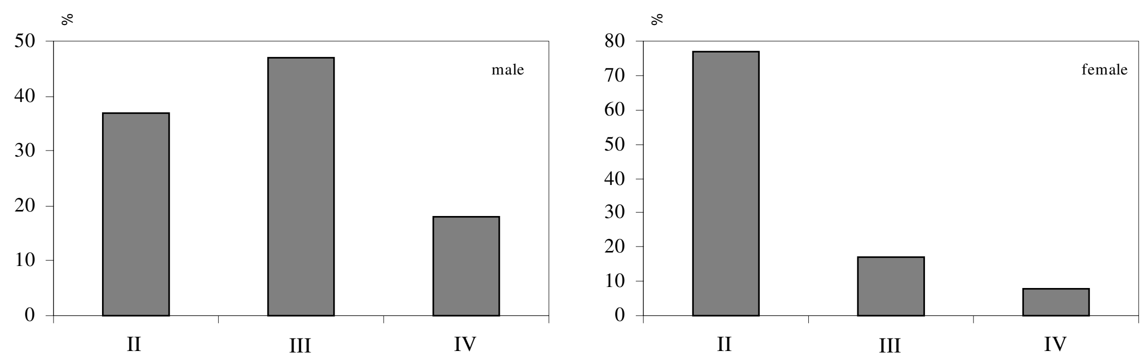


Fig. 21. Maturity stage of Skipjack tuna in Northeast monsoon.

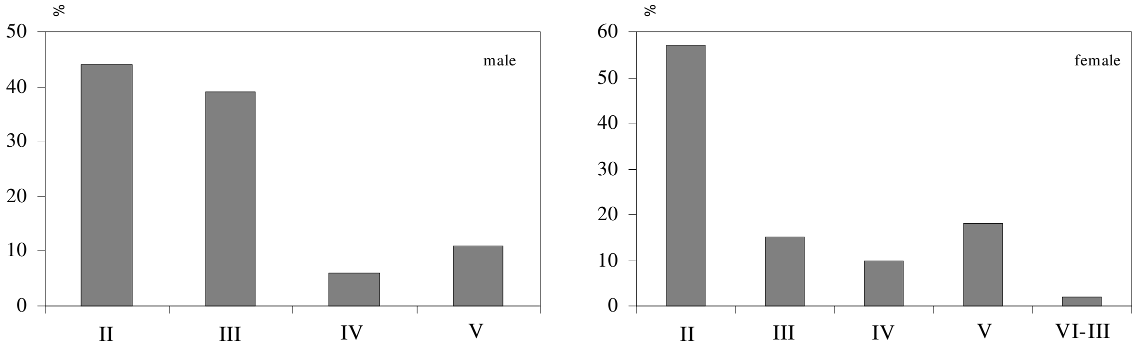


Fig. 22. Maturity stage of Frigate mackerel in Southwest monsoon.

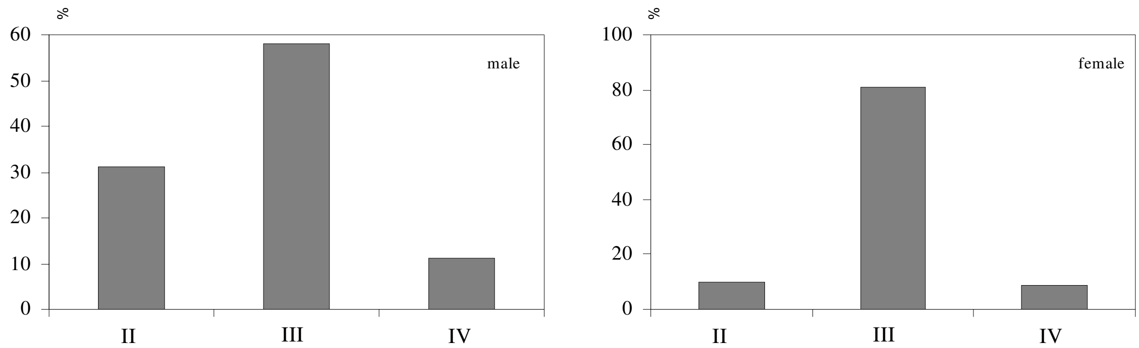


Fig. 23. Maturity stage of Frigate mackerel in Northeast monsoon.

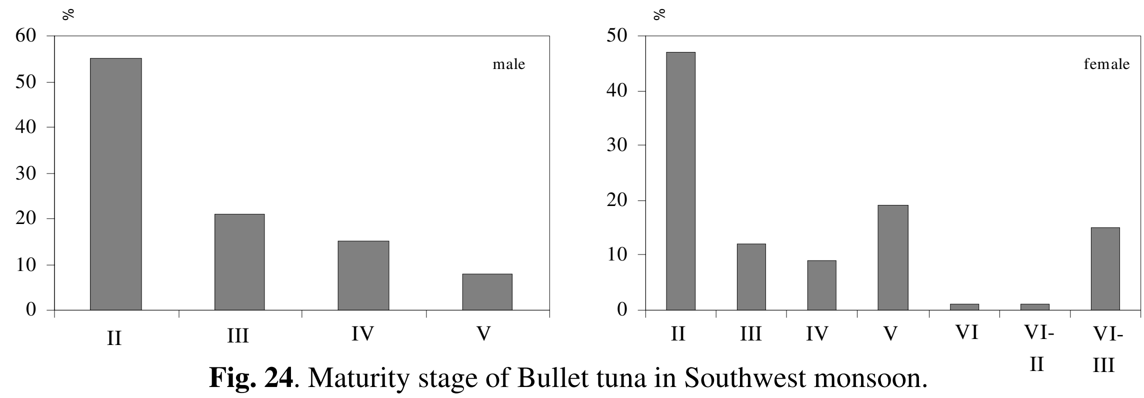


Fig. 24. Maturity stage of Bullet tuna in Southwest monsoon.

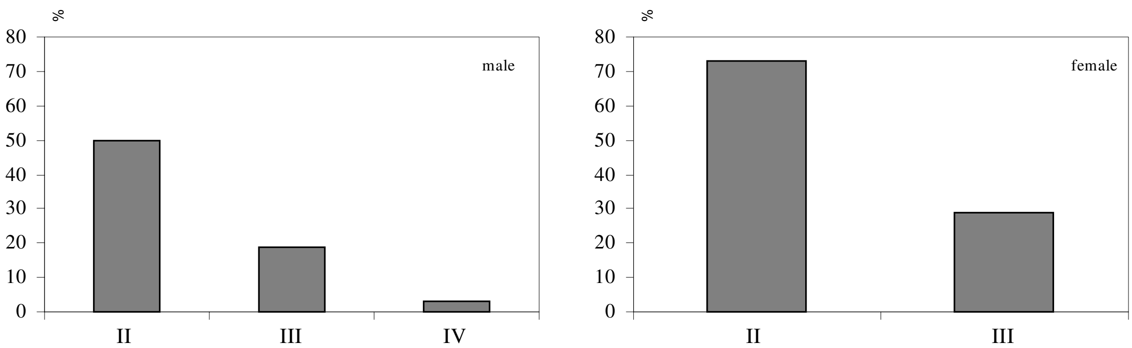
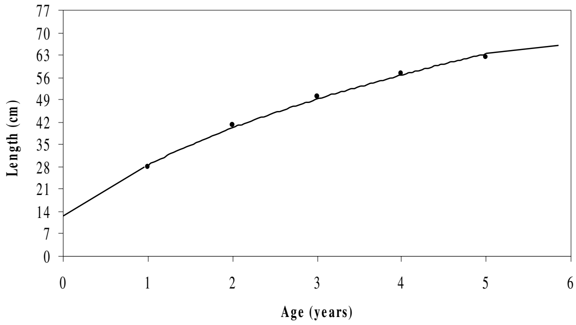


Fig. 25. Maturity stage of Bullet tuna in Northeast monsoon.

Species : *Katsuwonus pelamis*
Model : von Bertalanffy Growth Function (non-seasonalized)
Remarks : Data points were not weighted



PARAMETER ESTIMATES

L∞	:	77.665
K	:	0.299
t0	:	-0.510
φ'	:	3.256

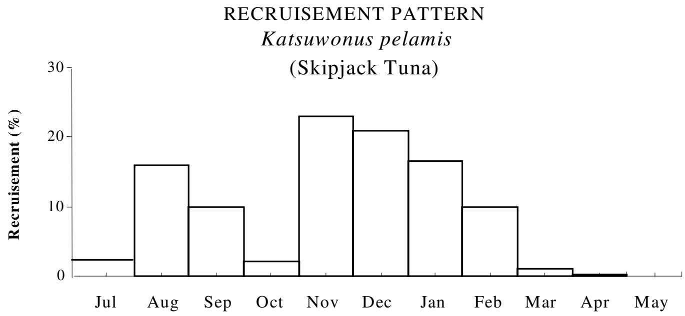
s.e. OF ESTIMATES

L∞	:	4.322
K	:	0.045
t0	:	0.153
φ'	:	0.481

CV OF ESTIMATES

L∞	:	0.0556
K	:	0.1498
t0	:	-0.3000

Fig. 26. Growth parameters of Skipjack tuna.



Loo = 77.66 , K = 0.299 , C = 0 , WP = 0 , t0

FILE : ST

Absolute Time	Percentage Recruisement
1 Jul	2.35
2 Aug	15.78
3 Sep	9.82
4 Oct	1.75
5 Nov	22.48
6 Dec	20.96
7 Jan	16.12
8 Feb	9.45
9 Mar	0.61
10 Apr	0.52
11 May	0.14
12 Jun	0.00

Select option in the right box. The Hasselblad' s NORMSEP may be used to estimate normal distribution (s).

Species name
Katsuwonus pelamis
Skipjack tuna

Fig. 27. Recruitment pattern of Skiplack tuna.

Species : *Auxis thazard*
Model : von Bertalanffy Growth Function (non-seasonalized)
Remarks : Data points were not weighted

PARAMETER ESTIMATES

L∞	:	49.018
K	:	0.426
t0	:	-0.867
φ'	:	3.010

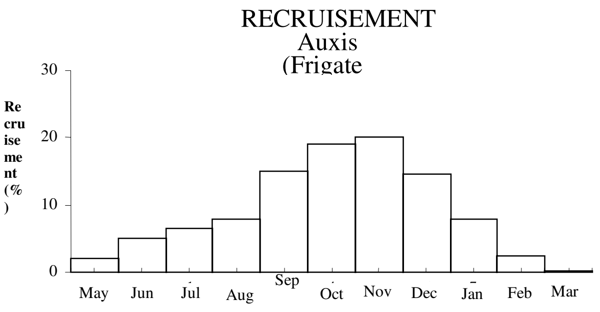
s.e. OF ESTIMATES

L∞	:	4.802
K	:	0.164
t0	:	0.492
φ'	:	0.187

CV OF ESTIMATES

L∞	:	0.0980
K	:	0.3846
t0	:	-0.5679
φ'	:	0.0623

Fig. 28. Growth parameters of Frigate mackerel.



Loo = 49.02 , K = 0.426 , C = 0 , WP

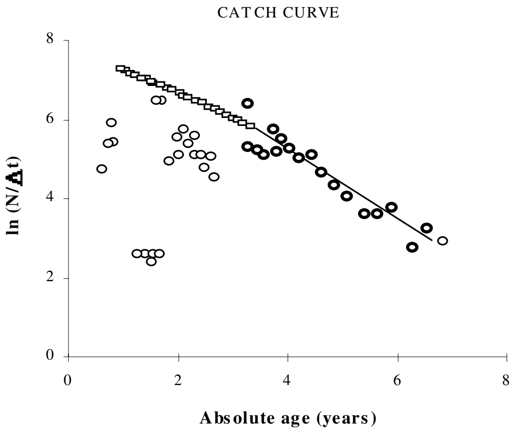
FILE : FRIMAC

Absolute Time	Percentage Recruisement
1 May	1.55
2 Jun	5.11
3 Jul	6.48
4 Aug	8.05
5 Sep	14.51
6 Oct	19.26
7 Nov	20.25
8 Dec	14.23
9 Jan	7.81
10 Feb	2.34
11 Mar	0.40
12 Apr	0.00

Select option in the right box. The Hasselblad' s NORMSEP may be used to estimate normal distribution (s).

Species name
Auxis thazard
Frigate mackeral

Fig. 29. Recruitment pattern of Frigate mackerel.



Filename : ST

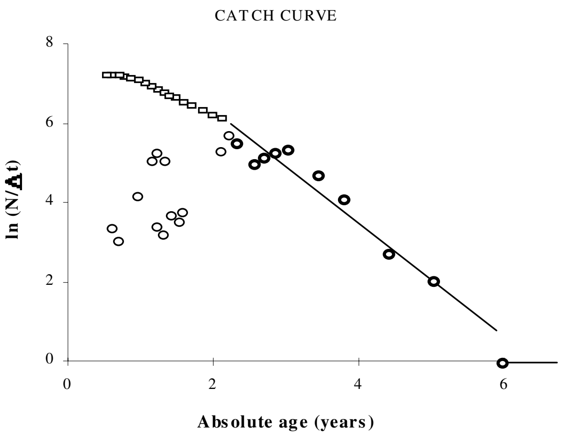
Growth Parameters
Loo : 77.66 cm K : 0.30
C : 0.00 WP : 0.00
t0 : -0.51

Cutoff length (L') = 53.000
Mean length (from L') = 58.856
Z from catch curve = 0.87
Z entered = 0.87
Natural mortality
(M, for T=28°C) = 0.62
M value used = 0.62
Fishing mortality (F=Z-M)
(Z & M as entered) = 0.25
exploit. Rate (E=F/Z) = 0.29

Species name :
Kasuwonus pelamis
Other file identifiers :
Skipjack tuna

Range of length observations :
27 – 71 cm
Class size :
1 cm

Fig. 30. Total, natural and fishing mortality of Skipjack tuna.



Filename : FRIMAC

Growth Parameters
Loo : 49.02 cm K : 0.43
C : 0.00 WP : 0.00
t0 : -0.867

Cutoff length (L') = 37.000
Mean length (from L') = 40.488
Z from catch curve = 1.44
Z entered = 1.44
Natural mortality
(M, for T=28°C) = 0.89
M value used = 0.67
Fishing mortality (F=Z-M)
(Z & M as entered) = 0.77
exploit. Rate (E=F/Z) = 0.53

Species name :
Auxis thazard
Other file identifiers :
Frigate mackerel

Range of length observations :
24 - 47 cm
Class size :
1 cm

Fig. 31. Total, natural and fishing mortality of Frigate mackerel.

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The Systematics and Distribution of Oceanic Cephalopods in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

Oceanic cephalopod exploration was conducted by M.V. SEAFDEC in Vietnamese waters during 21 April- 5 June 1999, as part of SEAFDEC's collaborative research survey on the fisheries resources of the South China Sea Area IV (Vietnamese waters) with focus on tuna, oceanic squid and other highly migratory species. Squid fishing activities were conducted in 10 stations, ranging in the depth from 600-4000 m, using four automatic jigging machines at night. The purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) was the only species caught throughout the fishing area. Diagnosis and distribution of the species in the study area are reported.

Key words: South China Sea; Vietnam; systematics; oceanic squids; squid jigging; Ommastrephidae; *Sthenoteuthis oualaniensis*

Introduction

Oceanic squids spend their entire life span in the open ocean. More than 200 oceanic species have been described from the world oceans (Worms, 1983). Of these, some species are commercially and potentially important. However, most of the oceanic squid resources in the South China Sea are poorly known. Vietnamese waters comprise a vast area of oceanic waters (depth > 200 m) in the eastern part of the country. The area offers vast potential for future harvesting of oceanic squids. A survey on oceanic squid, therefore, has been launched in this area as part of the SEAFDEC Interdepartmental Collaborative Research Program in the South China Sea, area IV (Vietnamese waters). Main objectives of the program are to collect and analyze data and information necessary for the management of fishery resources and protection of the environment through collaborative research among member countries and organizations concerned.

The aim of this study is to determine the species and distribution of the oceanic squids in Vietnamese waters based on automatic squid jigging machines. This research will provide information for the management of fishery resources in this area.

Materials and Methods

The study area is in the northern part of South China Sea (Area IV, Vietnamese waters). The area covers from latitude 7°N to 21°N and longitude 103°E to 112°E (Fig.1). A total of 10 stations for fishing surveys on the oceanic cephalopods were carried out using a squid jigging machine by M.V.

SEAFDEC during 21 April to 5 June 1999 in the study area. Descriptions of fishing method are described in Siriraksophon *et al.* (2000). Squid samples were preserved in 10% neutralized formalin. The fixed-specimens were later transferred to 75% ethyl alcohol for permanent storage.

All collected specimens were examined, and measurements, body proportions, counts and indices were obtained from the whole body as described by Roper & Voss (1983). Measurements are in millimeters (mm). Indices are expressed as percentage of dorsal mantle length and are denoted by the final initial I, *e.g.* HWI = HW/ML x 100. Diagram and summary of measurements, counts and indices are shown in Fig. 2 and Table 1.

Voucher material is lodged in the Fisheries Museum of Natural History, Department of Fisheries, Chatuchak, Bangkok 10900, Thailand.

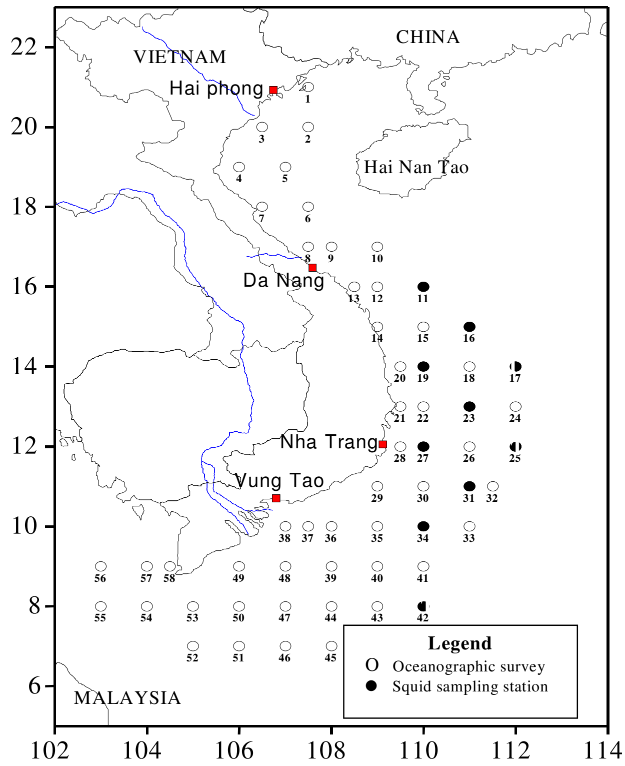

Fig. 1. Squid survey station in the Vietnamese waters.

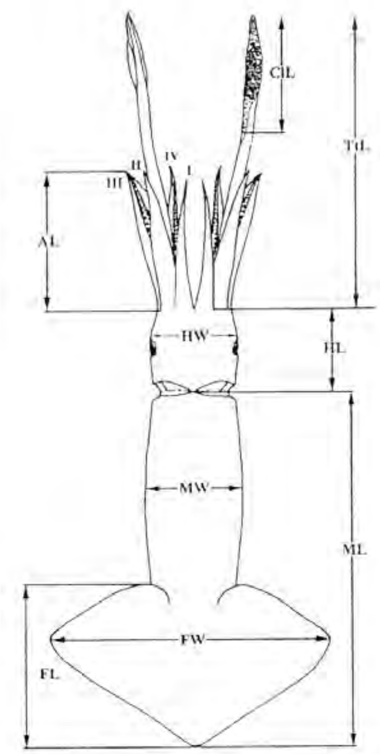

Fig. 2. Diagrammatic illustrations of the measurements in squids.Dosal view, AL=Arm Length, CIL = Club Length, FL=Fin Length, FW = Fin Width, HL=Head Length,HW= Head Width, ML=Mantle Width, MW = Mantle Width, I= dorsal arm, II= dorso- Lateral arm, III= ventro-laterral arm, IV= ventral arm, TtL = Tenta-cular Length.

Table 1. Definition of counts, measurements and indices.

ML	Mantle Length	Dorsal mantle length measured from the anterior most point of the mantle to the posterior tip.
MWI	Mantle Width Index	Greatest straight-line (dorsal width of mantle as a percentage of mantle length).
FLI	Fin Length Index	Greatest length of fins as a percentage of mantle length.
FWI	Fin Width Index	Greatest width (dorsally) across both fins as a percentage of mantle length.
HWI	Head Width Index	Greatest width of head at level of eyes as a % of mantle length.
HLI	Head Length Index	Dorsal length of head measured from point of fusion of dorsal arms to anterior tip of nuchal locking-cartilage as a percentage of mantle length.
ALI	Arm Length Index	Length of each designated arm (I, II, III, IV) measured from first basal (proximal most) sucker to the tip of arm as a percentage of mantle length.
TtLI	Tentacle Length Index	Total length of tentacular stalk and club as a percentage of mantle length.
ClLI	Club Length Index	Length of designated club as a percentage of mantle length.

Systematic Account

Family Ommastrephidae
Subfamily Ommastrephinae
Sthenoteuthis Verrill, 1880

Diagnosis: -Funnel groove with foveola and side pockets, dactylus of tentacular club with tetraserial suckers, large dorsal light organ may be present anteriorly on mantle in larger individuals; either left or right arm IV hectocotylized.

Sthenoteuthis oualaniensis (Lesson, 1830)
Fig.3 A-D

Loligo oualaniensis –Lesson, 1830: 240, pl. I, fig.2.
Ommastrephes oualaniensis –Steenstrup, 1880: 76
Symplectoteuthis oualaniensis –Pfeffer, 1900:180; -Pfeffer, 1912: 502, pl. 40-41, 42, figs.1-4; -Sasaki, 1929: 296, pl. xxx, fig.8, textfigs. 176-178; -Adam, 1954: 157; -Voss, 1963:134, fig. 29; -Voss & Williamson, 1971:74, pl. 23, figs. 20,27,30; -Roper *et al.*, 1984:180;
Sthenoteuthis oualaniensis –Zuev *et al.,* 1975:1475; -Nateewathana 1997: 453-464, figs. 2-5; Nateewathana *et al*. 2000: 84-93, figs.5A-D

Material Examined : A total of 99 sampling material from 10 stations were measured and examined (Table 2-11).
Description: Drawing figures of the species followed Nateewathana *et al*. (2000). Mantle (Fig.3A-a)

long, muscular and cylindrical up to the point of origin of fins and tapers abruptly to a narrow point at the posterior end (Fig.3A-b). Dorsal margin is slightly produced in the middle. Fins short, muscular and broad with convex anterior margin. Head (Fig.3B-a) large and as wide as mantle and bears comparatively short arms. Funnel short, compact and set in a deep pit present on the ventral side of the head; foveola (Fig.3B-b) with 7-9 longitudinal folds in the central pocket and 3-5 lateral pockets on either side. Funnel locking apparatus inverted T-shaped and fused in its middle portion with the mantle groove (Fig.3B-c).

Arms large, strong in the order III.II.IV.I and compressed with the third pair strongly keeled. Arm sucker biserial; the protecting membranes have prominent trabeculae; the larger arm suckers are provided with about 7-12 sharp teeth around the entire rim of the horny rings (Fig.3B-d). Left arm IV in males thick, longer than the right arm and hectocotylized (Fig.3C-a). Two rows of 14-15 suckers protected by flap-like membranes present on the basal portion of the hectocotylized arm. Suckers and papillae absent on about one half of its distal part. A series of pits present in a single row along the base of the protective membranes (Fig.3C-b). Tentacles are short, muscular and laterally compressed. Clubs (Fig.3C-c) small, slightly expanded; suckers (Fig.3C-d) quadriserial with the inner rows on the manus larger. Larger suckers of the club bear about 20 sharp teeth on the rims of which four are larger and located one in each quadrant. Gladius (Fig.3C-e) thin and very slender; rachis stout anteriorly, uniformly narrowing to the posterior tip, and with median rib and two marginal ribs along the edges; posterior end with a small vane about one-seventh of the total gladius length. Beaks (Fig.3D-a&b)strong. Radula (Fig.3B-e) with seven transverse rows of teeth; rachidian tooth tricuspid; first lateral tooth bicuspid, outer cusp small; second and lateral marginal teeth single and slightly curved. Spermatophore (Fig.3D-c,d&e) long and small, sperm mass comprises 50-60% of total length; cement body oval, slightly constricted at the posterior quarter of the body; ejaculatory apparatus coiled at oral end.

Head, dorsal mantle, fins and arms are uniformly of chestnut brown colour. An oval photophoric patch present on the antero-dorsal surface of mantle.

Distribution: Tropical and subtropical seas of the Indo-Pacific region.

Remarks: A unique character of *S. oualaniensis* is mantle element of T-shaped locking apparatus curved with an anterior bifurcation, fused to funnel element along the posterior third of the longitudinal groove.

The species has been considered as a single species by Nesis (1993). It was first described as *Loligo oualaniensis* by Lesson (1830). Later Pfeffer (1900) transferred to genus *Ommastrephes*, and subsequently to genus *Symplectoteuthis*. Finally, *Symplectoteuthis oualaniensis* (Lesson, 1830) and *Ommastrephes pteropus* Steenstrup, 1855 were united in the genus *Sthenoteuthis* (Zuev *et al*. 1975; Roeleveld 1982). The typical of the genus is the funnel and mantle cartilage fused at a single point. At present, the genus contains two species; *S. oualaniensis* and *S. pteropus*. The first species is distributed in the Indo-West pacific, while the latter lives in the Atlantic Ocean (Nesis, 1987).

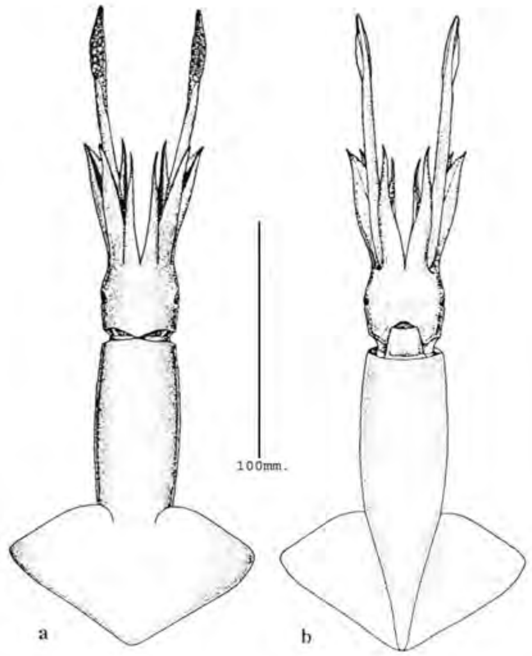

Fig. 3A. *Sthenoteuthis oualaniensis.* a, dorsal view and b, ventral view.

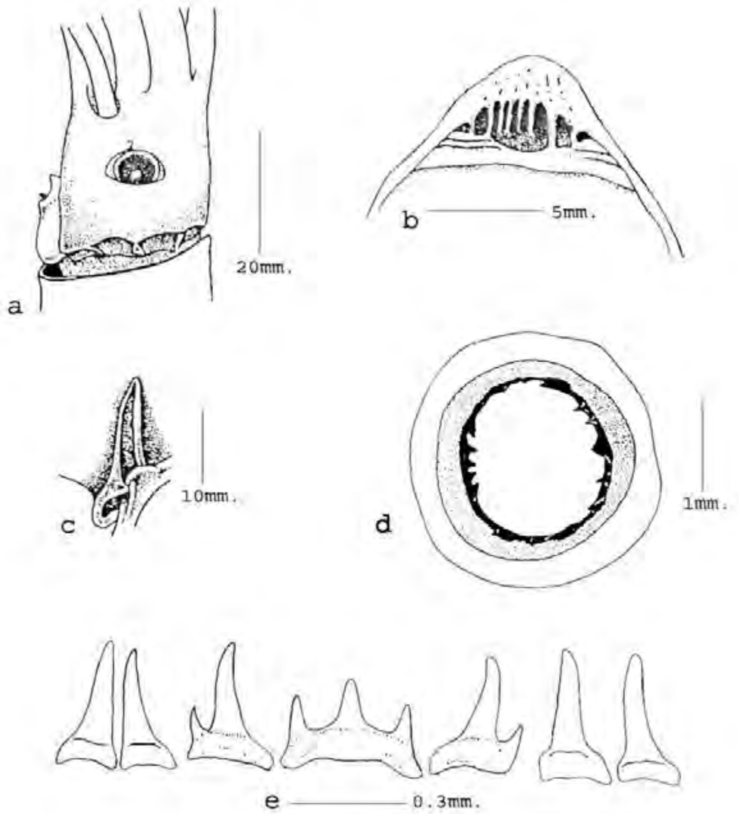

Fig. 3B. *Sthenoteuthis oualaniensis*. a, head. b, foveola and side pockets. c, funnel and mantle locking cartilaages., d, arm sucker. e, radula.

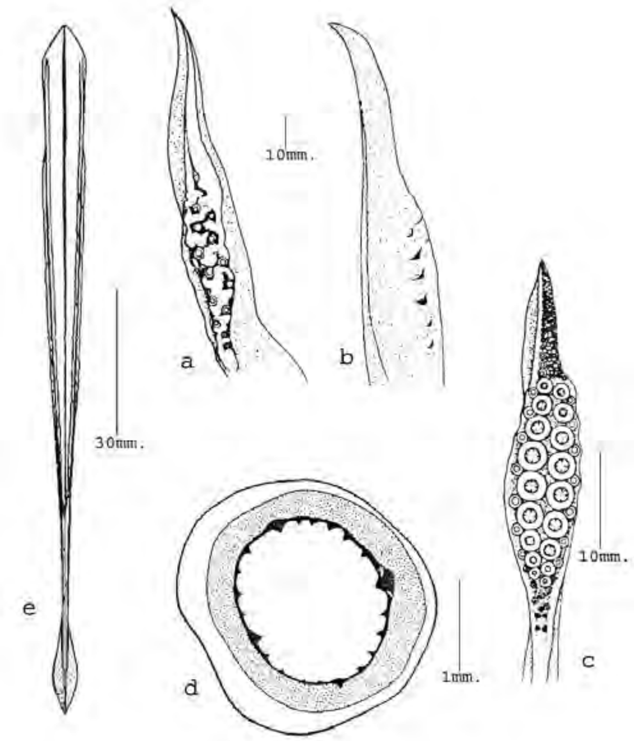

Fig. 3C. *Sthenoteuthis oualaniensis.* a, hectocotylised arm. b, lateral view of hectocotylised arm showing series of pits. c, tentaculaar club. d, club suckers. e, gladius.

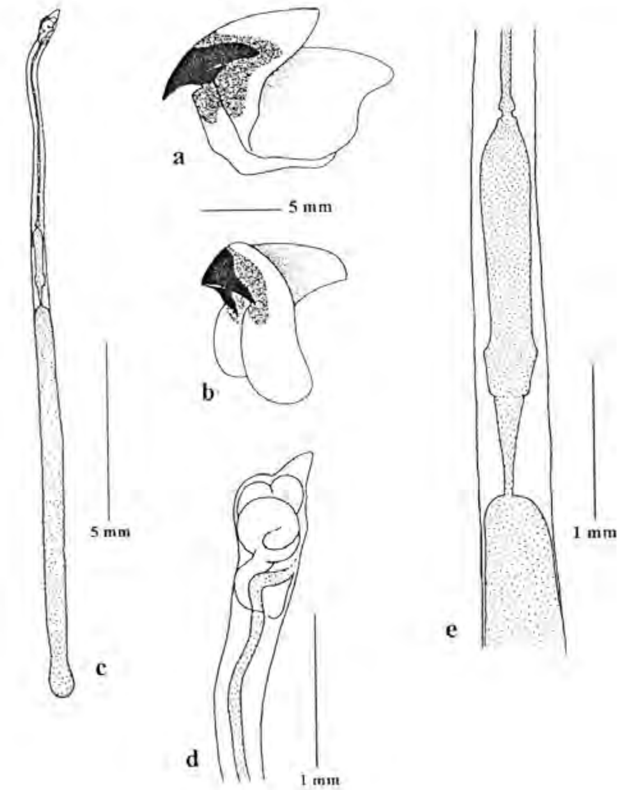

Fig. 3D. *Sthenoteuthis oualaniensis.* a., upper beak. b, lower beak. c, spermatophore. d, enlargement of oral cap. e, enlargement of cement body.

Table 2. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 11. Lat. 16º N, Long. 110ºE. M.V.SEAFDEC, automatic squid jigging machines, depth 844 m. 3 May 1999.

	MALES				FEMALES			
Index	**n**	**mean**	**s.d (n-1)**	**Range**	**n**	**mean**	**s.d. (n-1)**	**Range**
ML(mm)	2	132.9	10.2	125.7-140.1	11	143.2	27.4	107.3-182.0
MWI	2	23.6	2.6	21.8-25.5	11	23.4	1.4	21.8-25.6
HLI	2	22.4	2.7	20.5-24.3	11	21.3	2.7	16.9-26.1
HWI	2	20.9	0.5	20.6-21.3	11	20.8	1.7	18.8-24.0
FLI	2	47.2	0.0	47.2-47.2	11	44.9	2.4	40.5-48.1
FWI	2	86.1	1.3	85.2-87.1	11	74.1	3.2	68.3-79.4
$AL_I I$	2	36.6	1.7	35.4-37.8	11	36.1	3.8	28.2-40.6
$AL_{II} I$	2	42.0	5.6	38.1-46.0	11	42.1	5.7	29.3-49.2
$AL_{III} I$	2	45.1	2.8	43.2-47.1	11	43.6	4.0	35.2-48.5
$AL_{IV} I$	2	42.9	1.3	42.0-43.8	11	41.2	4.9	31.4-47.3
TtLI	2	67.5	23.5	50.9-84.2	11	91.1	15.9	70.0-117.0
ClLI	2	35.9	1.2	35.1-36.8	11	33.9	5.0	24.9-42.2

Table 3. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis.* Station 16. Lat. 15ºN, Long. 111ºE, M.V. SEAFDEC, automatic squid jigging machines, depth 1,277 m. 7 May 1999.

	MALES				FEMALES			
Index	**n**	**mean**	**s.d (n-1)**	**Range**	**n**	**mean**	**s.d. (n-1)**	**Range**
ML(mm)	6	122.1	8.0	110.7-129.8	5	115.5	12.1	104.7-131.1
MWI	6	20.4	1.0	19.5-22.4	5	23.1	2.4	19.8-25.5
HLI	6	20.1	2.2	17.2-22.9	5	21.5	0.9	20.1-22.4
HWI	6	20.7	0.4	18.5-24.0	5	19.7	1.4	18.2-21.7
FLI	6	44.1	1.0	42.9-45.8	5	44.7	2.1	41.2-46.4
FWI	6	75.0	4.2	70.6-80.8	5	76.1	13.4	64.6-98.3
$AL_I I$	6	34.0	3.3	30.1-39.0	5	31.5	3.4	26.2-34.9
$AL_{II} I$	6	37.6	1.5	36.0-39.7	5	37.7	1.1	36.8-39.4
$AL_{III} I$	6	41.3	1.6	39.0-43.4	5	40.0	3.0	36.3-44.5
$AL_{IV} I$	6	38.5	1.5	37.0-41.3	5	38.9	3.1	35.5-43.8
TtLI	6	82.2	12.0	66.1-94.7	5	76.9	10.9	69.1-95.4
ClLI	6	32.0	1.5	29.8-34.0	5	28.8	2.8	25.8-32.5

Table 4. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 17. Lat. 14ºN, Long. 112ºE. M.V.SEAFDEC, automatic squid jigging machines, depth 1,207 m. 8 May 1999.

	MALES				FEMALES			
Index	**n**	**mean**	**s.d (n-1)**	**Range**	**n**	**mean**	**s.d. (n-1)**	**Range**
ML(mm)	5	129.3	11.3	118.8-147.4	7	157.7	27.0	115.2-177.0
MWI	5	22.4	1.4	20.7-24.0	7	22.7	2.0	20.0-25.2
HLI	5	23.1	1.8	20.7-25.3	7	22.6	1.7	20.3-25.1
HWI	5	23.7	2.4	21.0-25.6	7	23.7	1.5	21.8-26.2
FLI	5	45.1	1.2	44.1-46.9	7	45.1	1.5	43.1-47.3
FWI	5	77.8	2.6	74.0-80.0	7	74.1	2.0	71.8-77.5
$AL_I I$	5	39.0	3.0	35.0-42.0	7	38.6	2.8	34.3-42.2
$AL_{II} I$	5	46.4	2.5	43.2-48.9	7	45.3	3.9	39.9-51.1
$AL_{III} I$	5	49.2	4.0	43.4-54.2	7	45.5	5.4	35.8-51.6
$AL_{IV} I$	5	48.3	3.9	42.0-52.9	7	46.0	2.5	41.4-48.9
TtLI	5	109.6	7.4	101.1-117.4	6	101.8	46.0	96.6-138.4
ClLI	5	36.7	2.3	34.5-39.2	6	36.6	3.3	33.0-41.7

Table 5. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 19. Lat. 14° N, Long. 110°E. M.V.SEAFDEC, automatic squid jigging machines, depth 1,000 m. 10 May 1999.

Index	n	value	n	mean	s.d. (n-1)	Range
ML(mm)	1	126.7	5	158.8	28.8	143.6-210.2
MWI	1	21.6	5	23.4	3.2	19.3-26.7
HLI	1	22.7	5	21.4	0.8	20.1-22.4
HWI	1	23.4	5	20.7	2.9	16.9-23.9
FLI	1	45.5	5	46.9	1.1	45.5-47.9
FWI	1	77.3	5	78.3	5.4	71.6-84.3
$AL_{I}I$	1	35.2	5	38.1	2.6	35.6-41.2
$AL_{II}I$	1	42.5	5	41.3	3.7	35.7-45.1
$AL_{III}I$	1	48.5	5	45.2	7.0	34.2-54.0
$AL_{IV}I$	1	46.9	5	45.5	4.2	41.5-52.0
TtLI	1	108.0	5	104.1	24.1	77.9-139.3
ClLI	1	36.2	5	34.2	4.5	28.9-38.8

Table 6. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 23. Lat. 13°N, Long. 111°E. M.V.SEAFDEC, automatic squid jigging machines, depth 2,703 m 12 May 1999.

	MALES				FEMALES			
Index	n	mean	s.d (n-1)	Range	n	mean	s.d. (n-1)	Range
ML(mm)	6	120.5	4.5	115.6-128.0	6	145.5	43.1	112.3-210.3
MWI	6	24.4	1.4	22.6-26.2	6	24.7	2.1	22.2-27.3
HLI	6	22.6	1.3	20.8-24.2	6	23.3	1.3	21.8-25.0
HWI	6	22.3	1.9	19.8-25.3	6	23.2	1.2	21.6-24.7
FLI	6	45.0	1.2	43.4-47.0	6	45.2	1.1	43.6-46.3
FWI	6	82.1	3.4	77.9-87.2	6	81.5	1.7	78.8-83.8
$AL_{I}I$	6	39.5	4.9	35.3-48.7	6	39.1	2.4	34.5-40.9
$AL_{II}I$	6	45.7	3.1	42.7-50.2	6	46.5	1.5	44.7-48.8
$AL_{III}I$	6	48.1	4.7	43.4-54.5	6	49.1	2.1	46.2-52.0
$AL_{IV}I$	6	46.6	5.0	41.9-55.1	6	47.2	3.6	42.6-53.0
TtLI	6	97.5	32.4	52.1-140.6	6	113.2	19.6	85.6-138.0
ClLI	6	30.3	6.5	17.6-35.5	6	38.4	6.7	27.9-47.5

Table 7. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*.Station 25. Lat. 12° N, Long. 112°E. M.V.SEAFDEC, automatic squid jigging machines, depth 4,412 m. 13 May 1999.

	MALES				FEMALES			
Index	n	mean	s.d (n-1)	Range	n	mean	s.d. (n-1)	Range
ML(mm)	4	125.8	11.5	116.3-142.5	6	131.7	19.1	112.1-160.9
MWI	4	24.7	4.3	21.3-30.8	6	26.5	4.8	20.6-33.9
HLI	4	24.3	1.4	22.7-25.7	6	21.3	2.1	17.8-23.8
HWI	4	23.1	2.6	19.4-25.5	6	24.0	2.2	20.5-26.8
FLI	4	44.0	2.4	41.5-46.5	6	46.2	2.2	43.5-49.3
FWI	4	76.3	4.2	70.9-80.6	6	77.6	5.7	67.8-82.7
$AL_{I}I$	4	39.2	1.4	37.4-40.6	6	37.8	3.7	33.8-43.7
$AL_{II}I$	4	44.7	1.3	42.9-46.0	6	44.4	4.8	40.6-53.6
$AL_{III}I$	4	46.9	5.0	42.4-53.9	6	46.8	2.6	43.2-50.1
$AL_{IV}I$	4	47.3	2.4	44.5-50.0	6	45.2	3.7	40.6-51.8
TtLI	4	114.6	14.5	92.9-123.9	6	118.5	14.0	107.9-143.3
ClLI	4	35.8	2.1	34.1-38.9	6	37.6	4.9	32.0-46.1

Table 8. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 27. Lat. 12º N, Long. 110ºE. M.V.SEAFDEC, automatic squid jigging machines, depth 883 m. 14 May 1999.

	MALES				FEMALES			
Index	**n**	**mean**	**s.d (n-1)**	**Range**	**n**	**mean**	**s.d. (n-1)**	**Range**
ML(mm)	8	121.9	8.9	111.6-134.4	6	120.9	14.3	111.1-149.5
MWI	8	23.0	2.0	21.3-26.6	6	23.1	1.6	20.5-25.2
HLI	8	22.4	1.8	20.0-25.6	6	20.7	1.8	18.6-23.2
HWI	8	22.7	1.6	20.0-24.6	6	21.6	1.5	19.7-23.9
FLI	8	45.4	1.1	43.5-46.6	6	43.4	1.7	41.6-45.9
FWI	8	78.9	3.7	73.5-84.4	6	75.4	5.7	65.8-83.7
$AL_{I}I$	8	35.2	3.4	32.4-39.5	6	33.8	3.3	30.2-37.0
$AL_{II}I$	8	40.7	5.8	29.5-47.6	6	38.6	3.1	33.7-42.6
$AL_{III}I$	8	43.8	3.4	38.3-47.7	6	41.2	3.0	37.8-45.2
$AL_{IV}I$	8	42.2	4.4	35.2-48.3	6	41.1	3.8	36.4-46.0
TtLI	8	96.3	20.9	67.4-125.1	6	89.5	15.4	70.5-110.1
ClLI	8	30.0	2.8	27.3-33.9	6	32.0	7.0	22.5-43.3

Table 9. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 31. Lat. 11º N, Long. 111ºE. M.V.SEAFDEC, automatic squid jigging machines, depth 2,940 m. 18 May 1999.

	MALE		FEMALES			
Index	**n**	**value**	**n**	**mean**	**s.d. (n-1)**	**Range**
ML(mm)	1	124.1	3	136.6	55.1	102.9-200.2
MWI	1	24.0	3	20.3	3.7	17.1-24.4
HLI	1	22.4	3	22.2	1.3	20.8-23.5
HWI	1	26.3	3	21.7	1.9	19.6-23.4
FLI	1	53.3	3	43.7	4.4	39.6-48.4
FWI	1	74.0	3	65.5	7.8	60.9-74.5
$AL_{I}I$	1	39.5	3	31.3	2.8	29.3-34.5
$AL_{II}I$	1	44.7	3	37.2	4.9	31.7-41.3
$AL_{III}I$	1	45.3	3	39.3	3.9	36.7-43.8
$AL_{IV}I$	1	54.0	3	38.9	3.3	36.5-42.7
TtLI	1	100.8	3	101.5	11.9	93.1-109.9
ClLI	1	30.5	3	35.9	15.1	25.2-46.6

Table 10. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 34. Lat. 10º N, Long. 110ºE. M.V.SEAFDEC, automatic squid jigging machines, depth 1,640 m. 22 May 1999.

	MALES				FEMALES			
Index	**n**	**mean**	**s.d (n-1)**	**Range**	**n**	**mean**	**s.d. (n-1)**	**Range**
ML(mm)	7	125.8	6.9	117.6-138.8	5	116.4	26.2	90.2-160.0
MWI	7	22.8	1.7	20.6-25.6	5	21.5	3.0	18.5-26.3
HLI	7	23.3	2.8	19.6-27.5	5	22.1	2.9	18.7-26.3
HWI	7	22.1	1.6	20.0-24.0	5	20.9	1.9	18.2-23.6
FLI	7	45.9	2.0	43.7-48.6	5	42.1	2.2	40.0-45.9
FWI	7	77.9	5.3	70.6-84.3	5	68.7	6.2	60.7-77.8
$AL_{I}I$	7	37.3	2.9	32.4-40.5	5	35.5	5.5	29.7-44.4
$AL_{II}I$	7	43.3	1.9	39.8-45.2	5	43.4	9.4	36.9-58.6
$AL_{III}I$	7	48.2	4.2	41.8-52.6	5	44.5	8.6	33.8-55.4
$AL_{IV}I$	7	46.3	4.0	42.0-51.9	5	42.6	5.4	35.7-48.2
TtLI	6	101.0	18.3	75.0-128.0	4	107.8	13.9	93.1-122.5
ClLI	6	33.6	3.3	30.7-38.2	4	31.0	2.9	28.5-35.1

Table 11. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station 42 Lat. 8° N, Long. 110ºE. M.V.SEAFDEC, automatic squid jigging machines, depth 640 m. 26 May 1999.

	MALES				FEMALES			
Index	No sampling specimens				n	mean	s.d. (n-1)	Range
ML(mm)	-	-	-	-	5	130.4	7.8	123.8-144.0
MWI	-	-	-	-	5	23.0	2.3	20.4-25.5
HLI	-	-	-	-	5	22.7	2.8	19.5-26.6
HWI	-	-	-	-	5	22.1	2.8	19.1-25.2
FLI	-	-	-	-	5	45.5	2.2	41.8-47.1
FWI	-	-	-	-	5	74.5	3.8	68.2-77.8
AL_{I}I	-	-	-	-	5	34.4	2.9	31.6-38.4
AL_{II}I	-	-	-	-	5	41.2	2.7	38.2-44.9
AL_{III}I	-	-	-	-	5	43.0	5.4	37.6-51.4
AL_{IV}I	-	-	-	-	5	41.9	4.2	36.4-46.3
TtLI	-	-	-	-	5	93.9	26.2	63.8-117.4
ClLI	-	-	-	-	5	32.3	6.7	21.0-38.5

Discussion

Species composition of cephalopods in the Vietnamese waters at the 100 - 1300 m depth has been reported by Duc (1997). The list comprises of 69 species belonging to 24 genera, 14 families and 3 orders. Five species of the family Ommastrephidae are recorded *i.e. Symplectoteuthis (=Sthenoteuthis) oualaniensis* (Lesson, 1830), *Nototodarus sloani* (Gray, 1849), *N. hawaiiensis* (Berry, 1912), *Ornithoteuthis volatilis* (Sasaki, 1915) and *Todarodes pacificus* Steenstrup, 1880. The two genera, *Nototodarus* and *Todarodes* were mainly caught in the depth between 300-500 m, while *Sthenoteuthis* and *Ornithoteuthis* were caught in the deeper water between 500-700 m depth. Since during the fishing operations of 10 stations in the present survey, the depth of sampling area is between 600-4,000 m. It is only one species of the purpleback flying squid, *S. oualaniensis*, was caught by the automatic jigging gears operated at night. The result of the present fishing operations in Vietnamese waters is the same as those in the Western Philippines waters (Labe, 2000; Nateewathana *et al.* 2000; Siriraksophon *et al.* 2000). It is shown that the most abundant oceanic squid sampling by the automatic jigging gear in the South China Sea is *S. oualaniensis*. Besides, other oceanic commercially species recorded in the area were not caught a single specimen during the surveys might be due to many factors, such as type of fishing gear (jigging, trawl, purse seine *etc*.), biology (positive or negative phototactic) and ecology of the squids (depth and environment).

Squids having the following conditions are potentially useful as fisheries resources, especially for human consumption: (1) medium or large-sized, (2) sufficient biomass for sustainable fishing and (3) forming dense aggregation at least some stages of their lives (Okutani, 1995). The above results on the *S. oualaniensis* in the South China Sea seem to satisfy these conditions. However, the real potential of this squid as a fishery resource in this area must be evaluated. Catch-per-unit-effort (CPUE) of the species is provided by Siriraksophon *et al.* (in prep.).

Acknowledgements

We thank scientists and crew of M.V. SEAFDEC for their assistance in collecting various data and biological specimens during the survey.

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Exploration of Oceanic Squid, *Sthenoteuthis oualaniensis* Resources in the South China Sea, Vietnamese Waters

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ABSTRACT

Results from 10 sampling stations show that only one species of the purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) were caught by automatic squid jigging gear. The distribution and abundance of the purpleback flying squid in term of the CPUE (number of squid per line hour) are presented. Over the entire survey area, the CPUEs of the squid were ranged between 0.25-9.11squids per line hour. Drop-off rates for jigs fished on the jigging machines were averaged 3 squid/line hour. Angling depth where the squid were abundant ranged between 50 and 100m.

A total of 1,439 squids were measured and mantle length ranged from 90 to 240 mm. Female dominated the catch, accounting for 80% of the all squid sexed. Males were generally smaller than females. The mantle length composition for males was single peak mode at between 120 and 130 mm. Females also had one peak between 120 and 130 mm mantle length with means of 150.5 mm. A similar length-weight relationship coefficients between male and female was found. The main prey of the squid were crustaceans, fishes (mainly flying fish) and squid.

The squid were found in a warm water mass where the sea temperature ranged from 18˚c to 30˚c at the depth from 125m up to sea surface at night. Good fishing ground of the squid was at 14˚N latitude and 112˚E longitude (9.11 squids/line hour) nearby the existing upwelling at 111˚E longitude.

Keywords: purpleback flying squid, *Sthenoteuthis oualaniensis,*
Vietnamese waters, South China Sea, upwelling,

Introduction

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), which totalled about 2.6 million in 1991 (FAO 1993). The purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson) and flying squid, *Ommastrephes bratamii* are the oceanic squid species of this family which their geographical distribution are found from the Indo-Pacific to Indian Ocean. Voss (1973) speculates a potential of the purpleback flying squid of at least 100,000 metric tons in the Central eastern Pacific. It is on record that the purpleback flying squid are caught commercially in the eastern and southern East China Sea, Taiwan to Okinawa by hook and line with light at night (Tung 1981, Yoshikawa 1978, Okutani and Tung 1978, Okutani 1980). In addition the most promising evidence were for the exploitation of this squid in the eastern Arabian and in the western Pacific Ocean to the eastward of the Philippines and Indonesia

(JAMARC 1977). The studies of this species in the Vietnamese waters were reported in 1998 under the study on Marine Resources in Vietnam by Fuyo Ocean Development & Engineering Co., Ltd. (FODECO, 1998).

In the Southeast Asian region due to the extreme over-exploitation of both demersal and pelagic resources raises suspicion, the "oceanic squid" should be a sustainable catch that might have been taken. It is premature to say much about the feasibility of commercial fishing for these oceanic squid at this stage with the exception of the existing fisheries in the region as found in the Philippines and Vietnam. The availability of these species in terms of likely catch rates for local fisheries is still unknown even though the potential yield is believed to be large. Oceanographic and environmental condition also are need to be examined in connection with the ecological/biological requirements of the squid. In an attempt to come up with this initial jigging fishery on oceanic squid therefore, SEAFDEC has planed to conduct a comparative study on the squid in the region covered the South China Seas and Andaman Sea since 1998 under the SEAFDEC Collaborative Research Program in the South China Sea. The survey will determine distribution and abundance of the oceanic squid in relation to oceanographic conditions and examine the feasibility of harvesting squid with jig gear. This paper reports the experimental fishing on the automatic squid jigging gear which was carried out in the Exclusive Economic Zone of Vietnamese waters by M.V. SEAFDEC.

Materials and Methods

Survey Area

Experimental fishing and oceanographic conditions were conducted by M.V.SEAFDEC in the Exclusive Economic Zone of Vietnamese waters from 29 April to 30 May 1999. All 58 oceanographic survey stations and 10 experimental fishing stations were designed covered from 7˚ to 21˚ N Latitude and from 103˚ to 112˚ E longitude as shown in **Figure 1**.

Fishing Gear

Squid sampling were collected by four automatic squid jigging machines model: **SE-88,** Sanmei, Co. Ltd. that were installed at port side consisting of eight main lines. Each main line was attached to a series of 25 typical japanese squid jigs spaced approximately 1m apart by nylon mono-filament leaders (30 to 50 lb test) as show in **Figure 2**. The jig was lowered to the desired depth and the line moved up and down approximately 1 m in a slow jigging motion until a squid was hooked. Attractive lights were suspended 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. 54 lights or a total of 27kW were used. No sea anchor was used during the fishing operation.

Data Collection

Catch and data effort data were collected at each fishing station. Target species caught were counted and if not all weighted, a sub-sample was weighted and counted to extrapolate the total catch weight at each station. Effort was recorded in line 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.

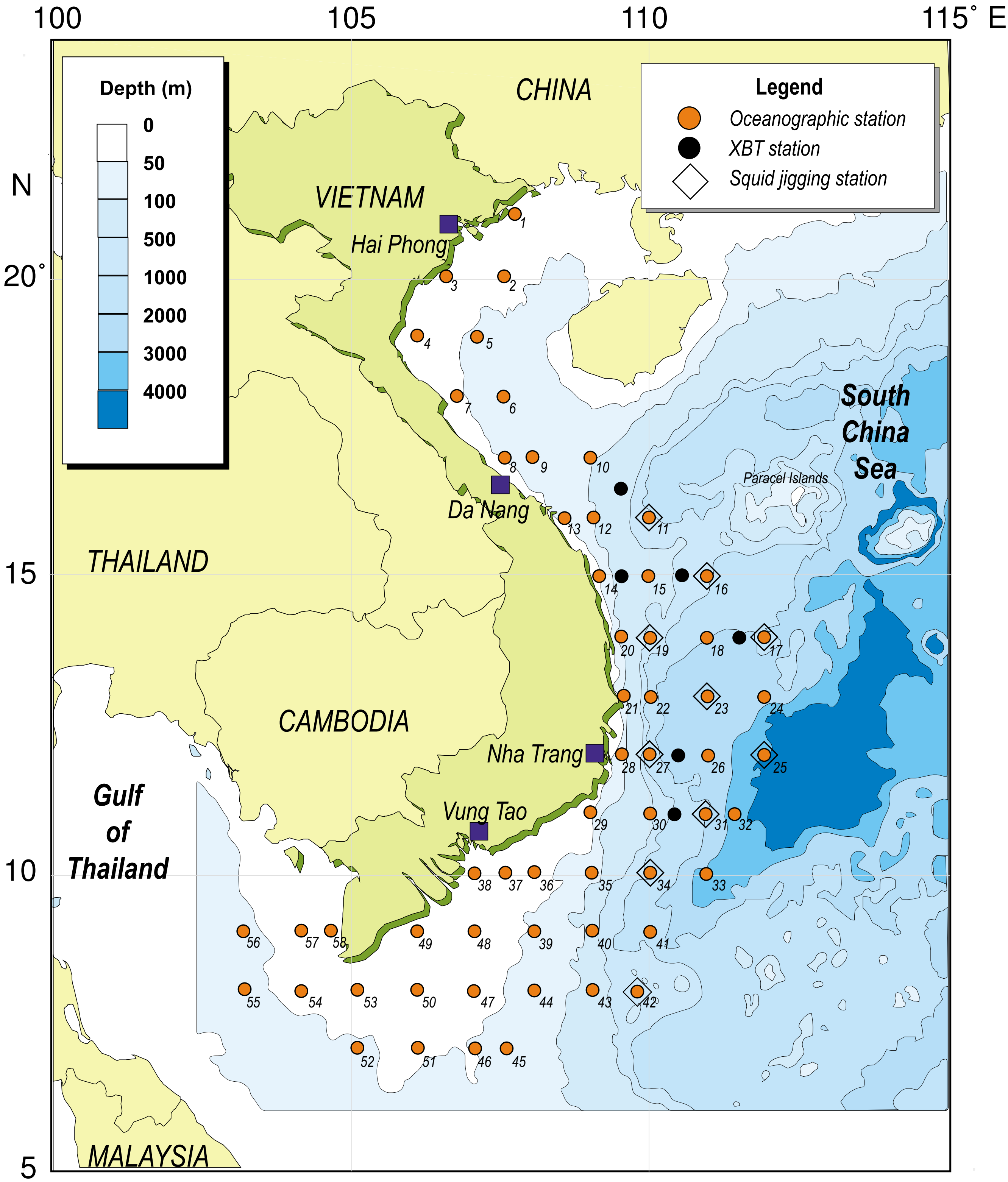
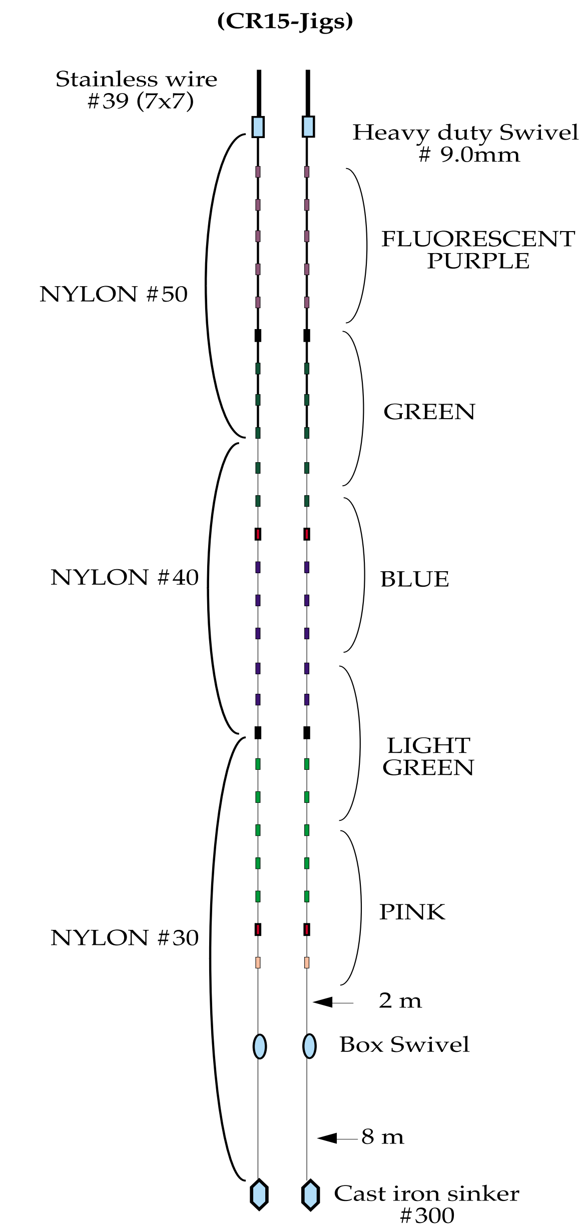
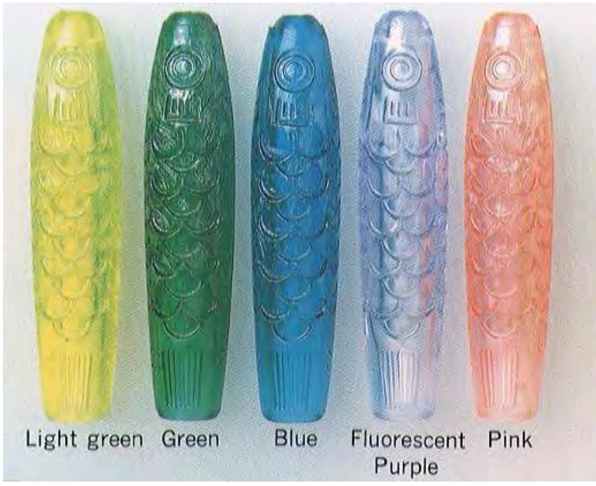
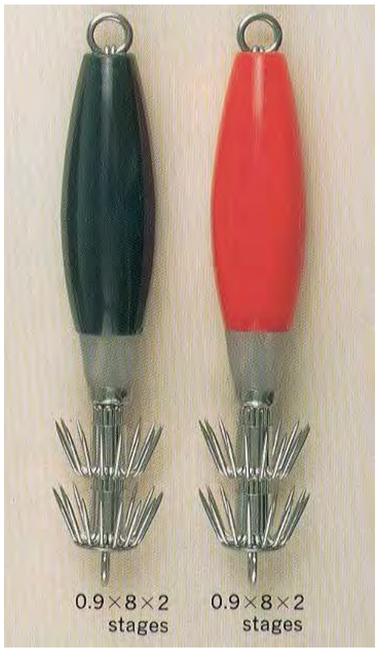


Fig. 1. Fish sampling and oceanographic survey stations in the South China sea, Vietnamese waters during 29 April - 30 May 1999.





CR15 New Kaio Hook



CR20 Bakelite Cased Hook

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

Biological feature information was collected from target species. Length frequencies (mantle length) were recorded in millimetres and weight in grams, Length and weight data were transformed with a log transformation and length-weight relationships calculated using a least squares regression method.

Oceanographic characteristics observations were conducted to clarify the oceanographic features in the Vietnamese waters. The physical oceanographic parameters were measured by the Falmouth Scientific Integrated CTD unit [ICTD], using the sampling rate of 25 Hz. Temperature was corrected to ITS 90 standard. Salinity was calculated by the PSS 78 scale. Dynamic depth relative to the surface was calculated by the EG & G CTD Post-acquisitive Analysis Software at every dbar pressure interval. Continuous oxygen profiles at each station were obtained using the Beckman Polarographic electrode connected to the ICTD unit and the raw data was averaged at every dbar pressure level (The data was calibrated at some stations by the Winkler titration method).

Environmental factors such as wind, current, moon age and other navigational data were observed.

Data Analysis

The vertical profiles of physical oceanographic parameter were prepared along longitude of each Line-1 to 2 for the north-south direction and along latitude of each Line-A to D for the west-east direction as shown in **Figure 3**. Horizontal distribution of each oceanographic parameter are based on the measurements at the 10m depth layer, not the values at the sea surface in order to avoid meteorological disturbance. All vertical profiles and horizontal distribution were analysis and plotted from a data processing application "Transform version 3.4" (Fortner software).

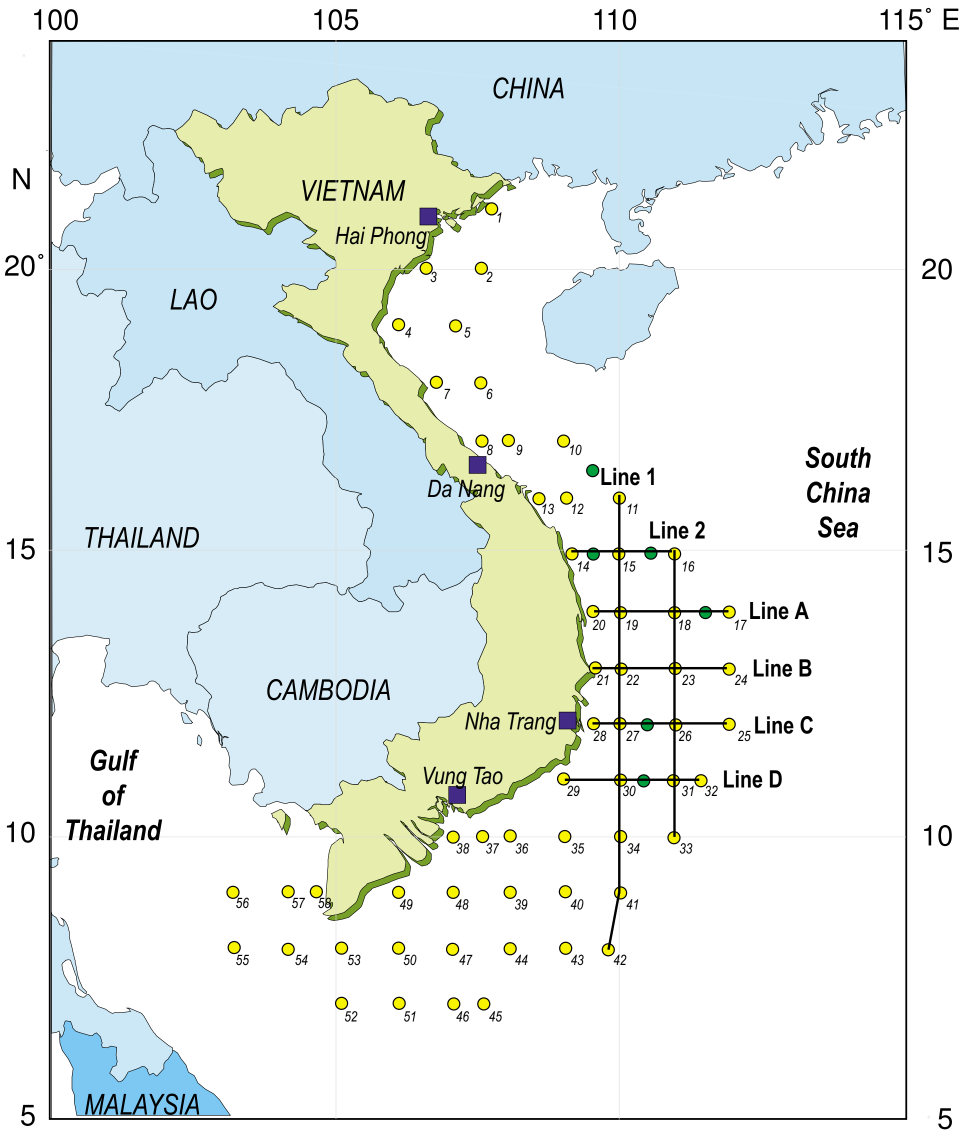


Fig. 3. Lines of cross section

Results and Discussion

Catch

Results from 10 sampling stations of the survey area show that only purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) were caught by the automatic squid jigging gear. This target species was confirmed by Anuwat *et al*. 2000. **Table 1** shows the information of sampling stations and catch results of the purpleback flying 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 averaged 3.08 squids/line hour. Minimum and maximum of the CPUE of the squid were 0.25 and 9.11 squids/line hour, respectively.

Figure 4 shows the CPUEs distribution of the purpleback flying squid in the overall survey area. It is found that high CPUE areas where the squid were caught more than 5 squids per line hour were found at St.#16 and St.#17. Drop-off rates for jigs fished on the jigging machines averaged 3.0 squid/line hour.

Biological characteristics

Sex ratio

Sex ratio of the catch in the Vietnamese waters varied between 68 - 91% by females. The sex ratio observed in the Vietnamese waters and in the western Philippines are close to 80% by females but vary slightly between areas. The sex ratio of catch in the Vietnamese waters and western Philippines were averaged to be 75% and 81% by females, respectively.

Length distribution

Figure 5 shows the length frequency distribution for the purpleback flying squid from each fishing stations. Two sizes of specimens, small and large were found in the survey area. At

Table 1. Information of sampling stations and catch results of the purpleback flying squid in the Vietnamese Waters during May 1999.

Opt. No.	St. No.	Date (d-m)	Location Lat. (N)	Location Long. (E)	Sounding Depth (m)	No. of line	No. of jig	Effort (h)	Total Catch Weight (kg)	Total Catch Number (ind.)	CPUE (ind./line hour)
1	11	3-May	16° 01.4'	109° 58.0'	847	8	200	5.00	12.61	73	1.83
2	16	7-May	15° 02.5'	110° 58.8'	1,230	8	200	6.75	52.59	492	9.11
3	17	8-May	14° 06.5'	111° 56.5'	2,100	8	200	6.50	36.72	262	5.04
4	19	9-May	14° 10.7'	109° 58.9'	653	8	200	4.50	44.48	174	4.83
5	23	11-May	12° 55.3'	111° 00.3'	2,703	8	200	6.00	13.43	87	1.81
6	25	12-May	12° 00.1'	111° 59.5'	4,117	8	200	5.50	20.08	135	3.07
7	27	14-May	11° 46.2'	109° 56.1'	1,734	8	200	4.00	8.37	83	2.59
8	31	18-May	10° 59.7'	111° 01.0'	2,940	8	200	4.50	1.47	9	0.25
9	34	21-May	09° 59.9'	110° 00.3'	1,614	8	200	5.50	8.98	72	1.64
10	42	26-May	08° 01.2'	109° 49.9'	628	8	200	5.00	4.74	25	0.63

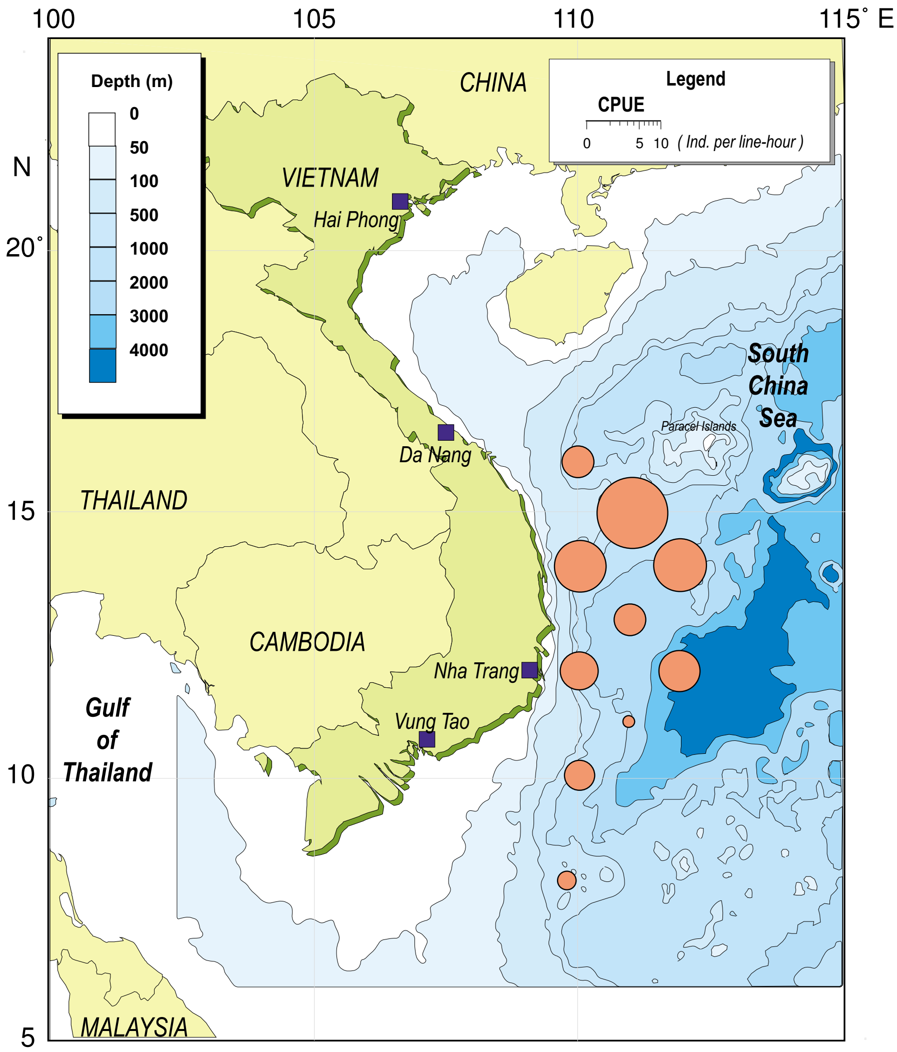


Fig. 4. CPUEs distribution of the purpleback flying squid in the South China sea, Vietnamese waters during 29 April - 30 May 1999.

abundant areas of squid, St.# 16 and St.#17, about 80% of the female specimens were small size squid with the mantle length ranged between 110 and 150mm. About 40% of large squid with the length ranged between 190 and 240mm were found at St.#19. Mantle length size of males were smaller than females.

Figure 6 show the overall mantle length distribution of the squid, a total of 1,439 specimens indicates that their mantle length ranged between 90 and 240mm with a mean length of 147mm and an averaged weight of 170g. Modal length of the squid for both females and males was 130mm with means of 150.5 and 127.5mm, respectively.

Length-weight relationships

Length-weight relationship coefficients for male, female of the purpleback flying squid are presented in **Figure 7**. The coefficients of both male and female squid were about 3.2 and it can be concluded that there are no difference in length-weight relation between them. In the western Philippines waters, the coefficients of both male and female are smaller especially for male is less than 3.

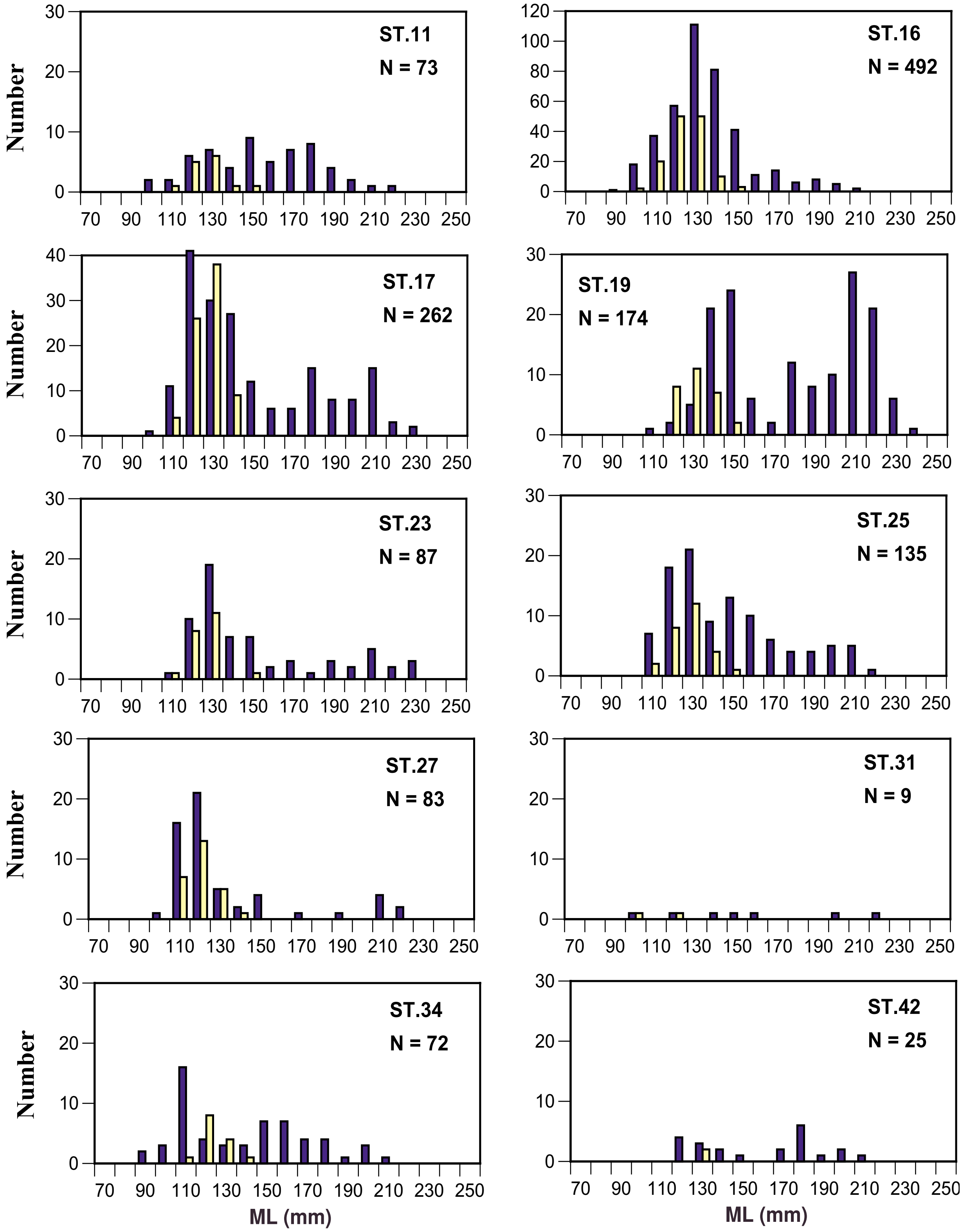


Fig. 5. Mantle length distributions of the males and females purpleback flying squid in each fishing station during May 1999 in the Vietnamese Waters.

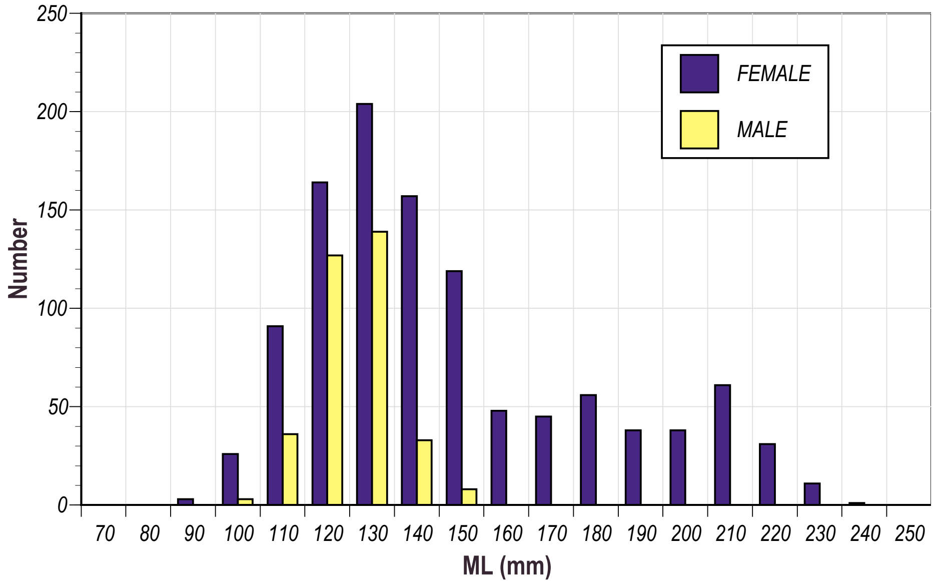


Fig. 6. Overall mantle length distributions of the males and females purpleback flying squid during May 1999 in the Vietnamese Waters.

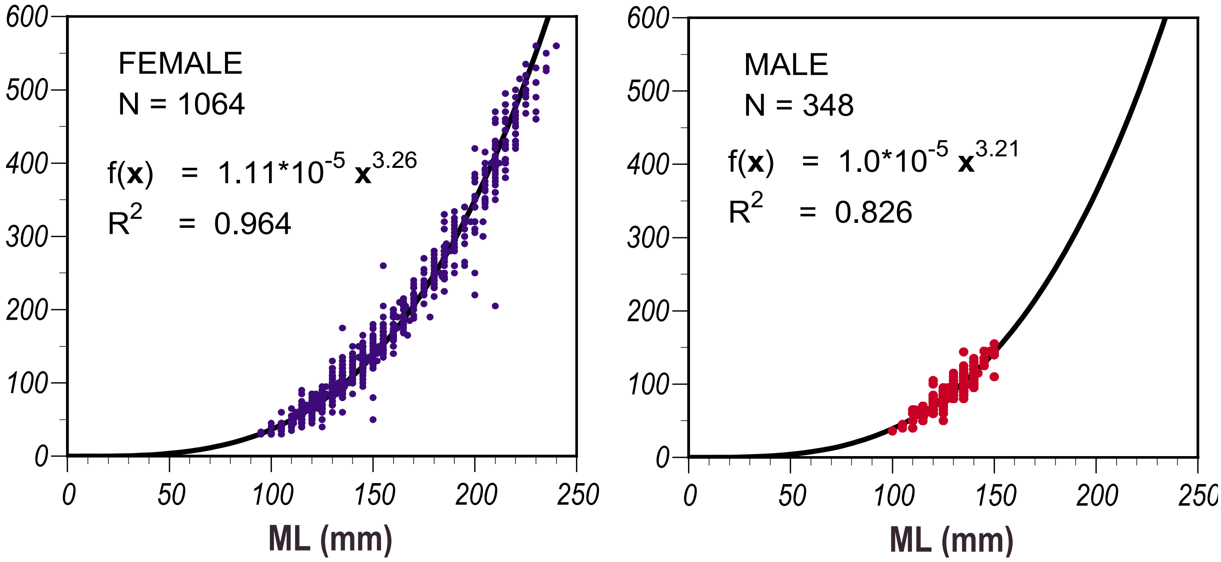


Fig. 7. Length-weight relationships of the males and females purpleback flying squid during May 1999 in the Vietnamese Waters.

Diet and Feeding

The diet and feeding habits of the *S. oualaniensis* are found that the main prey of the squid were crustaceans, fishes (mainly flying fish) and squid (including *S. oualaniensis*). It was observed by sight and echo sounder that the squid have a diet vertical migration, it was found that they migrate upwards to the surface for feeding at dusk and night and downwards to the deep layer before dawn and day time.

Oceanographic conditions

Horizontal distribution of temperature, salinity and fluorescence

Figure 8 show the horizontal profile of temperature at sea surface layer (a) and 100m (b) in the survey area. The water temperature were between 24.04 and 30.15˚c at the surface layer (10m) and between 17.15˚ and 23.15˚c at 100m deep. The figure clearly shows the water temperature was low ranging between 24 and 27˚c in the north and about 30˚c in the south at the surface layer. In the central part of Vietnamese waters where squid samplings were carried out, the waters temperature at surface layer was between 28˚ and 30˚c.

At 14˚N and 111˚E, the cold water of 18˚c was found at 100m deep, while the surrounding temperature were between 20 and 22˚c. This cold waters was 14˚c at 200m deep and 22.9˚c at 50m. It is likely that up-welling existed in this location during the survey period of May or southwestern monsoon season. Fuyo Ocean Development and Engineering (1998) has reported existence of the upwelling in the same area and season.

Figure 9 show the horizontal profiles of salinity (a) and fluoresences (b) at the surface layer. The salinity showed remarkable variation in the sea surface. Low salinity was observed in the north at Station # 1-4 and in the south particularly at the river mouth appeared lowest value of about 31.6 PSS. In the low saline water, it was found that the water temperature was almost homogeneous at around 30˚c in the South and about 25˚c in the north. These indicate the existence of mixing layer. At the central area from Danang to NhaTrang, the salinity of sea surface water were high at about 33.4 PSS. The water temperature variation were observed in the range between 26 and 29˚C.

For the fluorescence values in the sea surface were high and varied between 1.6 and 3.2 V at the station near by shore speciality at the river mouth off Haiphong, VungToa and Danang. In the central area where the squid were caught found that the fluorescence at sea surface was low at about 0.4-0.6 V. It is indicated that the fluorescence at sea surface has no relation to the fishing ground

By the results of water temperature and salinity distribution, it is clearly show that the water of high salinity was transported along the coast of Vietnam to the south due to the northeast monsoon, so that the low saline water from Mekong discharge was rapidly carried away by the strong currents off the coast.

Horizontal distribution of transparency depth and water colour

Figure 10 shows a horizontal profile of sea colour (a) water transparency depth (b) of the survey area. The clear water with water transparency depth values more than 41m were found at Station no.24 off NhaTrang and no.40 off Vuntao. The water transparency depth in the Central area where fishing activities were carried out were ranged between 30 and 38m. Comparisons with the catch results indicate that at the good fishing ground at Station #17 the transparency depth value was deep upto 38m.

Vertical profiles of water temperature and salinity

Figure 11 show the vertical profiles of salinity and temperature varied by depth upto 900m at each fishing stations. In these areas, it clearly show that the mixed layer were very

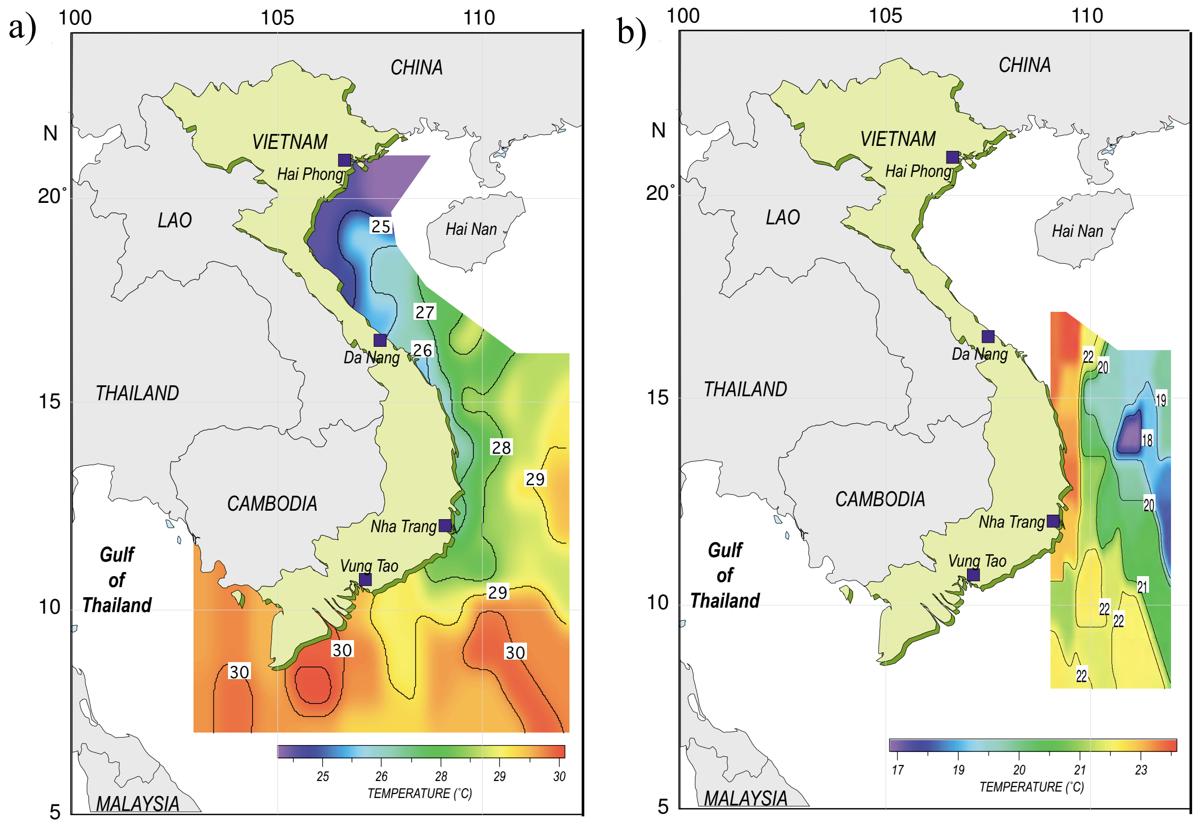


Fig. 8. 30 days synoptic chart of the sea surface temperature (a) and 100m deep (b) of the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

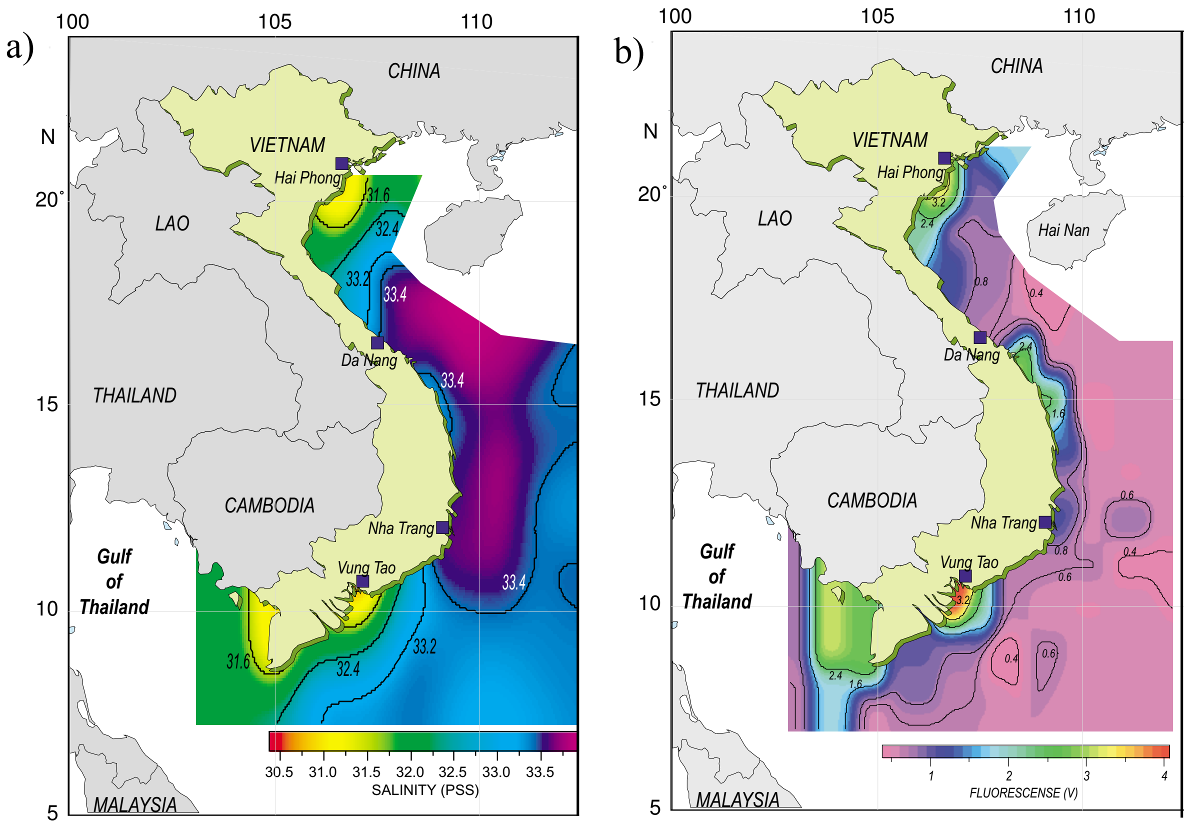


Fig. 9. 30 days synoptic chart of the salinity (a) and fluorescense (b) at the sea surface in the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

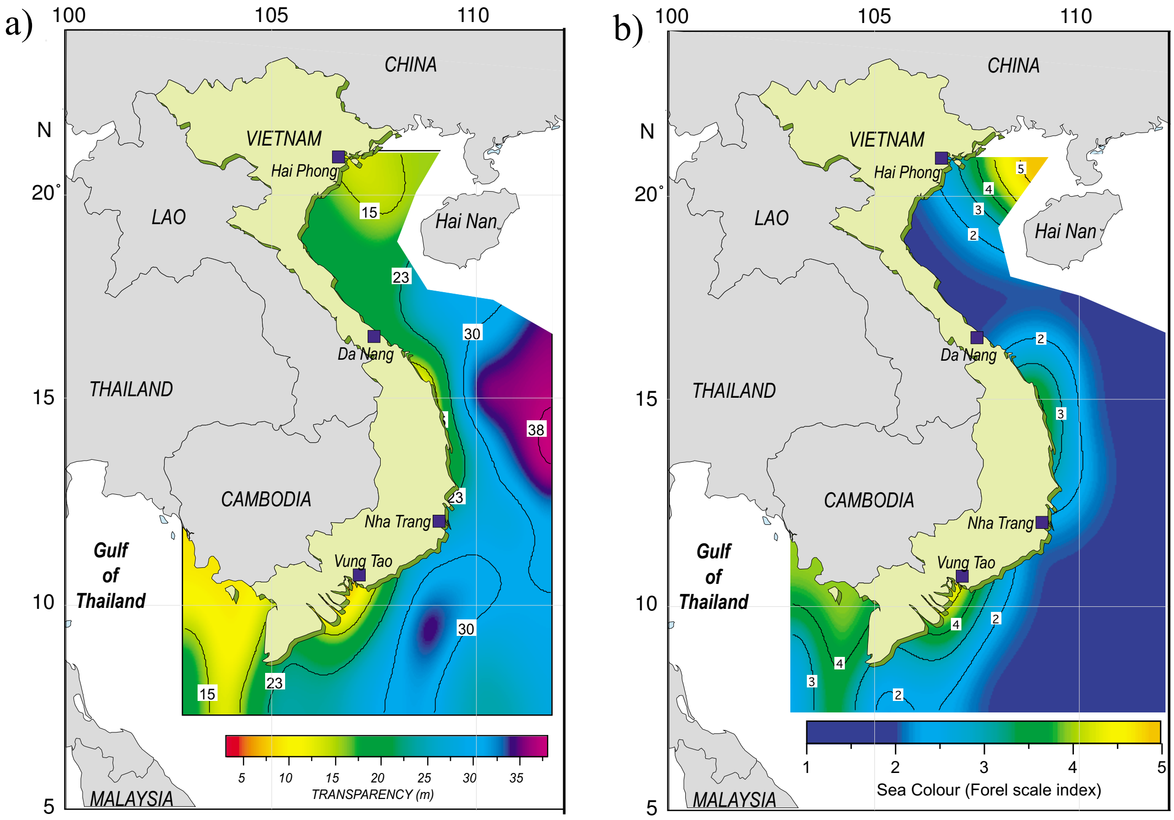


Fig. 10. 30 days synoptic chart of the transparency depth (a) and water color (b) of the South China Sea: Vietnamese waters during 30 April - 29 May 1999.

narrow and shallow ranged from the sea surface down to about 15m. Permanent thermocline generally appeared at about 15m deep from the surface where sea temperature was about 28˚c in the north and 29.5˚c in the south down to 1,500m deep where sea temperature was about 2.9˚c. Salinity from depth between sea surface to 110m deep irregularly changed from 33.31 to 34.69 PSS, the salinity at deeper than 110m slightly reduce upto 34.47 PSS at the depth of about 300-500m deep, and then increase to be constant about 34.6 PSS.

Figure 12 shows the vertical profile of water temperature at LINE 1 and LINE 2 along longitude 110˚ and 111˚E . The vertical profiles along the LINE 1 and LINE 2 indicate that the mixing layer was not much change, it was in a range from 15 to 45m for LINE 1 and 15m for LINE 2. Along LINE 1, the thermocline represented by 27˚c was located at a depth of about 40m in the north from latitude 12˚ to 15˚ , while at depth of about 25m, shallower by 15m, at latitude 11˚N. Along LINE 2, the thermocline represented by 28˚c was located at a depth of about 15m in the north to south of latitude 15˚-11˚N, while at 10˚Ñ, was at 35m.

Salinity showed remarkable variation in near by sea surface. The results of salinity profile showed a remarkable relation to the water temperature. It was found that the upper layer surface (0-15m) where the water temperature was higher than 27˚c the salinity was lower than 33.8 PSS. For the 24˚c and 20˚c water masses, the salinity were about 34.1 and 34.4 PSS, respectively.

Figure 13 shows the vertical profile of temperature at LINE A, B, C and LINE D. Along all LINE, the position of thermocline represented by 27˚c and the thickness of mixing layer showed significant west-east variation. Low temperature at 27˚c at sea surface was found in the coastal area and off shore by 29˚c.

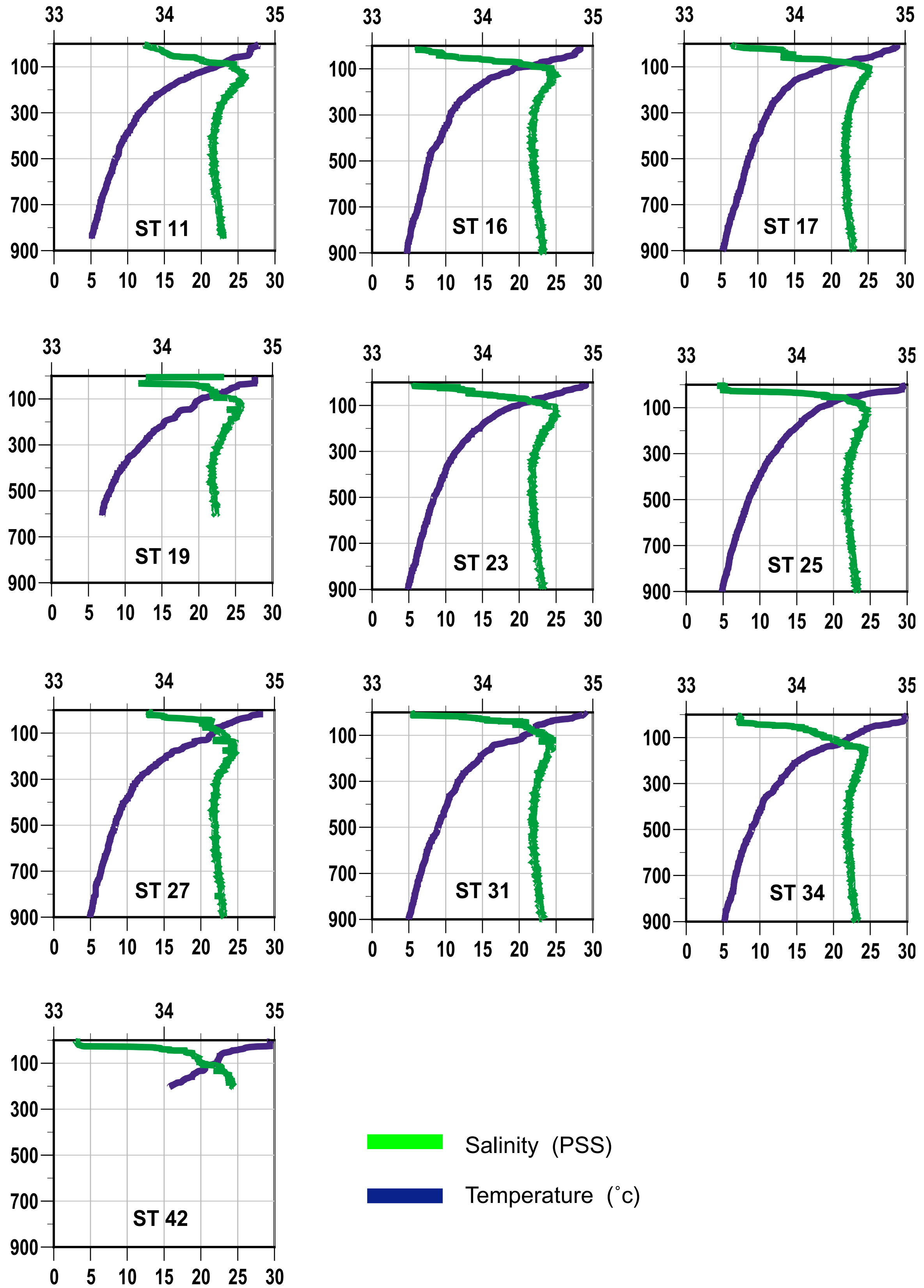


Fig. 11. Vertical profiles of the Salinity and Temperature of each fishing station in the Vietnamese Waters during May 1999.

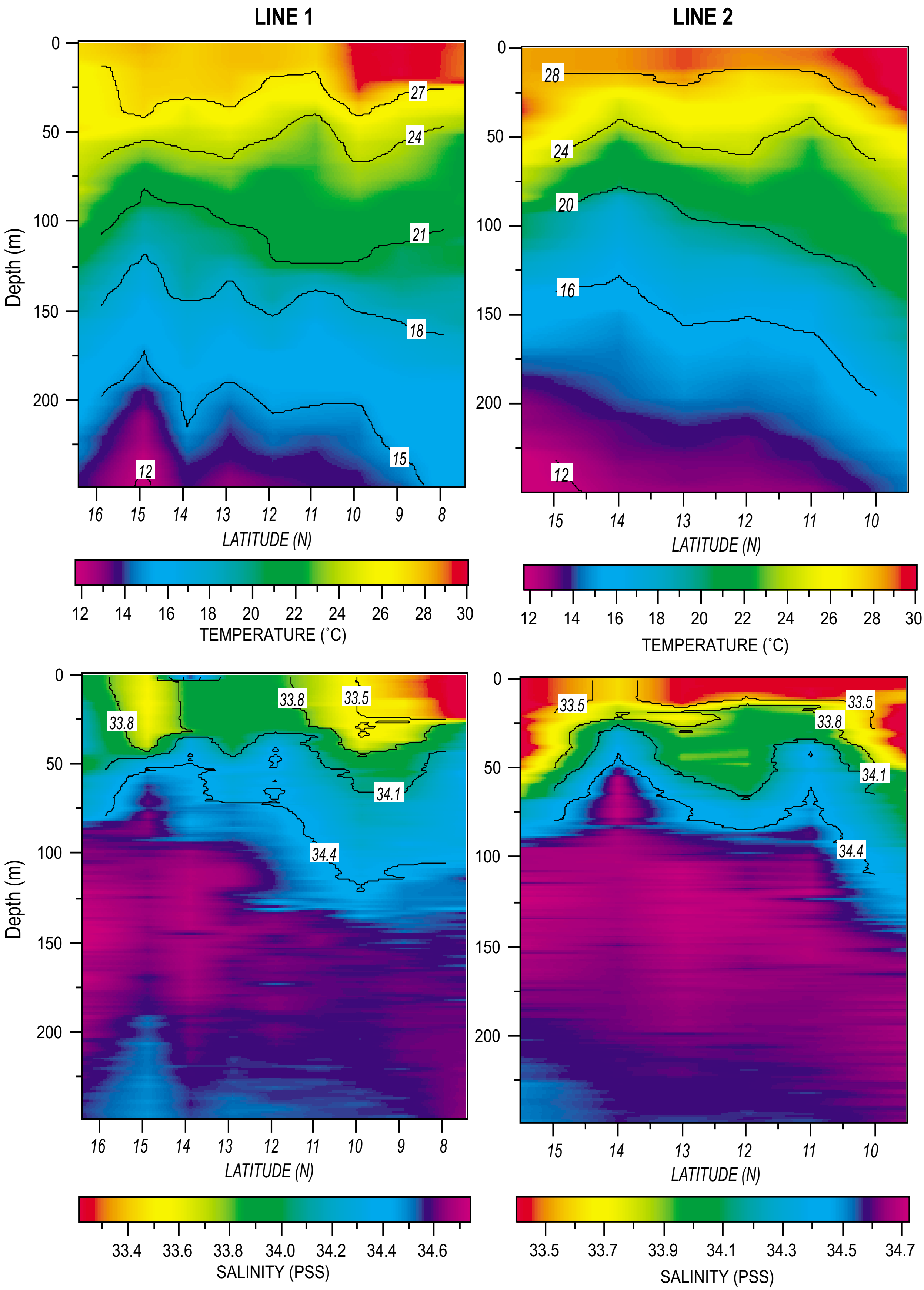


Fig. 12. Vertical profiles of water temperature and salinity at the cross section of LINE 1 and LINE 2 in the South China Sea: Vietnamese waters during May 1999.

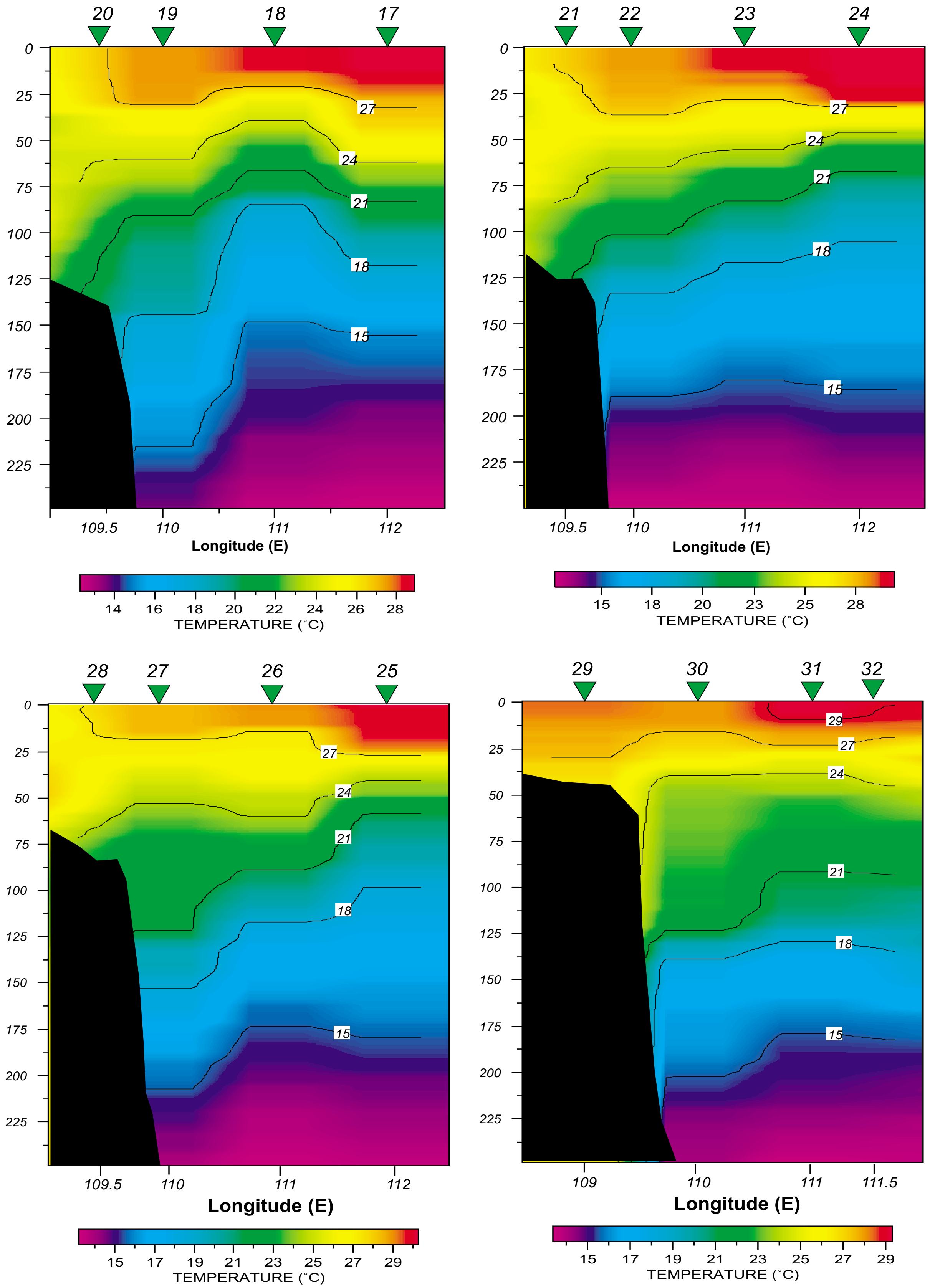


Fig. 13. Vertical profile of temperature (3°c interval) at the cross section of LINE A , LINE B, LINE C and LINE D in the South China Sea: Vietnamese waters during May 1999.

It is noted that the vertical profile of temperature along LINE 1, the upwelling of 18˚c cold water move upwards to 80m deep in longitude 111˚E at Station #18. Due to this appearances, many squid were caught near by the upwelling front/border in longitude 117˚E at Station#17.

Angling Depth

By sight observation found that the squid behave aggregating nature and positive phototaxis, they swim on the surface of the sea at night. The results showed that purpleback flying squid scattered covering the entire area and generally caught at the depth ranged from sea surface down to 150m deep at night. The abundant depth was ranged from 50m to 100m.

Acknowledgement

We wish to express our appreciation to the MV SEAFDEC captain and his crew for their kind cooperation during the survey.

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Nanoplankton Distribution and Abundance in the Vietnamese Waters of the South China Sea

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ABSTRACT

A collaborative sea cruise in the Vietnam waters of the South China Sea was conducted in the postmonsoon (21 April to 5 June, 1999) period on board MV SEAFDEC. The nanoplankton from 21 sampling stations consisted of 134 taxa comprising predominantly of centric nanodiatom (29 species), pennata nanodiatom (40 species) and dinoflagellate (65 species). Among the minute plankton collected, three species of nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous dinoflagellate species were present. The pennate nanodiatom comprised of the species of *Asterionella, Psammodiscus* and *Amphipleura* ranging from 5.25×10^2 to 1.67×10^4 cell/L; all which were <20µm in size. The dominant centric nanodiatom comprised of species of *Thalassiosira, Minidiscus, Chaetoceros* and *Cyclotella*, ranging from 1.36×10^2 to 4.61×10^4 cell/L. The genera of *Chaetoceros, Minidiscus, Cyclotella, Coscinodiscus, Navicula, Fragilaria* and *Thalassiosira* contained a wide range of species; however, majority of these species were new records and have not been taxonomically identified. The Prymnesiophyta (mostly small flagellate cells and *Prasinophyta* species) were rarely present; while those of dinoflagellate consisted of a wide range of species of genera *Amphidoma, Centrodinium, Palaephalacroma, Peridinum, Planodinium, Gyrodinium, Gonyaulax, Scrippsiella, Protoperidinium* and *Protocentrum*. The genera of *Protoperidinium, Peridinium, Gonyaulax* and *Prorocentrum* had a wide range of species. The class Heptophyceae comprising of Prymnesiaceae, Coccolithaceae and Gephyrocapsaceae were rarely present. The total nanoplankton population (ranging from 0.24×10^4 to 5.47×10^4 L^{-1}) was dense in nearshore regions (especially in waters between Da Nang and Nha Trang) and tend to spread out in concentric semicircle into the open sea. The presence of the dinoflagellate species of *Amphidoma, Centradinium* and *Planadinium* were detected in considerable amounts at midshore Vietnam waters of the South China Sea. Blooms of *Gyrodonium* sp. and *Amphidoma* sp. (to a limited extend) occurred during the study period.

Key words: algae, dinoflagellate, nanoplankton, Vietnam, South China Sea

Introduction

For the past many years, the nanoplankton study has not been emphasised or given priority due its minute size (<20 µm) and difficulty in identifying; however, this should not lead to its reglect since in many waters it is responsible for more than 50% biomass carbon fixation and production in the ocean than the more immediate microplankton whose size is much bigger (20 to 200 µm) Only a few studies of plankton (especially the minute nanoplankton) and other related parameters were carried out on the Malaysian waters in the South China Sea. Chua and Chong (1973) showed that the distribution and abundance of pelagic species especially the small tuna (*Euthynus affinis*), chub mackerel (*Rastrelliger* sp.) and anchovies (*Stolephorus* sp.) were related to the density of phytoplankton.

Qualitative studies of microplankton (20-200 µm in size) in the Malaysian coastal waters, especially the Malacca Straits have been conducted by Sewell (1933), Wickstead (1961) and Pathansali (1968). Primary productivity in the same location had been carried out by Doty *et al.* (1963); however, a detailed study of the nanoplankton community structure, distribution and abundance in such waters had been lacking. Studies by Shamsudin *et al.* (1987) in the South China Sea around coasts of Johore, Terengganu and Kelantan found that majority of the phytoplankton found were diatoms which comprised of numerous species of *Bacteriastrum, Chaetoceros, Rhizosolenia* and *Pleurosigma*. The blue green, *Trichodesmium erythraeum* was found in abundance in such tropical waters (Chua & Chong, 1973). Studied on plankton (Shamsudin, 1987; Shamsudin & Baker, 1987; Shamsudin *et al.*, 1987; Semina, 1967; Markina, 1972) had raised questions about the qualitative and quantitative seasonal availability of these organisms as sources of food for those organisms higher up in the food chain and the relative production of these organisms in various study sectors of the South China Sea.

In the present study, the nanoplankton community structure has been analysed during the postmonsoon study period (April/June 1999) in the Vietnam waters of the South China Sea. The species community structure patterns, distribution, composition and species abundance at various study sectors of the South China Sea had been highlighted and emphasized in this study.

Materials and Methods

Study Area

The study area (Fig. 1) covers an area which extends from the northern tip of Vietnam (21° 0' N; 107° 55' E) to the south west covering the Mekong Delta (9° 0.1' N; 104° 30.5' E) of the South China Sea. The estimated study area is ca 6000 nautical square miles (ca 2000 sq. km) covering the economic exclusive zone (EEZ) of the Vietnam waters of the South China Sea. The sea cruise track followed a zig-zag manner starting from the northern coastal Vietnam waters and ended up at the southern end of the Vietnam waters (facing the Mekong Data) covering a total of 21 sampling stations. The Gulf of Tongking and the Hainan Dao island are situated in the north of the Vietnam waters while the Paracel island and Spratly island to the south of Hainan Dao island. The Mekong river delta is at the southern tip of Vietnam, while the Song Pa river with its river tributaries passing through Hai Phong.

Sampling Method & Preparation

The research survey was carried out during the cruise survey in April/June 1999 covering twenty one stations. Water sampler (twin 10 L sampler) was used to collect water sample from the depth of the maximum chlorophyll layer (MCL). The water sampel was first filtered through the 40 µm mesh-size filtering net; it was again subsequently filtered through a membrane filter paper (0.8 µm mesh-size) with square grid marks on its surface. The samples which had been fixed and preserved in absolute alcohol, were then mounted on (SEM) stubs with double-sided cellotape. The stubs with adhering samples were then coated with an alloy (gold with pelladium) before being observed under the scanning electron microscope (Barber & Haworth, 1981). For each stub, only 5 square grids (one grid having 20 fields of observation; one field measures 32.5 x 25 µm area) were considered whereby the organisms found on the grid were countered. The subsamples or subportions of original sample were preserved in 10% formalin and subsequently examined for species composition and abundance using an inverted microscope (Vollenweider *et al.*, 1974; Tippett, 1970; Shamsudin, 1987, 1993, 1994, 1995; Shamsudin & Shazili, 1991; Shamsudin & Sleigh, 1993, 1995; Shamsudin *et al.*, 1987, 1997). Algal were identified with reference to Okada and McIntyre (1977), Gaardnar and Heindel (1978) and Heimdal and Gaarder (1980, 1981).

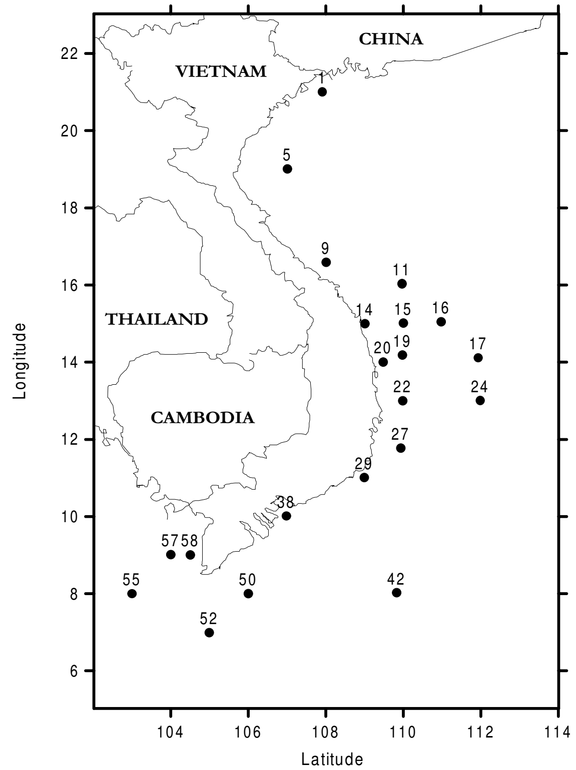

Fig. 1. The map showing the sampling stations in the Vietnam waters of the South China Sea (cruise April-June 1999).

Statistical Analysis

An index of the composition of the plankton community in the aquatic habitat is given by calculating the diversity index (H) and evenness (J) of the community structure using the Shannon-Weiner index (1949). The formula for calculating Shannon-Weiner (diversity) index (H) is:

$$H = P_i \log_2 P_i, \quad \text{Where } P_i = n_i/N$$

n_i = The number of individuals of the i th species
N = The total number of individuals

The diversity index can measure species richness (H) and species evenness (J)

$$J = H/\log_2 S \text{ - (ii)}, \quad S \text{ is the number of species}$$

One way analysis of variance can be imployed when comparisons are made between a number of independent random samples, one sample from each population. All counts must be classified in the same manner, but the number of counts in the various samples can be different (Elliott, 1977). Analysis of variance can be used to assess the relative importance of different sources of variation, e.g. between sites, between dates, etc., but it may be necessary to transform the data before analysis of variance tests are applied.

Coefficients of similarity are simple measures of the extent to which two habitats have species (or individuals) in common (Southwood, 1978). Essentially, such coefficient can be of two types, as given below, and both types reflect the similarity in individuals between the habitats.

(i) Jaccard Cj = j / (a + b-j)

(ii) Sorensen Cs = 2j / (a+b)

where a, b are the total individuals sampled in habitat a and b respectively, and j is the sum of the lesser values for the species common to both habitats (Southwood, 1978). In habitats where one or few species have high dominance the coefficients under-estimate the contributions of the moderately common species which may be more stable indicators of the characteristic fauna of an area while the rare species have little impacts (Southwood, 1978). It is apparent that Cs is greater than Cj and the inequality reduces as j approaches the magnitude of 1/2 (a+b).

The microplankton can be classified into species assemblages or associations in cluster analysis on species sampled from the nearshore and offshore stations according to their preference on environmental conditions using the Unweighted Pair Group Average (UPGA) Pearson Correlation Iindex (Pielou, 1984; Ludwig & Reyholds, 1988).

Multivariate statistical analyses, performed by the computer program PC – ORD version 2.0 (ter Braak 1988, 1990), were used to identify relationship between the measured environmental variable and the species assemblages. Our calibration model included a total of 50 diatom taxa, using a cut-off criterion of $\geq$1% relative abundance. Because of space constraints and the limitations of inferring ecological preferences for rare taxa, we present here information for only the 40 most abundant diatom taxa (i.e. taxa with a relative abundance $\geq$2%).

Canonical Correspondence Analysis (CCA), using forward selection and Monte Carlo permutation tests, was then used to identify variables which were significant in explaining the variation in the diatom assemblages (ter Braak & Verdonschot 1995). Species data were square root transformed and rare taxa were down-weighted in order to maximize the signal:noise ratio within the data set.

Results

The nanoplankton from 21 sampling stations comprising of 134 taxa consisting predominantly of centric nanodiatom (29 species), pennate (40 species) and dinoflagellate (65 species) was collected from the Vietnam waters of the South China Sea (Appendix). Among the minute plankton collected were three species of centric nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous other pennate species (Tables 1.1, 1.2 & 1.3).

The nanodiatom population in the Vietnam waters of the South China Sea toward the south was sparse (1.3 x 10^3 to 2.4 x 10^3 L^{-1}) while the Vietnam waters toward the central and south wastern parts were high (5.7 x 10^3 to 3.9 x 10^3 L^{-1}) (Fig. 2a). The dominant centric nanodiatom, ranging from 2.4 x 10^3 to 4.6 x 10^3 L^{-1} comprised of species of *Thalassiosira, Minidiscus, Chaetoceros, Cyclotella* and *Stephanodiscus*; while the dominant pennate nanodiatom (ranging from 8.9 x 10^3 to 16.7 x 10^3L^1) comprised of species of *Asterionella, Psammodiscus, Amphipleura, Navicula, Deadesmis, Fragilaria* and *Nitzschia* (Fig. 2b).

The Diversity H and Evenness J indices were especially high in central Vietnam waters with values ranging from 1.5 – 3.1 and 0.70 to 0.87 respectively (Fig. 2c & d). The *Thalassiosira* species were dominant (ranging from 6.3 x 10^3 to 10.8 x 10^3 L^{-1}) in the northern, central and southern Vietnamese waters; while the *Minidiscus* species (ranging from 5.8 x 10^3 – 8.14 x 10^3 L^{-1}) were predominant to the north of central Vietnam waters (Fig. 2.1).

The *Chaetoceros* and *Cyclotella* species were less abundant ranging from 1.12 x 10^3 to 7.2 x

10^3 L^{-1} toward the southern and south eastern portion of the Vietnamese waters. The pennate species of *Asterionella* and *Psammodiscus* were also present in the south of the central Vietnamese waters with values ranging from 4.8 x 10^3 to 7.19 x 10^3 L^{-1}) (Fig. 2.2). Patches of pennate species belonging to genera *Amphipleura, Navicula, Diadesmis* and *Fragilaria* with values ranging from 1.57 x 10^3 to 4.76 x 10^3 L^{-1} were also present (Fig. 2.3). The distribution of the pennate nanodiatom genera of *Nitzschia* (north and south west tips of the Vietnamese waters), *Thalassionema* (central and around Mekong Delta of the Vietnamese waters) and *Fallacia* (south west tip of the Vietnamese waters) had moderate values ranging from 1.02 x 10^3 to 2.84 x 10^3 L^{-1} (Fig. 2.4). The toxic dinoflagellate species of *Pseudo nitzschia* was less predominant (1.02 x 10^3 to 1.42 x 10^3 L^{-1}) in the south of central Vietnamese waters.

Distribution of the nanodinoflagellate genera of *Amphidoma* and *Centrodinium* were widespread, stretching right from the central Vietnamese waters via the south to the south west of the Vietnamese waters with values ranging from 0.81 x 10^3 to 2.38 x 10^3 L^{-1} (Fig. 2.5). Species of *Gonyaulax* and *Paleophalacroma* were also present (0.8 x 10^2 to 9.5 x 10^2 L^{-1}) in offshore Vietnam waters (Fig. 2.5c & d). The other 3 nanodinoflagellate species of *Protoperidinium, Planodinium* and *Scrippsiella* were present in lesser amounts (3.42 x 10^2 to 14.3 x 10^2 L^{-1}) in the central and south western Vietnamese waters; while *Prorocentrum* species were found in considerable amounts (3.42 x 10^2 to 4.78 x 10^2 L^{-1}) in the northern coastal and southwest offshore regions of the Vietnamese waters.

Species Distribution and Density in Vietnamese Waters

The three nanodiatom species of *Minidiscus* (*M. comiscus, M chilensis, M. trioculus*) were centric diatom whose density ranging from 4.08 x 10^3 to 7.34x 10^3 L^{-1}; while the pennate forms consisted of the genera *Navicula, Fragilaria, Diploneis, Pseudo-nitzschia* and *Amphiplaura* including those belonging to the minute species whose size range was between 5-50µm (Tables 1.1 & 1.2). Some of the known *Navicula* species consisted of *Navicula grevileana, N. schonkenii, N. fucicola* and *N. pseudanglica* var. signata (mean density 18.6 x 10^3 L^{-1}); while the *Thalassiosira* species comprised of Thal*assiosira tenera, T. climatosphaera, T. oestrupii* var. *ventrickae* and *T. pacifica* (ranging 4.49 x 10^3 to 9.39 x 10^3 L^{-1}). Among the nanodiatom, 5 genera were new records in the Vietnam waters during the study period.

Asterionella from nearshore had 4 species (2 of them are dominant) with a high total cell count (16749 L^{-1}); while the toxic *Pseudo-nitzschia* species (total cell count of 2859 L^{-1}) had 5 dominant species namely *P. seriata, P. lineata, P. fraudulenta, P. tugula* and *Sabpacifica* with values ranging from 4.08 x 10^2 to 12.2 x 10^2 L^{-1}. The genera of *Thalassiosira, Minidiscus, Chaetoceros, Stephanophyxis, Coscinodiscus* and *Navicula* had numerous species (6 to 17 species) while the others (*Amphipleura, Berkeleya, Raphoneis, Cosmioneis, Luticola, Cymbella*) had only 1 to 2 species.

The mean nanodiatom cell density from nearshore stations was significantly ($p<0.01$) higher than those away from the coast (Figs. 3.1, 3.2 & 3.3, Table 2.1). The cell density of the nearshore, middle shore and offshore zones ranged from 9.3 x 10^3 to 30.2 x 10^3 L^{-1}, 6.9 x 10^3 to 15.9 x 10^3 L^{-1} and 2.04 x 10^3 to 11.0 x 10^3 L^{-1} respectively. The pie chart diagram in percentage abundant of nanodiatom with depth shows that the percentage abundance is highest for the chlorophyll maximum layer (40.6%), followed by subsurface layer (32.6%), sub chlorophyll maximum layer (24%) and finally the thermocline layer (2.7%) (Fig. 3.4). The nanodiatom tend to aggregate at the chlorophyll maximum layer rather than at the other 3 levels namely subsurface, thermocline or sub chlorophyll maximum layer (Fig. 3.5, Table 2.2). The *Thalassiosira* and *Minidiscus* species were well distributed in the 4 depth zones while the other 4 dominant species of *Fragilaria, Cocconeis, Pseudo-nitzschia* and *Navicula* were found commonly in the chlorophyll maximum layer (Table 2.3).

Nanodinoflagellate Abundance

The dinoflagellate consisted of a wide range of species of *Amphidoma, Centrodinium, Gonyaulax, Scrippsiella, Protoperidinium, Palaeophalacroma, Oxytoxum* and *Prorocentrum* ; many of which were in the cyst forms found especially in the cental Vietnam waters (Table 3.1). The Vietnam waters of the South China Sea contained significantly ($p>0.01$) high cell density of *Gonyaulax* sp., *Gymnodinium* sp. and *Amphidoma* ; these species have the potential to form blooms. The presence of the dinoflagellate species of *Protoperidinium* sp. and *Prorocentrum* were detected in considerable amounts in the middle shore of Vietnam waters of the South China Sea. Related genera belonging to Haptophyceae comprising of Prymnesiaceae and Coccolithceae were rarely present in the Vietnam waters during the study period.

The nanodinoflagellate commonly found in the three zones of the Vietnam waters of the South China Sea comprised of 11 genera; among the genera, *Amphidoma, Centrodinium* and *Gonyaulax* were frequently sampled (Table 3.1). The offshore Vietnam waters had significantly ($p<0.01$) high nanodinoflagellate cell count when compared to those of the coastal or middle zones. The nanodinoflagellate distribution of the Vietnam waters showed that the highest cell density was at the subchlorophyll maximum layer; while the subsurface layer at the middle zone of the Vietnam waters had the highest cell count (Table 3.2). The nanodinoflagellate genera of *Prorocentrum* and *Gonyaulax* had a wide range of species (8 – 9 species) with cell density values ranging from 800 to 1225 L^{-1} especially at stations 55F and 52F (both offshore) respectively (Table 3.3). *Prorocentrum* comprised of 4 dominant species (*P. gracile, P. micans, P. minimun* and *P. sigmoides*) while *Gonyaulax* had also 4 main species (*G. diagenis, G. polygramme, G. scrippsae, G. polyedro*).

Species Association and Assemblage

The species assemblage in the Vietnam waters of the South China Sea consisted of at least 8 groups comprising of the combined pennate and centric nanodiatom (group A, B, D, E and F) as well as the groups consisting of the only centric nanodiatom member (group C, G and H) (Fig. 4.1, Table 4.1). The all centric nanodiatom member species assemblage comprised of group C (*Mastogloia, Luticola, Cosmioneis*), group G (*Psammodiscus, Nitzschia, Raphoneis, Fragilaria, Amphipleura*) and H (*Navicula, Thalassionema*).

The dendrogram from Fig. 4.2 shows the similarity in species community composition between stations in at least 5 groups (A, B, C, D and E) during the 1999 cruise survey in the Vietnam waters of the South China Sea. The 3 groups comprising of A, B and C were actually coastal zone stations while the other two were mixed stations (coastal and offshore). The species association or assemblage of nanodinoflagellate in the Vietnam waters comprises of 4 groups; namely group A (*Gyrodinium, Centrodinium*), group B (*Palaeophalacroma, Amphidoma*), group C (*Scrippsiella, Gonyaulax*) and group D (*Planodinium, Goniodium*) (Fig. 4.3, Table 4.2).

Canonical Correspondence Analysis

The environmental parameters for the water masses from different zone and depth layer are given in Table 5. The salinity and temperature profile values showed the existence of the thermocline stratified layer in the Vietnam waters of the South China Sea. The PC-ORD statistical program using the Canonical Correspondence Analysis (CCA) is used to show the relationship between the nanoplankton with the environmental physical factors of the water masses. The copper concentration in the Vietnam waters of the South China Sea (especially around the vicinity of the Mekong Delta) ranged from 3.2 to 9.7 nM in the water column (Hungspreugs *et al.*, 1998).

The Canonical Correspondence Analysis (CCA) of algal species assemblage in the Vietnam waters during the April/June 1999 cruise showed that the majority of the species were dependent on specific environmental parameters such as salinity, electrolyte metal concentration (especially Cu), depth and pH (Fig. 3.1, Table 5). The depth and salinity parameters were the strongest variable influencing algal assemblage composition within our sample set of species communities from different water masses. High salinity and depth were characterized by a higher abundance of stenohaline species of *Cymbella, Cosmioneis, Asterionella, Amphora, Psammodiscus* and *Mastogloia*. Lower salinity values favoured species such as *Nitzschia* and *Diploneis*.

The pH value also showed significant (p>0.05) influence on certain species association and assemblage. Low pH values favoured association of species of *Diadesmis, Pseudo-nitzschia* and *Fragilaria*; while at higher pH favoured species of *Thalassiosira* and *Minidiscus*. The CCA analysis on the relationship between algal cells in the water masses from different water depth showed that the species such as *Amphora, Psammodictyon* and *Berkeleya* were sensitive to depth and salinity while *Cyclotella* and *Navicula* were sensitive to temperature. *Thalassiosira* and *Minidiscus* species were highly influenced by dissolved oxygen; whereas high pH value favoured the presence of *Minidiscus*.

The CCA analysis on the relationship between nanodinoflagellate in water masses from different depth showed that most species were dependent on two specific parameters namely, salinity and depth (Fig. 3.3). These two parameters were the strongest variable influencing nanodinoflagellate preference, especially species of *Prorocentrum, Peridinium, Scrippsiella, Centrodinium* and *Goniodema*. Other species of *Gonyaulax, Amphidoma* and *Oxytoxum* were dependent on temperature as environmental preference. Dissolved oxygen did not show any strong influence on the presence of dinoflagellate species; however, the influence of pH was even less.

Discussion

Prior to this present survey, a collaborative cruise in the waters of the South China Sea of the Western Philippines was conducted in the postmonsoon (April and May, 1998) periods on board MV SEAFDEC (Shamsudin & Kartini, 1999). Surprising, the most abundant nanoplanktonic Coccolithophorid species comprised of *Emilinia huxleyi, Oolithotus fragilis* and *Gephyrocapsa oceanica* (collectively up to 10^5 L^{-1}) which occurred in sharp subsurface maximum chlorophyll layer down to 40 m depth; however, these species never occur in the Vietnam waters during the study period. The cosmopolitan Coccolithophorid species in the Philippines waters originated from the ocean gyre of the central Pacific ocean; whereas the Vietnam waters are completely block from this gyre by long streaches of islands (eg. Spratly island to the south east and Paracel island in the centre of Vietnam waters) including the Philippines.

The other explanation is probably due to the seasonality occurrence of the *Coccolithophorid* in the seawater (Hallegraeff, 1984). The 4 physical factors influencing the dynamic motion in the sea comprise of the pressure gradient, *Coriolis force*, gravity and friction. The calculated dynamic height of the sea surface can be obtained (usually <1m) when the slope of the sea surface in the ocean gyre circulation is formed due to the geostrophic surface current which has the tendency to balance the pressure gradient. The surface gyre sea water circulation plays an important role in transporting nanoplankton from a given region to the other in the ocean. The sea surface height anomaly from the Topex/Ers-2 analysis (satellite data) can also be used to explain this phemomenon (Snidvongs – personal communication).

The nanoplankton (including the smaller microplanktonic species) from 31 sampling stations during the 1998 cruise consisted of more than 200 taxa comprising predominantly of nanodiatom (>150 species), Dinoflagellata (>30 species) and Prasinophyta (>18 species). However, the present study in the Vietnam waters showed that the nanoplankton comprised of centric and pennate diatoms as well as the nanodinoflagellate. The coccolithophorids in the Australian waters of the South China Sea showed a dominant change from *Emiliania huxleyi* to *Gephyrocapsa oceanica* and a southward transport of many tropical species (eg. *Scyphosphaera apsteinii* and *S. pulichra* (Hallegraeff, 1984).

Among the minute plankton collected during the 1998 cruise of the Philippines waters of the South China Sea, three species of the nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous flagellate species were present. The dominant pennate diatom comprised of *Synedra parasitica, Fragilaria brevistriate, Diploneis crabro* and *Neodenticula* sp., all of which were <20 μm in size. However, the present study in the Vietnam waters shows high density of centric nanodiatom especially *Thalassiosira* and *Minidiscus* species. The central diatom comprised of *Cyclotella striata, C. meneghiniana* and *Stephenopyxis palmeriana* were also encountered.

In both study areas, the genera of *Synedra, Navicula, Fragilaria* and *Thalassiosira* contained a wide range of species; while those of dinoflagellate consisted of a wide range of species of genera *Gyrodinium, Pyrodinium, Gonyaulax, Scrippsiella, Protoperidinium, Protoceratium, Ceratocorys* and *Alexandrium*. The genera of *Protoperidinium, Minidiscus* and *Thalassiossira* had a wide range of species. The total nanoplankton population in the Philippines waters was dense in nearshore regions (especially around Subic and Manila bays) and tend to spread out in concentric semicircle into the open sea. The presence of the dinoflagellate species of *Protoperidinium* and *Alexandrium* were detected in considerable amounts at nearshore and midshore Philippines waters of the South China Sea. However, high density of the nanodinoflagellate species of *Amphidoma* and *Centrodinium* were present in the Vietnam waters.

Semina and Tarkhova (1972) recorded 1000 species of phytoplankton, mainly of diatoms and dinoflagellates in the Pacific Ocean. They also reported that the only other conspicuous marine microplanktonic forms are the spherical green cells belonging to Prasinophyta (*Halosphaera, Pterosperma*) and the bundles of filaments of the Cyanophyte genus, *Trichodesmium* (*Oscillatoria*): both of these groups tend to float to the surface, the former buoyed up by oil globules and the latter by gas vacuoles in the cells. The nanoplankton is almost entirely composed of small flagellate cells belonging to the Prymnesiophyta. They possess two flagella with a haptonema. This group now contains the genera of the *Prymnesiales* (= Coccolithophoridaceae) since many of these have been shown to possess a haptonema. Some are delicate and are assually damage beyond recognition or are destroyed by preservatives (formalin, is not an ideal preservative for phytoplankton) and their numerical abundance is rarely determined.

Prymnesiophyta bearing calcareous plates (coccoliths) are more easily damage than the delicate forms bearing organic scales (*Chrysochromulina*), but the latter can make up a considerable amount of the biomass in some seas. It is also interesting to note that the present study did not show that Prasinophyta and Phrymnesiophyta were present in the Vietnam waters of the South China Sea. An increase in the diversity value of the nanoplankton population could be due to an increased number of species or even distribution of individuals per species as described by Gray (1981). In reality, such community organisation is constantly acted on by biological and physical factors in many different ways to produce, perhaps a different organisation in the future as a response to such environmental changes. When a bloom occurs, only a few plankton species will predominate and thus effect or influence the number of species or the even distribution of individual species.

Nanoplankton species tend to occur in groups throughout natural communities and it ought to be possible to distinguish associations of species in the plankton. Observations from some detailed surveys and from the continuous plankton recorded certainly suggest that there are discrete associations. These associations appear to be linked with geographical zones (currents, water masses) rather than with subtle differences in water chemistry. The present cruise survey shows that the bulk of the nanoplankton comprised of nanodiatom, dinoflagellate and flagellate; all of these organisms reach a value close to 150 taxa, many of which are yet to be carefully identified.

The fact that the nanoplankton is small should not lead to its neglect since in many waters it is responsible for more carbon fixation than the more immediately obvious microplankton. On an annual basis 70-80%(total carbon 82-78 meq m-2) was attributable to the nanoplankton. McCarthy, Rowland Taylor & Loftus (1974) found that over a two year study in Chesapeake Bay the nanoplankton (in this case species passing through a 35 mm mesh net) was responsible for 89.6% of the carbon fixation.

In the open ocean, especially in oligotrophic regions, the nanoplankton are often the most abundant organisms (Hulbert, Ryther & Guillard, 1960). Pomeroy (1974) gives a table which shows that over 90% of total fixation is by forms smaller than 60 µm in diameter. It is necessary to measure cells and to calculate cell volumes if more detailed information of the biomass of individual species species is required. The nanoplankton together with the Coccolithophoridaceae were present in significant quantities and many of these organisms are minute having the size range between 5 to 50 µm; these organisms have been shown to contribute >50% in total biomass and productivity in the sea.

Acknowledgements

The authors would like to thank the Captain and the crews of the MV SEAFDEC for collecting water samples during the cruise; Che Ku Haslinda (Kolej Universiti Terengganu, Malaysia) for her help in mapping out the microplankton population and for typing this manuscript.

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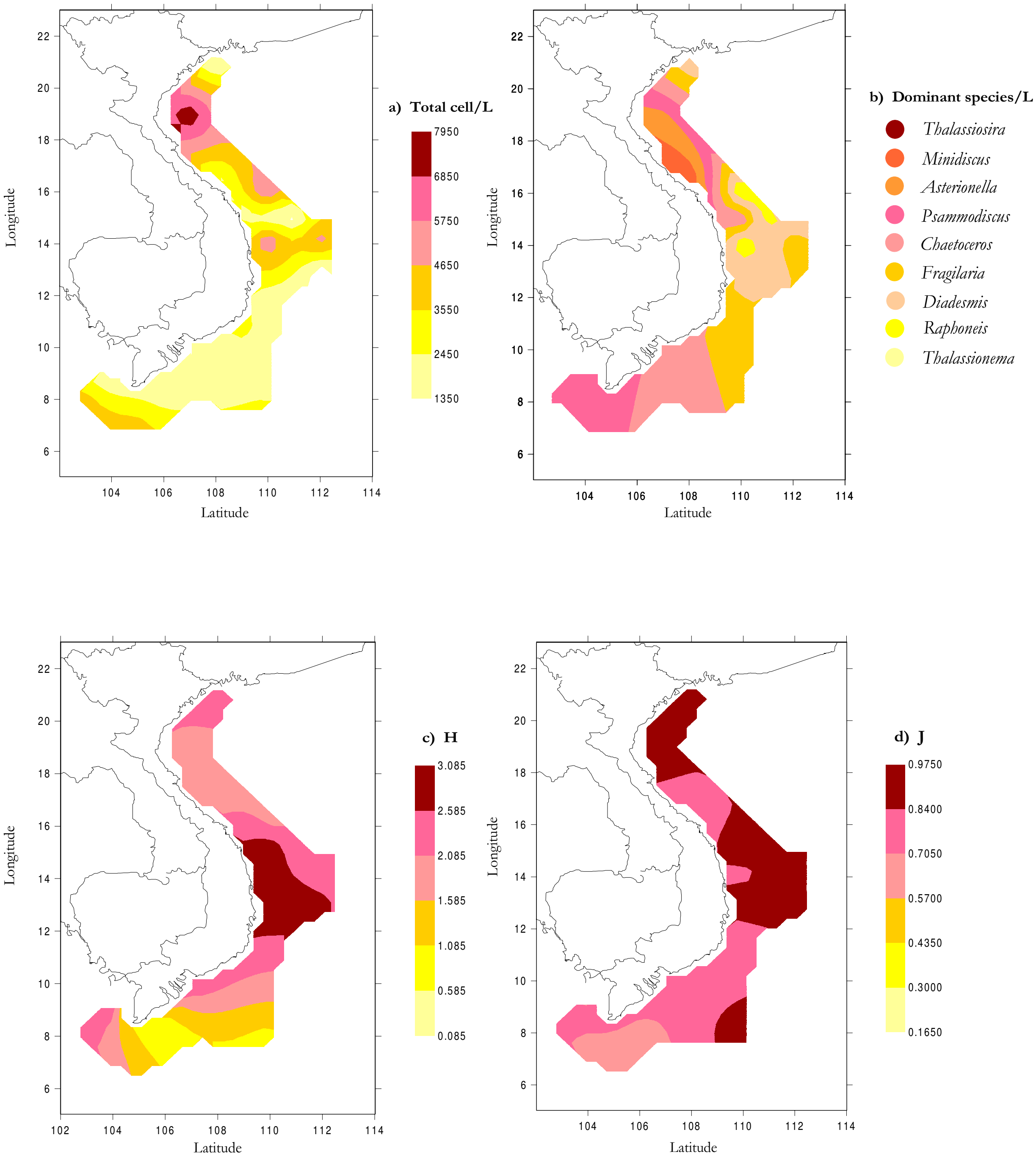

Fig. 2. a) Total cell/L density, b) Dominant nanoplankton species, c) Diversity H index and d) Evenness J index in the Vietnamese waters of the South China Sea (April-June 1999 cruise survey).

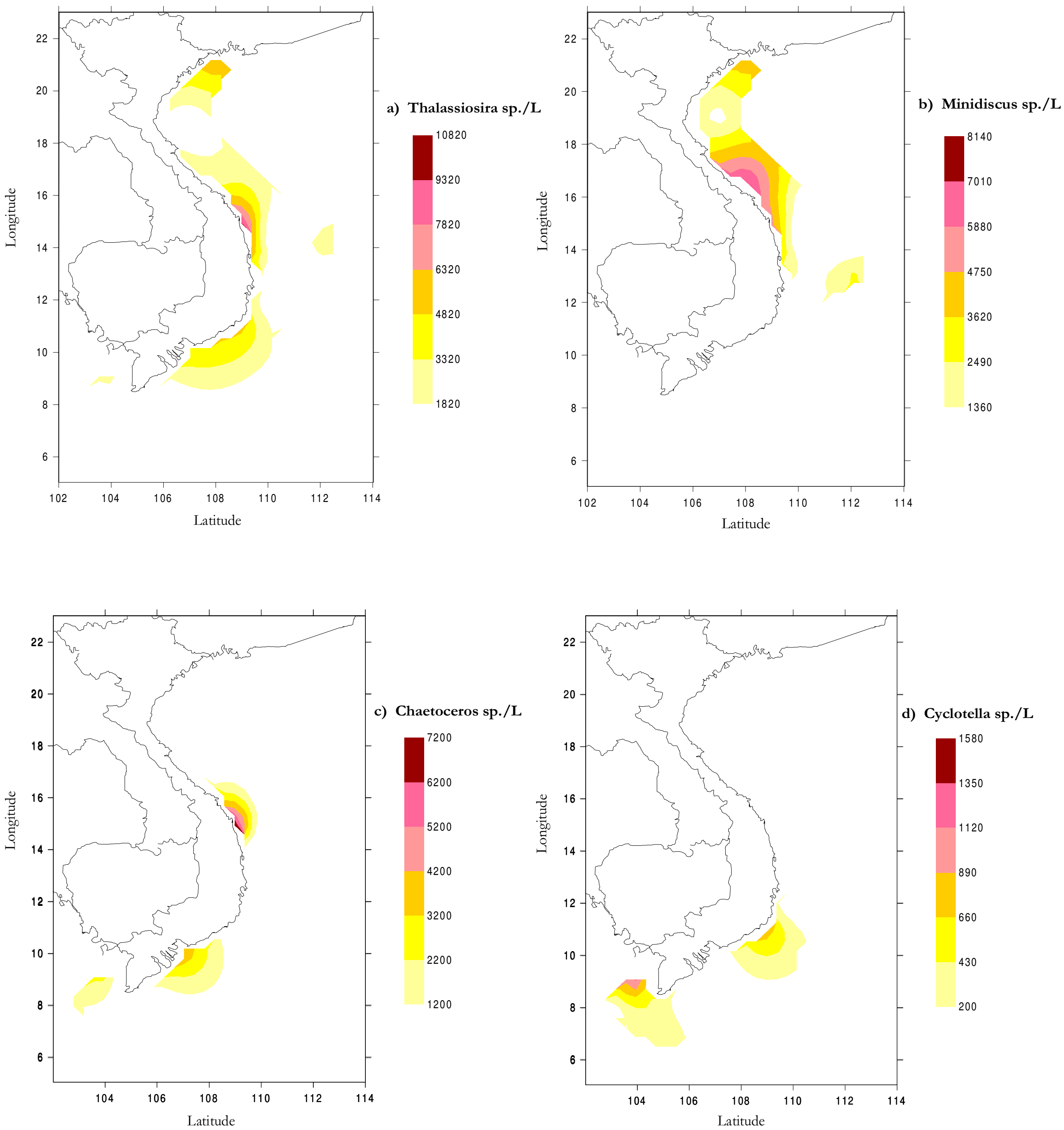

Fig. 2.1. Distribution of the centric nanodiatom genera (a) *Thalassiosira*, (b) *Minidiscus,* (c) *Chaetoceros*and (d) *Cyclotella* in the Vietnamese waters of the South China Sea (April-June 1999 cruise survey).

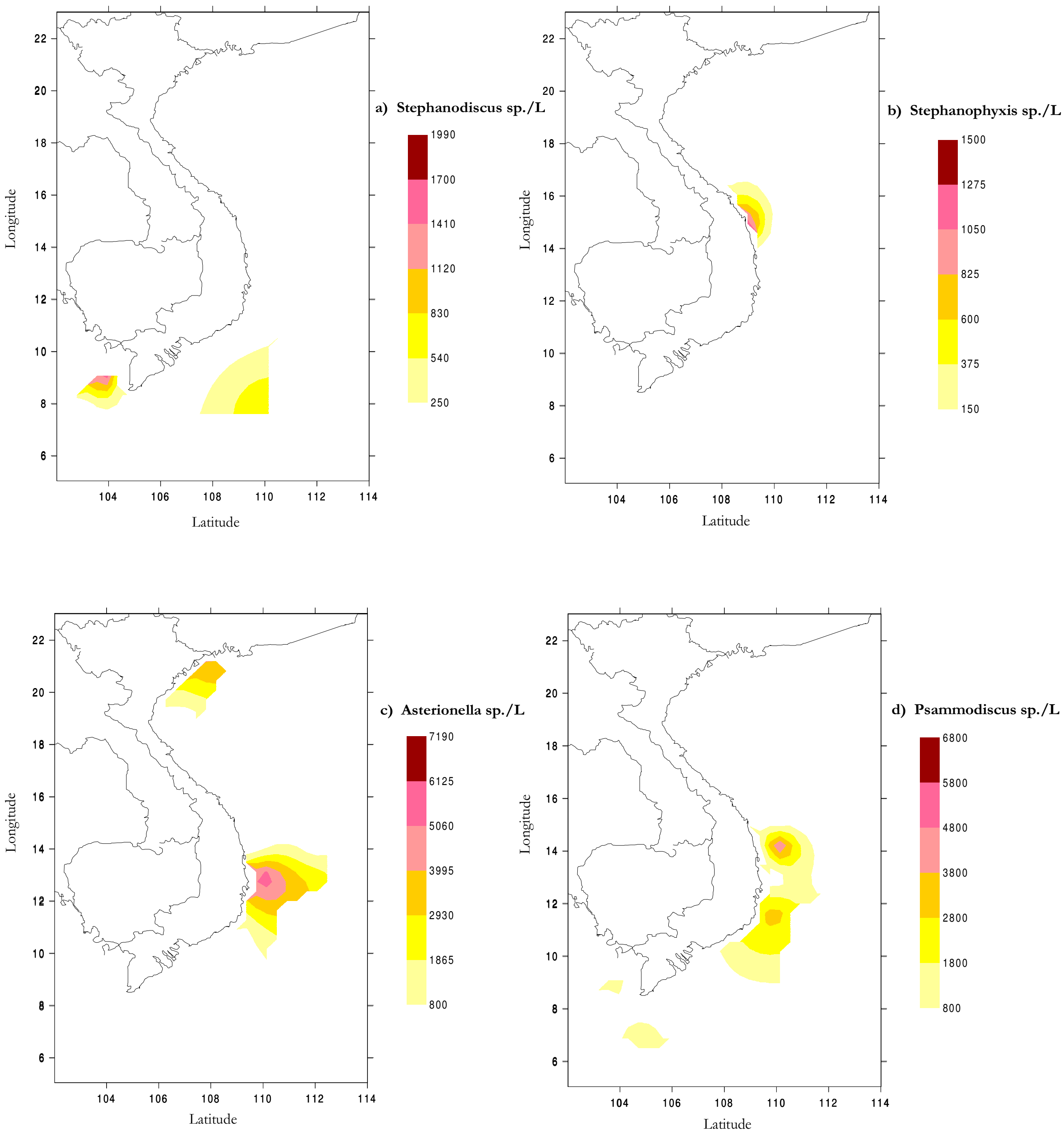

Fig. 2.2. Distribution of the centric nanodiatom genera (a) *Stephanodiscus*, (b) *Stephanophyxis* ; the pennate genera (c) *Asterionella* and (d) *Psammodiscus* in the Vietnamese waters of the South China Sea (April-June 1999 cruise survey).

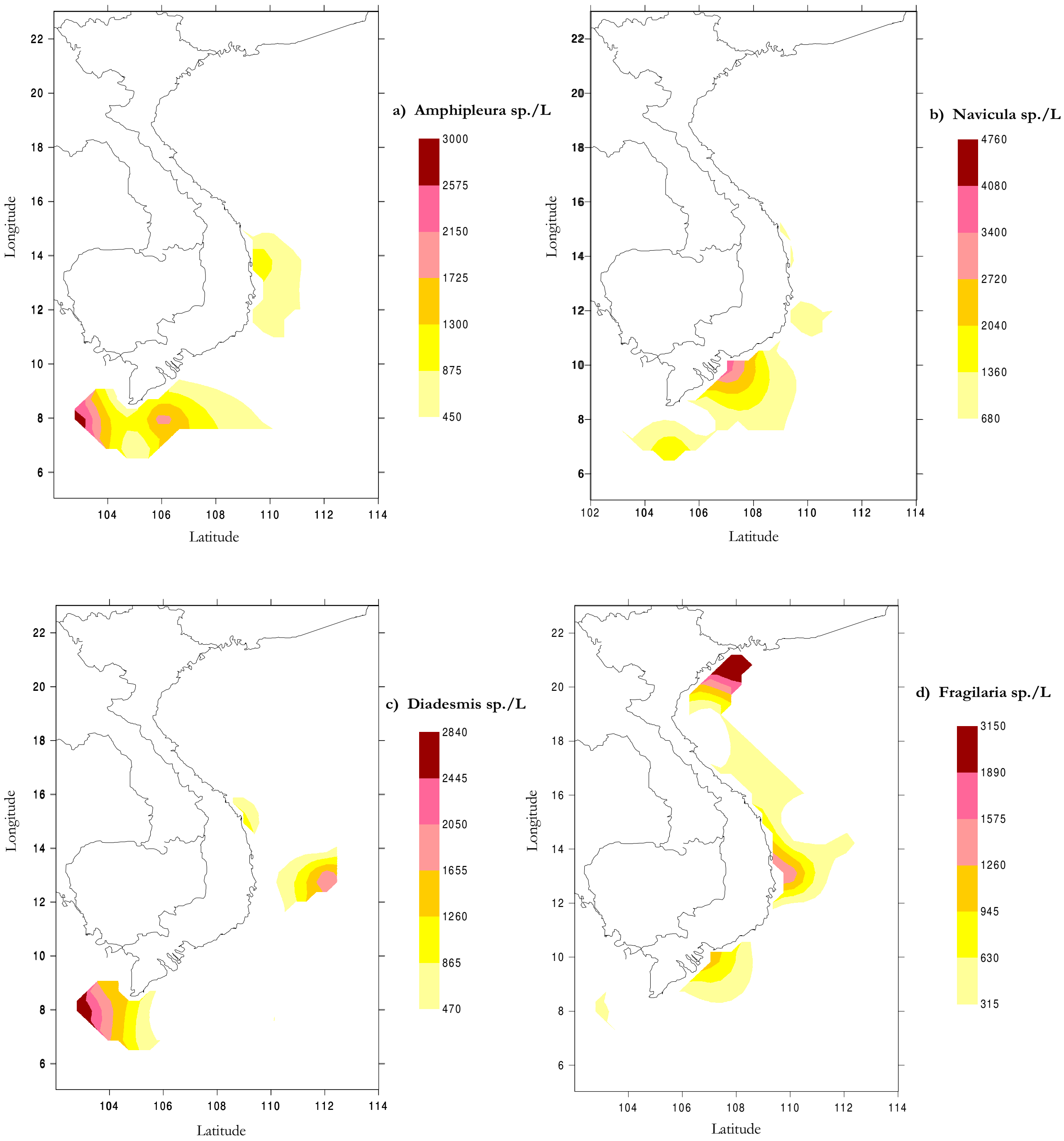

Fig. 2.3. Distribution of the pennate nanodiatom genera (a) *Amphipleura*, (b) *Navicula*, (c) *Diadesmis* and (d) *Fragilaria* in the Vietnamese waters of the South China Sea (April-June 1999 cruise survey).

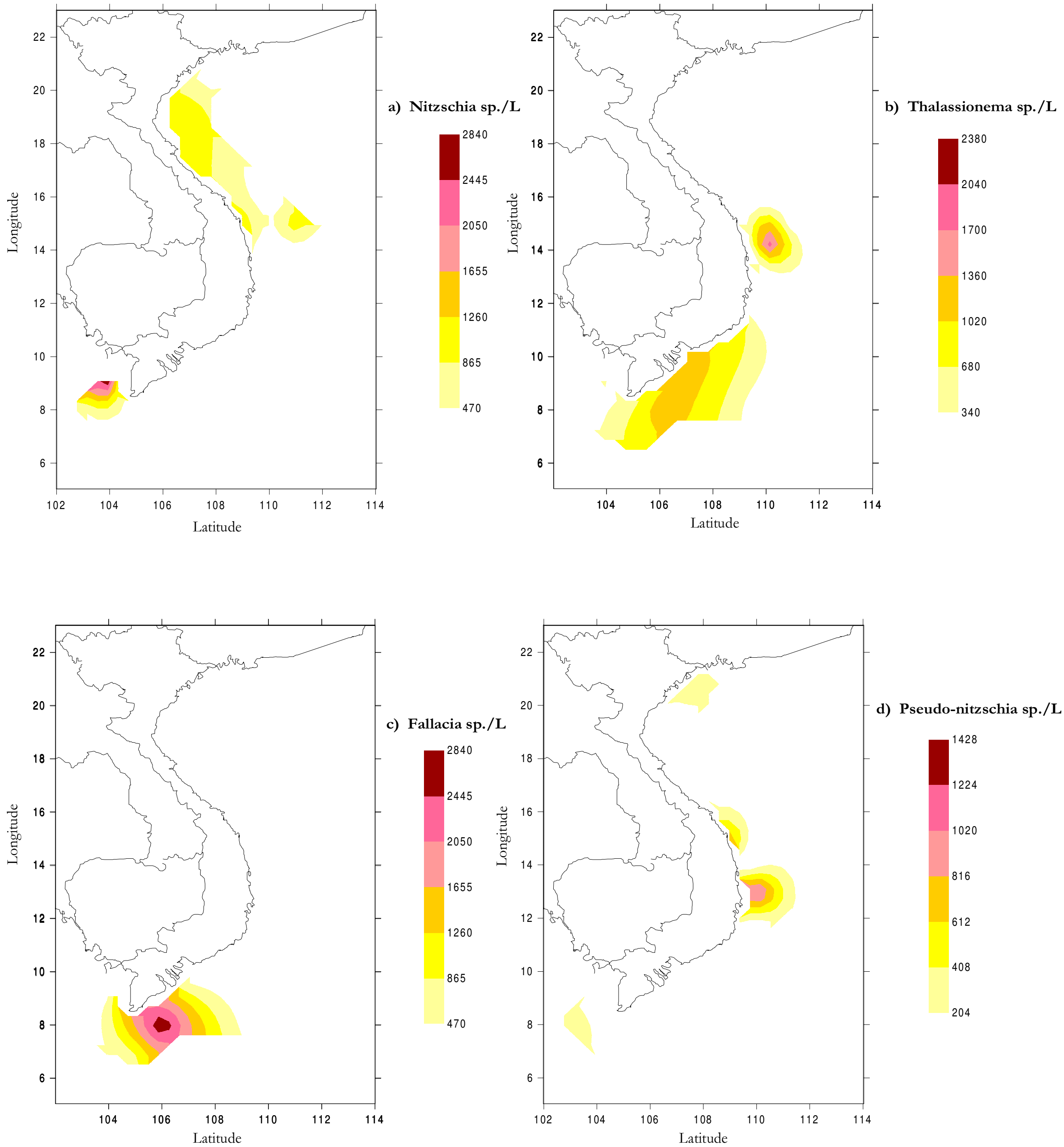

Fig. 2.4. Distribution of the pennate nanodiatom genera (a) *Nitzschia*, (b) *Thalassionema*, (c) *Fallacia* and (d) *Pseudo-nitzschia* in the Vietnam waters of the South China Sea (April /June 1999 cruise survey).

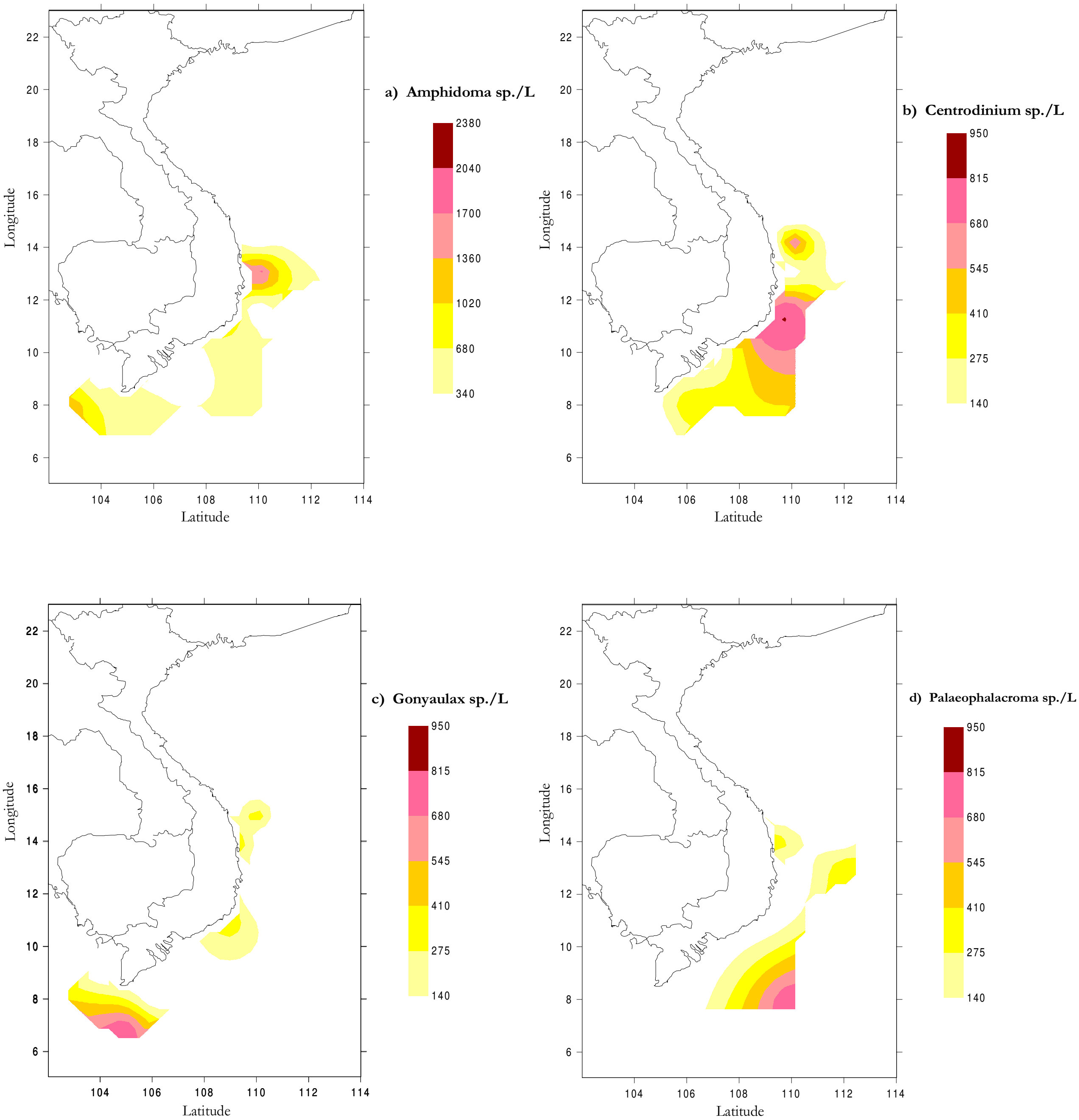

Fig. 2.5. Distribution of the nanodinoflagellate genera (a) *Amphidoma*, (b) *Centrodinium*, (c) *Gonyaulax* and (d) *Palaeophalacroma* in the Vietnamese waters of the South China Sea (April- June 1999 cruise survey).

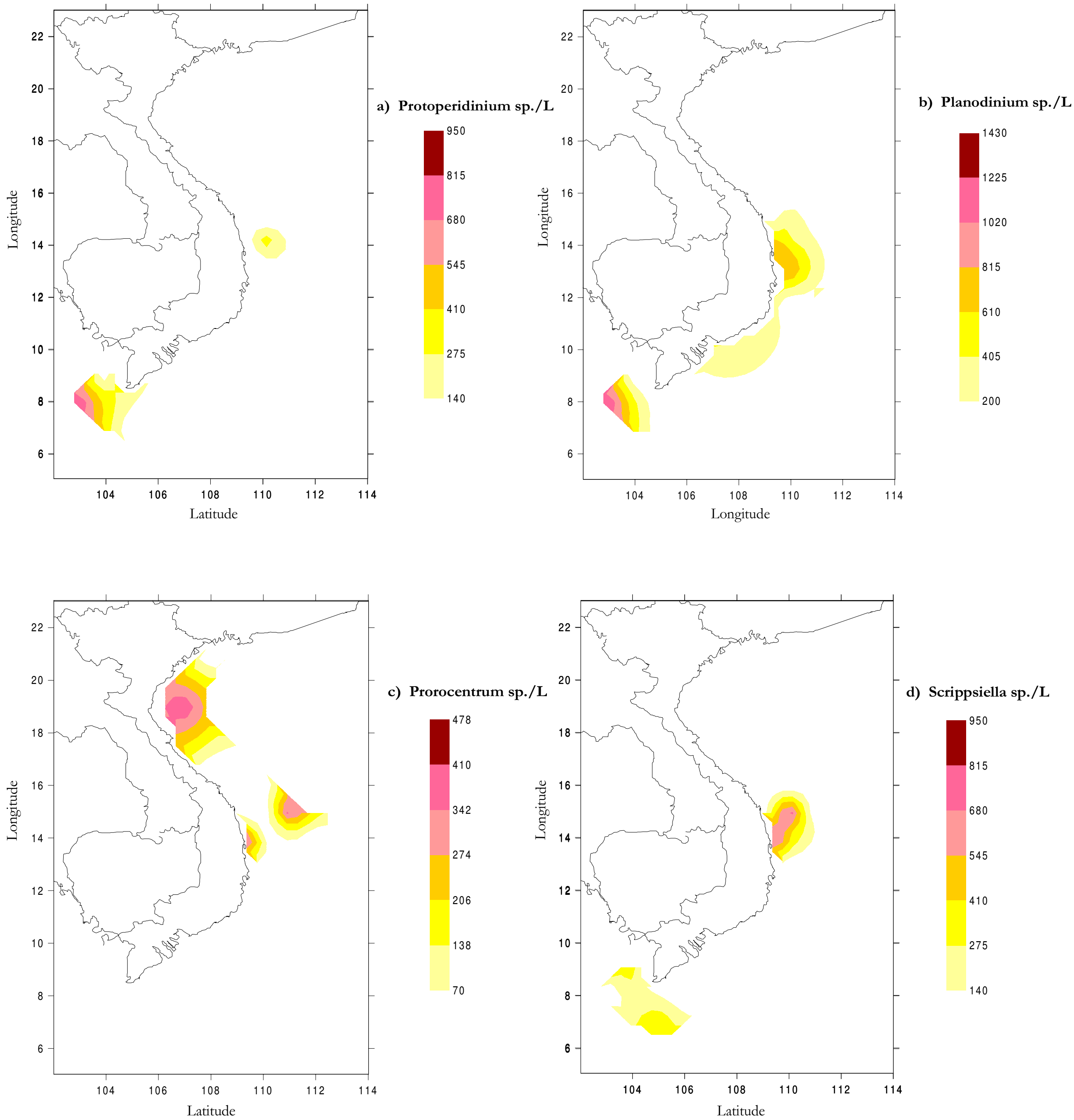

Fig. 2.6. Distribution of the nanodinoflagellate genera (a) *Protoperidinium*, (b) *Planodinium*, (c) *Prorocentrum* and (d) *Scrippsiella* in the Vietnamese waters of the South China Sea (April - June 1999 cruise survey).

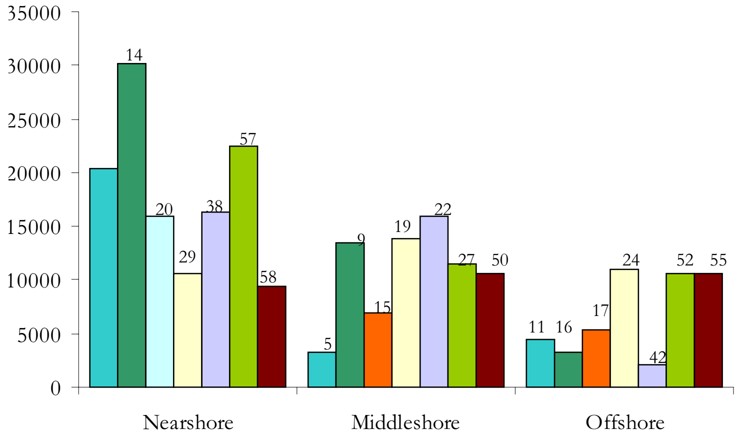

Fig. 3.1. Distribution and abundance of nanodiatom from chlorophyll maximum layer at 3 different zones in the Vietnamese waters (cruise April-June 1999).

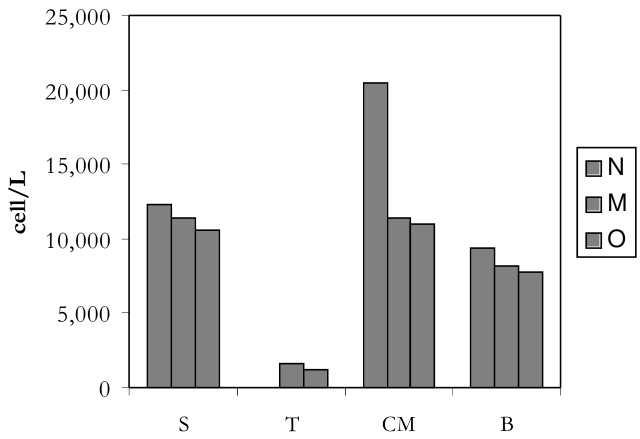

Fig. 3.2. Nanodiatom abundance (L^{-1}) of selected stations from different zones (coastal, middle and offshore) during the April-June 1999 cruise in the Vietnam waters (S – subsurface, T - thermocline, CM – chlorophylla maximum, B – sub chlorophyll maximum layer).

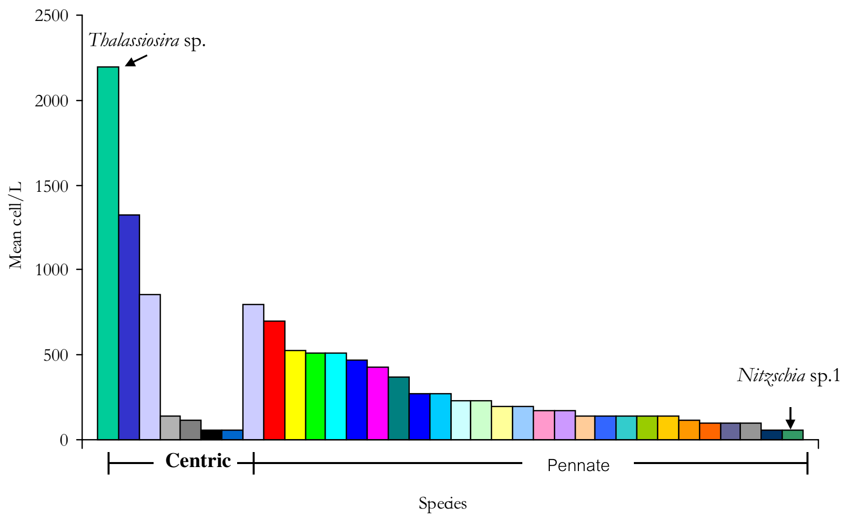

Fig. 3.3. Distribution and abundance of nanodiatom species (centric, pennate) in the Vietnamese waters (cruise April-June 1999).

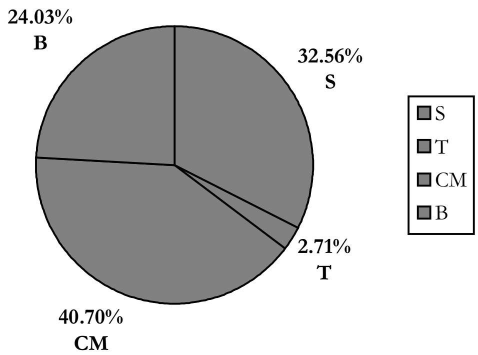

Fig. 3.4. Pie-chart graph in percentage abundance of nanodiatom with depth from selected stations during the April-June 1999 cruise in the Vietnamese waters (S – subsurface, T – thermocline, CM – chlorophylla maximum, B – sub chlorophyll maximum layer).

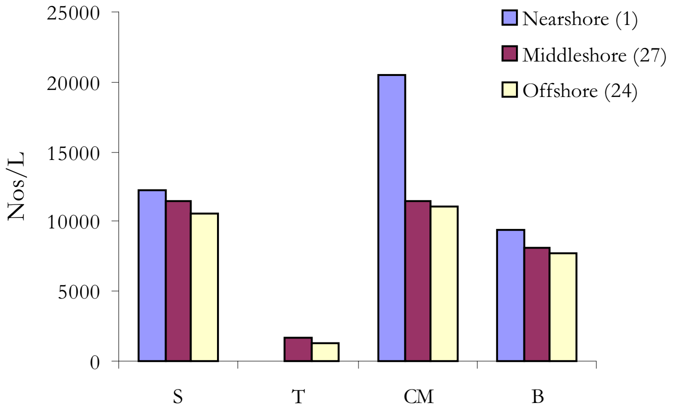

Fig. 3.5. Distribution and abundance of nanodiatom from different depth level (S – sub surface, T – thermocline, CM – chlorophyll maximum layer, B – sub chlorophyll maximum layer) from selected stations (1, 24, 27) in the Vietnamese waters (cruise April-June 1999).

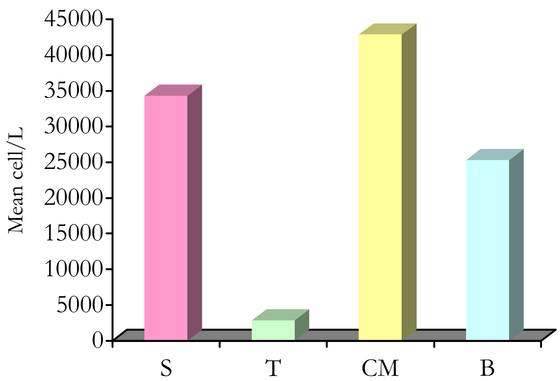

Fig. 3.6. Distribution and abundance of nanodiatom cell from different depth (S – sub surface, T – thermocline, CM – chlorophyll maximum layer, B – sub chlorophyll maximum layer) from selected stations (1, 24, 27) in the Vietnamese waters (cruise April-June 1999).

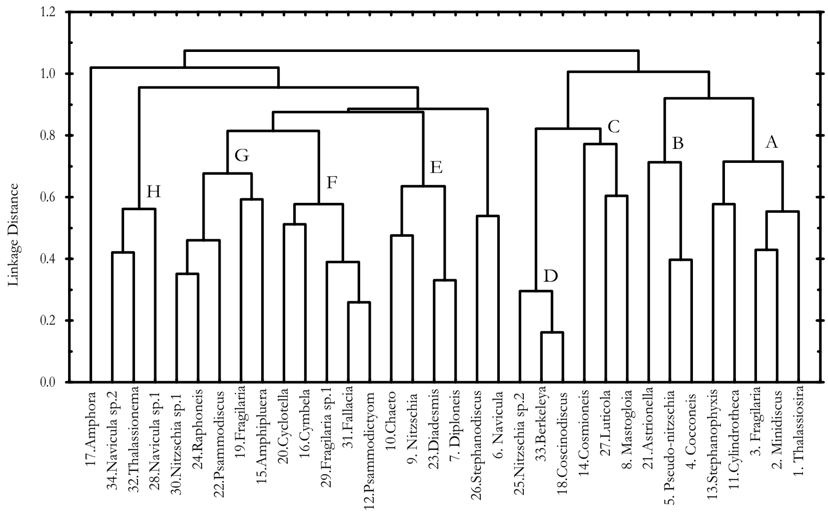

Fig. 4.1. Dendrogram showing nanodiatom species association during the 1999 cruise survey in the Vietnamese waters (cruise April-June 1999).

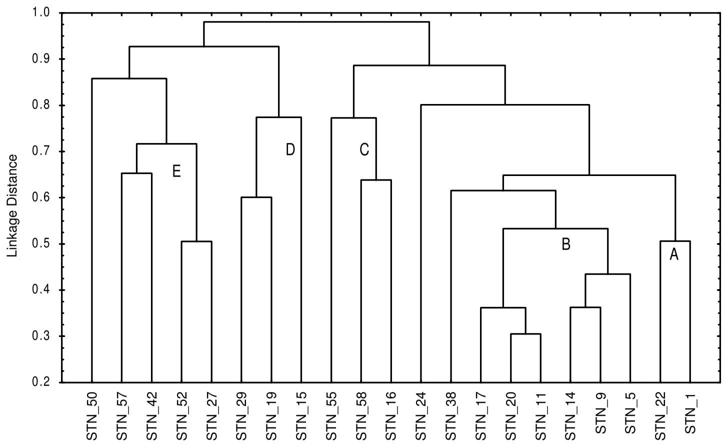

Fig. 4.2. Dendrogram showing similarity between stations in the Vietnamese waters (cruise April - June1999).

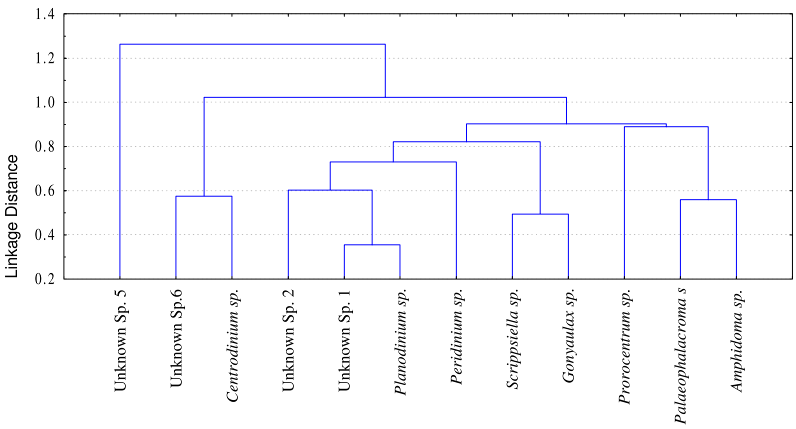

Fig. 4.3. Dendrogram showing nanodinoflagellate species association in Vietnamese waters (cruise April - June 1999).

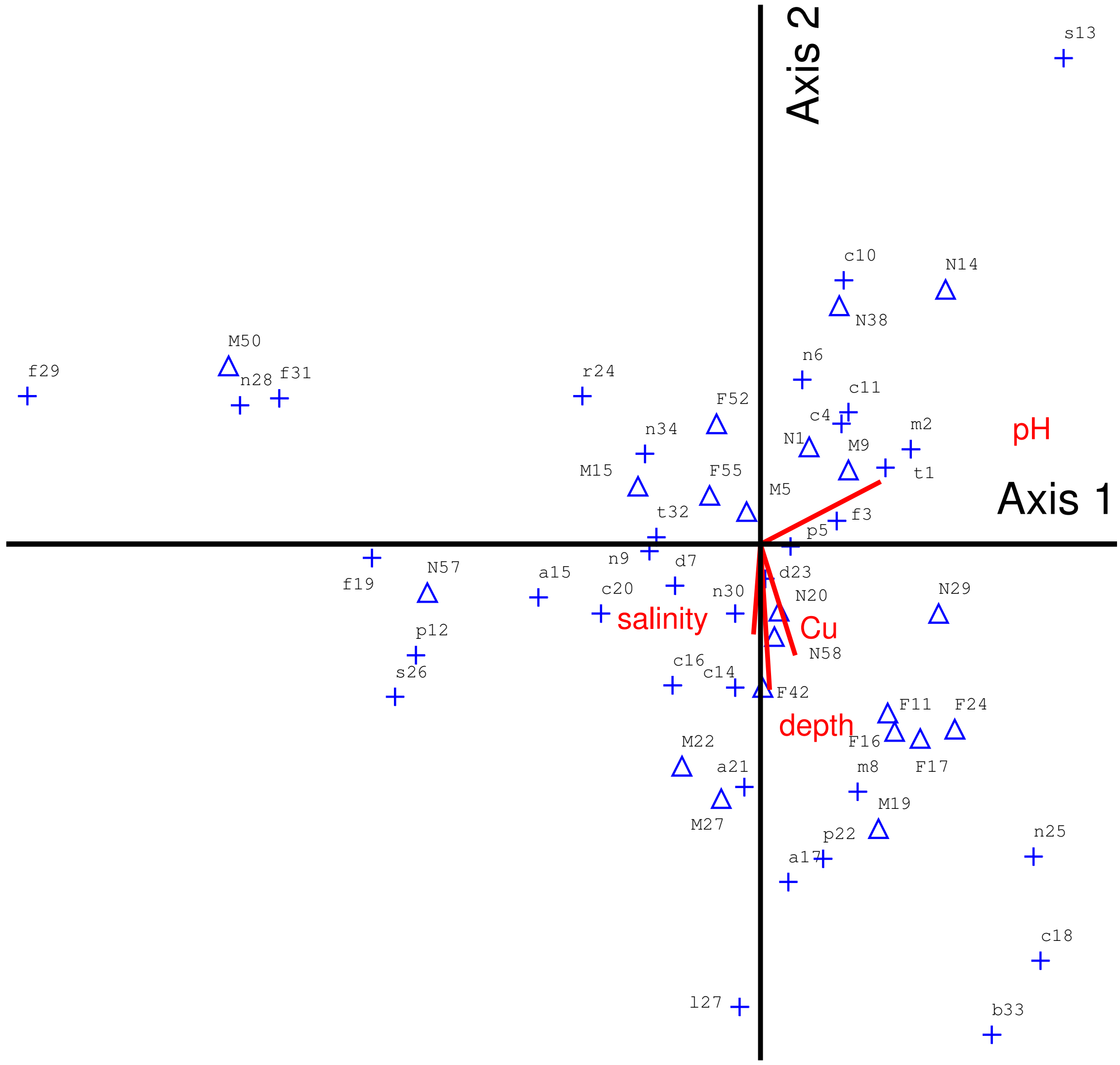

Fig. 5.1. CCA analysis on the relationship between algal cells in water masses from different stations during April/June 1999 cruise in Vietnamese waters (t1 – *Thalassiosira* sp., m2 – *Minidiscus* sp., f3 – *Fragilaria* sp., c4 – *Cocconeis* sp., p5 – *Pseudo-nitzschia* sp., n6 – *Navicula* sp., d7 – *Diploneis* sp., m8 – *Mastogloia* sp., n9 – *Nitzschia* sp., c10 – *Chaetoceros* sp., c11 – *Cylindrotheca* sp., p12 – *Psammodictyon* sp., s13 – *Stephanophyxa* sp., c14 – *Cosmioneis* sp., a15 – *Amphipluera* sp., c16 – *Cymbella* sp., a17 – *Amphora* sp., c18 – *Coscinodiscus* sp., f19 – *Fragilariopsis* sp., c20 – *Cyclotella* sp., a21 – *Asterionella* sp., p22 – *Psammodiscus* sp., d23 – *Diademis* sp., r24 – *Raphoneis* sp., n25 – *Nitzschia* sp. 2, s26 – *Stephanodiscus* sp., l27 – *Luticola* sp., n28 – *Navicula* sp. 1, f29 – *Fragilaria* sp., n30 – *Nitzschia* sp. 1, f31 – *Fallacia* sp., t32 – *Thalassionema* sp., b33 – *Berkeleya* sp., n34 – *Navicula* sp. 2, D – Station, N – Nearshore, M – Middle Shore, F – Offshore/Farshore, Cu – Copper mg/L).

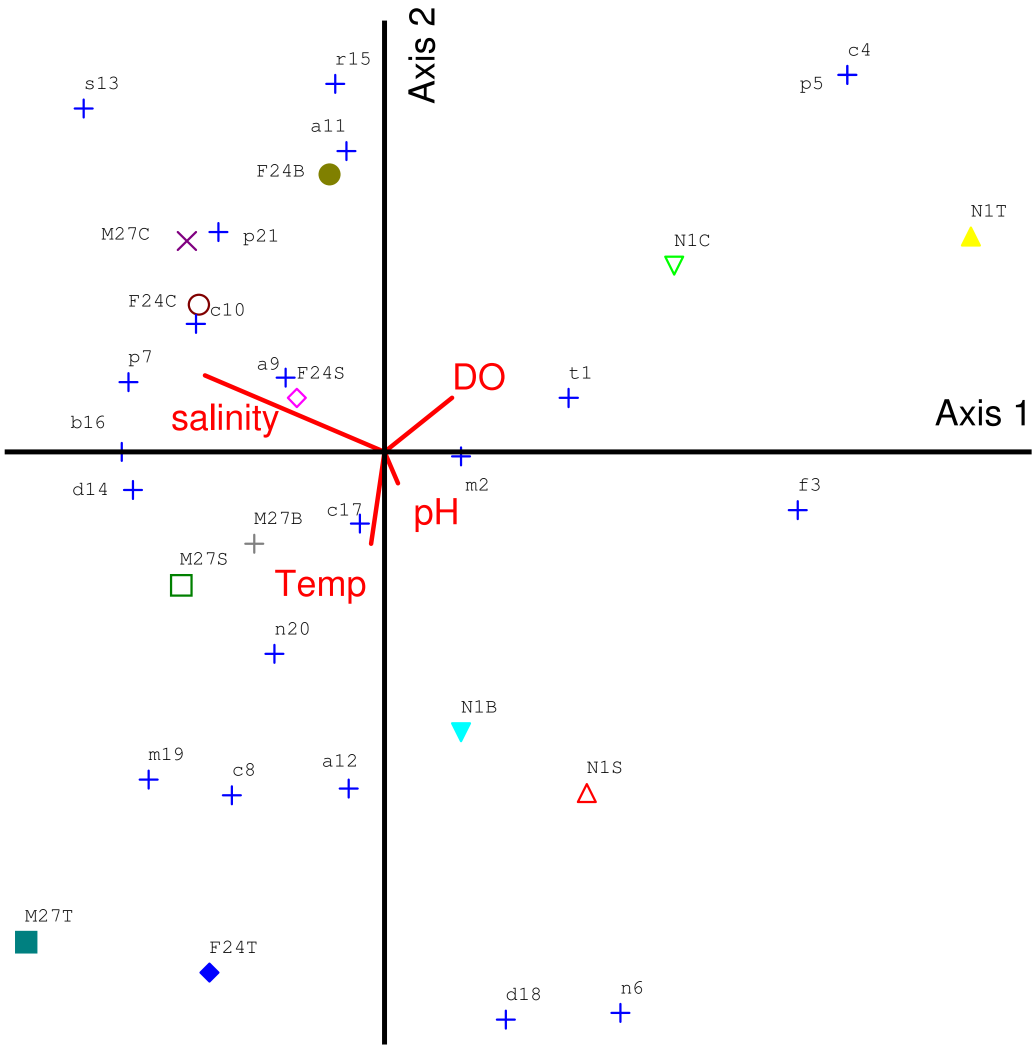

Fig. 5.2. CCA analysis on the relationship between nanodinoflagellate cells in water masses from different depth at selected stations during April/June 1999 cruise in Vietnam waters (N – Nearshore, M – Middle shore, F – Farshore, S – Subsurface, T – Thermocline, CM – Chlorophyll Maximum layer, B – Sub Chlorophyll Maximum layer; D.O – Dissolved Oxygen, t1 – *Thalassiosira* sp., m2 – *Minidiscus* sp., f3 – *Fragilaria* sp. 3, c4 – *Cocconeis* sp., p5 – *Pseudo-nitzschia* sp., n6 – *Navicula* sp., p7 – *Psammodictyon* sp., c8 – *Cosmioneis* sp., a9 – *Amphora* sp., c10 – *Coscinodiscus* sp., a11 – *Asterionella* sp., a12 – *Amphipluera* sp., s13 – *Stephanophyxa* sp., d14 – *Diademis,* r15 – *Raphoneis,* b16 – *Berkeleya,* c17 – *Chaetoceros,* d18 – *Diploneis,* m19 – *Mastogloia,* n20 – *Nitzschia,* p21 - *Psammodiscus*).

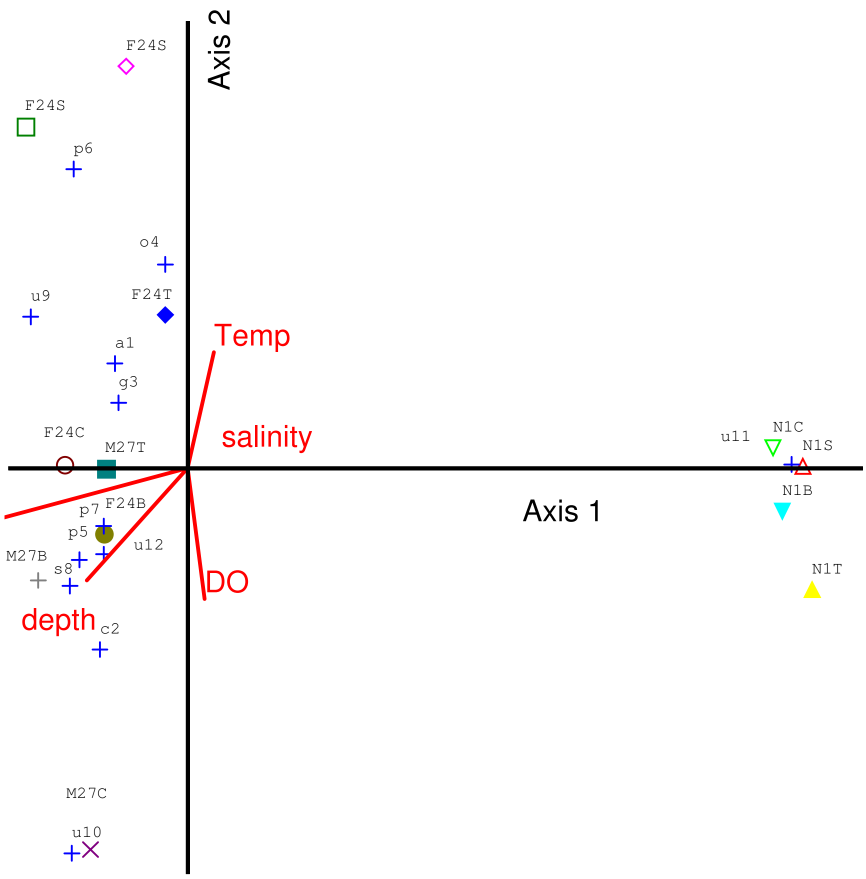

Fig. 5.3. CCA analysis on the relationship between algae cells in water masses from different depths at selected stations during April-June 1999 cruise in Vietnamese waters (a1 – *Amphidoma* sp., c2 – *Centrodinium* sp., g3 – *Gonyaulax* sp., p4 – *Palaeophalacroma* sp., p5 – *Protoperidinium* sp., p6 – *Planodinium* sp., p7 – *Prorocentrum* sp., u1 – *Goniodoma* sp., u2 – *Gyrodinium* sp., u3 – *Gymnodinium* sp., u4 – *Protoceratium* sp., u5 – *Heterodinium* sp., N – Nearshore, M – Middleshore, F – Offshore, D.O – Dissolved Oxygen mg/L).

Table 1.1. Mean and total nanodiatom cell number L^{-1} of the centric and pennate type from Cruise April-June 1999 in Vietnamese waters.

	Centric			Pennate		
	Species	Total (L^{-1})	Mean (L^{-1})	Species	Total (L^{-1})	Mean (L^{-1})
1	*Thalassiosira* sp.	46164	2198	*Asterionella* sp.	16749	797
2	*Minidiscus* sp.	27781	1322	*Psammodiscus* sp.	14707	700
3	*Chaetoceros* sp.	17975	855	*Fragilaria* sp.	9804	466
4	*Cyclotella* sp.	2859	136	*Fragilaria* sp.1	3676	175
5	*Stephanodiscus* sp.	2451	116	*Nitzschia* sp.2	2859	136
6	*Stephanophyxis*	1225	58	*Berkeleya* sp.	2859	136
7	*Coscinodiscus* sp.	1225	58	*Pseudo-nitzschia* sp.	2859	136
8				*Fragilariopsis* sp.	2042	58
9				*Nitzschia* sp.1	1225	58

Table 1.2. Abundance and distribution of centric nanodiatom in the Vietnamese waters of the South China Sea during April - June cruise 1999 (N-nearshore, M-middleshore, F-offshore, H-diversity index, J-evenness index).

Centric Genus	No. of species	Main species	Total cell/ L	Stations	Nos/L	% Abundance	H	J
1. *Thalassiosira*	16	*T. binata* (Fryxell)	46,164	14N	9396	20.8	2.8	0.84
		T. conferta (Hasle)		20N	6128	13.3	2.38	0.85
		T. eccentrica (Ehr) Cleve		1N	5719	12.4	2.37	0.71
		T. alenii (Takano)		29N	5310	12.2	2.55	0.76
		T. curviseriata (Takano)		38N	4491	9.7		
		T. oestrupii (Ostenfeld) Hasle						
		T. tenera (Proschkina-Lavrenko)						
		T. punctigera (Castrare) Hasle						
2. *Minidiscus*	3	*M. comicus* (Tanako)	27,781	9M	7354	26.5	2.03	0.72
		M. chilensin (Rivera et Koch)		14N	5310	19.1	0.8	0.84
		M. trioculatus (Taylor) Hasle		1N	4085	14.7	0.38	0.85
3. *Chaetoceros*	9	*C. didymum* (Ehr.)	17,975	14N	7354	40.9	2.8	0.84
		C. daricum (Cleve)		38N	4085	22.7	2.55	0.76
4. *Cyclotella*	3	*C. striata* (Kutz) Grunow	2,895	57N	1225	42.3	2.47	0.69
		C. meneghiniana (Kutz)		38N	817	28.2	2.55	0.76
		C. cryptica (Reimann)						
5. *Stephanodiscus*	2	*Stephanodiscus* sp. (Ehr.)	2451	57N	1634	66.7	2.47	0.69
6. *Stephanophyxis*	6	*S. nipponica* (Gran & Yando)	1225	14N	225	18.3	2.8	0.84
		S. palmeriana (Grunow)						
		S. turris (Greville)						
7. *Coscinodiscus*	8	*C. asteromphalus* (Ehr)	1225	19M	408	33.3	2.72	0.78
		C. curvatulus (Grunow)						

Table 1.3. Abundance and distribution of pennate nanodiatom in the Vietnamese waters of the South China Sea during April-June cruise (N-nearshore, M-middleshore, F-offshore, H-diversity index, J-evenness index).

Pennate Genus	No. of species	Main species	Total cell/ L	Stations	Nos/L	% Abundance	H	J
Pennate								
1. *Asterionella*	4	*A. japonica* (Cleve)	16,749	1N	4085	24.3	2.38	0.85
		A. notata (Grunow)		22M	6128	36.6	3.08	0.97
2. *Navicula*	8	*N. grevileana* (Henley)	18,621	29N	2042	10.9	2.37	0.71
		N. schonkenii (Hustedt)						
		N. fucicola (Taasen)						
		N. pseudonglica var. *signata* (Hustedt)						
3. *Nitzschia*	4	*N. lavidensis* (W. Smith) Van Heurek	8987	5M	1225	13.6	1.91	0.95
		N. pungans (Grunow)		57N	2859	31.8	2.47	0.69
				14N	1225	13.6	2.8	0.84
4. *Fragilaria*	2	*F. brevistria* (Bory)	9804	16F	1225	12.4	2.16	0.93
		F. opephoraides (Takano)						
		F. striatula (Lyngbye)						
5.*Pseudo-nitzschia*	5	*P. seriata* (Cleve)	2859	22M	1225	42.8	3.08	0.97
		P. lineata (Perag.)		55F	408	14.2	2.34	0.74
		P. fraudulenta (Cleve)		1N	408	14.2	2.38	0.85
		P. tugidula (Fryxell)		14N	817	28.4	2.8	0.84
		P. subpacifica (Hasle)		55F	408		2.34	0.74
6.*Psammodiscus*	2	*Psammodiscus* sp. (Round & Menn)	14707	19M	5719	38.8	2.72	0.78

Table 1.3. (Continued).

Pennate Genus	No. of species	Main species	Total cell/ L	Stations	Nos/L	% Abundance	H	J
Pennate								
1. *Asterionella*	4	*A. japonica* (Cleve)	16,749	1N	4085	24.3	2.38	0.85
		A. notata (Grunow)		22M	6128	36.6	3.08	0.97
2. *Navicula*	8	*N. grevileana* (Henley)	18,621	29N	2042	10.9	2.37	0.71
		N. schonkenii (Hustedt)						
		N. fucicola (Taasen)						
		N. pseudonglica var. *signata* (Hustedt)						
3. *Nitzschia*	4	*N. lavidensis* (W. Smith) Van	8987	5M	1225	13.6	1.91	0.95
		Heurek		57N	2859	31.8	2.47	0.69
		N. pungans (Grunow)		14N	1225	13.6	2.8	0.84
4. *Fragilaria*	2	*F. brevistria* (Bory)	9804	16F	1225	12.4	2.16	0.93
		F. opephoraides (Takano)						
		F. striatula (Lyngbye)						
5. *Pseudo-nitzschia*	5	*P. seriata* (Cleve)	2859	22M	1225	42.8	3.08	0.97
		P. lineata (Perag.)		55F	408	14.2	2.34	0.74
		P. fraudulenta (Cleve)		1N	408	14.2	2.38	0.85
		P. tugidula (Fryxell)		14N	817	28.4	2.8	0.84
		P. subpacifica (Hasle)		55F	408		2.34	0.74
6. *Psammodiscus*	2	*Psammodiscus* sp. (Round & Menn)	14707	19M	5719	38.8	2.72	0.78

Table 2.1. Distribution and abundance of nanodiatom from nearshore, middle shore and offshore in the Vietnamese waters (cruise April-June 1999).

Nearshore		Middle shore		Offshore	
Stations	**Cell/L**	**Stations**	**Cell/L**	**Stations**	**Cell/L**
1	20426	5	3268	11	4493
14	30231	9	13482	16	3268
20	15932	15	6945	17	5310
29	10621	19	13890	24	11030
38	16341	22	15933	42	2042
57	22468	27	11438	52	10621
58	9396	50	10621	55	10621
Total	**125420**	**Total**	**75579**	**Total**	**47389**
Mean	**17917**	**Mean**	**10797**	**Mean**	**6769**

Table 2.2. Distribution and abundance of nanodiatom from different depth cruise in the Vietnamese waters (cruise April-June 1999.)

Stations and Zones	Water Mass Layer			
	Sub-surface	**Thermocline**	**Chlorophyll Max.**	**Sub-chlorophyll Max.**
1 (N)	12256	110	20426	9396
24 (F)	10621	1225	11030	7762
27 (M)	11438	1634	11438	8170
Total	34316	2859	14298	25329
Mean	11438	1540	-	8443

Table 2.3. Nanodiatom dominant species distribution with depth at selected stations during the April-June 1999 cruise in the Vietnamese waters (S-sub surface, T-thermocline, CM-chlorophyll maximum, B-sub chlorophyll maximum,N-nearshore,M-middle,F-offshore, + - present).

	Species	1N				24M				27F			
		S	**T**	**CM**	**B**	**S**	**T**	**CM**	**B**	**S**	**T**	**CM**	**B**
1	*Thalassiosira* sp.	+	+	+	+	+	+	+		+		+	+
2	*Minidiscus* sp.	+		+	+	+		+	+		+		+
3	*Fragilaria* sp.	+		+		+							
4	*Cocconeis* sp.			+									
5	*Pseudo-nitzschia* sp.			+									
6	*Navicula* sp.	+			+	+						+	+

Table 3.1. Distribution and abundance of nanodinoflagellate (L^{-1}) at 3 zones (namely nearshore, middle shore, offshore) in the Vietnamese waters (cruise April-June 1999).

Species	Nearshore	Middle shore	Offshore
1. *Amphidoma*	1634	2450	2450
2. *Centrodinium*	817	2042	408
3. *Gonyaulax*	817	408	1230
4. *Oxytoxum*	408	400	1225
5. *Palaeophalacroma*	408	1634	817
6. *Planodinium*	1634	418	1230
7. *Prorocentrum*	408	12230	400
8. *Scrippsiella*	1225	817	410
9. *Goniodema*	2859	2450	1220
10. *Gyrodinium*	2850	408	2042
11. *Gymnodinium*	-	12560	12250
Total	13075	24512	23695

Table 3.2. Distribution and abundance of nanodinoflagellate (L^{-1}) with depth at selected stations (N-nearshore, M-middleshore, F- offshore) in the Vietnamese waters (cruise April-June 1999 (H-diversity index; J-evenness index).

Species	1N				27M				24F			
	S	T	CM	B	S	T	CM	B	S	T	CM	B
1. *Amphidoma*	-	-	-	-	-	-	-	-	200	500	408	150
2. *Centrodinium*	-	-	-	-	-	-	-	-	50	150	100	1200
3. *Gonyaulax*	10	20	40	5	5	800	700	40	50	800	100	50
4. *Oxytoxum*	-	-	-	-	10	450	100	410	10	400	10	10
5. *Palaeophalacroma*	-	-	-	-	-	-	-	-	200	100	500	1600
6. *Planodinium*	10	20	30	10	1600	400	10	5	900	10	20	800
7. *Prorocentrum*	-	-	-	-	5	405	10	5	10	20	10	800
8. *Scrippsiella*	-	-	-	-	5	5	20	390	10	5	10	400
9. *Goniodema*	1000	50	1000	408	350	10	20	420	40	50	100	1200
10. *Gyrodinium*	-	-	-	-	-	-	812	404	-	-	-	-
11. *Gymnodinium*	-	-	-	-	5	10	30	10	-	-	-	-
Total	1120	90	1070	423	1980	1680	1702	1654	1290	2035	1038	6200
H	0.51	0.43	0.62	0.54	0.72	1.92	0.91	1.22	0.52	0.73	0.51	1.02
J	0.31	0.32	0.45	0.27	0.41	0.52	0.48	0.42	0.34	0.21	0.43	0.62

Table 3.3. The abundance and distribution of nanodinoflagellate in the Vietnamese waters (cruise April - June1999). N- nearshore, M- middleshore, F- offshore, H-diversity index, J-evenness index.

Genus	No. of species	Main species	Total cell/L	Stations	Nos/L	%	H	J
Amphidoma	1	*A. steini* (Schill)	6495	22M	2042	29.4	1.66	0.63
Centrodinium	1	*C. mimeticum* (Balech) Taylor	3268	27M	817	25.0	1.12	0.41
Gonyaulax	9	*G. diagenis* (Koch) *G. polygramme* (Stein) *G. scrippsae* (Kofoid) *G. polyedra* (Stein)	2450	52F	800	32.6	1.96	0.74
Oxytoxum	3	*O. tesselatum* (Stein) *O. milneri* (Murr & Whitt) *O. scolopax* (Stein)	400	22M	200	50.0	1.66	0.63
Palaeophalacroma	1	*P. unicinctum* (Schiller)	1634	42F	408	24.9	1.92	0.72
Planodinium	1	*P. striatum* (Sounder & Dodge)	4493	57N	1220	27.2	1.58	0.64
Prorocentrum	8	*P. gracile* (Shutt) *P. micans* (Ehr) *P. minimun* (Pavilland) *P. sigmoides* (Bohm)	2500	55F	1225	49.0	2.17	0.63
Scrippsiella	5	*S. crystalline* (Lewis) *S. rotunda* (Lewis) *S. trochoides* (Loeblica)	2859	20N	810	28.3	2.72	0.67
Goniodema	2	*G. polyedricum* (Jorgensen) *G. sphaericum* (Murray & Whitting)	4900	42F	810	16.5	1.92	0.72
Gyrodinium	5	*G. aureolum* (Hulburt) *G. dominans* (Hulburt)	27,300	5M	7300	26.7	0.52	0.30
Gymnodinium	5	*G. brufe* (Davis) *G. fungiforme* (Anissinova)	2040	50M	800	39.2	0.52	0.30

Table 4.1. Species assemblage or association of nanodiatom in the Vietnamese waters (April- June 1999 cruise survey).

Group association	Nanodiatom centric	Pennate
A	*Stephyanophyxis* sp. *Minidiscus* sp. *Thalassiosira* sp.	*Cylindrotheca* sp. *Fragilaria* sp.
B	*Navicula* sp.	*Asterionella* sp. *Pseudo-nitzschia* sp. *Cocconeis* sp.
C		*Cosmioneis* sp. *Luticola* sp. *Mastoglpia* sp.
D	*Coscinodiscus* sp.	*Nitzschia* sp. *Berkeleya*
E	*Chaetoceros* sp.	*Nitzschia* sp. *Diadesmis* sp. *Diploneis* sp.
F	*Chaetoceros* sp.	*Cymbella* sp. *Fragilaria* sp. 1 *Fallacia* sp. *Psammodictyon* sp.
G		*Psammodiscus* sp. *Nitzschia* sp.1 *Raphoneis* sp. *Fragilaria* sp. *Amphipluera* sp.
H		*Navicula* sp. *Thalasionema* sp.

Table 4.2. Species assemblage or association of nanodinoflagellate in the Vietnamese waters (cruise April - June 1999).

Group	Species association
A	*Gyrodinium, Centrodinium*
B	*Palaeophalacroma, Amphidoma*
C	*Scrippsiella, Gonyaulax*
D	*Scrippsiella, Gonyaulax*
E	*Planodinium, Goniodium*

Table 5. The mean values of various environmental parameters of water masses in the Vietnamese waters (cruise April- June 1999) .
S- sub surface, T-thermocline, CM-chlorophyll maximum layer depth(m), B - sub chlorophyll maximum layer, DO-dissolved oxygen mg/L

Parameter	Depth Level (m)	Nearshore	Middleshore	Offshore
pH	S	8.190	8.247	8.265
	T	8.192	8.272	8.270
	CM	8.194	8.233	8.148
	B	8.178	8.100	8.036
D.O. (mg/L)	S	4.415	3.798	3.733
	T	4.420	7.046	3.809
	CM	4.470	4.471	4.457
	B	4.664	4.564	4.850
Temp. (°C)	S	24.03	28.04	29.40
	T	23.76	27.37	29.39
	CM	23.47	22.14	21.29
	B	23.22	20.96	17.22
Salinity ppt.	S	31.64	33.85	33.30
	T	31.66	33.84	33.31
	CM	31.69	34.41	34.44
	B	31.82	34.54	34.62
CM depth (m)	S	3.5	5.5	5.5
	T	10	20	20
	CM	22	75	65
	B	30	125	125
Actual depth (m)		34	1734	3332

Appendix

Division : BACILLARIOPHYTA

Class : COSCINODISCOPHYCEAE

Subclass : THALASSIOSIROPHYCIDAE

Order : THALASSIORALES (Glezer & Makarova, 1986)
Family : Thalassiosiraceae (Lebour, 1930)
Genus : Thalassiosira
Thalassiosira sp. (P.T. Cleve, 1973)
T. alenii (Takano) 8μ
T. binata (Fryxell) 4μ
T. conferta (Hasle) 3.5μ
T. curviseriata (Takano) 7.8μ
T. diporocyclus (Hasle) 12μ
T. eccentrica (Ehr.) Cleve 10μ
T. guillardii (Hasle) 4μ
T. hyalina (Grunow) Gran 15μ
T. laudiana (Fryxell) 13μ
T. mala (Takano) 3μ
T. minima (Gaarder) 3.5μ
T. orstrupii (Ostenfeld) Hasle 5μ
T. punctigera (Castracare) Hasle 10μ
T. tealata (Takano) 6μ
T. tenera (Proschkina-Lavrenko) 10μ
T. weissflagii (Grunow) Fryxell et Hasle 5μ

Genus : Minidiscus
Minidiscus sp. (G.R. Hasle, 1973)
M. chilensis (Riversa et Koch)
M. comicus (Takano)
M. trioculatus (Taylor, Hasle)

Family : Stephanodiscaceae (Glezer & Makarova, 1986)
Genus : Cyclotella
Cyclotella sp. (F.T. Kutzing ex A. de Brebosson)
C. cryptica (Reimann) 5μ
C. meneghiniana (Kutz) 10μ
C. striata (Kutz) Grunow 10μ

Genus : Stephanodiscus
Stephanodiscus sp.
(C.G. Ehrenberg, 1845)

Subclass : COSCINODISLOPHYCIDAE

Order : MELOSIRALES (Crawford, ord. Nov)
Family : Stephynopyxidacea (Nikolaev)
Genus : Stephynopyxis
Stephynopyxis sp.
(C.G. Ehrenberg)

Order : COSCINODISCALES (Round & Crawford ord. Nov.)
Family : Coscinodiscaceae (Kutzing, 1844)
Genus : Coscinodiscus
Coscinodiscus sp.
(C.G. Ehrenberg)

Subclass : CHAETOCEROTOPHYCIDAE

Order : CHAETOCEROTALES (Round & Crawford ord. Nov.)
Family : Chaetocerotaceae (Rafs in Pritchard, 1861)
Genus : Chaetoceros
Chaetocceros sp. (C.G. Ehrenberg)
C. costatum (Pavillard) 12μ
C. danicum (Cleve) 8μ
C. debile (Cleve) 12μ
C. decipiens (Cleve) 10μ
C. didymum (Ehr.) 10μ
C. muelleri (Lemmermann) 5μ
C. pseudocurvisetum (Mangin) 15μ
C. salsugineum (Takano) 2μ
C. sociale (Lauder) 4μ

Family : Nitzschiaceae
Genus : Nitzschia
Species : *N. levidensis* (W. Smith) Van Heurck
N. martiana (Agardh) Van Heurck
N. pungens (Grunow)
N. tenuiarcuata (Takano)

Genus : Pseudo-nitzschia
Species : *P. multistriata*

Genus : *Amphora*
Species : *A. bigibba* (Grunow) 10μ
A. coffeaeformis (Agardh) Kutzing

Genus : *Berkeleya*
Species : *B. fragilis* (Greville) 10μ
B. rutilan (Grunow) 18μ

Genus : *Caloneis*
Species : *C. brevis* (Gregory) Cleve 30μ

Genus : *Fallacia*
Species : *F. pygmaen* (Kutz) Stickce et Mann 20μ

Genus : *Lauderia*
Species : *L. annulata* (Cleve) 26μ

Class : FRAGILARIOPHYCEAE

Subclass : FRAGILARIOPHYCIDAE

Order : FRAGILARIALES (Silva, 1962 sensu emend.)
Family : Fragilariaceae (Greville, 1833)
Genus : Fragilaria
Species : *Fragilaria* sp. (A.H. Lyngbye, 1819)
F. opephoroides (Takano) 2.5μ
F. striatula (Lyngbye) 4μ
Genus : Asterionella
Asterionella sp. (A.H. Lyngbye, 1850)

Order : RHAPHONEIDALES (Round, ord. nov.)
Family : Rhaphoneidaceae (Forti, 1912)
Genus : Raphoneis
Raphoneis sp. (C.G. Ehrenberg, 1844)

Family : Psammodiscaceae (Round & Mann, fam. nov.)
Genus : Psammodiscus
Psammodiscus sp. (F.E. Round & D.G. Menn)

Order : THALASSIONEMATALES (Round, ord. nov)
Family : Thalassionemataceae (Round, fam. nov.)
Genus : Thalassionema
Thalassionema sp. (A. Grunow ex F. Hustedt, 1932)

Subclass : BACILLARIOPHYCIDAE

Order : MASTOGLOIALES (D.G. Mann, ord. nov.)
Family : Mastogloiales (D.G. Mann, ord. nov.)
Genus : Mastogloia
Mastogloia sp. (G.H.K. Thwaites ex W. Smith, 1856)

Family : Cocconeidaceae (Kutzing, 1844)
Genus : Cocconeis
Cocconeis sp. (C.G. Ehrenberg, 1837)
Species : *C. placentula* (Ehr.) var euglypta (Ehr.) Cleve 10μ
C. stauroneiformis (W. Smith) Okuna

Order : NAVICULALES (Bessey, 1907 sensu emend)
Family : Berkeleyaceae
Genus : Berkeleya
Berkeleya sp. (R.K. Greville, 1827)

Genus : Navicula
Species : *N. fucicola* (Taasen) 5μ
N. grevilleana (Hendey) 10μ
N. pseudonglica var *signata* (Hustedt)
N. schonkenii (Hustedt) 10μ

Family : Cymbellaceae (Greville, 1833)
Genus : Cymbellaya
Cymbella sp. (C. Agardh, 1830)

Division : DINOPHYTA

Order : Dinoflagellate
Family : Prorocentridae
Genus : Prorocentrum
Species : *P. micans* (Ehrenberg) 2.0μ

Family : Peridiniidae
Genus : Amphidoma
Species : *A. steini* (Schill)

Genus : Gonyaulax
Species : *G. polyedra* (Stein)
G. polygramma (Stein)

Genus : Goniodoma
Species : *G. polyedricum* (Pouchet) Stein
G. sphaericum (Murr, Whitt) 35μ

Genus : Gymnodinium
Species : *G. maguelonnense* (Biecheler)
G. gracile (Berg)

Genus : Gyrodinium
Species : *G. glaucum* (Labour)

Genus : Oxytoxum
Species : *O. tesselatum* (Stein)
O. milneri (Murr & Whitt)
O. scolopax (Stein)

Genus : Peridinium
Species : *P. breve* (Paulsen)
P. lenticula (Bergh)
P. paulseni (Pavillard)
P. pellucidum (Lebour)
P. steini (Jorg)

Genus : Centrodinium
Species : *C. mimeticum* (Balech) Taylor

Order : Prorocentrales
Family : Prorocentraceae
Genus : Prorocentum
Species : *P. balticum* (Lohmann) Loeblich
P. compressum (Bailey) Abe ex Dodge
P. obtusidens (Schiller)
P. gracile (Schutt)
P. micans (Ehrenberg)
P. minimun (Pavillard) Schiller
P. sigmoides (Bohm)
P. triestinum (Schiller)

Family : Cladopyxidaceae
Genus : Palaeophalacroma
Species : *P. unicinctum* (Schiller)

Family : Gonyaulacaceae
Genus : Gonyaulax
Species : *G. diegenis* (Kofoid)
G. digitale (Pouchet) Kofoid
G. milneri (Murray et Whitting) Kofoid
G. polygramme (Stein)
G. scrippsae (Kofoid)
G. spinifera (Claparede et Lachmann) Diesing)
G. turbynei (Murray et Whitting)
G. verior (Sournia)
G. polyedra (Stein)

Family : Amphidiniopsidaceae
Genus : Planodinium
Species : *P. striatum* (Sounder & Dodge)

Order : Peridiniales
Genus : Scrippsiella
Species : *S. Crystallina* (Lewis)
S. precaria (Moutesor et Zingore)
S. rotunda (Lewis)
S. spinifera (Honsell & Cabrini)
S. trochoidea (Stein) Loeblich

Family : Triadiniaceae
Genus : Goniodoma
Species : *G. polyedricum* (Pouchet) Jorgensen
G. sphaericum (Murray et Whitting)

Order : Gymnodiniales
Family : Gymnodiniaceae

Genus : Gymnodinium
Species : *G. breve* (Davis) 15m
G. fungiforme (Anissinova) 8 m
G. mikimotoi (Miyoke et Kominami ex Oda) 14m
G. sanguineum (Hirasaka) 30m
G. striatissium (Hulburt) 35m

Genus : Gyrodinium
Species : *G. aureolum* (Hulburt) 20m
G. dominans (Hulburt) 10m
G. falcatum (Kofoid et Swezy) 25m
G. instriatum (Freudenthal et Leu) 30m
G. spirale (Bergh) Kofoid et Swezy) 20m

Genus : Protoperidinium
Species : *P. ventricum* (Abe) 30m
P. thulesense (Balech) 30m
P. steinii (Jorgensen) 22m
P. pyriforme (Paulsen) Balech 30m
P. punctulatum (Paulsen) 30m
P. pellucidum (Bergh) 30m
P. ovum (Schiller) Balech 30m
P. mite (Pavillerd) Balech
P. minutum (Kofoid) Loeblich 20m
P. divaricatum (Meunier) Parke et Dodge 30m
P. diabohes (Cleve) Balech 30m
P. bipes (Paulsen) 17m
P. avellana (Meuner) 30m

Studies on Phytoplankton Pigments: Chlorophyll, Total Carotenoids and Degradation Products in Vietnamese Waters

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ABSTRACT

Distribution of phytoplankton pigments was investigated in the relation to Chlorophyll a (Chl-a) and light intensity in Vietnamese waters located at longitude 102E - 112W, latitute 23N - 7N. Over 200 samples collected at 58 stations were analyzed for pigments(Chlorophyll a, b ,c and carotenoids) and degradation products (Phaeophytill). Chlorophyll a was measured by fluorescence. Results show that average values in the seawater were 0.18 ± 0.04 $mg.m^{-3}$for Chl-a; 0.05 ± 0.01 $mg.m^{-3}$ for Chl-b; 0.062 $mg.m^{-3}$ for Phaeophytill. Higher value of Chl-a occurred at the thermocline but maxima were found at 75 or 50m depths. Average value of Carotenoids concentration was very low about 0.052 ± 0.12 $mg.m^{-3}$. The report used a model for the relationship between Chlorophyll a content and light intensity to estimate the primary production. Average value of primary production was about 9.04 $mgC.m^3.day^{-1}$ at the surface and 2.63 $mgC.m^3.day^{-1}$ at the bottom. The relationship between Chlorophyll and some environmental parameters such as temperature, salinity was examined. The effects of thermocline and halocline to the primary production were analyzed.

Introduction

Study on the content distribution of Chlorophylls a,b,c and Carotenoids of phytoplankton in the seawater is very necessary. On the one hand, the Chlorophyll content allows the studies and estimation on some characters of the physiological status of phytoplankton community and primary production of the waters. On the other hand, these are important parameters to assess the environmental quality of the waters.

Based on characters of chemical structure, the pigment system of marine phytoplankton are separated into four groups (Vedernhikov, 1988):

- Chlorophyll a,b,c
- Biliprotein (Phicoeritrin and Phicocianin)
- Carotene
- Xanthophyll

Actually in the research, two last groups Carotene and Xanthophyll are joined in one system called Carotenoids (Vedernhikov, 1988). Chlorophyll a and Carotenoids are the most important characters because they are present in most phytoplankton species and play the key role in the photosynthesis process of phytoplankton.

However, the contents of Chlorophylls a,b,c in different phytoplankton species are not identical and normally the ratio of Chlorophylls a,b,c are used to assess the quantitative distribution of phytoplankton in the waters. When the content of Chlorophyll a is defined much higher than the contents of Chlorophyll b,c the Cyanophyceae are dominant in the waters. When the content of Chlorophyll c is higher than that of Chlorophyll b the Diatomea is dominant (Cirenko, 1988). Some ratio indexes have been published and used in research, for example: for green algae, the ratio of Chlorophylls a:b is 0.43 ± 0.22; for

Diatomea, the ratio of Chlorophylls c:a is 0.62 ± 0.13; for Peridinhea, the ratio of Chlorophylls c:a is 0.86 ± 0.56; for Xrizomonad, the ratio of Chlorophylls c:a is 0.58 ± 0.46 and for Kriptomonad the ratio of Chlorophylls c:a is 0.51 ± 0.24. If the Phaephytill content is high and the Chlorophyll a content is negligible, it is proved that the phytoplankton is in the withered period, the suspended matters in this region are mainly detrit.

Usually, the pigment content of phytoplankton varies strongly and depends on ecological conditions, their physiological state, it is also an important information source to consider the production. Besides, it is also possible to use the measurements of pigment content to assess the biomass of phytoplankton with carbon dimension by experimental expression. The Chlorophyll a content in the phytoplankton is not high. Chlorophyll a makes up about 0.2-2.2% of dried weight of phytoplankton. Total Chlorophylls a,b,a contents range in 0.8-3.7% of dried weight, average value is 2.5% of dried weight (Parson, 1961 and Vinberg, 1960). According to the research of Foy (1987), the correlation coefficient between the phytoplankton biomass and Chlorophyll a is 0.77 and Carotenoi is 0.91.

The Vietnam sea region has characters of the tropical mesotrophic waters, receiving relatively high energy source of solar radiation that creates favorable conditions for the photosynthesis of phytoplankton. So, on the basis of measured data of the field survey in combination with using some mathematical models, the relationship, correlation between the production of the waters and the problems of marine biological resources are analyzed. The report focused on presentation of some investigated results on the distribution of Chlorophylls and carotenoids in Vietnamese waters collected during the survey of cooperated program of Fishery Ministry of Vietnam and SEAFDEC from 29 April to 31 May of 1999. Based on the data and some available methods are applied to assess the process of primary production and water quality of the coastal area.

Aims, Materials and Methods

1. Aims of project:

- To study on the Chl-a content distributed in Vietnamese waters.
- To assess the relationship of Chl-a and marine resources in the studied area.
- Based on data analysis and used the concentration of Chl-a and light quantum intensity to make a model which has been developed to estimate primary production.

2. Materials and Methods :

- Phytoplankton pigment investigations were conducted aboard the M/V SEAFDEC (from 29 April - 31 May 1999). The scientists were from Japan, Thailand, Malaysia and Vietnam.
- Water samples were collected by ICTD system equipped with 12 Niskin bottles (V=2.5-l). Light (photosynthetically available radiation, PAR). Water samples for pigment analysis were drawn from Niskin bottles tripped at the surface, 10m, 50m, halocline and bottom (0-1500m). The seawater was filtered through 0.45mm membrane filters in the lab of the ship at the moment. After that, samples were keeping in refrigerator and analyzed at laboratory of Institute of Oceanography for Chlorophyll a,b,c and their degradation products: Phaeophytill, Carotenoids. Samples were extracted in acetone solution (90%) and prevented light direction.

+ Chlorophyll a was analyzed by the luminescence spectrophotometer (Parsons R.T, Yoshiaki Maita, Carol M. Lalli, 1984).

+ Chlorophylls b,c were determined by UV-visible and Phaeophytill was measured by the fluorescence of sample before and after acidification. (Parsons R.T, Yoshiaki M., Carol M. L., 1984).

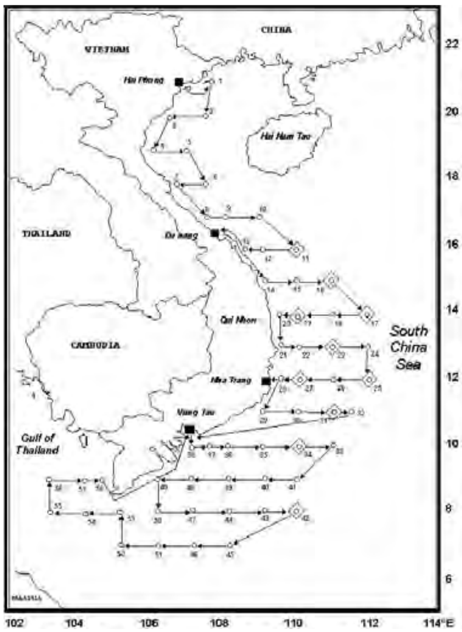
+ Total Carotenoids were measured by UV-visible spectrophotometer.

+ Light quantum intensity measurement : <u>Datalogger</u>, LI-1000, LI-COR, Inc.–with two sensors

In air	- LI-190SA Quantum Sensor (2p detecter), LI-COR, Inc.
Underwater	- LI-193SA Spherical Quantum Sensor (4p detecter), LI-COR, Inc.

Results

Survey was made at 58 stations which are given in the maps (Map1). The results of Chlorophylls a,b,c concentrations were analyzed in Table 1 that showed the average value of Chlorophyll a in the whole sea area of about 0.18 mg.m^{-3}, ranged from 0.02 to 1.41 mg.m^{-3}; Chlorophyll a concentration at: the surface was 0.14 mg.m^{-3}; 10m: 0.14 mg.m^{-3}; 50m: 0.20 mg.m^{-3}; the bottom: 0.25 mg.m^{-3}, ranged from 0.03 - 1.03 mg.m^{-3} (Table1.1 and Table1.2).



Map.1. Location of survey stations.

Geographically the sea area was divided as follows: North Vietnam (I) including 1–7 stations; Centre Vietnam (II) including 8–32 stations; South Vietnam (III) including: 32-58 stations, and average values of Chlorophylls and primary productivity were calculated and compared.

- Region I: Average value of Chlorophyll a in this area was about 0.24 mg.m^{-3}±0.09 (n=28), ranged from 0.11 to 0.36 mg.m^{-3} (Fig.1), most of stations were deep from 26.5 to 80m in depth and the maximum of Chl-a content was recognized at bottoms where the depth of station is < 50m. We were two parameter Chlorophylls b, c were considered and the Chl b:a ratio was reported for marine green algae or the Chl c:a ratio for diatoms. Average value of Chl-b concentration was 0.043 mg.m^{-3}±0.071(n=23), ranged from 0 to 0.27 mg.m^{-3}. For Chl-c concentration: average value was 1.51 mg.m^{-3}±0.48(n=23). Ratio of Chl b:a is 0.18 and Chl c:a is 6.29.
- Region II: Average value of Chlorophyll a in this area was about 0.12 mg.m^{-3}±0.08(n=87), ranged from 0.04 to 0.31 mg.m^{-3}(Fig. 2). The content of Chl-a in different depths varied in the order 75m > 50m > 0m > 10m > 150m. It is possible that maximum Chlorophylls were caused by phytoplankton sinking from the surface water because their photosynthesis might not adapt to high light. Average value of Chl-b concentration was 0.05 mg.m^{-3}±0.06(n=58), ranged from 0 to 0.27 mg.m^{-3}. For Chl-c concentration: average value was 0.08 mg.m^{-3}±0.09(n=58).
- Region III: The results show that average value of Chlorophyll a in this area was about 0.26 mg.m^{-3}± 0.20 (n=101), ranged from 0.07 to 0.77 mg.m^{-3} (Fig.3). Average value of Chl-b

Table 1.1. The results were analyzed seawater sample in Vietnamese waters.

Station	Depth (m)	Chlorophyll a (mg.m^{-3})					Phaeophytill (mg.m^{-3})					Primary production (mgC/m^3, day)			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom
ST31	2940	0.03	0.04	0.07	0.01		0.01	0.01	0.02	0.01		2.66	3.48	2.55	
ST32	3897	0.05	0.03	0.07	0.01		0.01	0.01	0.02	0.00		4.43	2.63	3.47	
ST33	3385	0.05	0.09	0.12	0.02		0.02	0.01	0.05	0.01		3.74	3.11	1.12	
ST34	1614	0.04	0.04	0.12	0.01		0.02	0.02	0.05	0.01		3.47	2.39	3.01	
ST35	156	0.04	0.05	0.08	0.02		0.04	0.02	0.02	0.01		2.88	1.67	0.74	
ST36	45	0.10	0.05		0.16		0.04	0.02		0.06					
ST37	32	0.29	0.09		0.18	0.39	0.04	0.03		0.06	0.04	25.54	3.23	3.37	
ST38	21	0.64	0.46		1.20	1.41	0.16	0.09		0.15	0.13	56.83	79.83	15.6	12.66
ST39	62	0.07	0.03		0.33		0.01	0.01		0.11		6.22	1.02	2.69	
ST40	129	0.18	0.17	0.10	0.10		0.05	0.03	0.04	0.05		4.52	1.58	0.24	
ST41	1250	0.11	0.14	0.16	0.01		0.02		0.08	0.02	0.03				
ST42	654	0.12	0.15	0.54			0.04	0.03	0.11			10.66	13.09	12.85	
ST43	147	0.09	0.11	0.18	0.05		0.05	0.06	0.07	0.02		2.55	1.1	0.35	0.03
ST44	79	0.12	0.06	0.23	0.55		0.02	0.02	0.09	0.05					
ST45	61	0.06			0.16	0.09	0.02			0.07	0.04				
ST46	51	0.13			0.31	0.08	0.03			0.04	0.03				
ST47	42	0.05	0.06		0.26		0.02	0.02		0.10					
ST48	32	0.07	0.13		0.31	0.11	0.02	0.02		0.04	0.02				
ST49	20	0.23	0.09		0.17		0.02	0.02		0.03					
ST50	33	0.11	0.23		0.50		0.03	0.03		0.09		9.75	15.66	2.42	
ST51	44	0.12	0.11		0.42		0.03	0.04		0.14		10.66	9.03	7.94	
ST52	51	0.09	0.18		0.47	0.13	0.03	0.02		0.16	0.04	4.74	5.52	2.12	
ST53	34	0.09	0.92		0.62		0.15	0.18			0.21				
ST54	26	0.26	0.38		1.11		0.08	0.08		0.15		2.17	10.3	5.99	
ST55	70	0.10		0.76	0.38	0.20	0.03		0.11	0.12	0.08	8.88	13.29	14.43	1.82
ST56	57	0.10	0.12		0.59	0.20	0.04	0.06		0.23	0.07				
ST57	23	1.21	0.49		0.38	0.50	0.32		0.14	0.10	0.15	33.06	3.61	1.42	0.23
ST58	34	0.32	0.33		0.67		0.09	0.08		0.17					

Table 1.1. (Continued).

St	Depth (m)	Chlorophyll b ($mg.m^{-3}$)					Chlorophyll c ($mg.m^{-3}$)					Carotenoids($mg.m^{-3}$)			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	bottom	Cline layer	0m	10m	50m	Bottom
ST31	2940		0.007	0.046				0.003	0.006			0.040	0.008		0.001
ST32	3897		0.008	0.048	0.011				0.041			0.027	0.012	0.040	0.015
ST33	3385	0.117	0.005	0.046			0.162	0.044	0.053			0.023	0.004	0.036	0.075
ST34	1614	0.055	0.034	0.080			0.061		0.081			0.020	0.020	0.050	0.010
ST35	156	0.014	0.025	0.014	0.017		0.020	0.029	0.010	0.010		0.023	0.006	0.035	
ST36	45	0.042	0.033		0.093		0.036	0.026		0.083			0.080		
ST37	32	0.036	0.035		0.090		0.025	0.028		0.076			0.004	0.070	
ST38	21	0.340		0.017	0.597	0.038			0.013	0.714	0.017		0.026	0.008	
ST39	62	0.022					0.027						0.010	0.003	
ST40	129		0.007	0.034	0.003		0.028		0.027			0.010	0.008	0.042	0.035
ST41	1250	0.002	0.068				0.004	0.073	0.033			0.070	1.569		
ST42	654	0.008	0.039	0.064			0.004	0.049	0.144			0.001	0.024	0.012	
ST43	147	0.008	0.039	0.070	0.064		0.004	0.049	0.157	0.144		0.012	0.009	0.012	0.013
ST44	79	0.114	0.106	0.067	0.344		0.206	0.197	0.133	0.486			0.017	0.044	
ST45	61	0.034		0.006		0.046	0.039		0.004		0.046				0.010
ST46	51	0.028			0.034	0.028	0.035			0.028	0.060				0.011
ST47	42		0.006		0.117			2.36	0.162			0.102			
ST48	32	0.048			0.060	0.022	0.054			0.064		0.005	0.006		
ST49	20	0.060	0.049		0.046		0.064	0.123		0.126		0.026	0.003		
ST50	33	0.069	0.144		0.082		0.150	0.247		0.151					0.027
ST51	44	0.109	0.044		0.522		0.128	0.042		0.610			0.015		
ST52	51	0.028				0.104	0.025					0.004	0.111	0.016	0.113
ST53	34	0.030	0.026		0.154		0.012			0.163		0.046			0.046
ST54	26	0.035			0.077		0.030	0.071		0.078			0.020		
ST55	70	0.009		0.043	0.096	0.037			0.018	0.095	0.028	0.006	0.02	0.172	
ST56	57	0.019			0.102	0.078	0.003			0.064	0.093	0.005	0.222	0.014	0.177
ST57	23	0.074	0.119		0.035	0.050	0.050	0.094		0.026	0.061	0.005	0.172		
ST58	34	0.027	0.017		0.133		0.011	0.010		0.140		0.033	0.029		

Table 1.2. The results were analyzed seawater sample in Vietnamese waters.

St. No.	Depth (m)	Chlorophyll b ($mg.m^{-3}$)					Chlorophyll c ($mg.m^{-3}$)					Carotenoids($mg.m^{-3}$)			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom
ST31	2940		0.007	0.046				0.003	0.006			0.040	0.008		0.001
ST32	3897		0.008	0.048	0.011				0.041			0.027	0.012	0.040	0.015
ST33	3385	0.117	0.005	0.046			0.162	0.044	0.053			0.023	0.004	0.036	0.075
ST34	1614	0.055	0.034	0.080			0.061		0.081			0.020	0.020	0.050	0.010
ST35	156	0.014	0.025	0.014	0.017		0.020	0.029	0.010	0.010		0.023	0.006	0.035	
ST36	45	0.042	0.033		0.093		0.036	0.026		0.083			0.080		
ST37	32	0.036	0.035		0.090		0.025	0.028		0.076			0.004	0.070	
ST38	21	0.340		0.017	0.597	0.038			0.013	0.714	0.017		0.026	0.008	
ST39	62	0.022					0.027						0.010	0.003	
ST40	129		0.007	0.034	0.003		0.028		0.027			0.010	0.008	0.042	0.035
ST41	1250	0.002	0.068				0.004	0.073	0.033			0.070	1.569		
ST42	654	0.008	0.039	0.064			0.004	0.049	0.144			0.001	0.024	0.012	
ST43	147	0.008	0.039	0.070	0.064		0.004	0.049	0.157	0.144		0.012	0.009	0.012	0.013
ST44	79	0.114	0.106	0.067	0.344		0.206	0.197	0.133	0.486			0.017	0.044	
ST45	61	0.034		0.006		0.046	0.039		0.004		0.046				0.010
ST46	51	0.028			0.034	0.028	0.035			0.028	0.060				0.011
ST47	42		0.006		0.117			2.36	0.162			0.102			
ST48	32	0.048			0.060	0.022	0.054			0.064		0.005	0.006		
ST49	20	0.060	0.049		0.046		0.064	0.123		0.126		0.026	0.003		
ST50	33	0.069	0.144		0.082		0.150	0.247		0.151					0.027
ST51	44	0.109	0.044		0.522		0.128	0.042		0.610			0.015		
ST52	51	0.028				0.104	0.025					0.004	0.111	0.016	0.113
ST53	34	0.030	0.026		0.154		0.012			0.163		0.046			0.046
ST54	26	0.035			0.077		0.030	0.071		0.078			0.020		
ST55	70	0.009		0.043	0.096	0.037			0.018	0.095	0.028	0.006	0.02	0.172	
ST56	57	0.019			0.102	0.078	0.003			0.064	0.093	0.005	0.222	0.014	0.177
ST57	23	0.074	0.119		0.035	0.050	0.050	0.094		0.026	0.061	0.005	0.172		
ST58	34	0.027	0.017		0.133		0.011	0.010		0.140		0.033	0.029		

Table 1.2. (Continued).

St.	Depth (m)	Chlorophyll b ($mg.m^{-3}$)					Chlorophyll c ($mg.m^{-3}$)					Carotenoids($mg.m^{-3}$)			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom
ST1	34		0.165		0.028		0.471	0.178		0.022					
ST2	29				0.009		0.417					0.009			0.022
ST3	28	0.195	0.002				0.204			0.500		0.009	0.024		0.019
ST4	26	0.059	0.033		0.023		0.058	0.018	0.004			0.020	0.023		0.032
ST5	58		0.011	0.186	0.022		0.107	0.047				0.008	0.011		0.031
ST6	80		0.013	1.061	0.038		0.011					0.010	0.009		0.034
ST7	40	0.640	0.103							0.025			0.002		0.011
ST8	45				0.006								0.007		0.004
ST9	75	0.021	0.030		0.048		0.022		0.056	0.072		0.002	0.001	0.024	0.012
ST10	107	0.178	0.169	0.243				0.158	0.287			0.010	0.010	0.020	0.080
ST11	847	0.014		0.016	0.040		0.024	0.007	0.030	0.010				0.005	
ST12	105	0.048					0.037	0.014				0.004	0.003	0.007	
ST13	42				0.010			0.031	0.013				0.021	0.001	
ST14	36	0.009										0.029	0.020	0.002	
ST15	412	0.022		0.005			0.095		0.001			0.015	0.014	0.016	0.013
ST16	1230														
ST17	2100		0.023	0.075	0.06		0.006	0.013	0.088			0.010	0.018		
ST18	2200			0.010	0.020			0.204		0.328					
ST19	653	0.029					0.034	0.004		0.801		0.006	0.013	0.014	0.004
ST20	143		0.233	0.006	0.022		0.066	0.276				0.020		0.020	0.045
ST21	134	0.035			0.002							0.021	0.027	0.027	0.005
ST22	1920	0.008		0.002	0.074		0.007		0.008	0.231				0.016	
ST23	2703	0.006	0.138	0.015	0.013			0.131		0.022		0.012		0.011	
ST24	3332	0.011	0.019	0.005	0.228		0.007	0.030		0.325		0.011	0.005	0.027	
ST25	4117		0.138		0.032		0.046	0.153	0.004	0.038		0.042			0.002
ST26	2889	0.006	0.025	0.012	0.009		0.002	0.143	0.010	0.011		0.020		0.017	0.020
ST27	1734	0.055	0.017	0.061	0.015		0.143	0.152	0.196	0.144					
ST28	110	0.050	0.036	0.021	0.083		0.187	0.033	0.019	0.095			0.010	0.011	
ST29	72	0.114	0.009	0.011	0.033		0.127	0.003		0.010		0.005	0.007	0.028	0.040
ST30	648	0.088		0.004	0.064		0.081			0.072				0.092	0.015

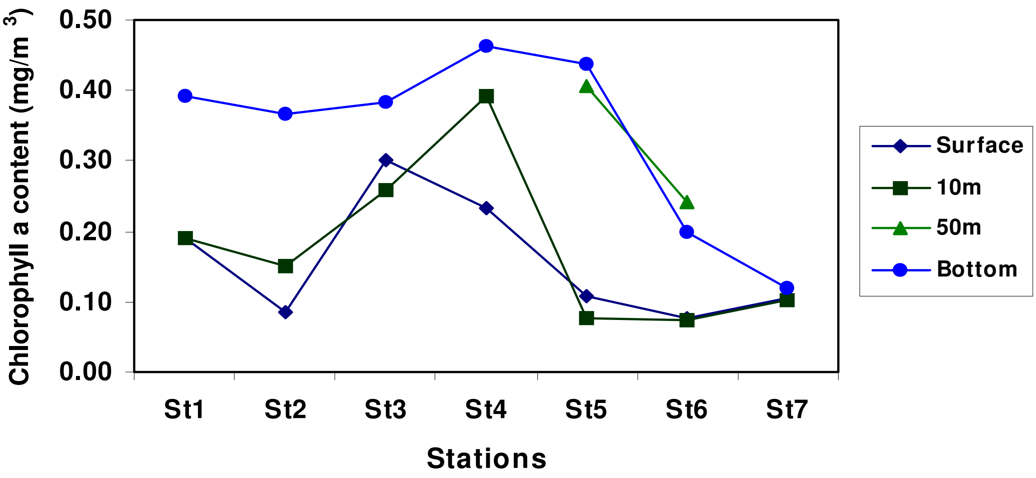


Fig. 1. Distribution of Chlorophyll a in seawater of region I .

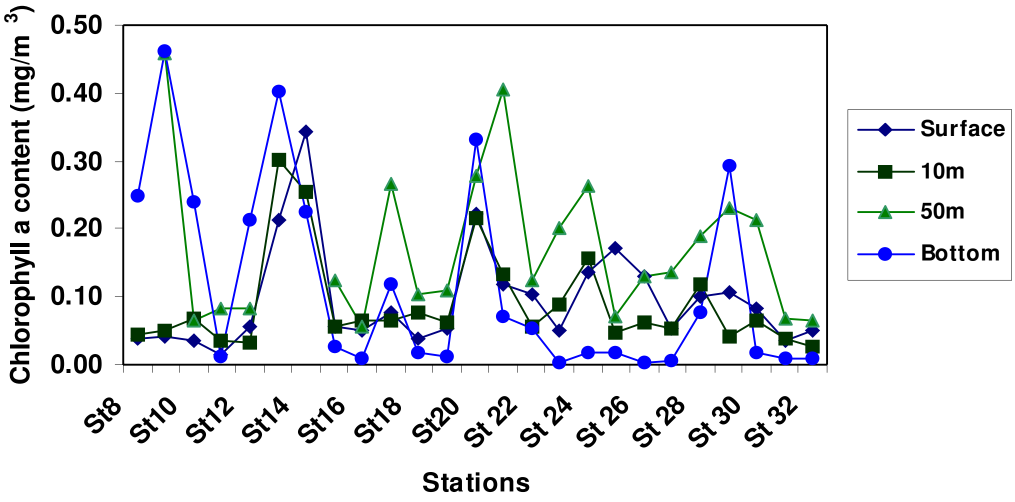


Fig. 2. Distribution of Chlorophyll a in seawater of region II.

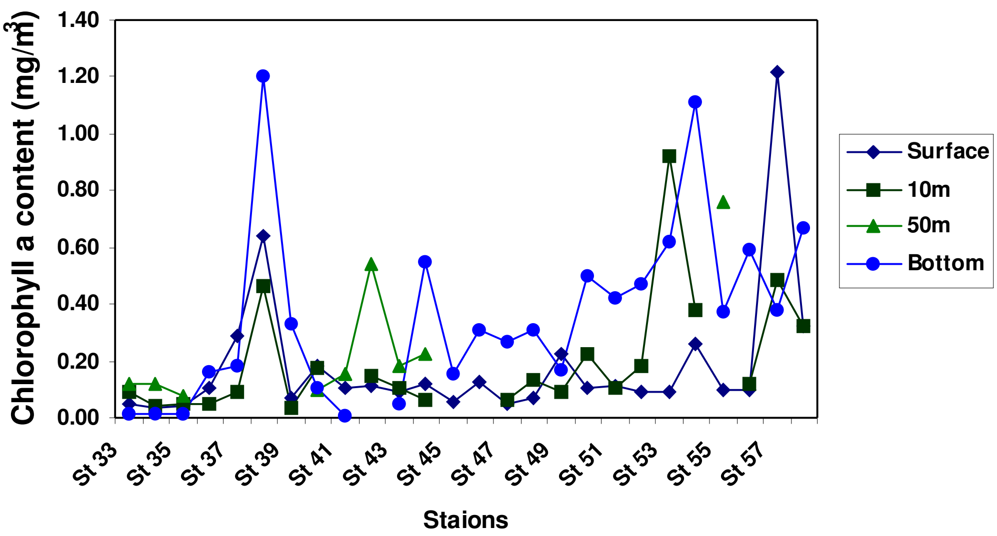


Fig. 3. Distribution of Chlorophyll a in seawater of region III.

concentration was 0.07 $mg.m^{-3}$±0.1(n=90), ranged from 0 to 0.6 $mg.m^{-3}$. For concentration of Chl-c: the average value was 0.09 $mg.m^{-3}$±0.12(n=90) ranged from 0 to 0.33 $mg.m^{-3}$. The values in the South Vietnam sea were higher than in the other parts perhaps because they relate to near shore waters and many river mouths entering into the sea.

The average Chlorophyll a content for individual region varied in following order: III > I >II, it represents that there was highest value in the South Vietnam sea. The concentration of Chlorophylls in different depths varied in the order 75 > 50 > 0 > 10 > over 150m. The above results show that the Chlorophyll a content in offshore region of the South China Sea (Vietnamese waters, Area IV) was lower than in nearshore region which related the source of nutrients inputted from rivers (Table1.1).

The results of Phaephytill and Carotenoids are shown in Tables 1 - 58, the average value of Phaeophytill in studied area was about 0.062 $mg.m^{-3}$. The Phaeophytill concentration was lowest at offshore station, especially, at some nearshore stations the phytoplankton was determined to be in withering stages. Average value of Carotenoids concentration was very low about 0.052 $mg.m^{-3}$± 0.12. At many stations the Carotenoids content could not be determined (Table1.2).

Phytoplankton pigments depend upon the ecological and environmental factors. Therefore, a quantitative analysis of Chlorophylls is main information to estimate the primary production. According to Herman the irradiance of light intensity was decreased at different depths. The profile of light quantum I (z) was measured by the equation over depths (z):

$$I(z) = I(z-1)*Exp^{-K(z)} \qquad (1)$$

- z is depth of station (unit - m)
- Kz : is decreasing coefficient : Kz = 0.18 when $z \le 12$m
  = 0.03 + 0.05*Chl-a when z > 12.

Our numerical model is based on the construction of production profile from the relationship between photosynthesis and light. In our representation, the dependence of primary production P(I) per unit mass of Chlorophylls ($mgC[mgC\ Chl\ a]^{-1}h^{-1}$) on available light is given by photosynthesis light saturation curve (Jassby, Platt, 1976; Platt, Jassby, 1976; Chalker, 1980):

$$P(I) = Pm\tanh(aI/Pm) - R \qquad (2)$$

- I is the irradiance (PAR- photosynthetically active radiation) $-w.m^{-2}$.
- a is the initial slope of light saturation curve - $mgC[Chl\ a]^{-1}.W^{-1}.m^{2}.h^{-1}$
- Pm is the assimilation number - $mgC[Chl\ a]^{-1}.h^{-1}$
- R is measure of dark respiration $mgC[Chl\ a]^{-1}.h^{-1}$. The magnitude of R is generally ≈ 0.1 in our self water and small enough to be ignored in equation (2). According to Herman *et al*., 1981; Herman, Platt, 1983 the validity of a and Pm was used in tropical sea that is Pm=3.7; a =0.08.

Absolute production profile in units of ($mgC.m^{-3}.h^{-1}$) is obtained by multiplying the production P(I) of equation (2) by the Chlorophyll a profile (units of $mgC.m^{-3}$) as measured with the pump profile and is given by:

$$Pv(z) = P(z) \,.\, B(z) \qquad (3)$$

- B(z) : is the Chlorophyll concentration and z is the depth in meters. The daily profile, Cd in unit of ($mgC.m^{-3}.d^{-1}$), can be obtained by integrating equation (4) over time t:

$$Cd(z) = \int_0^{24hr} Pv(z,t)dt \qquad (4)$$

The equation of I (z) was measured based on the data of light quantum intensity. From the model production curve Pv (z) of equation (3), we measured the primary production at layers to collect samples and analyzed Chlorophyll (Table1.1).

- Region I: Average value of primary production at: the surface was about 9.57mgC.m^3.day^{-1}±3.66, ranged from 6.75 – 15.8 mgC.m^3.day^{-1}; 10m layer: 5.42 mgC.m^3.day^{-1}± 1.29, ranged from 3.58 – 6.56 mgC.m^3.day^{-1}.
- Region II: Average value of primary production at: the surface was about 4.73mgC.m^3.day^{-1}±5.24, ranged from 0.33 – 15.08 mgC.m^3.day^{-1}; 10m layer: 2.0 mgC.m^3.day^{-1}± 1.42, ranged from 0.47 – 3.96 mgC.m^3.day^{-1}; 50m layer: 1.02 mgC.m^3.day^{-1}± 0.09.
- Region III: Average value of primary production at the surface was about 11.88 mg C.m^3.day^{-1} ±14.75, ranged from 2.17–56.8 mgC.m^3.day^{-1}; 10m layer: 10.44 mgC.m^3.day^{-1}± 19.14, ranged from 1.02 – 79.83 mgC.m^3.day^{-1}; 50m layer: 4.86 mgC.m^3.day^{-1}± 5.11, ranged from 0.24 – 15.60 mgC.m^3.day^{-1}.

The results of primary production measured by the above model showed that the primary production in region III was highest, average value varied in order III > I > II. The region III is euphotic waters, because it is nearby a mouths of Me Kong Delta. The waters were provided nutrients from the runoff river entering the sea. The phytoplankton growth rates depend on the nutrient recycling processes and light intensity of regions.

Discussion

The distribution of Chlorophyll a was analyzed at the depths of different transects: - the transects perpendicular to the coastline (5 transects) and the transect parallel to the coastline.

- Transect I: including 4 stations (T21, T22, T23, T24) (Fig. 4.1) located from 13°N latitude 109°30' E to 111°59' longitude. The temperature was measured from the depths of 0m to 1500m where it was approximately 3°C. The Chlorophyll a content ranged from 0.05 to 0.33 mg.m^{-3}, average value was 0.14 ± 0.10 mg.m^{-3} and the highest value was found at St 20 located near the coastline in this transect. The distribution pattern of Chlorophyll a was changed in different layers while the light intensity decreased with the depths.
- Transect II: including 4 stations (T28, T27, T26, T25) (Fig. 4.2) located from 12°N latitude – 109°30'E to 111°59' longitude. This region has slope topography and very deep bottom (ranged from 110m – 4200m). Chlorophyll a contents in this transect ranged from 0.01 – 0.19 mg.m^{-3}, average value was 0.08 ± 0.06 mg.m^{-3}.
- Transect III: including 5 stations (T38, T37, T35, T35, T34) (Fig. 4.3) located in southeastern part of Vietnam which is very rich of marine resources. The coastal zone of this area has developed mangrove forests and large estuaries. The Chlorophyll a content at each station was different between the coastal stations and offshore stations, the average value was 0.29 ± 0.41 mg.m^{-3}, ranged from 0.04 – 1.41 mg.m^{-3}.
- Transects IV and V: including 13 stations (Fig. 5). Almost stations are located at shallow waters, the depth is < 150m (depths ranged from 20 – 50m). This region is influenced by runoff of Maekong river into the sea through many estuaries. Its ecology is very particular and biodiversity is very abundant: estuaries, tidal flats, and mangroves. Therefore, the variation of Chlorophyll a distribution in the seawater is very complex. The freshwater input into the region causes the variation of salinity. This effects to the vertical distribution of phytoplankton species. Simultaneously, the nutrient contents also change strongly and depend upon each period of the river. Although, the seawaters is impacted from out side, the Chlorophyll a concentration in transects IV, V is not different, it still keeps the dimension: the shorter distance to the coastline the region has, the higher Chlorophyll a concentration it has, the value of Chlorophyll a at transect IV ranges from 0.03–0.33 mg.m^{-3} ; transect V ranges from 1.01–1.11mg.m^{-3}.

-Transect VI: is parallel with the coastline (Fig. 5) and located from 16°N – 9°N latitude on 110°E longitude, the stations are outspread in many different regions, but the observed results showthat the Chlorophyll a concentration in depths was changed little between surface and the weakest light intensity layer. The vertical distribution of Chlorophyll at stations is rather homogeneous. Therefore, at offshore stations (about 120km far from the continent), the Chlorophyll content is stable and is not effected by the impacts from the coastal zone, the average value is 0.08 ± 0.03 $mg.m^{-3}$.

Above analysed results show that transects (I, II, II, IV) are perpendicular to the coastline. The depths increase from the coast to offshore and the Chlorophyll a distribution is comparative in almost transects (at near shore stations, the concentration is higher than at the offshore ones). According to the data collected in 1986 (Table 3) (Nguyen Tac An and Vo Duy Son,1999.), the average value of Chlorophyll a in offshore is 0.37 $mg.m^{-3}$; in 1999, the value is 0.18 ± 0.04 $mg.m^{-3}$ which is smaller than other regions of the coastal zone. The variation of Chlorophyll a depends on depths of stations (the maximum value is often reached at the photosynthesis layers where the light intensity is approximately 25% of light intensity in surface).

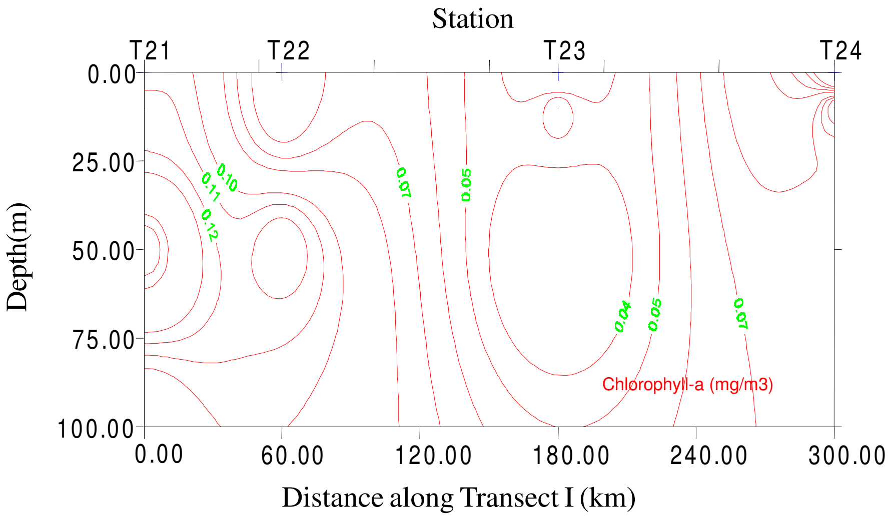


Fig. 4.1. The verticle profile of chlorophyll a from transects I.

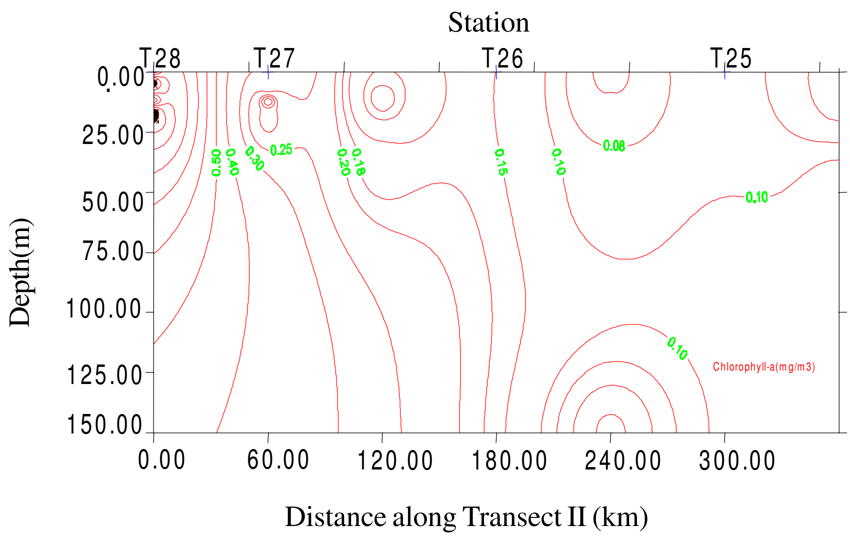


Fig. 4.2. The verticle profile of chlorophyll a from transects II.

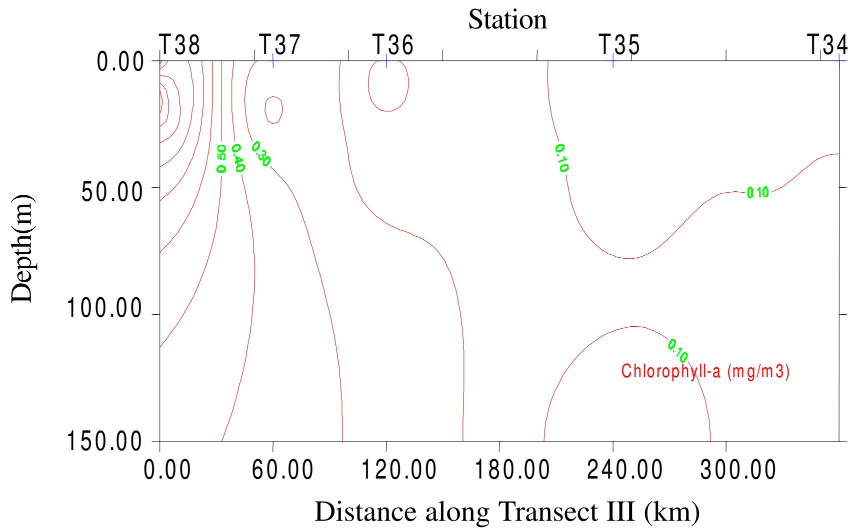


Fig. 4.3. The verticle profile of chlorophyll a from transects III .

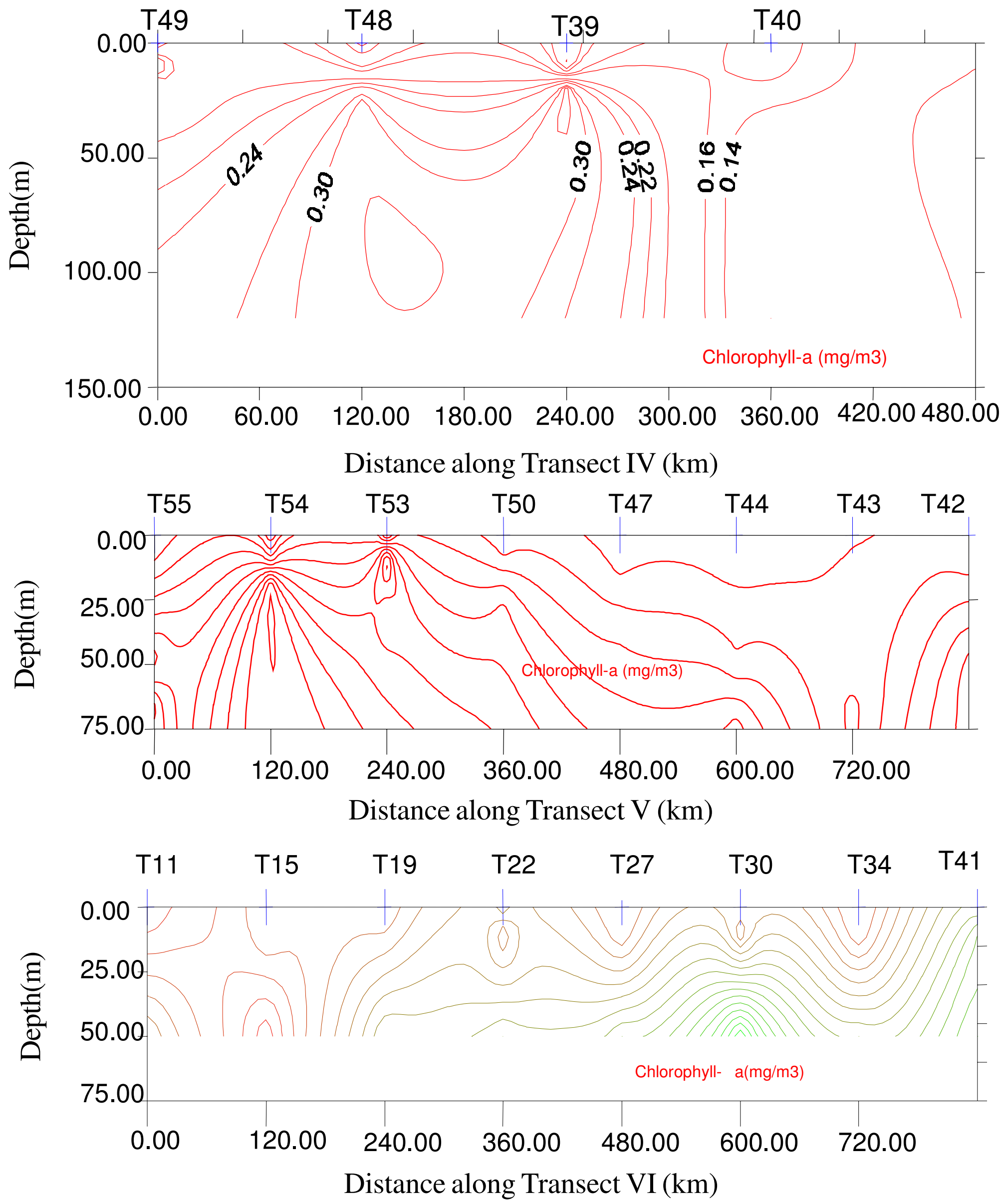


Fig. 5. The verticle profile of chlorophyll a from Transects IV,V and VI.

Table 3. The results studied in offshore of Vietnam in 1986.

Long – Lat.	P(mgC/m^3,day)	Chlorophyll (mg/m^3)			Assimilation Coefficient
		a	b	c	mgC/mgChl a.day
4^{O}5'N-106^{O}05'7E	0.31	0.22	0.029	0.174	1.39
9^{O}39'N-108^{O}32'E	0.24	0.16	0.048	0.263	1.46
10^{O}15'5N-107^{O}05'3E	1.65	1.24	0.180	0.950	1.33
9^{O}52'N-107^{O}00E	1.1	0.54	0.103	0.555	2.03
9^{O}51'N-107^{O}00E	1.6	0.74	0.131	0.711	1.16
9^{O}45'N-107^{O}09E	0.98	0.43	0.061	0.406	2.26
8^{O}47'N-107^{O}01E	0.13	0.09	0	0.128	1.31
9^{O}04'N-108^{O}44E	0.07	0.08	0.015	0.115	0.86
9^{O}51'N-107^{O}01'3E	3.1	0.73	0.127	0.684	4.25
13^{O}24'N-110^{O}050'7E	0.07	0.08	0.202	0.446	0.85
17^{O}40'N-116^{O}25E	0.08	0.05	0	0	0.84
19^{O}35'N-119^{O}15'E	0.25	0.12	0.006	0.034	2.17

Data in Table 3 show that the Chlorophyll a in off shore is continuous data, but the results reflect characteristics of ecology areas: in off shore of Vietnam sea. The Chlorophyll a is much lower than the other regions such as: the coastal zone, upwelling region, Coral reefs. The result studied in Vietnam seawaters in the stage 1979 - 1998 showed that Chlorophyll a concentration is higher in the cultural area, shallow waters. Averaged value in shallow waters is ranged from 0.29 - 6.10mg.m^{-3}; in near shore is ranged from 0.07 - 1.65 mg.m^{-3}; in the off shore is very lower which were ranged from 0.02 - 0.40 mg.m^{-3}. The Chlorophyll content distributed from 140m to 160m depth in off shore. In the coastal waters, the Chlorophyll a concentration is maximum in 5 -15m depth with light intensity is about 1000 -4000 lx which is useful for the photosynthesis phytoplankton or on thermocline layer and halocline. On the other hand, Chlorophyll is not factor that effects to the marine resources, but it relates to the biological production. Additionally, based on the result studied of Nguyen Tac An,1985 , the Chlorophyll concentration occupied about 0.14% of phytoplankton fresh weight. Average value of Chlorophyll a is about 0.18 mg.m^{-3}, ranged from 0.02 - 1.41 then biomass of phytoplankton is about 128 freshmg.m^{-3}, ranged from 14 - 1007 freshmg.m^{-3}.The results is agree with the data publishing by Sorokin Yu.I. *et al*,1982 and Nguyen Tac An,1989. Biomass of phytoplankton in coastal waters is average value about 500 freshmg.m^{-3}, The primary production force is average value from 20 -40mgC.m^{-3}.day^{-1} and it is a base food strain for zooplankton developing. Usually, the pigment content of phytoplankton varies strongly and depends on ecological conditions, physiological state, it is also an important information source to consider the production. Based on the changes of phytoplankton pigment, the nutrient changes as well as the impacts of human activity to the seawaters are also known.

Comparison of the results of primary production measured by model and studied in 1986 shows that the primary production force in offshore is lower than in coastal zone. At the observed stations, Chlorophyll a reaches to maximum value at the deep layers while the primary production does not reach to maximum value, the maximum value is reached in the surface layer. At the surface, the nutrients are more often supplied from cycle of nutrient. Simultaneously, primary production value depends on the cycle nutrients of waters (in offshore, the nutrients depend on the internal waters). In offshore, the high primary production is only observed in upwelling region because of its specific characteristics. The upwelling only appears in certain periods of year. The primary production value is ranged from 0.3 - 79mgC.m^3, to help assessment assimilation coefficient which is range from 1 - 56mgC.mgChla^{-1}.day^{-1} (Nguyen Tac An,1989.)

The characteristics of vertical distribution of production depend on the phytoplankton distribution, solar radiation, thermocline layer, halocline layers and the processing supplement nutrients for the photosynthesis of phytoplankton. The distribution curve of primary production may have two maxima in water column: at surface or thermocline, because, the surface is supplemented by nutrients making good conditions for the phytoplankton development. The phytoplankton community will photosynthesize maximally at certain daytime and depths in the water column corresponding to optimum conditions.

Conclusion

The concentration of phytoplankton Chlorophyll a (the main photosynthetic pigments) in the South China Sea, Area IV (Vietnamese Waters) was investigated from 29 April – 31 May, 1999. The analyzed results on the content of Chlorophyll a show that the average value of pigments of phytoplankton in the studied area was not high, ranged between 0.03-1.03 mg.m^{-3} . In all 58 stations from the north to the south, the Chlorophyll a contents at different depths: at

The contents of Chlorophylls were not much different between layers and have tendency of increase with depths. The Chlorophylls at the bottom were higher than at the surface 1.7 times.

- Region I: Average value of Chlorophyll a in this area was about 0.24 mg.m^{-3}± 0.09 (n =28), ranged from 0.11 to 0.36 mg.m^{-3}.
- Region II : Average value of Chlorophyll a in this area was about 0.12 mg.m^{-3}± 0.08(n = 87), ranged from 0.04 to 0.31 mg.m^{-3}. The content of Chl-a in different depths varied in the order 75m > 50m > 0m > 10m > 150m.
- Region III : The results show that average value of Chlorophyll a in this area was about 0.26 mg.m^{-3}± 0.20, ranged from 0.07 to 0.77 mg.m^{-3}.

  Contents of Phaeophytin and Carotenoids were negligible, the average values of Phaeophytin only reached to 0.06 mg.m^{-3} and Carotenoids – 0.052 mg.m^{-3} ± 0.12 .

The distribution of Chlorophyll a was analyzed at the depths of different transects: - the transects perpendicular to the coastline (5 transects) and the transect parallel to the coastline:

-Transect I,II,III,IV,V: the transects perpendicular to the coastline. The temperature was measured from the depths of 0m to 1500m where it was approximately 3°C. The Chlorophyll a content ranged at transect I: from 0.05 to 0.33 mg.m^{-3}, average value was 0.14 ± 0.10 mg.m^{-3}.At Transect II: ranged from 0.01 – 0.19 mg.m^{-3}, average value was 0.08 ± 0.06 mg.m^{-3}.; at transect III : the average value was 0.29 ± 0.41 mg.m^{-3}, ranged from 0.04 – 1.41 mg.m^{-3}. At Transect IV: ranges from 0.03 –0.33 mg.m^{-3} ; transect V ranges from 0.01 –1.11mg.m^{-3}.

-Transect VI: the transect parallel to the coastline. The stations are outspread in many different regions, but the observed results show that the Chlorophyll a concentration in depths was changed little between surface and the weakest light intensity layer. The vertical distribution of Chlorophyll at stations is rather homogeneous, the Chlorophyll content is stable and is not effected by the impacts from the coastal zone, the average value is 0.08 ± 0.03 mg.m^{-3}.

A model is used in the report for the relationship between Chlorophyll a content and light intensity to estimate the primary production. Average value of primary production was about 9.04 mgC.m^{3}.day^{-1} at the surface and 2.63 mgC.m^{3}.day^{-1} at the bottom. Concretely, in the region III, the primary production was 9.03 mgC.m^{3}.day^{-1} higher than the region I (6.63 mgC.m^{3}.day^{-1}) and region II (2.58 mgC.m^{3}.day^{1})

The result studied for Chlorophyll concentration to estimate phytoplankton biomass and assessment a assimilation coefficient. Phytoplankton biomass is range from 14 - 1007 freshmg.m^{-3} and assimilation coefficient is range from 1 -56mgC.mgchla^{-1}.day^{-1}

Our research results on the distribution of phytoplankton Chlorophylls contents and primary production in Vietnamese waters will be using basically to assessment fishery resources.

Propose

We would like the projects to supplement the detail data for fluorescense(digital data) and to help us could be comparison with the measurement result. We would like to co-operating with articipant in projects to discussion about our subject studied for us.

Acknowledgement

We would like express our sincere thanks to the leaders of Fishery Ministry of Vietnam, SEAFDEC, the Research Institute of Marine Products, Institute of Oceanography, Nhatrang and Our colleagues in other research agencies who participated in the program and the crew of M/V SEAFDEC ship for precious help in data collection and supply to complete the research.

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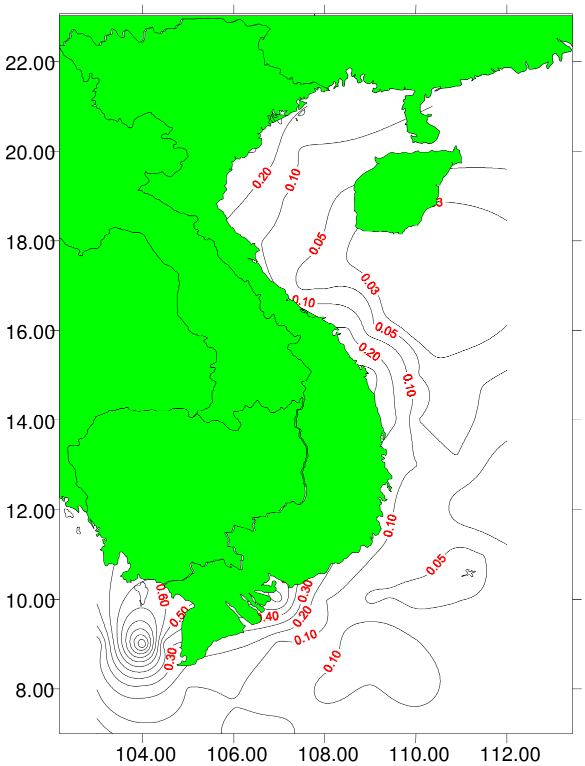
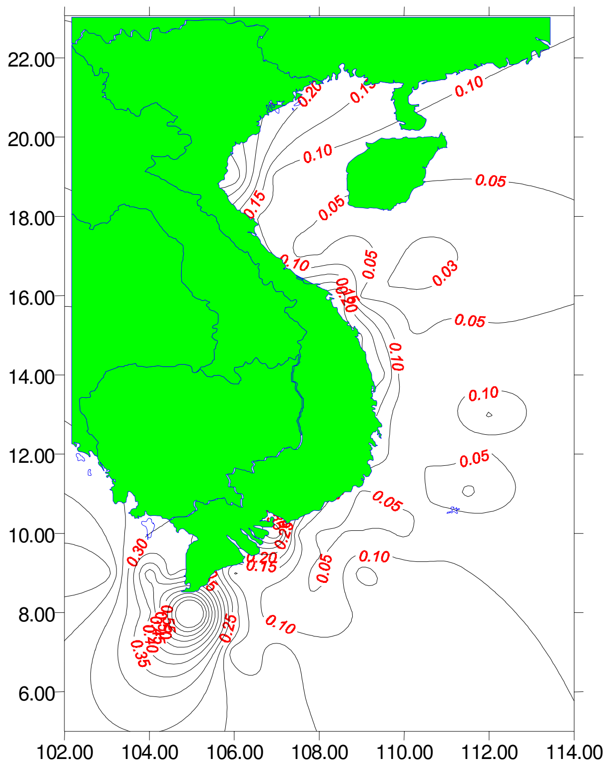
Appendix

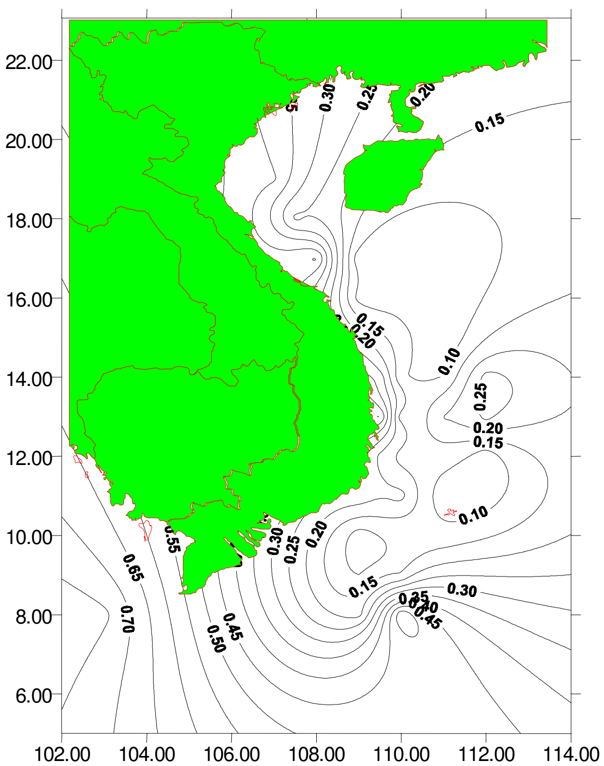
The maps of distribution Chlorophyll a and Phaeophytill



Distribution of Chlorophyll a at surdace layer. (mg.m^{-3})

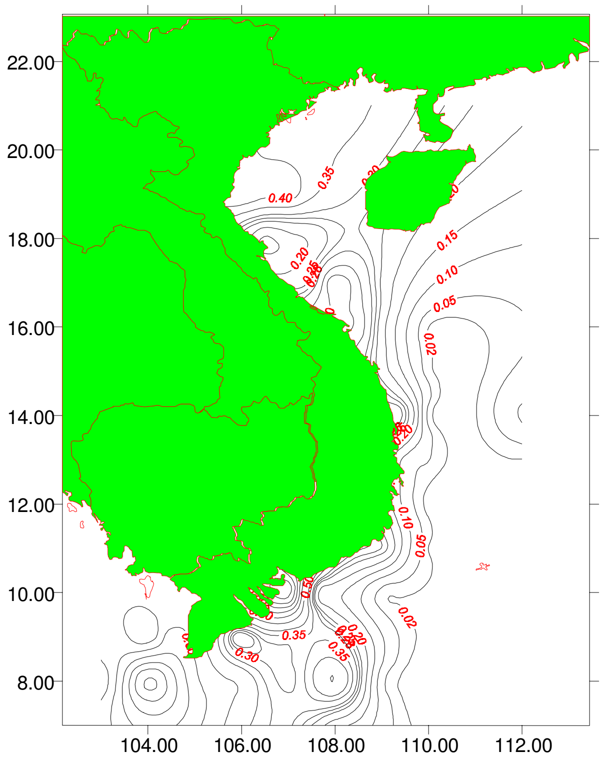


Distribution of Chlorophyll a at 10 m layer. (mg.m^{-3})



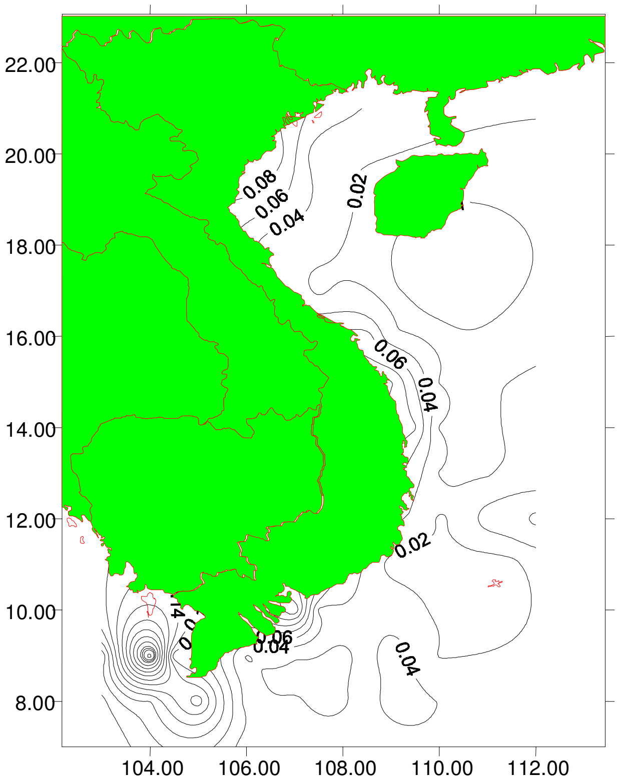
Distribution of Chlorophyll a at 50m layer.

(mg.m^{-3})

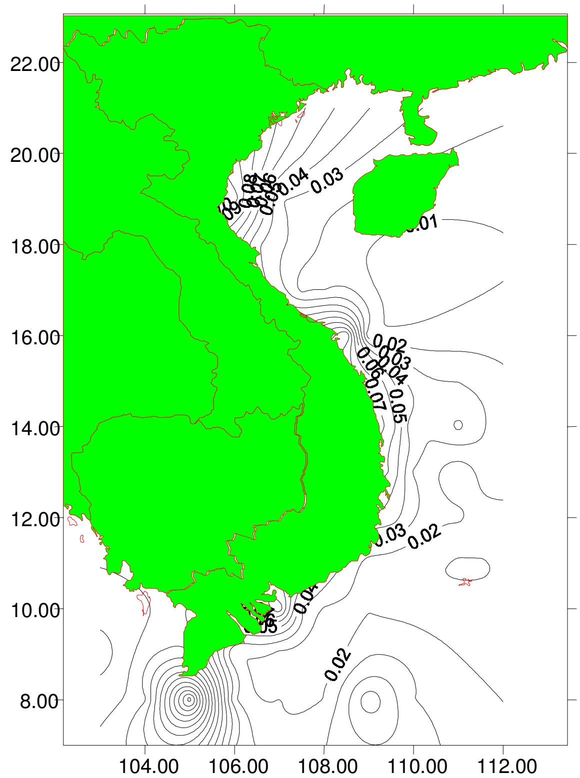


Distribution of Chlorophyll a at Bottom layer

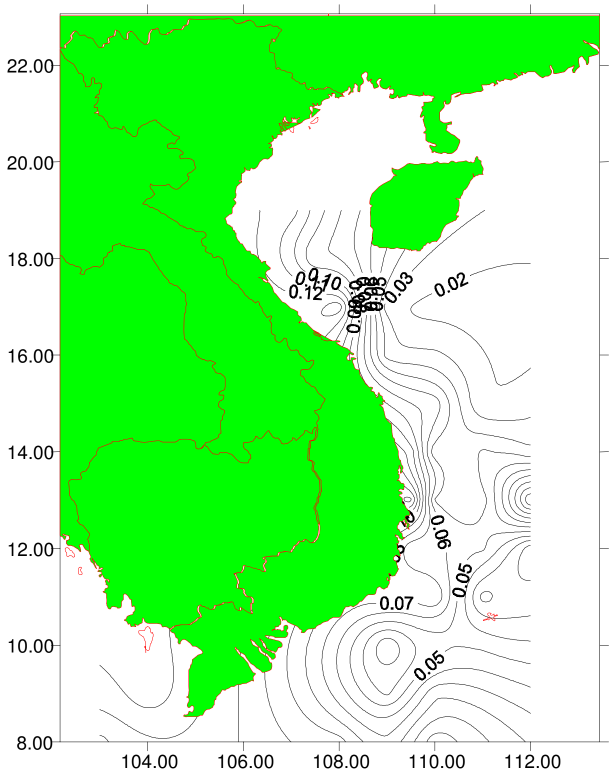
(mg.m^{-3})



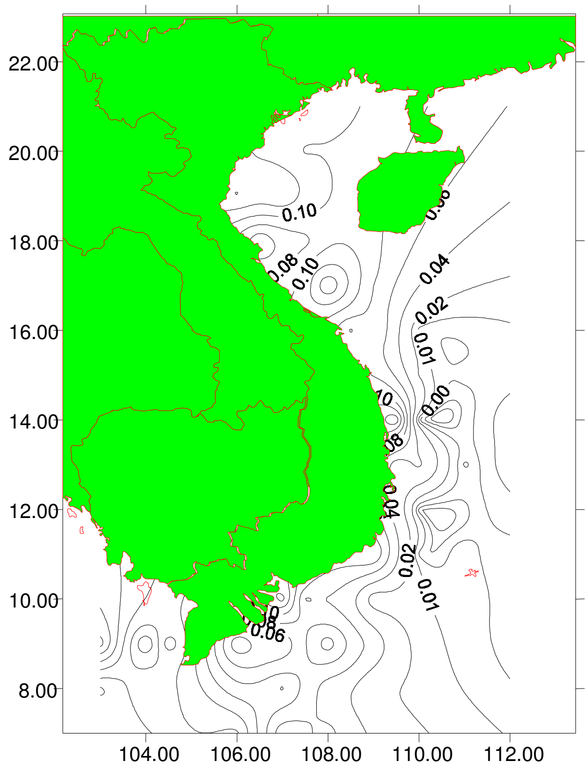
Distribution of Phaeophytill at surface layer. (mg.m^{-3})



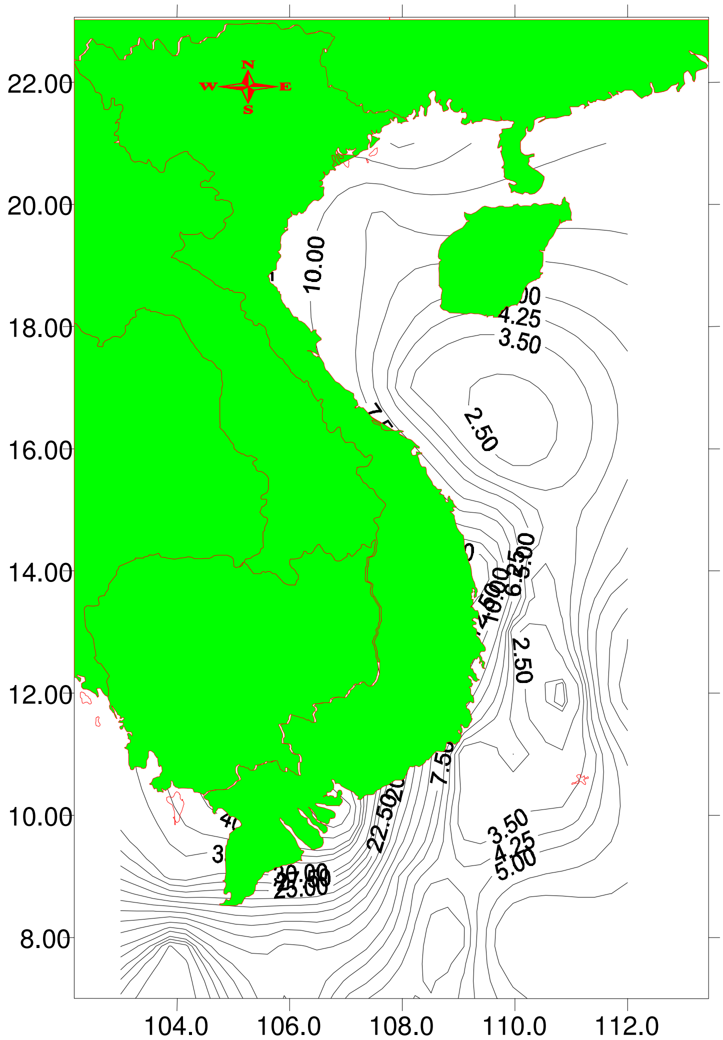
Distribution of Phaeophytill at 10m layer. (mg.m^{-3})



Distribution of Phaeophytill at 50m layer. (mg.m^{-3})



Distribution of Phaeophytill at Bottom. (mg.m^{-3})



Map of primary production distribution on surface water. (mgC.m^{-3}.day^{-1})

Sub-Thermocline Chlorophyll Maximum in the South China Sea, Area IV : Vietnamese Waters

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ABSTRACT

Shipboard measurement of chlorophyll a and b by HPLC system were carried out on the M.V. SEAFDEC Cruise No. 57/3-1999 from 21 April to 5 June 1999, in the South China Sea, Vietnamese waters. Chlorophyll a and b in surface water (2 m), seasonal thermocline below the mixed layer, chlorophyll maximum depth and sub-chlorophyll maximum depth from 58 stations in the studied area were investigated. Chlorophyll maximum depth ranged 7-90m and the concentration of chlorophyll a and b in this layer were 0.07-1.75 mg/m^3 and 0.003-0.31 mg/m^3 respectively. High concentration of chlorophyll a and b were observed in nearshore water which may reflected the effect of run off from the coastal cities and lower Maekong delta. Observed chlorophyll concentrations in this area agreed well with other values reported for tropical seas.

Key words: Primary production, Sub-thermocline, Chlorophyll maximum, South China Sea

Introduction

The phytoplankton provide the food base which supports directly or indirectly the entire animal population of the open oceans and they contribute significantly to climatic processes. Chlorophyll is the principal photosynthetic pigment of phytoplankton in the oceans. Measurement of chlorophyll have been used as indicator of biomass and productivity in marine environment for over 40 years. Chlorophyll a is a summarizing parameter of the pigment from several phytoplankton groups while chlorophyll b represents fewer phytoplankton groups [Jeffrey and Montura (1997)]. It has been assumed that concentration of chlorophyll b relative to chlorophyll a were low in marine system [Lorenzen (1981)].

Sub-thermocline chlorophyll maxima (SCM) are a well documented phenomena in tropic, subtropic and temperate seas. Many regions of the world's oceans show oligotrophic conditions during the period of vertical stratification and a deep chlorophyll maximum is frequently observed below the thermocline [Varela *et al.* (1992)]. Usually, SCM develops in water where or when the upper layer is stratified, primary production in the surface layer is limited by the availability of nutrients and photosynthetically active radiation penetrates into the nutrient- enriched water layer beyond the pycnocline. Lokman *et al*. (1988) studied the chlorophyll a content off the Sarawak waters of the South China Sea during the Matahari Expedition in 1987 and reported the range of chlorophyll a as 0.006-0.257 mg/m^3 and the SCM was observed at 60 m.

Ichikawa (1990) found that SCM in the South China Sea off Sabah occurred at 50 m and chlorophyll a ranged 0.14-0.43 mg/m^3. In the Gulf of Thailand, Musikasang (1999) also mentioned the occurrence of SCM. Strass and Woods (1991) have shown that the seasonal onset of oligotrophy after the spring bloom results in a poleward elevation of the SCM from a depth of about 60 m in the subtropic until it becomes an almost homogenous mixed layers in the subarctic.

The formation and maintenance of SCM have been regulated by many processes. In oligotrophic areas an approximate steady state requires balance between nutrient supply through vertical cross isopycnal mixing and export through sedimentation. Upwelled nutrient–rich coastal water often spreads at pycnocline depth and horizontal advection and isopycnal mixing enters the balance as well. Good growth conditions in a layer with both light and nutrients should favour phytoplankton species capable of regulating sink to avoid starvation in a nutrient–depleted surface layer and swimming to avoid the darkness deeper down [Djurfeldt (1994)].

There has been much debate concerning the SCM and a maximum in production/bio mass. In the Gulf of Mexico, Steele (1964) found that SCM did not correspond to a maximum in biomass but reflected the shade adaptation to lower light levels of the slowly sinking cells. Anderson (1969) on the other hand described a SCM made up of actively growing cells. Keifer and Kremer (1981) hypothesized that plankton community is locked in the developing stratification during the formation of the thermocline. In modern models, Varela *et al*. (1992) used physical–biological approach to study SCM. They concluded that the SCM depth and magnitudes is mainly determined by the vertical eddy diffusion and light extinction. The grazing parameters mainly affect the intensity of the SCM. They suggested that SCM is primarily the results of a balance between upward nutrient flux and light field characteristics. Regenerated production only plays a secondary role.

The objective of the present study is to collect information on the distribution of chlorophyll a and b in the South China Sea (Vietnamese waters) and attempt to elucidate the over all chlorophyll distributions in relation to marine fishery resources survey conducted by SEAFDEC member countries.

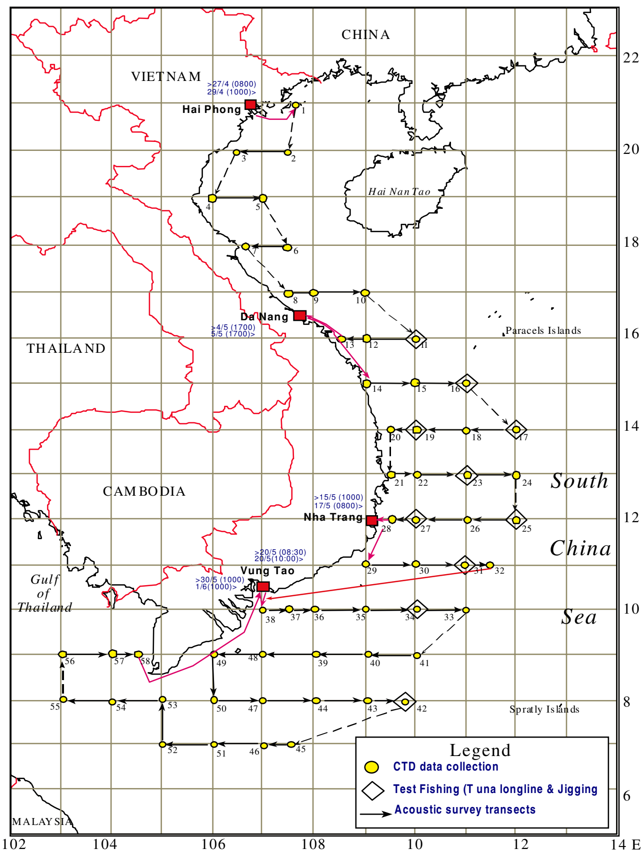


Fig. 1. Survey stations for M.V. SEAFDEC cruise No. 57/3-99 from 21 April-5 June 1999.

Materials and Methods

Sample collection. The present study is based on an oceanographic cruise of M.V. SEAFDEC conducted a survey between 21^0 00N, 107^0 55E and 8^0 95N 104^0 30E.[Fig.1] during 21 April to 5 June, 1999. Water samples from 58 stations were taken by 10 liters Vandorn water sampler at surface (2 m), seasonal thermocline (below the mixed layer), chlorophyll maximum depth and sub-chlorophyll maximum depth. The sampling depths were monitored through ICTD record at each station. The chlorophyll maximum depth for all stations were well below seasonal thermocline depths. The water samples of 2–5 liters were collected and prefiltered with plankton net of 300 mm mesh size then vacuum filtered through GF/F filters with 47 mm diameter under 10 inch of Hg in the dark place. Then the GF/F filters were blotted with tissue paper and wrapped with aluminium foil before keeping in glass vials and stored in freezer.

Sample extraction. Shipboard extraction of the collected samples were performed after filtration. The thawed GF/F filters were blotted dry with tissue paper and cut into small pieces. Then the filters were added with 2.5 ml Dimethylformamide [Furuya *et al*. (1998)] and ground with glass-Teflon homogenizer and kept in refrigerator for 30 minutes. Homogenates were centrifuged for 6 minutes and filtered with PTFE filters (Sartorius) with pore size of 0.2 mm. The filtrated DMF were kept in amber vials and stored in freezer for 1-3 days before commencing the analysis.

Sample analysis. The extracted samples were run by a Thermoseparation HPLC systems (a binary gradient pump, autosampler, UV detector, and degasser) filled with a 5 mm HiCHROM S5ODS (4.6x250 mm). HPLC grade reagents were used for all analysis. The pigment separated were identified on retention time of commercially available pigment (Chl a and b: Sigma USA.). Chlorophyll were quantified by peak area calibrated against that of the standard solution [Fig. 4]. The solvent programs of step-isocratic elution were as follow: Mobile phase, solvent A (MeOH: 0.5 M Ammonium Acetate; 80:20) and solvent B (MeOH:Acetone; 90:10). The first 3 minutes 100% solvent A got into the system followed by 100% solvent B for 15 minutes and again with solvent A for 5 minutes to equilibrate the system for the next sample. The flow rate was controlled at 1 ml/min and sample injection volume is 100 ml. The total running time of each sample was about 23 minutes.

Results

The concentration of chlorophyll a and b in this study were summarized in Table 1 and showed in Fig. 2 and Fig. 3 while bottom depth and sampling depth were reported in Table 2. The others physical parameter e.g. pH, dissolved oxygen, salinity and temperature were shown in Fig. 6, 7, 8, 9 respectively.

The surface layer. Concentration of chlorophyll a and b in the surface layer were shown in Fig. 2 and Fig. 3. In this layer, chlorophyll a and b ranged 0.006-1.75 mg/m^3 and 0.005-0.16 mg/m^3 respectively. Fig. 2 showed the spatial distribution of chlorophyll a in the surface water. It was cleared that near shore water had higher chlorophyll a than the off shore. Localized high chlorophyll a were observed at all major city along the coast of Vietnamese waters, among those cities, Vung Tao had the highest chlorophyll a concentration of 1.75 mg/m^3. Chlorophyll b also reflected the similar general patterns.

The thermocline layer. Chlorophyll a and b in this layer ranged 0.061-0.922 mg/m^3 and 0.002-0.103 mg/m^3 respectively. The spatial distribution of chlorophyll a and b were shown in Fig. 2 and Fig. 3. The general distribution is similar to those of surface layer. The thermoclines layer ranged 12-52 m.

The chlorophyll maximum layer. Chlorophyll a and b in this layer ranged 0.07-1.7 mg/m^3

and 0.003-0.31 mg/m^3 respectively. All chlorophyll a maximum concentration except at stations 10,13,14,16 had higher concentrations than the surface layer. Most of the chlorophyll b maximum in this layer had higher concentration than the surface layer. The spatial distribution of chlorophyll a and b in this layer were shown in Fig. 2 and Fig. 3. The depth of this layer ranged 7-90 m.

The sub-chlorophyll maximum layer. Concentration of chlorophyll a and b in this layer ranged 0.02-1.48 mg/m^3 and 0.01-0.195 mg/m^3 respectively. Their spatial distribution were shown in Fig. 2 and Fig. 3. The depth of this layer ranged 14-125 m but mostly exceed 100 m.

The magnitude of chlorophyll spatial distributions at various depths under this investigation were well within those values reported for the world oceans. Jeffrey and Montoura (1997) summarized that in the oligotrophic ocean gyres in surface water concentrations of chlorophyll was low (<0.05 mg/m^3) and their characteristic maxima at depth 100-150 m were 0.1-0.5 mg/m^3 but in the upwelling areas along continental shelf fronts and coastal sea and estuaries chlorophyll values ranged 1-10 mg/m^3.

Spatial distributions of chlorophyll a and b in the South China Sea off Vietnamese Coast lead us to suggest the preliminary conclusion as the following:-

Conclusions

- Chlorophyll a and b reached their maximum value in the chlorophyll maximum layer, which observed mostly in the sub-thermocline layer.
- High concentration of chlorophyll a and b were observed in near shore water especially at station 38 (Vung Tao) which may reflected the effect of run off from the city and lower Maekong Delta.
- Chlorophyll a and b appeared to show no close correlation but chlorophyll b had much smaller concentration than chlorophyll a as had been reported.
- HPLC Chromatograms of the chlorophyll maximum samples had more pigments distribution than other investigated layers. This may indirectly attributed to the much higher phytoplankton diversity in this layer. Furthermore, HPLC technique may use as alternative approaches to identify phytoplankton groups. [Fig. 5 and Table 3].

Chlorophyll a in some tropical waters.

Area	Chlorophyll a (mg/m^3)	References
South China Sea	0.11-0.16	Marumo (1972)
Indian Ocean	0.16	Marumo (1972)
Philippine Sea	0.10-0.17	Marumo (1972)
Celebes Sea	0.10-0.27	Marumo (1972)
North of New Guinea	0.10-0.40	Wauthy (1972)
Off Southern Makassar Strait, Indonesia	0.4-0.7	Ilahude (1978)
Off Sarawak : SCS	0.006-0.257	Lokman *et al.* (1988)
Off Sabah : SCS	0.14-0.43	Ichikawa (1990)
Western Phillipines : SCS	0.10-0.18	Bajarias (2000)
Vietnamese Water : SCS	0.06-1.75	This Study

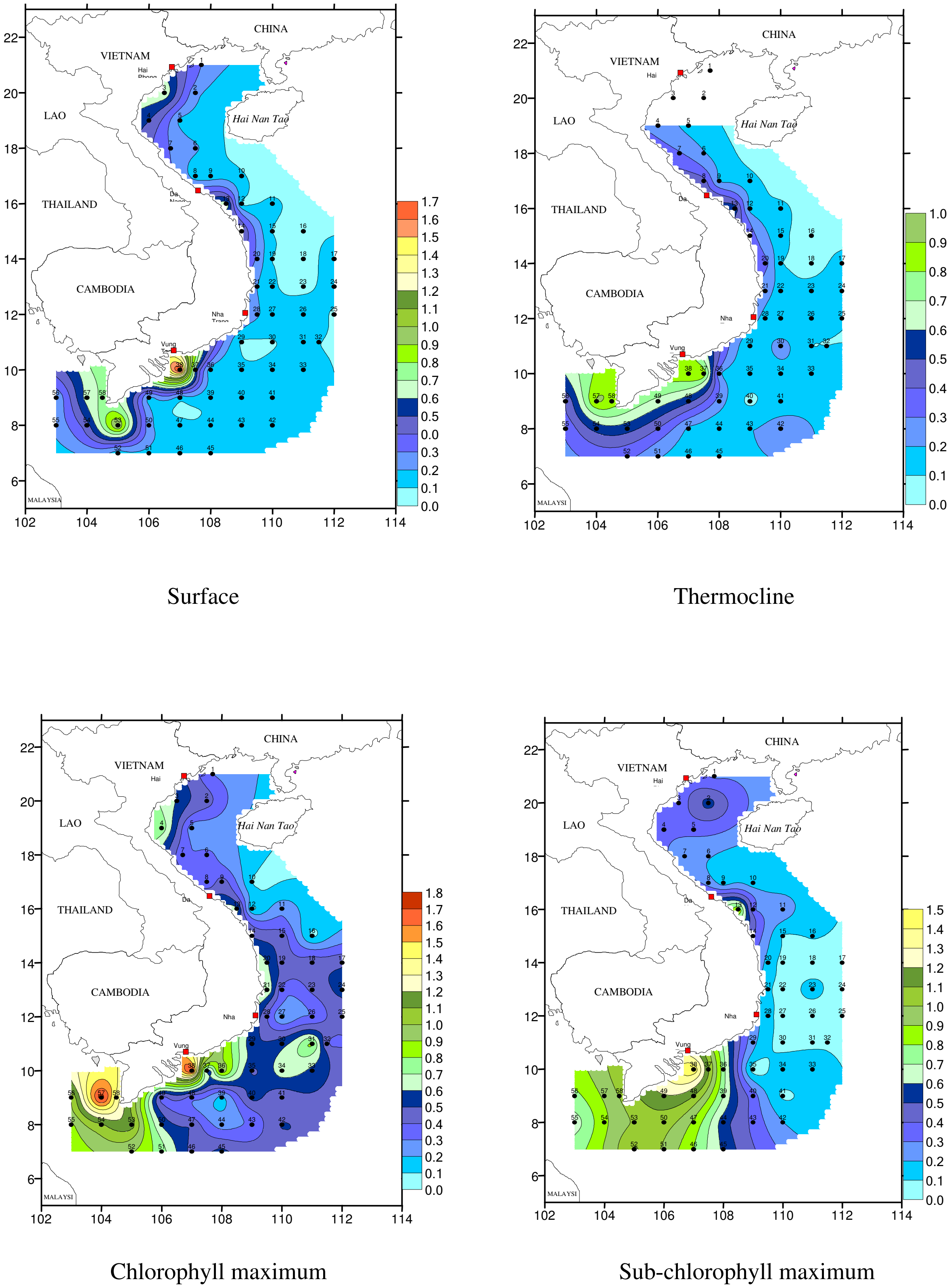
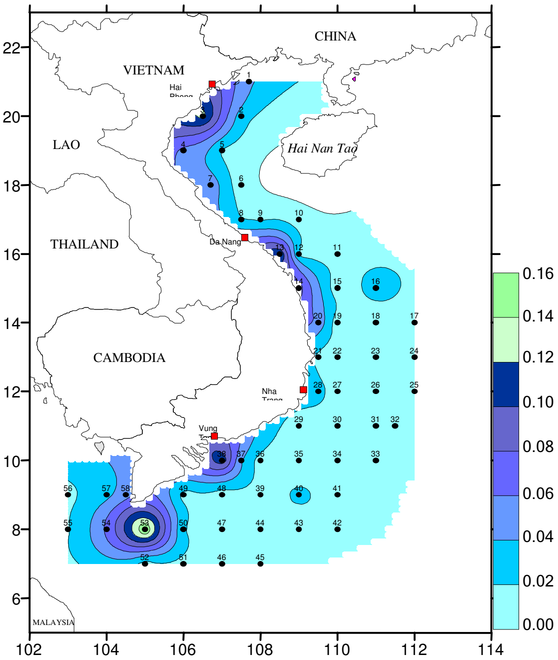
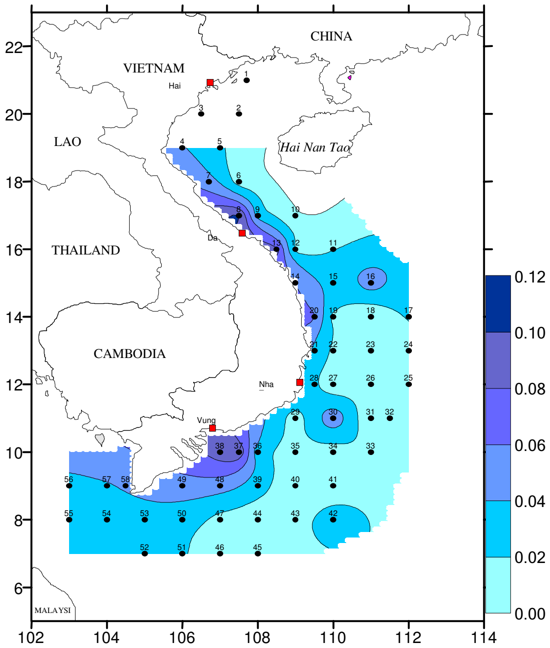


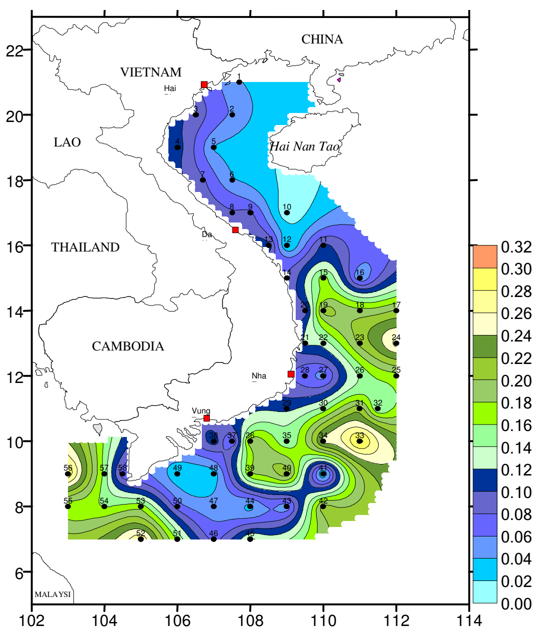
Fig. 2. Concentration of chlorophyll a (mg/m^3) at various sampling depths.



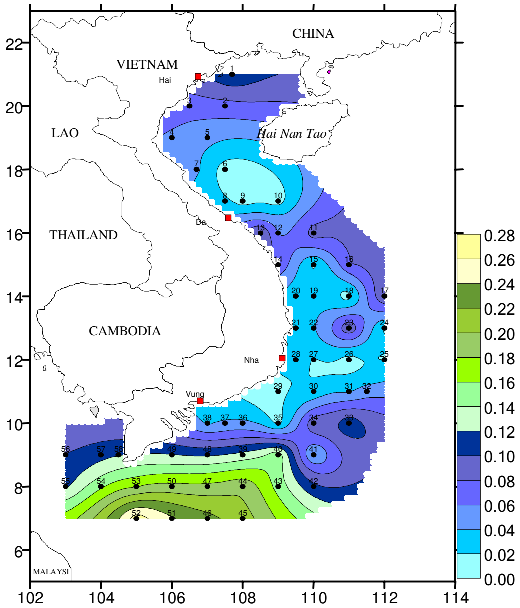
Surface



Thermocline



Chlorophyll maximum



Sub-chlorophyll maximum

Fig. 3. Concentration of chlorophyll b (mg/m^3) at various sampling depths.

Table 1. Concentrations of chlorophyll a and b (mg/m^3) at various depths.

Station	Surface		Thermocline		Chlorophyll maximum		Sub-chlorophyll maximum	
	Chl a	Chl b	Chl a	Chl b	Chl a	Chl b	Chl a	Chl b
1	0.297	0.044	-	-	0.297	0.041	0.278	0.116
2	0.234	0.029	-	-	0.456	0.058	0.548	0.072
3	0.692	0.127	-	-	0.591	0.093	0.348	0.069
4	0.502	0.054	-	-	0.777	0.109	-	-
5	0.172	0.018	0.167	0.024	0.233	0.038	-	-
6	0.224	0.008	0.208	0.011	0.332	0.042	0.210	0.011
7	0.293	0.054	-	-	0.316	0.083	0.227	0.044
8	0.146	0.020	0.445	0.103	0.293	0.082	-	-
9	0.144	0.017	0.177	0.031	0.460	0.085	0.136	0.011
10	0.116	0.009	0.134	0.002	0.088	0.003	0.144	0.012
11	0.126	0.014	0.123	0.020	0.293	0.107	0.267	0.089
12	0.079	0.015	0.141	0.015	0.082	0.015	0.320	0.057
13	0.672	0.121	0.580	0.086	0.647	0.113	0.905	0.103
14	0.504	0.088	-	-	0.487	0.080	0.403	0.077
15	0.091	0.008	0.122	0.033	0.460	0.170	0.090	0.017
16	0.087	0.032	0.085	0.050	0.071	0.040	0.110	0.078
17	0.142	0.008	0.127	0.022	0.487	0.203	0.083	0.100
18	0.062	0.005	0.061	0.002	0.474	0.188	0.045	0.010
19	0.088	0.009	0.104	0.014	0.452	0.212	0.065	0.033
20	0.289	0.056	0.346	0.063	0.612	0.082	0.168	0.029
21	0.197	0.015	0.246	0.037	0.728	0.124	0.120	0.024
22	0.116	0.009	0.157	0.016	0.327	0.126	0.060	0.039
23	0.074	0.005	0.128	0.001	0.425	0.207	0.155	0.098
24	0.132	0.008	0.162	0.018	0.537	0.269	0.025	0.017
25	0.086	0.000	0.103	0.016	0.452	0.172	0.032	0.019
26	0.176	0.014	0.134	0.013	0.304	0.142	0.038	0.013
27	0.104	0.008	0.107	0.008	0.179	0.049	0.064	0.019
28	0.226	0.027	-	-	0.413	0.070	0.133	0.030
29	0.084	0.006	0.109	0.013	0.528	0.114	-	-
30	0.098	0.018	0.249	0.056	0.562	0.146	0.064	0.026
31	0.102	0.007	0.100	0.005	0.853	0.215	0.080	0.038
32	0.101	0.006	0.100	0.008	0.389	0.135	0.086	0.051
33	0.131	0.012	0.160	0.017	0.570	0.311	0.163	0.113
34	0.133	0.010	0.184	0.011	0.662	0.249	0.188	0.095
35	0.121	0.011	0.149	0.015	0.480	0.139	0.032	0.014
36	0.137	0.012	0.201	0.028	0.996	0.198	-	-
37	0.552	0.041	0.904	0.096	0.505	0.051	-	-
38	1.750	0.113	-	-	1.750	0.113	1.485	0.037
39	0.118	0.014	-	-	0.154	0.181	-	-
40	0.196	0.024	0.079	0.011	0.542	0.219	0.358	0.154
41	0.108	0.014	0.141	0.014	0.421	0.011	0.079	0.035
42	0.178	0.013	0.259	0.025	0.510	0.212	0.203	0.105
43	0.155	0.011	0.195	0.017	0.311	0.046	0.376	0.152
44	0.124	0.009	0.103	0.008	0.250	0.031	0.538	0.195
45	0.122	0.008	0.141	0.011	0.536	0.146	-	-
46	0.129	0.008	0.140	0.003	0.465	0.071	-	-
47	0.132	0.010	0.179	0.014	0.498	0.051	-	-
48	0.127	0.009	-	-	0.321	0.028	-	-
49	0.151	0.013	-	-	0.344	0.025	-	-
50	0.241	0.022	-	-	0.584	0.069	-	-
51	0.160	0.013	0.211	0.023	0.748	0.155	-	-
52	0.125	0.010	-	-	0.909	0.279	1.115	0.272
53	1.029	0.162	-	-	1.157	0.173	1.006	0.179
54	0.454	0.064	-	-	1.078	0.157	-	-
55	0.230	0.018	0.313	0.025	0.872	0.162	0.642	0.116
56	0.200	0.015	0.396	0.035	0.991	0.300	-	-
57	0.648	0.034	0.923	0.038	1.702	0.153	-	-
58	0.712	0.052	-	-	1.350	0.064	-	-

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

St. No.	Bottom Depth	Thermocline	Chlorophyll maximum	Sub-chlorophyll maximum
1	34	-	22	30
2	29	-	20	25
3	28	-	7	20
4	26	-	20	-
5	58	25	54	-
6	80	30	45	70
7	40	-	25	35
8	45	25	40	-
9	75	29	45	70
10	107	45	72	100
11	847	52	90	125
12	105	40	65	90
13	42	-	15	30
14	36	-	10	30
15	462	42	75	100
16	1,230	40	88	125
17	2,100	20	80	120
18	2,200	20	60	100
19	653	32	82	125
20	143	-	40	100
21	134	-	45	100
22	1,910	35	88	125
23	2,703	20	70	125
24	3,332	20	65	125
25	4,117	20	70	125
26	2,889	15	84	125
27	1,734	20	75	125
28	110	-	45	100
29	72	-	60	-
30	648	35	50	125
31	2,940	12	62	125
32	3,897	14	73	125
33	3,385	26	80	125
34	1,614	25	90	125
35	156	42	80	125
36	45	-	40	-
37	32	-	27	-
38	21	-	2	14
39	62	-	55	-
40	129	25	82	100
41	1,250	22	75	125
42	654	25	85	125
43	147	20	75	-
44	79	25	50	75
45	61	-	55	-
46	51	-	46	-
47	42	-	38	-
48	32	-	26	-
49	20	-	16	-
50	33	-	28	-
51	44	-	39	-
52	51	-	35	46
53	34	-	16	28
54	26	-	22	-
55	70	25	48	65
56	57	-	50	-
57	34	-	29	-
58	23	-	19	-

Table 3. Classification of some phytoplankton groups by pigments.

Peak	Pigment	Occurrence	Colour
1	Chlorophyll c_1+c_2+c_3	Chromophyte algae, Prymnesiophytes, Chrysophytes	Light green
2	Divinyl chlorophyll b	*Prochlorococcus marinus*	Brown-green
3	Fucoxanthin	Diatoms, Prymnesiophytes,	Orange
4	Carotene	Cryptomonads, Chromophyte	Yellow-orange

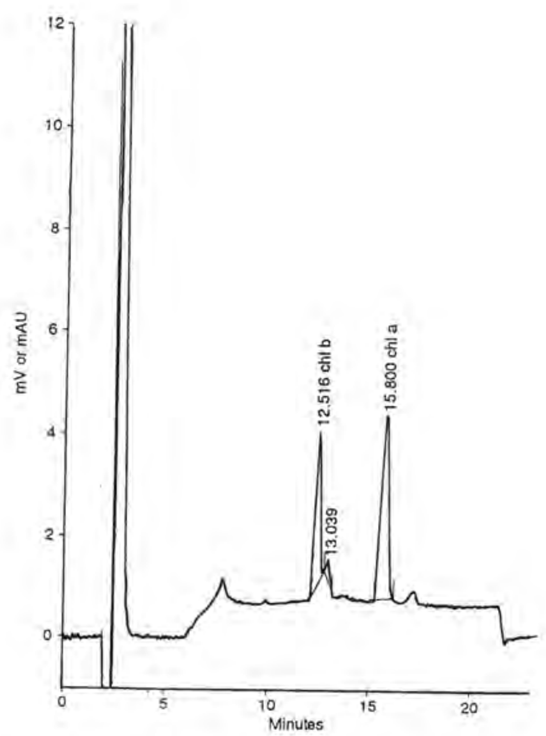


Fig. 4. HPLC chromatogram of reference standard chlorophyll a and b.

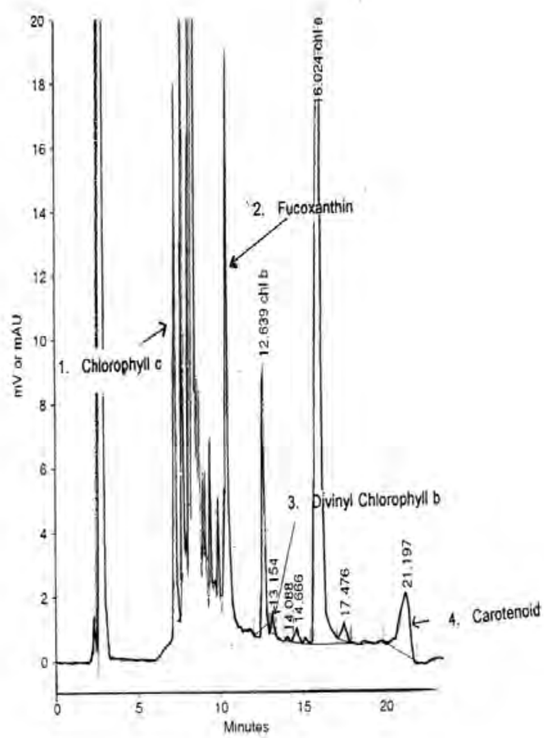


Fig. 5. HPLC chromatogram of extracted pigments.

Fig. 6. pH distributions at various sampling depths.

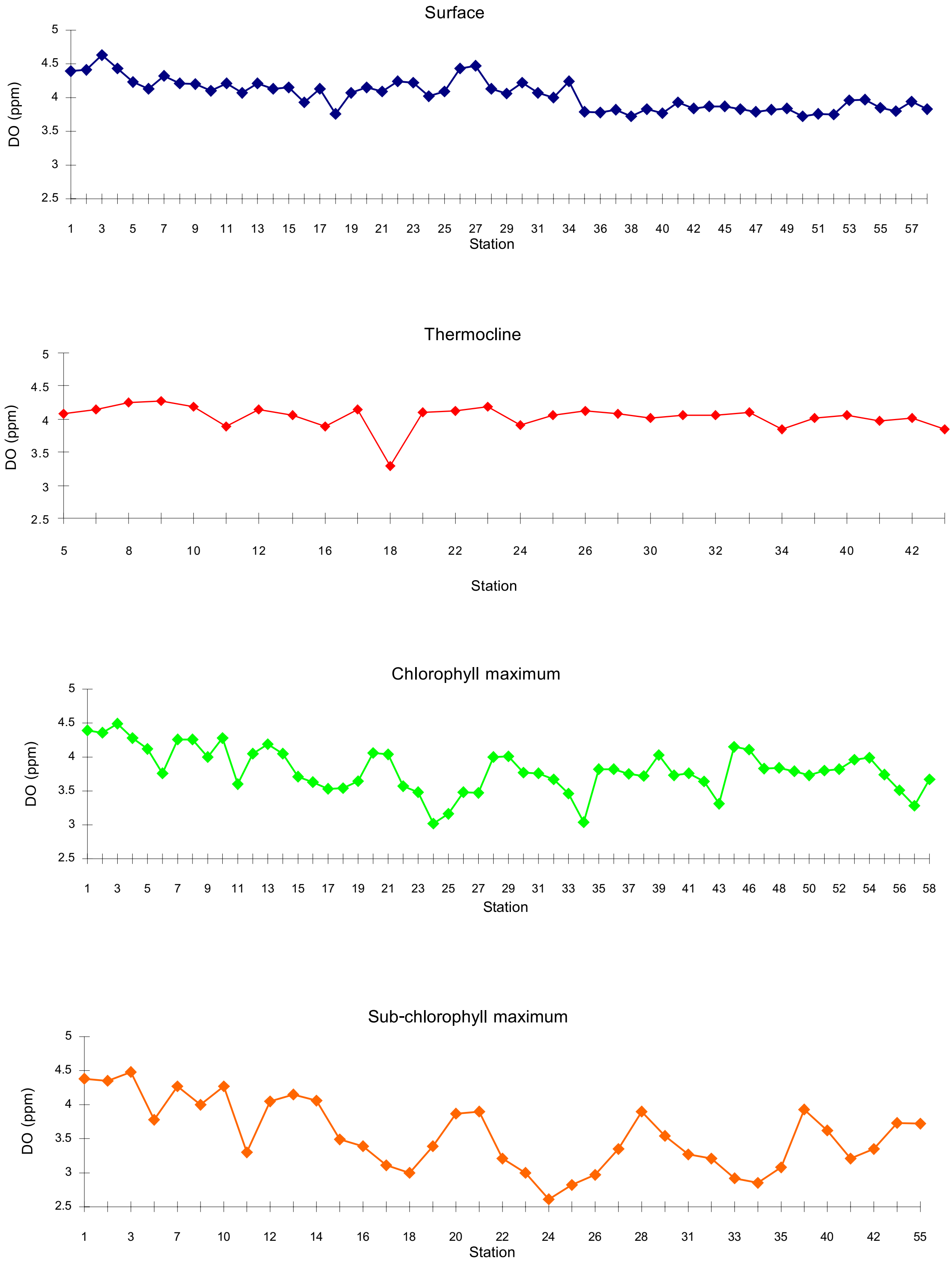


Fig. 7. Dissolved Oxygen (mg/l) distributions at various sampling depths.

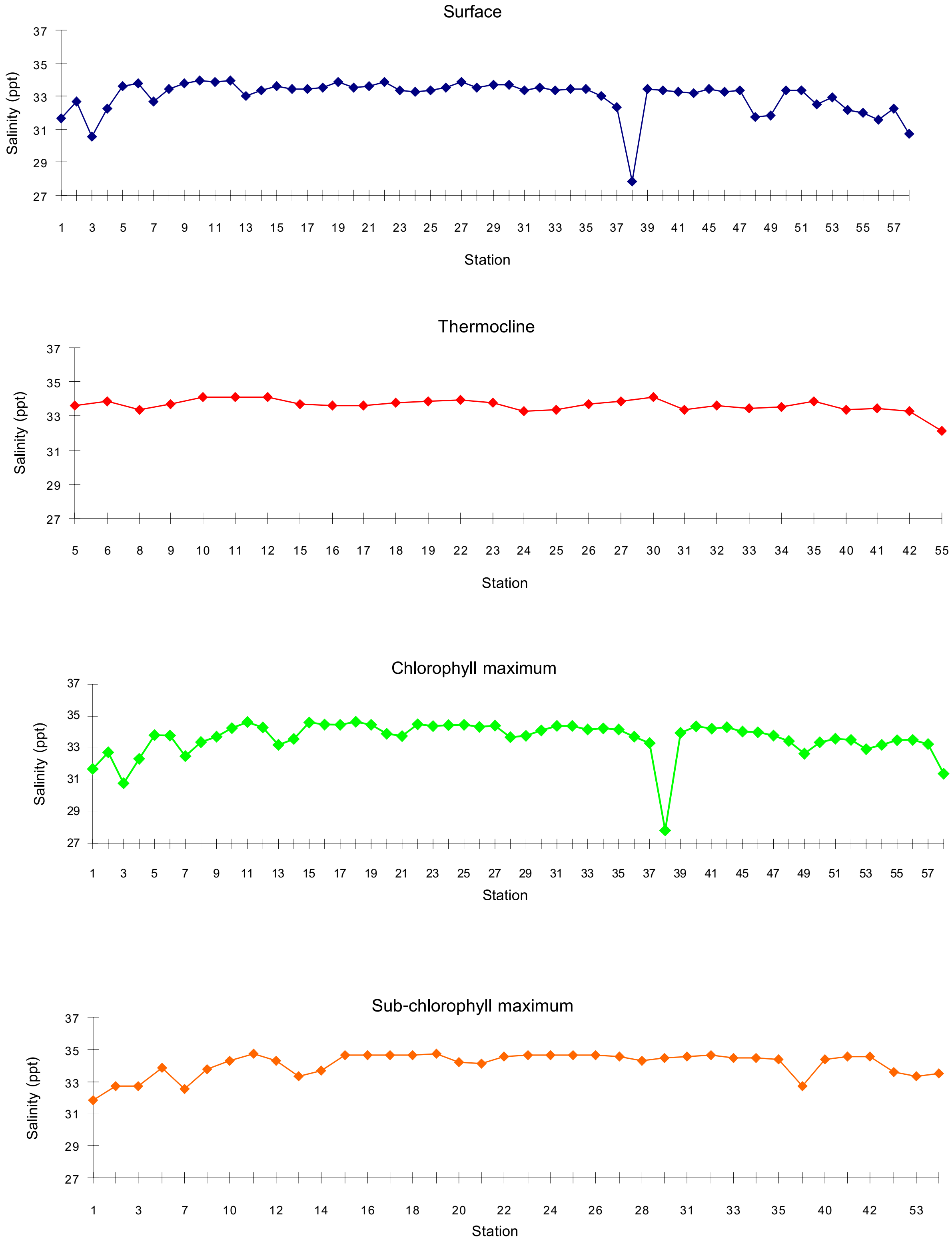


Fig. 8. Salinity (ppt) distributions at various sampling depths.

Fig. 9. Water temperature (°C) distributions at various sampling depths.

Acknowledgement

The authors would like to thank Miss Sopana Boonyapiwat for generous support of sharing Vandorn water sampler and to Dr. Shettapong Meksumpun for providing chlorophyll a and b referenced standards.

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Distribution, Abundance and Species Composition of Phytoplankton in the Vietnamese Waters

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ABSTRACT

Samples of phytoplankton were collected from 58 stations in the Vietnamese waters from 30 April to 21 - May, 1999 on boat M. V. SEAFDEC. The total of 508 taxa, which consisted of 1 genus, 3 species of Cyanophyta; 1 genus, 2 species of Silicoflagellata; 63 genera, 283 species of Bacillariophyta and 34 genera, 220 species of Pyrrophyta were identified. In the Cyanophyta, Oscillatoria (mainly *O. erythraea*) was the frequently dominant species. *Bacteriastrum elongatum, Bellerochea malleus, Chaetoceros cintus, Thalassionema nitzschioides* and *Thalassiothrix frauenfeldii* were dominant species only in some stations of the coastal region of area A, B and D. Average cell numbers of phytoplankton in the different parts of Vietnamese sea waters were in the range 5.984-53.570 cells/l.

The indices of species diversity were in the ranges:

- R: from 0.70 to 2.5
- H′: from 2.49 to 2.32
- H'_{max}: from 6.67 to 6.80
- J: from 0.37 to 0.48
- Dv: from 1.21 to 2.07

Key words: Phytoplankton, Vietnamese sea waters, species diversity indices

Introduction

Phytoplankton in the Vietnamese waters has been collected the specimens since 1920 by Maurice Rose. He is the first scientist, who published the list of 42 species of phytoplankton in the Vietnamese coast and the Gulf of Thailand in 1926.The study surveys on the number distribution and species composition of phytoplankton were carried out in the Vietnamese waters as in 1959 -1962 was the Vietnam - China collaborative research program and in 1960 - 1961 was the Vietnam - Soviet Union collaborative research program in the Gulf of Tonkin; from 1962 to 1965 and from 1976 to 1978 were the study survey in the West of the Gulf of Tonkin; in 1978 - 1980 was the survey in the Thuan Hai - Minh Hai sea waters, etc...

The above mentioned surveys which were used the phytoplankton net with mesh size is 100µM.

Phytoplankton was collected by the sampling equipment of Van Dorn sampler and filtered through net of 20µM mesh size in this study survey.The objectives of this study were:

- To identify phytoplankton species and their distribution.
- To study phytoplankton abundance.
- To describe the diversity indices of phytoplankton.

Materials and Methods

Phytoplankton sampling surveys were carried out on board M. V. SEAFDEC at 58 stations in the Vietnamese waters [Fig. 1] from 30 - April to 21- May,1999.

The Vietnamese waters can be divided into four areas:

A - The Gulf of Tonkin
B - The Central sea waters
C - The South - East sea waters
D - The South - West sea water (The Gulf of Thailand)

The samples were collected by a 20 liter Van Dorn water sampler at 0m, 50m and 100m water layers.

Forty liters of water samples were filtered though a phytoplankton net which its mesh size 20µM and preserved in a 3 - 4% sea water formaline solution.

The samples were concentrated by precipitation. Cell count and identification were 0.09ml in 5 - 40ml of precipitive samples. Number of phytoplankton were calculated into cells/l. Regions with different density were drawn by defining the isoplankta. Statistical analytical indices of phytoplankton were described following the methods in Shannon - Viener (1963).

$$H' = -\sum_{i=1}^{s} P_i \log P_i$$

The diversity can measure species evens (J):

$$J = \frac{H'}{\log_2 S} = \frac{H'}{H'_{max}} \text{ (Pillow, 1965).}$$

Value of diversity index (Dv) can also measure:

$$Dv = H'.J \text{ or } \frac{H'^2}{\log_2 S} \text{ (Chen Qing Chao, 1994).}$$

The richness index (R) measured by: $R = \frac{S}{\sqrt{n}}$

Where: $Pi = \frac{n_i}{n}$; n_i = The number of individuals of the i th species; n = The total individual number; S: The total species.

Results

Identification

In the Vietnamese waters, the total of 508 taxa consisted of 1 genus, 3 species of Cyanophyta, 1 genus, 2 species of Silicoflagellata; 63 genera, 283 species of Bacillariophyta and 34 genera, 220 species of Pyrrophyta were identified.

The taxonomic list is given in Table 1. However, some other species of phytoplankton have not been met in this time.

The occurrence of phytoplankton species in the different areas was also given in table 1. In the Area B, which had highest species number was 387. The number of species in the area C, A, D were 320, 271, 218 respectively.

Table 1. The taxonomic list of phytoplankton identified at the surface layer in the different parts of Vietnamese waters(April-May, 1999).

A: The Gulf of Tonkin — +: Present
B: The Central sea waters — ++: Frequent
C: The South - East sea waters — +++: Abunda
D: The South - West sea waters (The Gulf of Thailand)

No.	Species	A	B	C	D
	Cyanophyta				
1	*Oscillatoria erythraea* (Ehrenberg) Geitler	+++	+++	+++	+++
2	*O. contortum* Wille	++	++	+	+
3	*O. thiebautii* (Gem) Geitler	+	+	+	+
	Silicoflagellata				
4	*Dictyocha fibula* Ehrenberg	+++	+++	++	+++
5	*D. octonaria* Ehrenberg		+		
	Bacillariophyta				
6	*Achnanthes brevipes* Agardh	+			
7	*Actinoptyclus crassus v.* Heurck		+	+	+
8	*A. hexagonus* Grunow		+		
9	*A. splendens* (Shadbolt) Ralfs	++			
10	*A. stella v. thumii* A Schmidt		+		
11	*A. trilingulatus* Brightwell		+	+	
12	*A. undulatus* (Bailey) Ralfs		+	+	
13	*Amphipleura pellucida* Kutzing		+		
14	*Amphiprora alata* Kutzing	+++	++	++	+++
15	*A. gigantea Grunow v. sulcata* (Meara) Cleve	+	+	+	+
16	*A. surirelloides* Hendey	+			
17	*A. sp.*	+			
18	*Amphora graeffi v. minor* Peragallo				+
19	*A. lineata* Gregory			+	
20	*A. ovalis* Kutzing	++			
21	*A. quadrata* Brebisson	+++	++	++	+++
22	*A. ventricosa* Gregory				+
23	*Asterionella japonica* Cleve	+	++	+	+
24	*Asterolampra grevillei* Wallich	+			
25	*A. marylandica* Ehrenberg	+	++	++	++
26	*A. vanheurckii* J. Brun		+		
27	*Asteromphalus cleveanus* Grunow	+	++	+	++
28	*A.elegans* Greville		+	+	
29	*A. flabellatus* (Brebisson) Greville		+	+	++
30	*A. heptactis* (Brebisson) Greville	+	+	+	
31	*A. robustus* Castracane			+	
32	*Bacteriastrum comosum* Pavillard	+++	+++	++	+++
33	*B. comosum v. hispida* (Castracans) Ikari	+++	+	+	+
34	*B. delicatulum* Cleve	+++	+		+
35	*B. elongatum* Cleve	+	++	+	

Table 1.(Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
36	*B. hyalinum* Lauder	+++	+++	+++	+++
37	*B. hyalinum v. princep* (Castracane) Ikari		+	+	+
38	*B. mediterraneum* Pavillard	++	+		
39	*B. minus* Karsten	++	+	+	+
40	*B. varians* Lauder	+	+	++	+
41	*Bellerochea malleus* (Brightwell) v. Heurck				+
42	*B. indica* Karstein			+	
43	*Biddulphia aurita* (Lyngbye) Brebisson & Godey		+	+	
44	*B. dubia* (Brightwell) Cleve	+			++
45	*B. granulata* Roper		+		
46	*B. longicruris* Greville		++	++	+++
47	*B. mobiliensis* Bailey	+	++	+	++
48	*B. obsuta* Kutzing			+	+
49	*B. regia* (Schultze) Ostenfeld	++	+++	++	+++
50	*B. reticulatum* (Ehrenberg) Boyer		+		
51	*B. sinensis* Greville	+		+	++
52	*Brebissomia boeckii* (Ehrenberg) Grunow	+			
53	*Caloneis linearis* (Grunow) Boyer	+			
54	*Campyloneis grevillei* Grunow	+			
55	*Campylodiscus biangulatus* Greville	++	+	+	+
56	*C. brightwellii* Grunow	+			
57	*C. echineis* Ehrenberg		+		
58	*C. fastuolosus* Ehrenberg		+		
59	*Ceratalus tugidus* Ehrenberg	+			
60	*Cerataulina bergoni* Pelagallo	++	+++	++	++
61	*C. compacta* Ostenfeld		++	+	++
62	*Chaetoceros affinis* Lauder	+++	+++	+++	+++
63	*C. affinis v. circinalis* Hustedtt	+	+	+	++
64	*C. affinis v. willei* Hustedtt	++	+	++	++
65	*C. anastomosans* Grunow	+			
66	*C. atlanticus* Cleve	+	++	+	
67	*C. atlanticus v. neapolitana* (Schroder) Hustedtt	+	+++	++	+
68	*C. atlanticus v. skeleton* (Schutt) Hustedtt	+	+++	++	+
69	*C. borealis* Bailey	+	+		
70	*C. brevis* Schutt	+	+		
71	*C. castracanei* Karsten	++	+++	++	+
72	*C. cinctus* Gran	+	+	+	++
73	*C. coartatus* Lauder	+++	++	++	+++
74	*C. compressus* Lauder	+++	+++	+++	+++
75	*C. constrictus* Gran		+	+	+
76	*C. covolutus* Castracane	+	+	+	
77	*C. costatus* Pavillard	+	+	+	+
78	*C. crinitus* Schutt	+++	+++	++	++

Table 1. (Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
79	*C. curvisetus* Cleve	++	+++	+++	+++
80	*C. debilis* Cleve			+	
81	*C. decipiens* Cleve	+++	++	++	++
82	*C. decipiens f. singularis* Gran	+	+	+	++
83	*C. densus* Cleve	+++	+		
84	*C. denticulatus* Lauder	+++	+++	+++	+++
85	*C. didymus* Ehrenberg	++	+	+	++
86	*C. didymus v. anglica* (Grunow) Gran	+++	+	+	+
87	*C. didymus v. protuberans* Gran & Yendo	+			
88	*C. distans* Cleve	++	+	+	+++
89	*C. diversus* Cleve	+++	+++	+++	+++
90	*C. eibenii* Grunow	++	+	+	
91	*C. indicum* Karsten		+		+
92	*C. laciniosus* Schutt	+++	++	+	+
93	*C. laevis* Leuduger - Formorel	+++	++	++	+++
94	*C. lauderi* Ralfs	+	+		+
95	*C. lorenzianus* Grunow	+++	+++	+++	+++
96	*C. messanensis* Castracane	++	+++	+++	++
97	*C. muelleri* Lemmermann	++	+		
98	*C. nipponica* Ikari		+		
99	*C. paradoxus* Cleve	++	++	+	++
100	*C. pelagicus* Cleve	+	+	++	++
101	*C. pendulus* Karsten	+++	+++	+++	++
102	*C. peruvianus* Brightwell	++	+++	+++	+++
103	*C. peruvianus f. robusta* (Cleve) Hustedtt	++	++	++	+++
104	*C. pseudocurvisetus* Margin	++	+	+	++
105	*C. pseudodichaeta* Ikari			+	
106	*C. radicans* Schutt		++	+	
107	*C. rostratus* Lauder	++	+		
108	*C. seychelarum* Karsten	++	++	+++	++
109	*C. siamense* Ostenfeld	+		+	+
110	*C. similis* Cleve	+	+	+	
111	C. simplex Ostenfeld		+++	++	
112	*C. socialis* Lauder	++	+	+	+
113	*C. subsecundus* (Grunow) Hustedtt	++	+	+	++
114	*C. subtilis* Cleve	+			
115	*C. teres* Cleve	+	+	+	
116	*C. tetrastichon* Cleve	++	+	+	
117	*C. tortissimus* Gran	++	+++	+++	++
118	*C. vanheurcki* Gran	++	+		+
119	*C. weissflogii* Schutt	+	+		
120	*Climacodium frauenfeldianum* Grunow	+++	+++	+++	+
121	*C. bivoncavum* Cleve	+++	+++	+++	+++
122	*C. moniligera* Ehrenberg	+			
123	*Coconeis scutellum* Ehrenberg			+	
124	*Corethron hystrix* Hensen	+	+++	+++	++

Table 1. (Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
125	*C. pelagicum* Grunow	+++	++	++	+++
126	*Coscinodiscus argus* Ehrenberg		+	+	+
127	*C. bipartitus* Rattray	+	++	++	+++
128	*C. curvisetus* Cleve	+			
129	*C. centralis* Ehrenberg				+
130	*C. curvalutus* Grunow	+	+	+	+
131	*C. curvalutus v. minor* (Ehrenberg) Grunow		+		
132	*C. divisus* Grunow	+			+
133	*C. excentricus* Ehrenberg	++	+++	++	+
134	*C. granii* Grough			+	
135	*C. janischii* A. Schmidt	++	+		+
136	*C. jonesianus* Ostenfeld	+	++	+	+++
137	*C. lineatus* Ehrenberg	++	++	++	+
138	*C. marginatus* Ehrenberg	++	++	++	++
139	*C. oculatus* (Fauv.) Petit	+	+	++	+++
140	*C. oculus-iridis* Ehrenberg	+++	++	++	++
141	*C. radiatus* Ehrenberg	+++	+++	++	+
142	*C. sub-buliens* Jorgensen		+	+	
143	*C. subtilis* Ehrenberg	+	+	++	+++
144	*C. spinosus* Chin				+
145	*C. thorii* Pavillard	++	++	++	++
146	*C. wailesii* Gran & Angst	+			+
147	*Cymbella naviculiformis* Auerswald	+			
148	*C. turgida* (Greg) Cleve		+	+	
149	*C. ventricosa* Kutzing	+	+		
150	*Cyclotella stylorum* Brightwell	+	+		
151	*Dacttyliosolen mediterraneus* Peragallo	+++	+++	+++	+++
152	*Denticula sp.*	+			
153	*Diploneis bombus* Ehrenberg	+++	++	++	++
154	*D. crabro* Ehrenberg				++
155	*D. elliptica* (Kutzing) Cleve				+
156	*D. fusca* (Gregory) Cleve			+	
157	*D. lineata* (Donkin) Cleve		+		
158	*D. notabilis* (Grevill) Cleve			+	
159	*Ditylum brightwellii* (West) Grunow	+++	++	+	+
160	*D. sol* Grunow	+++	+++	++	+++
161	*Donkinia rectatifer v. intermedia* Donkin	+++	+	+	++
162	*Eucampia cornuta* (Cleve) Grunow	++	++	++	++
163	*E. zoodiacus* Ehrenberg	++	+	+	+
164	*Fragilaria construens* (Ehrenberg) Grunow		+	++	
165	*F. crotonensis* Kitton			+	+
166	*Guinardia flaccida* (Castracane) Peragallo	+++	+++	+++	+++
167	*Gossleriella tropica* Schutt	+	++	++	

Table 1. (Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
168	*Gyrosigma balticum* Ehrenberg	+	+	++	+++
169	*G. spenceri* (Quekett) Cleve	++	++	++	+++
170	*G. strigile* Smith	+	+	+	
171	*G. wansbeckii* (Donkin) Cleve		+		
172	*Grammtophora marina* (Lyngbye)	+			
173	*G. undulata* Ehrenberg		+		
174	*Hemiaulus hauckii* Grunow	+++	+++	+++	+++
175	*H. indicus* Karsten	+	++	+	++
176	*H. membranacea* Cleve	+++	++	+	+
177	*H. sinensis* Greville	+++	+++	+++	+++
178	*Hemidiscus cuneiformis* Wallich	+	+	+	+
179	*H. hardmannianus* (Greville) Mann	+	+	+	++
180	*Lauderia borealis* Gran	++	++	+++	++
181	*Leptocylindrus danicus* Cleve	+++	++	++	+++
182	*Mastogonia heptagona* Ehrenberg			+	
183	*Mestogloia minuta* Greville	+			
184	*Melosira distans v. lirata* (Ehrenberg) Bethge	+			
185	*M. juergensi* Agardh		+	+	
186	*M. mummuloides* (Dillw.) Agardh		+		
187	*M. sulcata* (Ehrenberg) Cleve	+	+	+	
188	*Navicula atlantica* Schmidt				+
189	*N. cancellata* Donkin	+		+	
190	*N. barberi* Barber	+			+
191	*N. crucigera* (W. Smith) Cleve	++	+		
192	*N. cruciloides* Brockmann		+	+	
193	*N. directa v. remota* Cleve		+		
194	*N. elegans* W. Smith	+	+		
195	*N. forcipata* Greville			+	
196	*N. granii* Jorgensen	+			
197	*N. hennedyii* W. Smith				+
198	*N. lanceolata* W. Smith	+			
199	*N. linearis* (Grunow) Boyer	+			
200	*N. marina* Ralf		+		
201	*N. membranacea* Cleve	++	++	+	+++
202	*N. menaiana* Hendey		+		
203	*N. rostellata* Kutzing		+		
204	*N. septentrionalis* (Grunow)	+			
205	*N. tuscula* (Ehrenberg) Van Heurck			+	
206	*N. vanhoffenii* Gran		+		
207	*Nitzschia angularis* Smith		+		
208	*N. bilobata* Smith		+		
209	*N. closterium* Smith			+	
210	*N. delicatissma* Cleve	+++	+++	++	+

Table 1. (Continued).

No.	Species Bacillariophyta	A	B	C	D
211	*N. frigida* Grunow		+	+	++
212	*N. longissima* (Breb.) Ralfs	+++	+++	++	+++
213	*N. lorenziana* Grunow		+		+
214	*N. paradoxa* (Gmelin) Grunow	++	++	++	+++
215	*N. pungens* Grunow	+++	+++	+++	+++
216	*N. pungens v. atlanticum* Grunow		+	++	+++
217	*N. seriata* Cleve		+		
218	*N. sigma* (Kutz) W.Smith		+		
219	*N. vitrea* Normann		+		
220	*N. sp*	+++	+++	+++	+++
221	*Pinularia ambigna* Cleve		+		
222	*P. cruciformis* (Donkin) Cleve			+	
223	*P. rectangulata* (Gregory) Rabenhorst		+		+
224	*Planktoniella sol* (Wallich) Schutt	++	+++	++	+
225	*Pleurosigma affine* Grunow	++	+++	+	+++
226	*P. angulatum* (Quekett) Smith	+	+	+	+
227	*P. formosum* W. Smith	+++	+	++	+++
228	*P. naviculaceum* Brebisson	+	++	+++	+++
229	*P. normanii* Ralfs		+		
230	*P. pelagicum* Peragallo	+++	++	++	+++
231	*P. rectum* Donkin	+	++	++	+++
232	*Pseudocunotia doliolus* (Wallich) Grunow		++	++	+
233	*Pyxidicula weyprechtii* Grunow		+	+	
234	*Rhizosolenia acuminata* (Peragallo) Gran	+	+	+	++
235	*R. alata* Brightwell	++	++	+++	+
236	*R. alata f. curvirostric* Gran	+		+	
237	*R. alata f. genuina* Gran	++	+	++	+++
238	*R. alata f. gracillima* Cleve	+++	+++	+++	+++
239	*R. alata f.indica* (Peragallo) Ostenfeld	++	++	+	+++
240	*R. alata f. inermes* (Caster.)	+			
241	*R. bergonii* Peragallo	+++	+++	+++	+++
242	*R. calca-avis* M. Schultze	+++	+++	+++	+++
243	*R. castracanei* Peragallo	++	+	++	++
244	*R. clevei* Ostenfeld	++	++	++	++
245	*R. cochlea* Grunow	+		+	+
246	*R. crassispina* Schroder	++	++	+	++
247	*R. cylindrus* Cleve	+++	+++	++	++
248	*R. delicatula* Cleve	+	+	+	+
249	*R. fragilissima* Bergon	+++	++	++	+++
250	*R. hebetata f. semispina* (Hensen) Gran	+++	+++	+++	++
251	*R. hyalina* Ostenfeld	++	++	++	
252	*R. imbricata* Brightwell	++	+++	+++	+++
253	*R. imbricata v. shrubsolei* (Cleve) Schroder	+++	+	+	++

Table 1. (Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
252	*R. imbricata* Brightwell	++	+++	+++	+++
253	*R. imbricata v. shrubsolei* (Cleve) Schroder	+++	+	+	++
254	*R. robusta* Norman	+++	++	++	+++
255	*R. setigera* Brightwell	+++	++	++	+++
256	*R. stolterfothii* Peragallo	+++	+++	+++	+++
257	*R. styliformis* Brightwell	++	+++	+++	+++
258	*R. styliformis v. latissima* Brightwell	+++	+++	++	++
259	*R. styliformis v. longispina* Hustedt	+	+	+	+++
260	*Schrodella delicatula* (Peragallo) Pavillard		+	+	+
261	*Skeletonema costatum* (Greville) Cleve	++	++	++	
262	*Stauroneis amphyoxys* Greyory				+
263	*Stephanopyxis palmeriana* (Greville) Grunow	+++	+	+	
264	*Stigmophora rostrata* Wallich	+	++	+	++
265	*S. turris* (Greville & Arnott) Ralfs				
266	*Streptotheca indica* Karsten		+	+	++
267	*S. thamesis* Shrubsole	+	++	+	+
268	*Suriella amoricana* Peragallo				+
269	*S. fastuosa* Ehrenberg	+	+	+	
270	*S. ovata* Kutzing			+	+++
271	*S. ovalis* Brebisson			+	
272	*S. smithii* Ralfs				+
273	*Synedra acus v. radians* Kutzing	+	+	+	
274	*S. gaillonii* (Bory) Ehrenberg			++	
275	*Thalassionema nitzschioides* Grunow	+++	+++	+++	+++
276	*Thalassiothrix delicatula* Cupp	+			
277	*T. frauenfeldii* Grunow	+++	+++	+++	+++
278	*T. longissima* Cleve & Grunow	+++	+++	+++	+++
279	*Thalassiosira condensata* (Cleve)	+		+	+
280	*T. nordens kioldii* Cleve	+	+	+	
281	*T. pacifica* Gran & Angst		+++	+++	+
282	*T. subtilis* (Ostenfeld) Gran	++	+++	+++	+++
283	*Trachyneis aspera* (Ehrenberg) Grunow	+++	++	+++	++
284	*Triceratium favus* Ehrenberg	+		+	+
285	*T. formosum* Brightwell		+	+	+
286	*T. pentacrinus* Wallich				+
287	*T. pentacrinus f. quadrata* Peragallo			+	+
288	*T. shadboldtianum* Grelle				+
	Pyrrophyta				
289	*Amoebophyra ceratii* (Coppen) Cachon		+		
290	*A. fursimorme* Martin	+			
291	*Amphisolenia bidentata* Schroder	++	+++	+++	++
292	*A. globifera* Stein		+	+	
293	*A. palacotheroides* Kofoid			+	

Table 1. (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
294	*A. schauinslandii* Lemmermann		+	+	
295	*A. thrinax* Schutt		+	+	
296	*A. sp.*		+		
297	*Ceratium arcuatum* (Gouret) Pavillard		++	++	+
298	*C. areticum* (Ehrenberg) Cleve		+	+	
299	*C.arietinum* Cleve		+		
300	*C. belone* Cleve	+	+		
301	*C. bigelowii* Kofoid		+		
302	*C. breve* (Ostenfeld & Schmidt) Schroder	+++	+	+	+
303	*C. breve v. parallelum* (Schmidt) Jorgensen	+	+	+	
304	*C. breve v. curnultum* Jorgensen	+	+	+	
305	*C. bucephalum v. heterocamptum* Jorgensen	+	+		
306	*C. candelabrum* (Ehrenberg) Stein		+		
307	*C. candelabrum* (Ehrenberg) *v. dilatalum* (Gourret)		+	+	
308	*C. cariense* Gourret	+	++	++	+
309	*C. cariense v. volans* (Cleve) Jorgensen		+	+	+
310	*C. cariense* Gourret *v. volans f. ceylannicum* (Schroder) Jorgensen	+	++	+	
311	*C. cephalotum* (Lemmermann) Kofoid			+	
312	*C. contortum* (Gourret) Cleve	+	++	+	+
313	*C. contortum v. saltan* (Schroder) Jorgensen	+	+	+	++
314	*C. declinatum* (Karsten) Jorgensen	+	+		
315	*C. dens* Ostenfeld & Schmidt			+	
316	*C. digitatum* Schutt			+	
317	*C. extensum* (Gourret) Cleve	+++	+++	+++	++
318	*C. furca* (Ehrenberg) Claparede & Lachmann	+++	+++	+++	+++
319	*C. furca v. eugranum* Jorgensen	++	+	++	++
320	*C. fusus* (Ehrengerg) Duraidin	+	+	+	
321	*C. fusus v. seta* (Ehrenberg) Jorgensen	+	++	+	
322	*C. fusus* (Ehrenberg) *v. schuttii* Lemmerman	+	+		
323	*C. geniculatum* (Lemm.) Cleve		+		
324	*C. gibberum v. sinistrum* Gourret	+	+	+	
325	*C. hirundinella* O.F. Muller	+	+		
326	*C. horidum* (Cleve) Gran			+	
327	*C. humile* Jorgensen	+	+		
328	*C. incisum* (Karsten) Jorgensen		+	+	
329	*C. inflatum* (Kofoid) Jorgensen		+		
330	*C. inflexum* (Gourret)Kofoid		+		
331	*C. karsteinii v. robustum* Jorgensen	+			
332	*C. kofoidii* Jorgensen	+++	+++	+++	+++
333	*C. lamellicorne* Kofoid		+		
334	*C. longinum* Karsten		+	+	
335	*C. longipes* (Bailey) Gran		+		

Table 1. (Continued).

No.	Species Pyrrophyta	A	B	C	D
336	*C. longirotrum* (Gourret) Jorgensen		+		
337	*C. lineatum* (Ehrenberg) Cleve	+		+	
338	*C. lunula* Schimper		+		
339	*C. lunula f. megaceros* Jorgensen	++	+		
340	*C. macroceros* (Ehrenberg) Vanholf	+++	+++	+	+
341	*C. macroceros* (Ehrenberg) *v. gallicum* (Kofoid) Jorgensen	+	+	++	++
342	*C. massiliense* (Gourret) *v. armatum* (Karsten) Jorgensen	+			
343	*C. nipponicum* Okamura		+		
344	*C. palaeotheroides* Kofoid			+	
345	*C. Palmatum* (Schroder) Schroder			+	
346	*C. palmatum* (Schroder) *v. ranipes* (Cleve) Jorgensen			+	
347	*C. paradoxides* Cleve		+		
348	*C. pavillardii* Jorgensen	+			
349	*C. pennatum* Kofoid	+	+		
350	*C. pennatum* Kofoid *f. falcata* Kofoid	+	+		
351	*C. pennatum* Kofoid *f. propria* Kofoid	+	+	+	
352	*C. pennatum* Kofoid *v. scapiforme* (Kofoid) Jorgensen	+	+	+	
353	*C. pentagonum* Gourret	+++	+++	++	+
354	*C. platicorne* Won Daday		+		
355	*C. pulchellum* Schroder		+	+	
356	*C. reticulatum* (Pouchet) Cleve		+		
357	*C. reticulatum* (Pouchet) *v. spiralis* (Kofoid) Jorgensen	+	++		
358	*C. schroderi* Schroder	+	+		
359	*C. sclunidti* Jorgensen		+		
360	*C. strictum* (Okamura & Niokikawa) Kofoid	+++	++	++	++
361	*C. sumatranum* (Karsten) Jorgensen		+	+	
362	*C. tenue* (Ostenfeld & Schmidt) Jorgensen		+		
363	*C. tenue f. inclinatum* (Kofoid) Jorgensen	+			
364	*C. teres* Kofoid			++	
365	*C. trichoceros* (Ehrenberg) Kofoid	+++	+++	+++	+++
366	*C. tripos f. atlanticum* Ostenfeld	+	+		
367	*C. tripos f. balticum* Schutt		+		
368	*C. tripos var. neglecta* (Ostenfeld) Paulsen		+		
369	*C. tripos typica* (O.F. Muller) Nitsch	+	+		
370	*Ceratocorys horrida* Stein		++	+	
371	*Cladopysis brachiolatum* (Stein) Pavillard	+	+	+	
372	*Cochlodinium pellucidu* Lohmann	+			
373	*Corythodinium globosum* (Kofoid)		+		
374	*C. compressum* (Kofoid)		+		
375	*Dinophysis acuta* Ehrenberg		+		
376	D. *diegens* Kofoid *v. caudata* Pavillard	+	+		
377	*D. exigua* Kofoid & Skogsberg		+		
378	*D. expulsa* Kofoid & Miche		+	+	

Table 1. (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
379	D. *hastata* Stein		+	+	
380	*D. homuculus* Stein	+++	+	+	
381	*D. intenmedia* Pavillard			+	
382	*D. ovum* Schutt		+		
383	*D. parvula* (Schutt) Balech			+	
384	*D. schuttii* Murrays & Whitting		+		
385	*D. rapa* (Stein) Abe		+		
386	*Diplopsalis lenticulata* Berg *f. asymmetrica* (Mang) Steid.,Davis&Will.			+	
387	*Diplopsalopsis sp.*		+		
388	*Distephanus speculatum v. octonarium* (Ehrenberg) Jorgensen		+++	++	+
389	*Glenodium danicum* Paulsen	+	+		
390	*G. apiculata* (Penard) Entz.			+	
391	*G. gymnodinium* Pernard	+	+		
392	*Gonyaulax polygramma* Stein		+		
393	*G. heighleii* (Bailey) Ostenfeld		+	+	+
394	*G. kofoidii* Pavilard		+		
395	*G. levanderi* Lemmermann		+		
396	*G. pacifica* Kofoid			+	
397	*G. polyedra* Stein	+	+		
398	*G. spinifera* (Clap & Lachm.) Dies			+	
399	*G. triacantha* Jorgensen		+		
400	*G. turbynaii* Murray & SW		+		
401	*Gonyodoma ostenfeldii* Paulsen		+		
402	*Gymnodinium abbreviatum* Kofoid & Swezy		+	+	
403	*G. crassum* Pouchet			+	
404	*G. gacile* Bergh	+	+		
405	*G. heterostriatum* Kofoid & Swezy		+		
406	*G. lohmanni* Paulsen		+	+	+
407	*G. sp*		+	+	+
408	*G. spirale* (Bergh) Kofoid & Zwezy		+		
409	*G. vestifici* Schuft		+		
410	*Histioneis hippoperoides* Kofoid & Mich			+	
411	*H. mitchellana* Murray & whitting			+	
412	*H. pulchra* Kofoid			+	
413	*Mesocena polymorpha* Ehrenberg				
414	*M. polymorpha v. bioctonaria* (Ehrenberg) Lemmermann		+	+	
415	*Murrayella punctata* (Cleve) Kofoid		++	+	
416	*Ornithocercus heteroporus* Kofoid		+	+	
417	*O. magnificus* Stein		++	+	
418	*O. serratus* Kofoid		+	+	
419	*O. splendidus* Stein	++	++	+	

Table 1. (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
420	*O. steinii* Murray & Whitting		+		
421	*O. quadratus* Schutt	+	+	+	
422	*Oxytoxum diplocunus* Stein		+	+	
423	*O. gladiolus* Stein		+		
424	*O. laticeps* Schiller			+	
425	*O. milneri* Murray & Whitting		+	+	
426	*O. nanum* Halldal		+		
427	*O. parvum* Schiller		+		
428	*O. reticulatum* (Stein) Schutt		+	+	
429	*O. scolopax* Stein		++	+++	
430	*O. subulatum* Kofoid		+		
431	*O. tesselatum* (Stein) Schutt		+	+	
432	*Parahistioneis para* Murray & White		+	+	
433	*Peridinium abei* Pauls		+		
434	*P. achromaticum* Levander		+		
435	*P. balticum* (Levander) Lemmermann		+		
436	*P. breve* Paulsen		++	+	
437	*P. brochii* Kofoid & Swezy	+	+		
438	*P. cantenatum* Levander		+		
439	*P. cerasus* Pauls	+++	+++	+++	+++
440	*P. clavus* Abe	+	+		
441	*P. corniculum* Kofoid & Micher		+		
442	*P. crassipes* Kofoid	+	+		+
443	*P. curtipes* Jorgensen		+		
444	*P. decipiens* Jorgensen	+			
445	*P. depressum* Bailley		++		
446	*P. divergens* Ehrenberg	+	+		
447	*P. elegans* Cleve		+	+	
448	*P. Facoceros* Paulsen		+		
449	*P. faltipes* Kofoid	+	+		
450	*P. globulus* Stein			+	
451	*P. grande* Kofoid		+	+	
452	*P. hemispherium* Abe		+++	+++	+++
453	*P. heteracanthum* P. Dangeard		+		
454	*P. logipes* Karsten		+		
455	*P. majus* P. Dang		+		
456	*P. marukawai* Abe		+	+	
457	*P. oceanicum* Vanhoff	++	++	+	+
458	*P. oceanicum v. oblongum* (Aurivillius) Cleve	+++	+++	++	++
459	*P. orbiculare* Pauls	+	+		
460	*P. pallidum* Ostenfeld		+	++	+
461	*P. parahistioneis para* Murray & White		+		
462	*P. paradoxum* Gaarder			+	

Table 1. (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
463	*P. parallelum* Broch	+	+		
464	*P. pentagonum v. depressum* Abe				
465	*P. quarnerense* (Schroder) Broch	+			
466	*P. rectum* Kofoid	+	+++	+++	++
467	*P. roseum* Paulsen		+		
468	*P. rotundata* Abe		++	+++	+
469	*P. sphaerium* Okamura		++	++	++
470	*P. spheroides* P. Dangeard		+++	+++	+++
471	*P. spiniferum* Schiller	+		++	+
472	*P. steinii* Jorgensen	+	+		
473	*P. temissimum* Kofoid		+		
474	*P. thorianum* Paulsen			+	
475	*P. trochoideum* (Stein) Lemmermann	+	+		
476	*P. sp.*			+	
477	*Phalacroma cuneus* Schutt			+	
478	*P. doryphorum* Stein		+	+	
479	*P. mitra* Schutt		++	++	
480	*P. parvulum* (Schutt) Jorgesen			+	
481	*P. porodicum* Stein		+++	+++	+
482	*P. rotundatum* (Claparede & Lachmann) Kofoid & Micherner		++	++	+
483	*P. umbonatum* Stein			+++	+
484	*Podolampas bipes* Stein			++	+
485	*P. palmipes* Stein	+++	+++	+++	++
486	*P. spinifera* Okamura	++	+++	+++	+
487	*Pronoctiluca pelagica* Fabre-Domergue			+	
488	*Prorocentrum compressum* (Bailey) Abe' & Dodge			+	
489	*P. cordatum* (Ostenfeld) Dodge			+	
490	*P. gracile* Schutt		+		
491	*P. lenticulatum*(Matzenauer)		+	+	
492	*P. micans* Ehrenberg	++	+	+	
493	*P. minimum* (Pavilard) Schiller			+	
494	*P. pyriforme* (Schiller) Hasle		+	+	
495	*P. rostatum* Stein			+	
496	*P. scutelum* Schroder			+	
497	*Protoceratium reticulatum* (Clap & Lachm.) Butschli			+	
498	*Pyrocystis fusiformis* Murray		++	+	+
499	*P. hamulus* Cleve *v. inaequalis* Schroder	+	+		
500	*P. lunula* Schutt	+	++	+	
501	*P. noctiluca* Murray	+++	+++	++	+
502	*P. obtusa* Pavillard		+	+	+
503	*P. robusta* Kofoid		+		
504	*Pyrophacus horologicum* Stein	++	++	++	++

Table 1. (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
505	*Pseudoamphiprora stauroptera* (Baley) Cleve		+		
506	*Scripstella trochoidea* (Stein) Balech		+++	+++	+++
507	*Triposolenia bicornis* Kofoid		+		+
508	*Warnowia schuttii* (Kofoid & Swezy) Schiller			+	

Phytoplankton abundance

Phytoplankton densities in the surface layer were hight abundance in the coastal area (A, B, C and D).The highest cell count was 204,342 cells/l found at the station 57 in the area D;185,258 cells/l at the station 3 in the area A; 62,420 cells/l at the station 37 in the area C.

At the station 10 in the off - shore of area B, the highest cell count was 147,186 cells/l [Table2, Fig.2].

Average total cell number of phytoplankton in the same abundance which have been found in the area A and D 77,301 and 66,153 cells/l. In the area B and C phytoplankton abundance was mostly lower than that in area A and D - 11,287 and 8.585 cells/l (Table 3).

In general the distribution of phytoplankton was concentrated at the surface water layers and decreased at the deeper water layers [Fig. 2 -5].

The average of cell number of phytoplankton in the Vietnamese seawaters was 24,804 cells/l at the surface layer, follow up 3,226 cells/l and 1,264 cells/l at the 50m and 100m layer [Table 3].

It was observed that total cell number densities of Cyanophyta were concentrated at lower area A, upper area B and all area D.

In the upper area A, central and lower area B and C, total cell number densities of Cyanophyta were relatively poor. Its distribution was concentrated at the surface layer and at the same time densities decreased at the deeper water layers. [Fig. 6 - 8].

The average cell number of Cyanophyta, Bacillariophyta and Pyrrophyta in the different water layers of the Vietnamese sea waters and its areas are given in Table 3.

In the above mentioned table, the cell number is shown that total cell number densities of these phytoplankton were concentrated at the surface water layers and decreased clearly at the deeper water layers. Figures 6-14 are shown the abundance distribution of these phytoplanton at the different water layers.

Cell number abundance of Silicoflagellata was relatively poor in the Vietnamese sea water. *Dictyocha octonaria* was only appeared at some stations in the area B.

High cell number densities of *Dictyocha fibula* were found in the coastal areas A, B and C. The distribution of densities of this species at the different water layers in the Vietnamese sea waters were given in Figures from 15 to 17. These figures and Table 3 were shown that at the 50m water layer cell of number densities of this species was more abundant than at the other layers.

Occurrence of dominant species.

In the Cyanophyta, Oscillatoria (principal of *O. erythraea)* presented at all the study parts from areas A to D with abundant number and the frequently dominant species. The relative abundance of the

Oscillatoria was 11.09 - 99.07 % of total phytoplankton number while other dominant species reached only 9.31 - 55.63 %.

Bacteriastrum elongatum, Bellerochea malleus, Chaetoceros cinctus, Thalassionema nitzschioides and Thalassiothrix frauenfeldii were dominant species only in some stations in the coastal region of area A, B and D [Table 4] and distribution of these dominant species was shown in Figure 18.

For Pyrrophyta, there was no high percentages of occurrence.

Table 2. Cell number density of phytoplankton at the surface layer in the Vietnamese sea waters (April - May 1999).

St.	cells/l	St.	cells/l	St.	cells/l	St.	cells/l
1	3,876	16	4,420	31	1,182	46	3,974
2	87,779	17	1,398	32	1,143	47	5,387
3	185,258	18	934	33	4,733	48	7,913
4	148,500	19	1,863	34	8,803	49	17,598
5	504	20	2,797	35	1,463	50	6,046
6	5,036	21	2,036	36	6,440	51	11,359
7	110,158	22	2,787	37	62,420	52	21,614
8	1,504	23	592	38	22,566	53	13,393
9	2,865	24	2,567	39	2,426	54	28,184
10	147,186	25	2,333	40	3,154	55	9,656
11	5,595	26	3,845	41	5,601	56	15,830
12	1,583	27	2,918	42	8,483	57	204,342
13	21,108	28	2,269	43	1,904	58	170,050
14	25,001	29	7,635	44	1,567		
15	1,443	30	786	45	4,806		

Table 3. Average cell number densities of phytoplankton in the different water layers in Vietnamese sea water (April - May 1999).

Area	Layer (m)	*Cells/l*				
		Bacillariophyta	*Pyrro - phyta*	*Cyano-phyta*	*Silico-flagellata*	*Total Phytoplankton*
A	0	42,001	446	34,853	1	77,301
	50	2,745	83	1,212	30	4,070
B	0	2,303	256	8,720	8	11,287
	50	1,838	199	1,715	9	3,760
	100	616	85	670	4	1,376
C	0	4,291	257	4,036	1	8,585
	50	769	114	1,392	5	2,280
	100	721	69	282	1	1,073
D	0	36,515	473	29,162	3	66,153
	50	1,040	93	3,115	4	4,251
Areas	0	12,011	305	12,484	4	24,804
	50	1,385	155	1,679	7	3,226
	100	655	79	527	3	1,264

Table 4. Average abundance of phytoplankton from 100m (or the upper bottom) to surface water layers in the Vietnamese Waters (April - May 1999).

St.	Total phyto. (cells/l)	Dominant species		Associated species	
		Species	(%)	Species	(%)
1	3,293	*Oscillatoria*	18.12	*Guinardia flaccida*	13.81
2	67,467	*Oscillatoria*	15.37	*Chaetoceros paradoxus*	6.31
3	146,990	*Bellerochea malleus*	31.40	*Oscillatoria*	2.01
4	78,787	*Oscillatoria*	74.13	*Chaetoceros compressus*	5.75
5	2,487	*Thalassiothrix frauenfeldii*	9.74	*Oscillatoria*	9.41
6	3,981	*Oscillatoria*	72.79	*Climacodium bivoncavum*	4.19
7	56,210	*Oscillatoria*	98.04	*Bacteriastrum hyalinum*	0.22
8	1,391	*Oscillatoria*	62.91	*Climacodium bivoncavum*	7.66
9	2,941	*Oscillatoria*	69.57	*Climacodium bivoncavum*	6.71
10	59,981	*Oscillatoria*	99.07	*Podolampas palmipes*	0.11
11	2,586	*Oscillatoria*	88.84	*Peridinium cerasus*	1.53
12	1,371	*Oscillatoria*	74.76	*Thalassiosira subtilis*	3.63
13	22,020	*Thalassionema nitzschioides*	9.31	*Rhizosolenia styliformis v. latissima*	7.34
14	13,930	*Thalassionema nitzschioides*	11.43	*Asterionella japonica*	8.49
15	1,261	*Oscillatoria*	85.06	*Rhizosolenia calcar-avis*	2.55
16	1,929	*Oscillatoria*	74.30	*Thalassiothrix frauenfeldii*	3.05
17	1,418	*Oscillatoria*	34.38	*Thalassiothrix frauenfeldii*	5.71
18	2,491	*Bacteriastrum elongatum*	15.66	*Oscillatoria*	15.16
19	1,392	*Oscillatoria*	42.55	*Peridinium cerasus*	6.23
20	1,573	*Oscillatoria*	38.68	*Thalassiothrix frauenfeldii*	7.37
21	1,284	*Oscillatoria*	11.09	*Thalassiothrix frauenfeldii*	10.34
22	1,284	*Oscillatoria*	77.68	*Peridinium cerasus*	2.22
23	599	*Oscillatoria*	45.30	*Thalassiothrix frauenfeldii*	5.35
24	1,257	*Oscillatoria*	74.32	*Thalassionema nitzschioides*	1.86
25	2,102	*Oscillatoria*	39.02	*Thalassionema nitzschioides*	7.90
26	1,798	*Oscillatoria*	86.15	*Peridinium cerasus*	2.37
27	1,252	*Oscillatoria*	78.79	*Peridinium cerasus*	2.48
28	1,804	*Oscillatoria*	46.30	*Chaetoceros curvisetus*	4.08
29	4,740	*Oscillatoria*	77.44	*Peridinium cerasus*	1.61
30	579	*Oscillatoria*	31.38	*Thalassiothrix frauenfeldii*	7.98
31	622	*Oscillatoria*	53.20	*Peridinium cerasus*	7.88
32	546	*Oscillatoria*	72.20	*Peridinium cerasus*	6.49
33	3,548	*Oscillatoria*	87.05	*Chaetoceros tortissimus*	1.77
34	5,268	*Oscillatoria*	81.78	*Chaetoceros messanensis*	1.73
35	990	*Oscillatoria*	79.87	*Dacttyliosolen mediterraneus*	4.61
36	6,857	*Thalassiothrix frauenfeldii*	15.75	*Oscillatoria*	14.29
37	41,452	*Nitzchia pungens*	6.53	*Chaetoceros diversus*	6.25
38	17,657	*Chaetoceros cinctus*	55.63	*Thalassionema nitzschioides*	8.27
39	1,925	*Oscillatoria*	70.40	*Thalassiothrix frauenfeldii*	4.57
40	1,986	*Oscillatoria*	94.29	*Dacttyliosolen mediterraneus*	0.55
41	3,648	*Oscillatoria*	94.11	*Peridinium cerasus*	0.65

Table 4. (Continued).

St.	Total phyto. (cells/l)	Dominant species		Associated species	
		Species	(%)	Species	(%)
42	4,766	*Oscillatoria*	80.25	*Chaetoceros curvisetus*	1.71
43	2,026	*Oscillatoria*	50.86	*Thalassionema nitzschioides*	10.98
44	1,191	*Oscillatoria*	81.34	*Peridinium cerasus*	3.23
45	2,785	*Oscillatoria*	86.85	*Pleurosigma naviculaceum*	1.82
46	2,574	*Oscillatoria*	89.59	*Peridinium cerasus*	1.65
47	3,165	*Oscillatoria*	86.03	*Peridinium cerasus*	2.81
48	9,079	*Oscillatoria*	56.11	*Rhizosolenia calcar-avis*	8.71
49	22,248	*Oscillatoria*	32.84	*Chaetoceros laevis*	5.74
50	4,852	*Oscillatoria*	59.23	*Thalassiothrix frauenfeldii*	4.28
51	7,397	*Oscillatoria*	88.85	*Thalassiothrix frauenfeldii*	1.79
52	12,698	*Oscillatoria*	91.97	*Thalassiothrix frauenfeldii*	1.87
53	9,266	*Oscillatoria*	36.17	*Nitzchia paradoxa*	5.49
54	25,650	*Oscillatoria*	61.44	*Chaetoceros pseudocurvisetus*	3.55
55	6,792	*Oscillatoria*	80.70	*Gyrosigma spenceri*	1.06

Species diversity indices

All species number at different water layers of each station were summed, total cell number of phytoplankton and number of each species at different water layers were summed and calculated in average of each station for calculating the species diversity indices [Table 5].

Table 5. Species diversity indices of phytoplankton in the Vietnamese sea waters (April - May, 1999).

St	Total species	Total number of individuals (cells/l)	Richness indices (R)	H'	J	H'_{max}	Dv
1	117	3,293	2.04	4.97	0.72	6.87	3.58
2	110	67,467	0.42	5.20	0.76	6.78	3.95
3	190	146,990	0.50	3.24	0.43	7.57	1.39
4	109	78,787	0.39	2.07	0.31	6.77	0.64
5	101	2,487	2.03	5.28	0.79	6.65	4.17
6	87	3,981	1.38	2.21	0.34	6.44	0.75
7	90	56,210	0.38	0.25	0.03	6.49	0.01
8	61	1,391	1.64	2.66	0.44	5.93	1.17
9	64	2,941	1.18	2.33	0.39	6.00	0.91
10	89	59,981	0.36	0.12	0.02	6.48	0.002
11	97	2,586	1.91	1.07	0.16	6.60	0.17
12	106	1,371	2.86	2.12	0.31	6.73	0.66
13	137	22,020	0.92	5.48	0.77	7.10	4.22
14	129	13,930	1.09	5.52	0.79	7.01	4.36
15	89	1,261	2.51	1.40	0.22	6.48	0.31
16	104	1,929	2.37	2.15	0.32	6.70	0.69
17	132	1,418	3.51	4.52	0.64	7.04	2.89

Table 5. (Continued).

St	Total species	Total number of individuals (cells/l)	Richness indices (R)	H'	J	H'_{max}	Dv
18	112	2,491	2.24	4.72	0.69	6.81	3.26
19	115	1,392	3.08	4.22	0.62	6.85	2.62
20	147	1,573	3.71	4.55	0.63	7.20	2.87
21	161	1,284	4.49	5.89	0.83	7.33	4.89
22	112	1,284	3.13	2.06	0.30	6.81	0.62
23	97	599	3.96	3.95	0.60	6.60	2.37
24	89	1,257	2.51	2.18	0.34	6.48	0.74
25	92	2,102	2.01	4.00	0.61	6.52	2.44
26	97	1,798	2.29	1.29	0.20	6.60	0.26
27	113	1,252	3.19	1.94	0.28	6.82	0.54
28	158	1,804	3.72	4.36	0.60	7.30	2.62
29	129	4,740	1.87	2.12	0.30	7.01	0.64
30	119	579	4.95	4.85	0.70	6.89	3.40
31	104	622	4.17	3.51	0.52	6.70	1.83
32	97	546	4.15	2.29	0.34	6.60	0.78
33	106	3,548	1.78	1.25	0.19	6.73	0.24
34	131	5,268	1.80	1.64	0.23	7.03	0.38
35	92	990	2.92	1.76	0.27	6.52	0.48
36	120	6,857	1.45	4.72	0.68	6.91	3.21
37	105	41,452	0.52	5.45	0.81	6.71	4.41
38	86	17,657	0.65	3.26	0.51	6.43	1.66
39	104	1,925	2.37	2.45	0.37	6.70	0.91
40	85	1,986	1.91	0.63	0.10	6.41	0.06
41	92	3,648	1.52	0.65	0.10	6.52	0.07
42	147	4,766	2.13	1.86	0.26	7.20	0.48
43	134	2,026	2.98	3.56	0.50	7.07	1.78
44	103	1,191	2.98	1.69	0.25	6.69	0.42
45	76	2,785	1.44	1.23	0.20	6.23	0.25
46	82	2,574	1.62	1.02	0.16	6.36	0.16
47	81	3,165	1.44	1.26	0.20	6.34	0.25
48	108	9,079	1.13	3.17	0.47	6.75	1.49
49	103	22,248	0.69	4.61	0.69	6.69	3.18
50	100	4,852	1.44	3.18	0.48	6.64	1.53
51	75	7,397	0.87	1.05	0.17	6.23	0.18
52	98	12,698	0.87	0.81	0.12	6.61	0.10
53	117	9,266	1.22	4.48	0.65	6.87	2.91
54	116	25,650	0.72	3.03	0.44	6.86	1.33
55	107	6,792	1.30	1.82	0.27	6.74	0.49
56	97	32,257	0.54	0.32	0.05	6.59	0.02
57	110	144,077	0.29	5.25	0.77	6.78	4.04
58	91	144,253	0.24	4.26	0.66	6.51	2.81
Average		**17,410**	**1.93**	**2.88**	**0.42**	**6.71**	**1.60**

High diversity indices H′ of phytoplankton were found at the station No: 2, 5, 13, 14,21, 37, and No 57, and corresponding value of these stations were 5.20, 5.28, 5.48, 5.52, 5.52, 5.45 and 5.25.

High evenness indices J of phytoplankton occurred at the stations No 2, 5, 13, 14, 21, 37 and No 57 which had corresponding value: 0.76, 0.79, 0.77, 0.79, 0.83, 0.81 and 0.77.

Lowest diversity indices of phytoplankton occurred at the station No 7, 10, 40, 41, 52 and No 56 corresponding value 0.25, 0.12, 0.63, 0.81 and 0.32.

Lowest evenness indices were found at the stations No 7, 10, 40, 41, 52 and 56 which had corresponding value 0.03, 0.02, 0.10, 0.10, 0.12 and 0.05.

As the above mention description, it showed that the change of indices were high.

Richness indices R reached high value in the station of area B and C.

Maximum diversity indices H'_{max} were relatively stable in the range 5.93 - 7.57.

Value of diversity indices Dv were changed in the range from 0.002 at the station 10 to 4.89 at the station 21.

The average of species diversity indices of phytoplankton in the different areas of Vietnamese sea water were shown in the Table 6.

Table 6. Species diversity indices of phytoplankton in the different areas of the Vietnamese waters (April - May 1999).

Area	Total species	Total number of individuals (cells/l)	Richness indices (R)	Diversity indices (H')	Maximum diversity indices (H'_{max})	Evenness indices (J)	Diversity value (Dv)
A	271	51,316	1.02	3.32	6.80	0.48	2.07
B	387	5,984	2.51	3.17	6.73	0.46	1.84
C	320	6,517	2.03	2.49	6.67	0.37	1.21
D	218	53,570	0.74	2.85	6.71	0.42	1.67
Areas	**508**	**17,410**	**1.93**	**2.88**	**6.71**	**0.42**	**1.60**

Discussion and Conclusion

1. According to the data from Nguyen Tien Canh (1996), the phytoplankton collected by Van Dorn water sampler were reacher than that by phytoplankton net [Table 7].

2. Tendency of distribution of phytoplankton of this cruise was similar to the distribution of phytoplankton in the Vietnamese seawaters in the past years.

3. Diversity indices and their application to aquatic studies were described by Washington (1994) and Metealfe (1989) [in Mason (1995)]. The most widely used indices of diversity which were those based on the information theory, the most frequent measure was being used by the Shannon index which assumes that individuals are randomly sampled from an indefinittly large population:

$$H'= \sum_{i=1}^{s} P_i \log P_i .$$

The diversity indices$H'$of phytoplankton is to show the occured frequency at one of areas, it mainly related to the number that the character vietics of diversity phytoplankton had to relationship with the variation of number and of phytoplankton composition.

In order to have the index that refected typical characteristic of diversity, Chen Qing Chao (1993) calculated diversity value Dv for tropical marine regions:

$$Dv = H'.J \text{ or } Dv = H'^2/\log_2(S)$$

And provided level of diversity in Table 8.

Table 7. Average cell number of Phytoplankton sampled by Phytoplanton net (1959 - 1986) (1) and by Van Dorn water sampler (1999) (2) in the different areas of the Vietnamese waters.

Area / Sampler	A	B	C	D
(1)	1,926	437	827	5,549
(2)	51,316	5,984	6,517	53,570

Table 8. Field of phytoplankton diversity value in Vietnamese waters.

Value of phytoplankton diversity (Dv)	Level of phytoplankton diversity	Form of diversity
> 3.5	Richness diversity	I
2.6 - 3.5	Rich diversity	II
1.6 - 2.5	Fair diversity	III
0.6 - 1.5	Normal diversity	IV
< 0.6	Low diversity	V

According to the above mentioned issue, the diversity value of area A reached 2.07 (form III), which was the fair diversity area, the other areas that were normal diversity were from 1.21 - 1.34 (form IV).

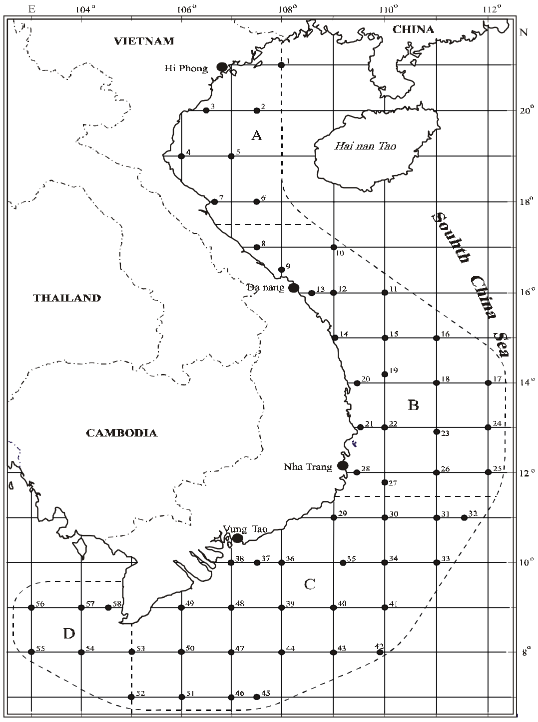

Fig. 1. Station system of collaborative research survey in the Vietnamese waters (April-May 1999).

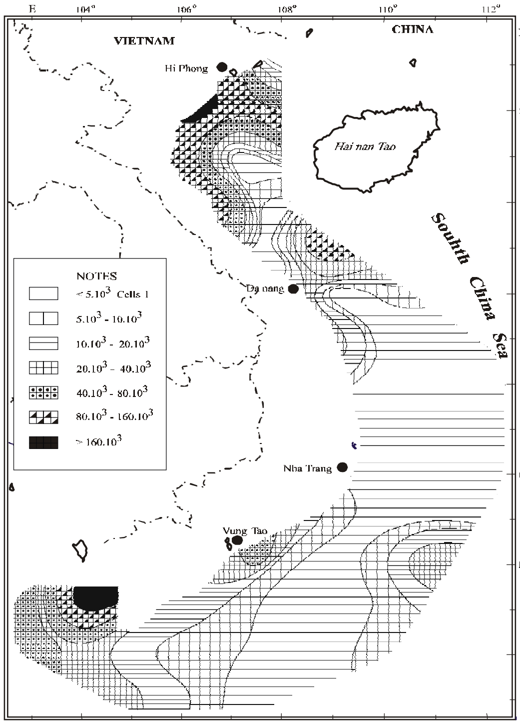

Fig. 2. Total phytoplankton density(cells/l)at the surface water layer in the Vietnamese waters (April-May, 1999).

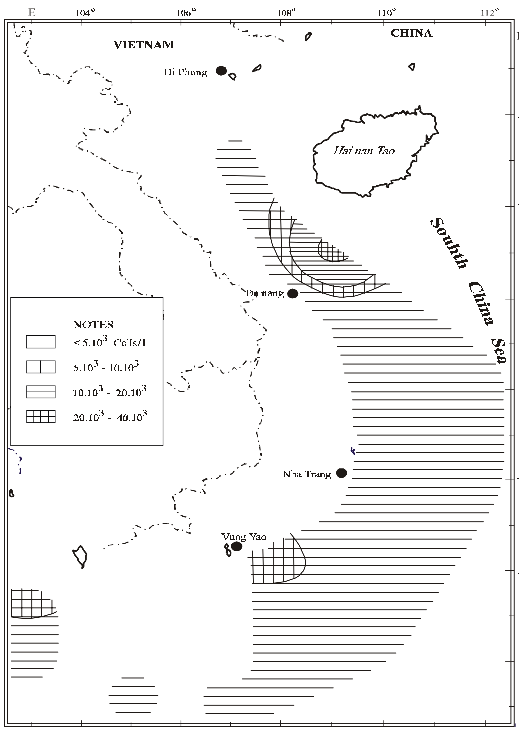

Fig. 3. Total phytoplankton density(cells/l) at the 50m water layer in the Vietnamese waters (April-May, 1999).

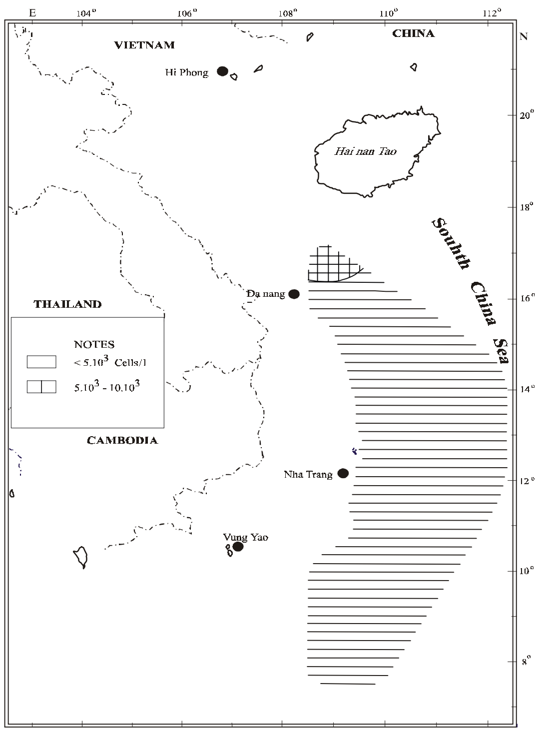

Fig. 4. Total phytoplankton density (cells/ l) at the100m water layer in the Vietnamese waters (April-May, 1999).

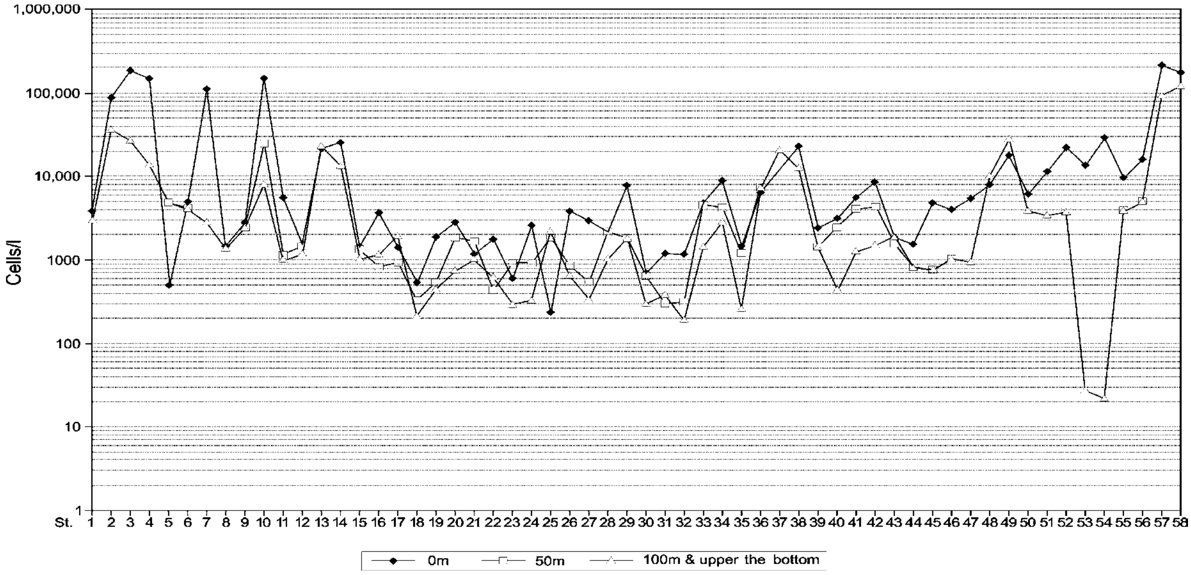

Fig. 5. Distribution of phytoplankton density at the different water layers in Vietnamese water (April-May, 1999).

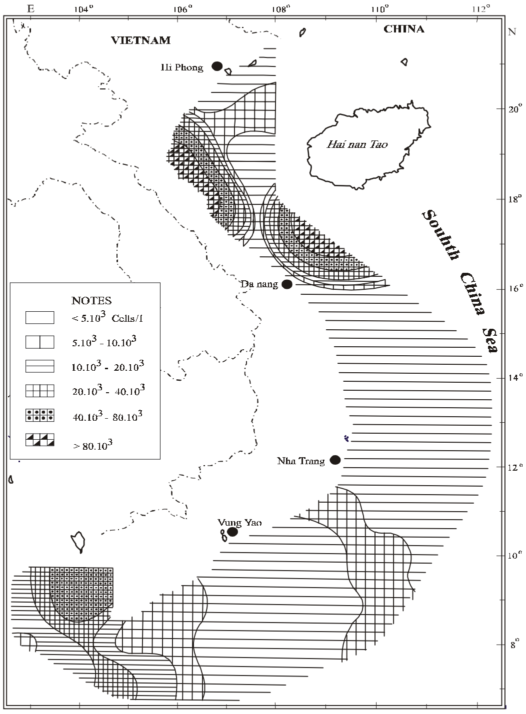

Fig. 6. Oscillatoria population density (cells/l) at the surface water layer in the Vietnamese waters (April-May, 1999).

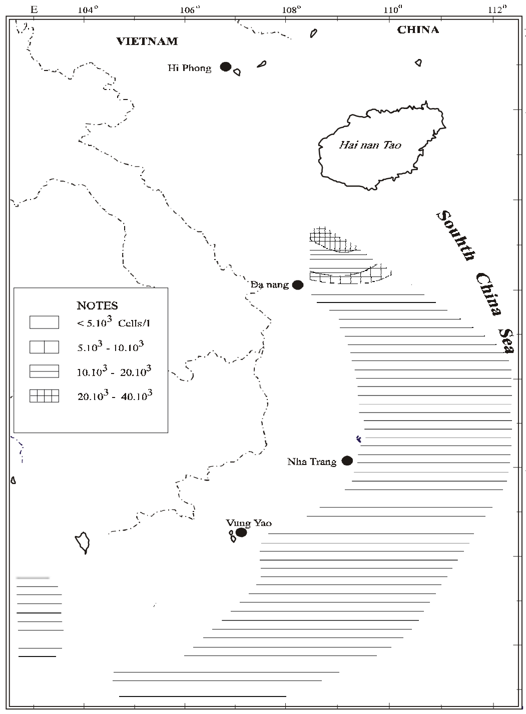

Fig. 7. Oscillatoria population density (cells/l) at the 50 m water layer in the Vietnamese waters (April-May,1999).

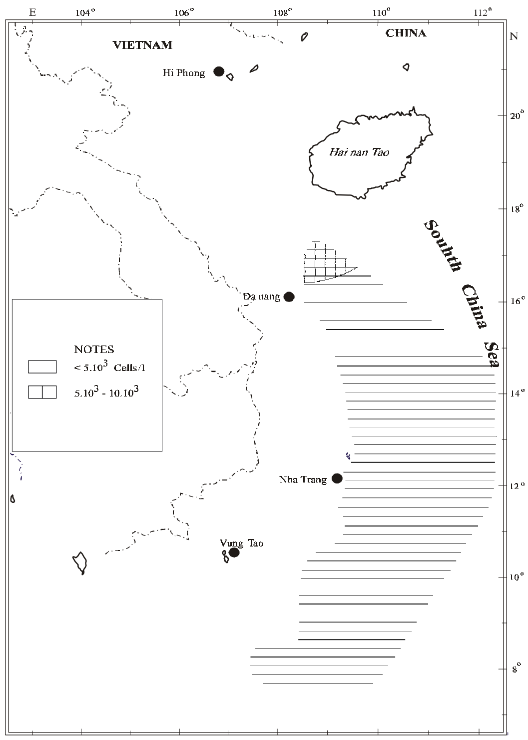

Fig. 8. Oscillatoria population density(cells/l)at the 100m water layer in the Vietnamese waters (April-May, 1999).

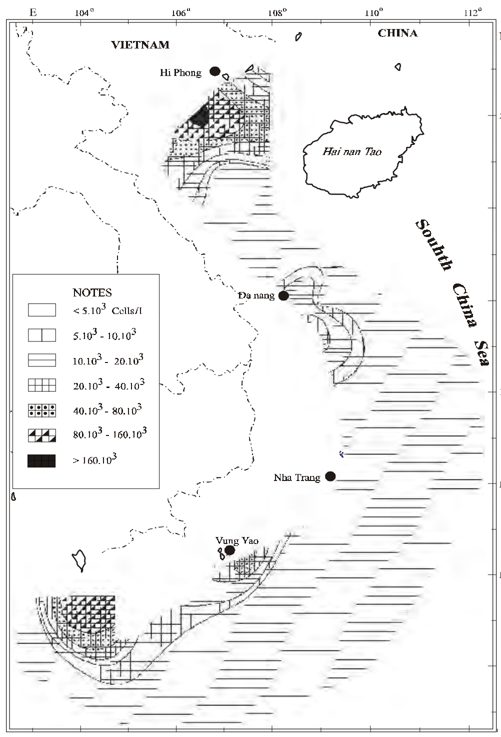

Fig. 9. Bacillariophyta population density(cells/l)at the surface water layer in the Vietnamese waters (April-May, 1999).

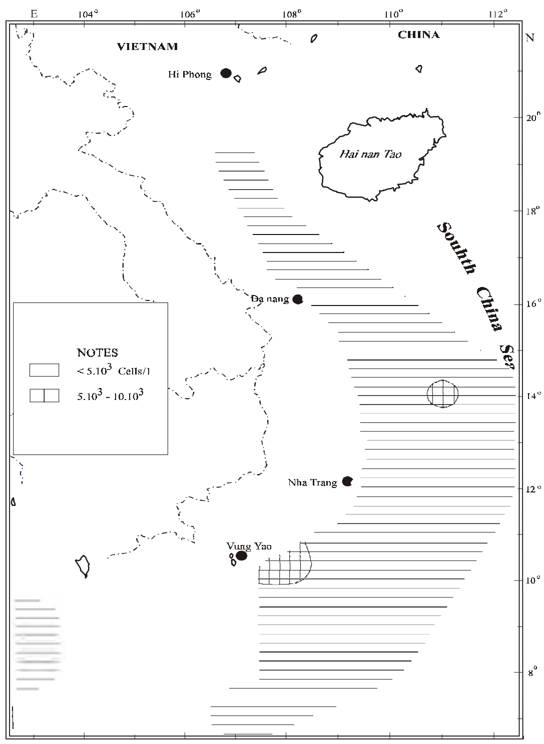

Fig. 10. Bacillariophyta population density (cell/l) at the 50m water layer in the Vietnamese waters (April-May, 1999).

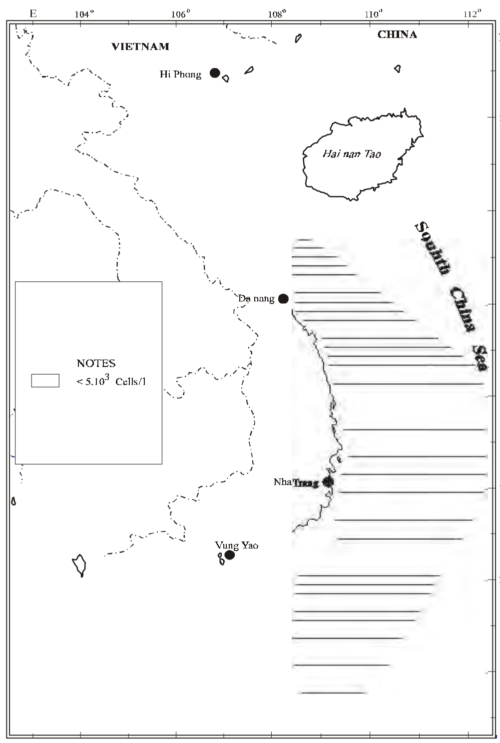

Fig. 11. Bacillariophyta population density(cell/l) at the 100m water layer in the Vietnamese waters (April-May,1999).

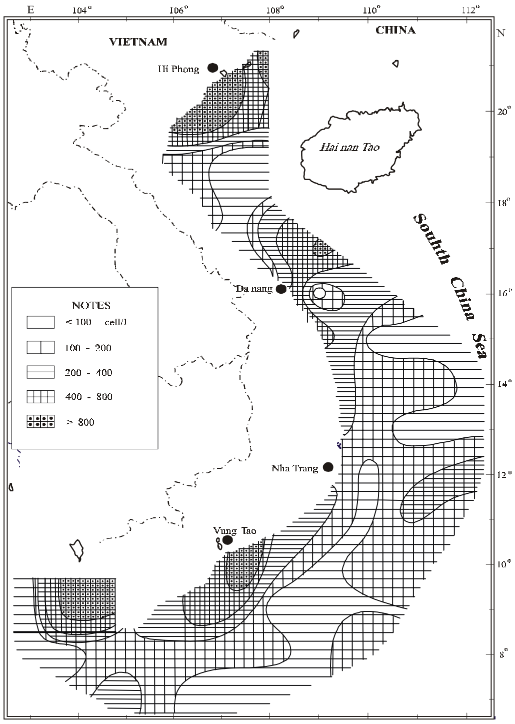

Fig. 12. Pyrophyta population density (cells/l)at the surface water layer in the Vietnamese waters (April-May, 1999).

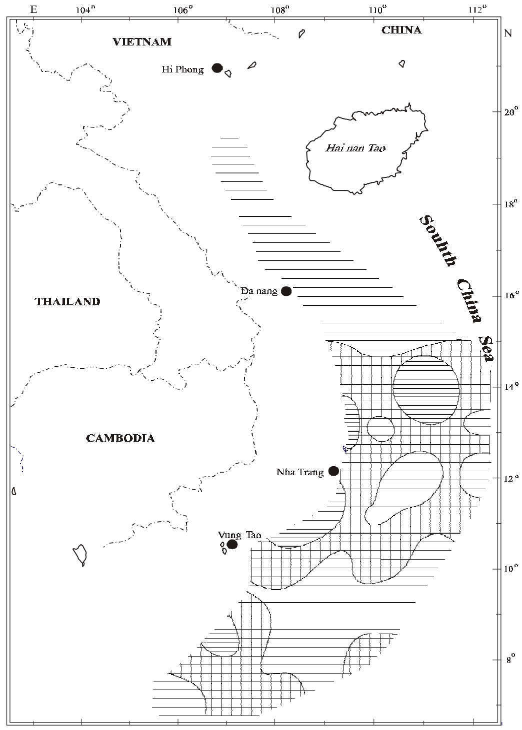

Fig. 13. Pyrophyta population density (cells/l) at the 50m water layer in the Vietname waters (April-May,1999).

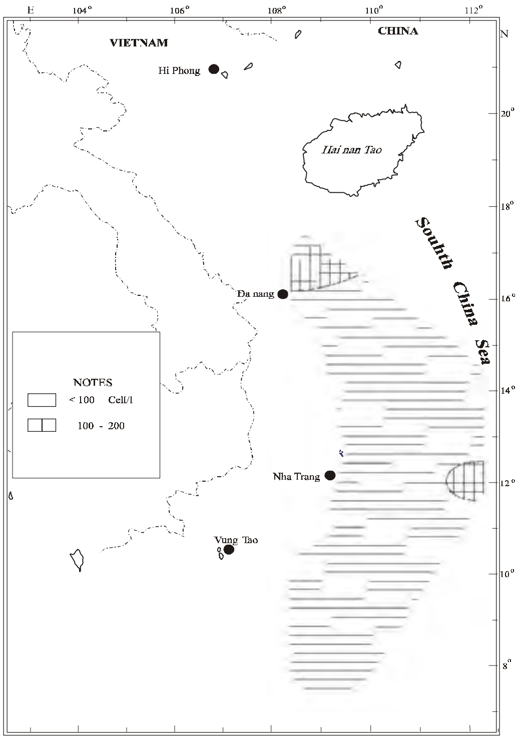

Fig. 14. Pyrrophyta population density (cells/l) at the 100m water layer in the Vietnamese waters (April-May, 1999).

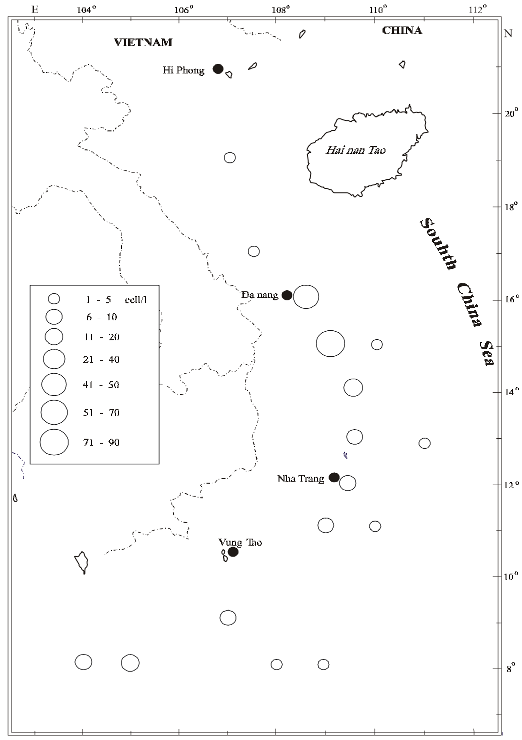

Fig. 15. Distribution *Dictyocha fibula* density (cells/l) at the surface water layer in the Vietnamese waters (April-May,1999).

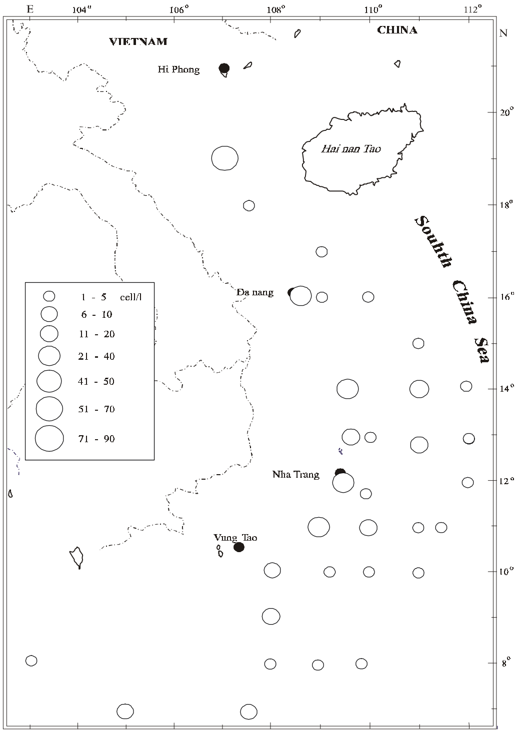

Fig. 16. Distribution *Dictyocha fibula* density (cells/l) at the 50 m water layer in the Vietnamese waters (April-May,1999).

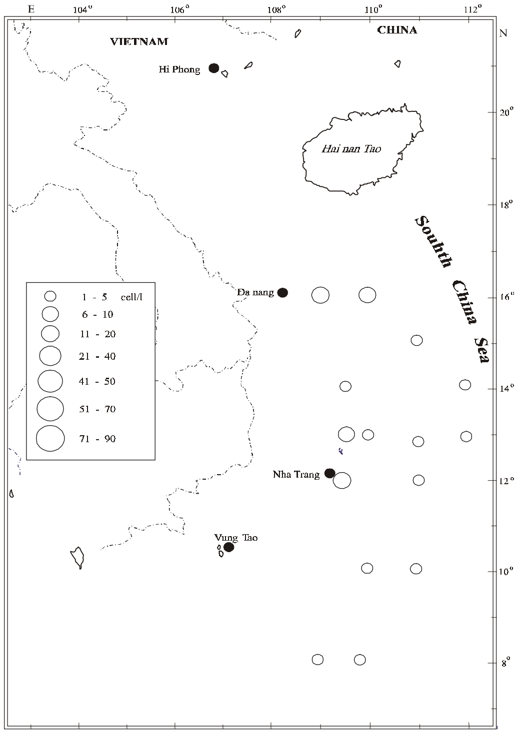

Fig. 17. Distribution *Dictyocha fibula* density (cells/l) at the 100m water layer in the Vietnamese waters (April-May,1999).

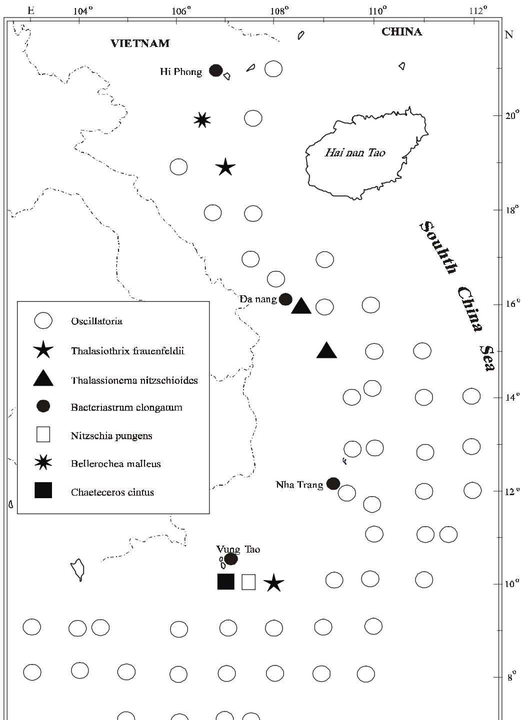

Fig. 18. Dominant species in the Vietnamese waters (April-May,1999).

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Species Composition, Abundance and Distribution of Phytoplankton in the Thermocline Layer in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

One hundred and eighty-five samples of phytoplankton were collected from 58 stations in the Vietnamese waters during 30 April – 29 May 1999 to investigated species composition, abundance and distribution in the thermocline layer compared with those in the surface layer. The samples were taken from surface, thermocline depth and chlorophyll maximum depth. In this study, thermocline depth and chlorophyll maximum depth were included in the thermocline layer. Three hundred and fifty- seven taxa, composed of 2 species of blue green alga, 159 species of diatoms and 161 species of dinoflagellates, were identified. The occurrence of species in each layer were recorded. The cell densities at chlorophyll maximum depth were highest among the sampling depths observed in most stations of the survey. Data obtained from the samples collected from surface to 150 m with 25 m interval to study vertical distribution indicates that maximum cell density of the water column presented between 60 – 110 m. The most abundance was 179,386 cells/l found at chlorophyll maximum depth near the Ca Mau Cape due to the bloom of many diatom species. *Oscillatoria (Trichodesmium) erythraea, Proboscia alata, Pseudosolenia calcar-avis* and *Thalassionema frauenfeldii* were dominant at all sampling depths. Five species of diatoms presented as dominant species only in the thermocline layer. *Alexandrium* was frequently found at surface through chlorophyll maximum depth in the south. Diversity and evenness indices of all sampling depths were high in the Gulf of Tonkin and decreased through the south of Vietnam. These indices were high in the thermocline layer.

Key words : Phytoplankton, thermocline layer, South China Sea, Vietnamese waters

Introduction

A study on distribution, abundance and species composition of phytoplankton in the South China Sea has been carried out since 1995 as one title of the Interdepartmental collaborative Program. The investigations were done in the Area I (Gulf of Thailand and east coast of Peninsular Malaysia), Area II (Sabah, Sarawak and Brunei Darussalam) and AeraIII (western Pilippines). The last area was focused on phytoplankton in the thermocline layer [Boonyapiwat (1999a, 1999b, 2000].

The earliest study on plankton in Vietnamese waters was reported by Rose (1926). From that time, many surveys have been carried out in both coastal and offshore area [Koi *et al.* (1995)]. After 1963, about 1,700 species of freshwater and marine plankton were arranged for the first time in Vietnam by hand of A. Shirota [Shirota (1966, 1967)]. However, phytoplankton in the thermocline layer and subsurface chlorophyll maxima in this region are unknown.

Subsurface chlorophyll maxima or deep chlorophyll maxima are well known phenomenon in temperate, subtropical and tropical oceanic regions. They are usually found at the depths around or below the seasonal thermocline [Saijo *et al.* (1969), Furuya and Marumo (1983)]. Thermocline zone is the productive area that thermocline ridges have been found to be the place where tunas aggregate [Silas and Pillai (1982)]. The most abundance of phytoplankton in the water column and high diversity were observed in this layer [Boonyapiwat (1999b, 2000)].

The purpose of this study is to describe species composition, abundance and distribution of phytoplankton in the thermocline layer compared with those in the surface layer and to determine species diversity indices.

Materials and Methods

Sampling, counting and identification

The survey was carried out on board M/V SEAFDEC during 21 April – 5 June 1999 in Vietnamese waters. Phytoplankton samples were collected from 58 stations during 30 April – 29 May 1999 [Fig.1]. The study area was divided into 3 parts as north (stations 1-10), central (stations 11 – 32) and south (stations 33 – 58). One hundred and eighty five samples were taken with Van Dorn water sampler from surface, the beginning of thermocline or thermocline depth and chlorophyll maximum depth. The sampling depths were determined using ICTD record at each station. The samples of 9 stations along 110° E were collected from surface to 150 m with 25 m interval for study on vertical distribution [Fig.1].

The water samples of 30 – 40 l were filtered through 20 mm mesh phytoplankton net and preserved with 1% formalin immediately. All samples were concentrated by sedimentation. Phytoplankton in the concentrated samples were counted and identified by using a small counting slide (0.25 ml), compound microscope fitted with a phase contrast device, inverted microscope and the electron microscope, both scanning electron microscope (SEM) and transmission electron microscope (TEM). Filament count was done for blue green algae.

Statistical analysis

The species diversity indices [richness index (R), diversity index (H) and evenness index (E)] were computed according to the methods in Ludwig and Reynolds (1988). The equations are as follows:

$$R = \frac{s}{\sqrt{n}}.$$

$$H' = -\sum_{i=1}^{s} [(n_i / n) \ln (n_i / n)]$$

$$E = \frac{(1/\lambda)-1}{e^{H'} - 1}$$

$$\lambda = \sum_{i=1}^{s} \frac{n_i(n_i-1)}{n(n-1)}$$

Where : s = the total number of species

n = the total cell number

n_i = the cell number of species i

Results

Thermocline and chlorophyll maximum depth from ICTD records

The thermocline depths (the depths at the beginning of thermocline) varied from 29 – 45 m, 12 – 50 m and 20 – 60 m in the north, central and south of the study area respectively. The chlorophyll maximum depths were found below thermocline depths and existed in the thermocline layer or thermocline zone. They were in the range of 40 – 72 m , 28 – 110 m and 14 – 90 m in the north, central and south respectively [Table 1]. At shallow stations, thermocline depths were not detected and chlorophyll maximum depths mostly reached near the bottom.

Identification

A total of 357 taxa, composed of 2 genera, 2 species of blue green alga, 62 genera, 159 species of diatoms and 37 genera, 161 species of dinoflagellates, were identified from the samples of this survey. The taxonomic list is given in Table 2.

Abundance and distribution

Total phytoplankton cell densities of the surface layer were abundant in the coastal area [Fig.2]. The abundance were noticed at the northern part of the study area or the Gulf of Tonkin and the southern part where the highest cell count of 115,925 cells/l near Ca Mau Cape was found. The cell density decreased with distance from the coast. The distribution pattern of blue green algae, diatom and dinoflagellate in the surface layer are shown in Figs. 3 – 5. Blue green algae was abundant and distributed in large area of the Gulf of Tonkin especially in coastal area while densities at the offshore stations were higher than those at the coastal stations in the central part. Like total phytoplankton, distribution and abundance of diatom and dinoflagellate showed the same pattern. The highest cell count of these 2 groups were found at the west coast of Ca Mau Cape.

The cell densities of total phytoplankton at 3 sampling depths shown in Figs. 6 – 8 reveal that highest density of almost all stations were observed at chlorophyll maximum depth except stations 4, 7, 38 & 49 where surface densities were highest. The maximum cell count was 179,386 cells/l found at chlorophyll maximum depth near the Ca Mau Cape. The vertical cross section along 110° E from 8° N – 16° N indicates that the maximum cell density of the water column presented between 60 – 110 m [Fig. 9].

The ranges of phytoplankton density at different depths in 3 parts of study area are shown in Table 1. The densities of 3 groups of phytoplankton (blue green algae, diatom and dinoflagellate) were low at thermocline depth in the whole area. Blue green algae density was high at surface in the Gulf of Tonkin. Diatom densities were relatively high at surface and chlorophyll maximum depth of the southern part while dinoflagellate densities showed less variation. The species number of diatom and dinoflagellate were highest at chlorophyll maximum depth and thermocline depth respectively [Table 3].

Vertical distribution of species

Most of phytoplankton species presented from surface through chlorophyll maximum depth [Table 2]. The species occurred predominant at all sampling levels were *Oscillatoria (Trichodesmium) erythraea, Proboscia alata, Pseudosolenia calcar – avis* and *Thalassionema frauenfeldii*. Thirty - four species of diatom were found below the mixed layer. Among these species, *Asteromphalus sarcophagus, Cocconeis* spp. and *Coscinodiscus reniformis* occurred only at chlorophyll maximum depth. *Chaetoceros radicans* were never observed at surface but frequently found at thermoclinedepth and occurred as dominant species at chlorophyll maximum depth. Dinoflagellate species were not abundant at any sampling level. Distribution of many species limited by depths. Thirteen species presented only at surface while 55 species occurred in the thermocline layer (thermocline depth and chlorophyll maximum depth), and 11 species were found only at chlorophyll maximum depth such as *Alexandrium concavum, Ceratium platycorne, Prorocentrum concavum* and *P. emarginatum.*

Dominant species

There were 10, 5, and 13 species dominated phytoplankton population at surface, thermocline depth and chlorophyll maximum depth respectively. *Oscillatoria erythraea* distributed with highest relative abundance at surface in most of the study area. *Pseudosolenia calcar – avis* and *Thalassionema frauenfeldii* occurred predominant at surface in the central part while *T. nitzschioides* was abundant at the coastal area [Fig.10]. *Pseudosolenia calcar – avis* also distributed at thermocline depth in large area of the central part and reached to chlorophyll maximum depth at some stations. *Thalassionema frauenfeldii* was the dominant species at chlorophyll maximum depth distributed in most of the study area except the Gulf of Tonkin. [Figs.11& 12].

Occurrence of toxic dinoflagellate

Low cell densities of toxic dinoflagellates were observed in this survey. *Alexandrium* was the selected genus for studying its distribution. It was frequently found at surface through chlorophyll maximum depth in the southern part of study area. The highest cell count, 25 cells/l, was observed at chlorophyll maximum depth at station 44 [Fig.13].

Species diversity indices

Based on the data obtained from the entire list of taxa at all sampling depths, richness indices, diversity indices and evenness indices were computed and summarized in Table 3. They varied considerably at surface in the Gulf of Tonkin due to the bloom of *Oscillatoria erythraea* at station 7 that led to low diversity and evenness index. In comparison with the Gulf and the central part, the values in the southern part was lowest. High richness indices were found in the central part. The average diversity and evenness indices of all sampling depths were high in the Gulf and decreased through the southern part of study area. These indices high in the thermocline layer.

Discussion and Conclusion

The thermocline and chlorophyll maximum depth of the present study area except the Gulf of Tonkin were observed in the deeper level than those of the Area II, Sabah, Sarawak and Brunei Darussalam [Boonyapiwat (1999b)] and nearly the same level as those of the Area III, western Philippines [Boonyapiwat (2000)] in the same period of the year. The Gulf of Tonkin is shallower and thermocline layer occurred at some stations that differed from the aforementioned areas.

Previous study of phytoplankton in Vietnamese waters revealed that cell density was less than that of the present study. The review of studies on phytoplankton in the sea waters of Vietnam during 70 years, 1924 – 1994 reported by Koi *et al.* concluded that the peak of density reached to 6,700 cells/l during January – March in the Gulf of Tonkin and 342 species of phytoplankyon with density of 248 cells/l in the south of Vietnam were observed in 1985. Thuoc (1997) found 192 species in Bach Long Vy waters and high density of 1,000 – 10,000 cells/l were determined in October. The present study shows the observation at chlorophyll maximum depth where phytoplankton was abundant and numerous species presented. Furuya and Marumo (1983) investigated phytoplankton community in the subsurface chlorophyll maxima in the western North Pacific Ocean and found that chlorophyll-a concentration of this layer was 2.1 – 7.5 times higher than that of the surface and high cell counts were observed. Boonyapiwat (1999b, 2000) also reported high cell density in the thermocline layer. The high cell density at surface of some stations in this survey was probably due to the upwelling.

In the post- NE monsoon period, surface current flowed southerly from the north of Vietnam along the coast and from the east coast of the Gulf of Thailand to the Ca Mau Cape [Shirota (1966)]. The current from both directions transported nutrients from the coast especially Mekong Delta to the Cape and caused phytoplankton blooms. The Gulf of Tonkin was the productive area. The present study shows high cell density of most stations in the Gulf. Nutrient – enriched water from land were brought by river – runoff into the Gulf and influenced phytoplankton blooms. Thuoc (1996), studied phytoplankton in the Tien Yen, Bach Dang and Red rivermouths, concluded that cell density in the Red rivermouth was high.

Most of phytoplankton species occurred in the thermocline layer seemed to be similar to those observed in the Area II and Area III and more taxa were observed in the present study [Boonyapiwat (1999b, 2000)]. The succession of *Oscillatoria erythraea* in the southern part of Vietnam was recorded as the characteristic of this area [Shirota (1966)]. Some dominant species were different from those in the Area II and Area III such as *Guinardia flaccida* and *Hemiaulus membranacea. Thalassionema frauenfeldii* and *Chaetoceros lorenzianus* also dominated phytoplankton population in the chlorophyll maximum layer of the East China Sea [Saijo *et al.* (1969)].

Although small number of toxic dinoflagellates were observed, many species presented in this area. The highest cell count (25 cells/l) of *Alexandrium* in this survey was more than that in the Area I (17 cells/l) and Area III (4 cells/l) but less than that in the Area II (36 cells/l) [Boonyapiwat (1999a, 1999b, 2000). It indicates that *Alexandrium* distributed all over the South China Sea.

The diversity and evenness indices of phytoplankton in the thermocline layer of the area were high that was similar to the results of the Area II and Area III [Boonyapiwat (1999b, 2000)]. Furuya and Marumo (1983) reported high diversity (>4.0) and evenness indices (0.8) of the samples collected from the subsurface chlorophyll maximum layer in the western North Pacific Ocean. Owing to the blooms of *Oscillatoria erythraea* at surface and thermocline depth, the species diversity indices were low at some stations.

It is concluded that phytoplankton density in the Vietnamese waters during April – May 1999 was high at surface through chlorophyll maximum depth in the Gulf of Tonkin and near the Ca Mau Cape. Phytoplankton was rather low at surface and high in the thermocline layer in most stations of the survey. The occurrence of some phytoplankton species were limited by depths. Toxic dinoflagellates presented from surface through the thermocline layer in low cell densities. *Alexandrium* distributed throughout the South China Sea. The diversity and evenness indices were high in the thermocline layer. Low indices caused by the blooms of *Oscillatoria erythraea.*

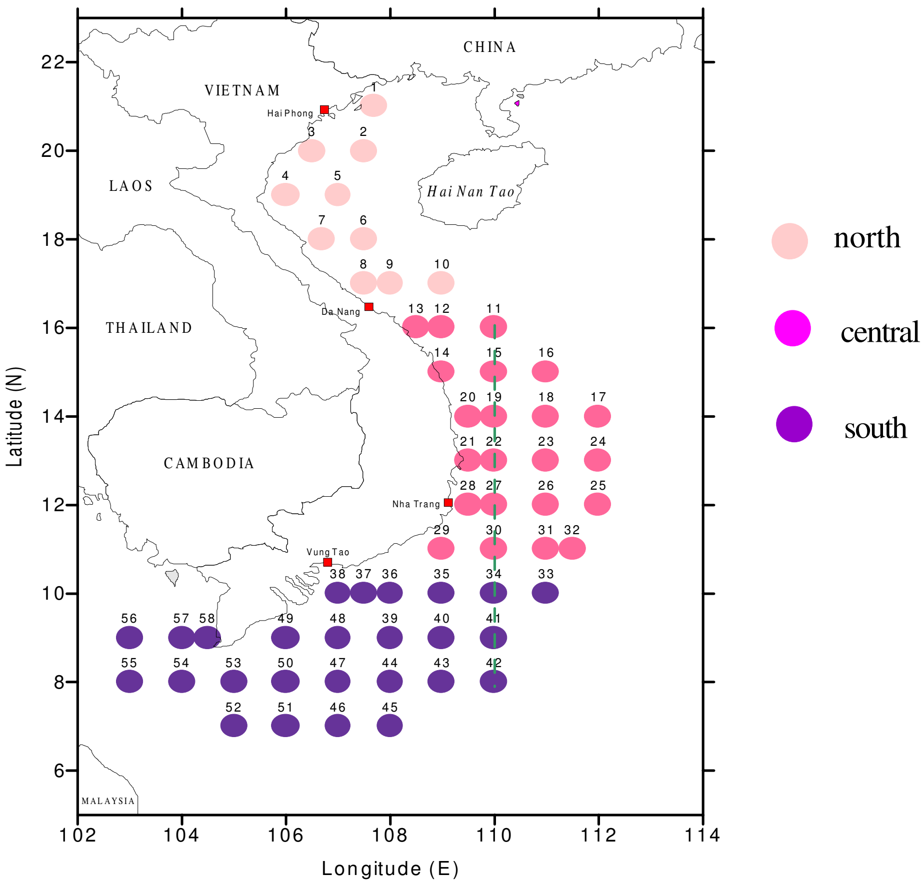


Fig. 1. Location of sampling stations in 3 parts of study area. The dashed line indicates the transect where vertical cross section is made.

Table 1. Ranges of phytoplankton densities at sampling depths in 3 parts of study area.
SD = Sampling depth BG = Blue green algae
S=Surface Th = Thermocline depth Ch = Chlorophyll maximum depth

Part	Station	Depth (m)	SD (m)	Phytoplankton (cells/l)	BG (filaments/l)	Diatom (cells/l)	Dinoflagllate (cells/l)
North (Gulf of Tonkin)	1-10	26-110	S : 2-4 Th : 29-45 Ch : 20-72	503-62,506 632-1,167 567-39,811	35-11,427 90-165 0-1,495	304-57,821 403-615 302-40,820	67-2,011 140-150 46-2,219
Central	11-32	42-4,117	S : 2-4 Th : 12-50 Ch : 28-110	283-12,093 306-878 532-15, 820	0-780 0-205 '0-684	105-9,749 71-563 395-15,300	71-1,188 61-249 35-1,456
South	33-58	20-3,385	S : 2-4 Th : 20-60 Ch : 14-90	324-115,925 351-1,238 578-179,386	71-2,600 16-1,080 0-9,100	87-113,290 59-548 463-176,415	48-2,229 21-118 14-2,414

Table 2. Taxonomic list and occurrence of phytoplankton at different sampling levels.
S = Surface, Th= Thermocline depth , Ch= Chlorophyll maximum depth
x = present, xx = frequent , xxx = abundant

Species	Sampling levels		
	S	Th	Ch
Phylum Cyanophyceae (Blue green algae)			
Calothrix crustacea Schouseboe & Thuret	x	x	x
Oscillatoria (*Trichodesmium*) *erythraea* (Ehrenberg) Kutzing	xxx	xxx	xxx
Phylum Bacillariophyceae (Diatom)			
Achnanthes spp.	-	x	x
Actinocyclus spp.	xx	xx	xx
Actinoptychus senarius (Ehrenberg) Ehrenberg	xx	x	x
Asterolampra marylandica Ehrenberg	xx	xx	xx
Asteromphalus elegans Greville	x	-	-
A. heptactis (Bre'bisson) Greville	xx	x	-
A. flabellatus (Bre'bisson) Greville	x	x	-
A. sarcophagus Wallich	-	-	x
Azpeitia africana (Janisch ex A. Schmidt) G. Fryxell & T.P. Watkins	-	x	x
A. nodulifera (A. Schmidt) G. Fryxell & P.A. Sims	xx	x	xxx
Bacillaria paxillifera (O.F. Muller) Hendey	x	xx	xx
Bacteriastrum comosum Pavillard	xx	xx	xx
B. delicatulum Cleve	xx	xx	xx
B. elongatum Cleve	x	xx	xx
B. furcatum Shadbolt	x	xx	xx
B. hyalinum Lauder	x	x	x
B. minus Karsten	-	x	x
Bellerochea horologicalis von Stosch	xx	x	-
B. malleus (Brightwell) van Heurck	x	x	-
Bleakeleya notata (Grunow) Round	-	x	-
Campylodiscus spp.	x	xx	xx
Cerataulina bicornis (Ehrenberg) Hasle	x	x	x
C. pelagica (Cleve) Hendey	x	x	x
Chaetoceros aequatorialis Cleve	x	x	-
C. affinis Lauder	xx	xx	xx
C. affinis var. *willei* (Gran) Hustedt	-	x	xx
C. anastomosans Grunow	x	x	-
C. atlanticus Cleve	x	xx	xx
C. atlanticus var. *neapolitana* (Schroder) Hustedt	-	x	xx
C. aurivillii Cleve	x	xx	-
C. bacteriastroides Karsten	-	x	-
C. brevis Schütt	x	-	-
C. buceros Karsten	x	-	-
C. castracanei Karsten	-	x	-
C. clavigera Ostenfeld	x	x	-
C. coarctatus Lauder	xx	xx	xx
C. compressus Lauder	xxx	xx	xxx
C. costatus Pavillard	x	x	-
C. curvisetus Cleve	x	x	-
C. dadayi Pavillard	x	x	x
C. danicus Cleve	-	x	x
C. debilis Cleve	x	x	-
C. decipiens Cleve	x	x	x

Table 2. (Continued).

Specices	Sampling levels		
	S	Th	Ch
C. densus (Cleve) Cleve	x	x	-
C. denticulatus Lauder	xx	xx	xx
C. didymus Ehrenberg	xx	xx	x
C. diversus Cleve	xx	xx	xx
C. laevis Leuduger - Fortmorel	xx	xx	xx
C. lorenzianus Grunow	xxx	xx	xxx
C. messanensis Castracane	xx	xx	xxx
Chaetoceros nipponicus Ikari	x	x	x
C. paradoxus Cleve	xx	x	-
C. peruvianus Brigtwell	xxx	xx	xx
C. pseudocurvisetus Mangin	xxx	xx	xxx
C. pseudodichaeta Ikari	xx	xx	xx
C. radicans Shutt	-	xx	xxx
C. rostratus Lauder	x	x	x
C. seiracanthus Gran	x	xx	x
C. siamensis Ostenfeld	x	x	-
C. simplex Ostenfeld	x	xx	xx
C. socialis Lauder	x	x	-
C. subtilis Cleve	x	x	-
C. tetrastichon Cleve	x	x	x
C. tortissimus Gran	x	xx	xx
C. weissflogii Schütt	x	x	-
C. vanheurecki Gran	x	x	x
Climacodiam biconcavum Cleve	xx	xx	xx
C. frauenfeldianum Grunow	xx	xx	xx
Cocconeis spp.	-	-	x
Corethron hystrix Hensen	xx	xx	xx
Coscinodiscus centralis Ehrenberg	x	xx	xx
C. concinniformis Simonsen	x	-	-
C. concinnus W. Smith	x	xx	x
C. gigas Ehrenberg	x	x	xx
C. granii Gough	x	-	-
C. jonesianus (Greville) Ostenfeld	xx	xx	xx
C. perforatus Ehrenberg	x	x	x
C. radiatus Ehrenberg	x	x	x
C. reniformis Castracane	-	-	x
C. thorii Pavillard	x	x	x
C. weilesii Gran & Angst	x	x	x
Cyclotella spp.	x	xx	xx
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin	xx	xx	xx
Cymatosira lorenziana Grunow	-	x	x
Dactyliosolen blavyanus (Bergon) Hasle	-	x	x
D. fragilissimus (Bergon) Hasle	-	x	-
D. phuketensis (Sundström) Hasle	x	x	x
Diploneis spp.	-	xx	xx
Detonula pumila (Castracane) Gran	x	xx	xx
Ditylum brightwelii (West) Grunow	xx	xx	xx
D. sol Grunow	xx	xx	xx
Entomoneis spp.	xx	xx	xx
Eucampia cornuta (Cleve) Grunow	x	x	xx
E. zodiacus Ehrenberg	x	x	x
Fragilaria cylindrus Grunow	x	xx	xx
F. oceanica Cleve	x	x	x

Table 2. (Continued).

Specices	Sampling levels		
	S	Th	Ch
F. striatula Lyngbye	x	xx	xx
Fragilariopsis doliolus (Wallich) Medlin & Sims	x	xx	xx
Gossleriella tropica Schütt	x	xx	xx
Guinardia cylindrus (Cleve) Hasle	xx	xx	xx
G. flaccida (Castracane) H. peragallo	xxx	xx	xxx
G. stiata (Stolterfoth) Hasle	xx	xx	xx
Gyrosigma. spp.	x	x	x
Halicotheca thamensis (Shrubsole) Ricard	x	x	x
Haslea gigantea (Hustedt) Simonsen	xx	xx	xx
H. wawrikae (Hustedt) Simonsen	x	xx	xx
Hemiaulus hauckii Grunow	xx	xx	xx
Hemiaulus indicus Karsten	x	x	x
H. membranacea Cleve	xx	xxx	xx
H. sinensis Greville	xx	xx	xx
Hemidiscus cuneiformis Wallich	x	x	x
Lauderia annulata Gran	x	xx	x
Leptocylindrus danicus Cleve	x	x	x
L. mediterraneus (H. Peragallo) Hasle	x	x	xx
Lioloma delicatulum (Cupp) Hasle	x	x	x
L. elongatum (Grunow) Hasle	-	x	x
L. pacificum (Cupp) Hasle	-	xx	xx
Lithodesmium undulatum Ehrenberg	x	x	-
Melosira nummuloides C.A.Agardh	x	x	x
Meuniera membranacea (Cleve) P.C.Silva	xx	xx	xx
Navicula distans (W.Smith) Ralfs	x	x	x
N. transitrans (Grunow) Cleve	-	x	x
N. spp.	x	x	x
Neostreptotheca subindica von Stosch	x	x	x
Nitzschia bicapitata Cleve	x	x	x
N. longissima (Bre'bisson) Ralfs	x	x	x
N. frigida Grunow	xx	xx	xx
N. spp.	x	x	x
Odontella mobiliensis (Bailey) Grunow	x	xx	xx
O. sinensis (Greville) Grunow	xx	xx	xx
Pachynesis gerlachii Simensen	x	xx	xx
Palmeria hardmaniana Greville	-	xx	xx
P. ostenfeldii (Ostenfeld) von Stosch	-	x	-
Paralia sulcata (Ehrenberg) Cleve	xx	xx	xx
Planktoniella blanda (A. Schmidt) Syvertsen & Hasle	-	x	x
P. sol (Wallich) Schütt	x	xx	xx
Pleurosigma angulatum W. Smith	x	x	-
P. normanii Ralf	xx	xx	xxx
P. spp.	xx	xx	xx
Porosira denticulata Simonsen	-	x	x
Proboscia alata (Brightwell) Sundström	xxx	xxx	xxx
Pseudoguinardia recta von Stosch	x	x	x
Pseudo-nitzschia australis Frenguelli	x	x	x
P. cuspida (Hasle) Hasle	-	x	-
P. pseudodelicatissima (Hasle) Hasle	xx	xx	xx
P. pungens (Grunow & Cleve) Hasle	xx	xx	xx
P. subpacifica (Hasle) Hasle	-	x	x
P. spp.	-	x	x
Pseudosolenia calcar - avis (Chultz) Sundström	xxx	xxx	xxx

Table 2. (Continued).

Specices	Sampling levels		
	S	Th	Ch
Rhizosolenia acuminata (H. Peragallo) Gran	x	x	x
R. bergonii H. Peragallo	x	x	xx
R. castracanei var. *castracanei* H. Peragallo	x	x	x
R. castracanei var. *neglecta* Sundström	-	xx	x
R. clevei var. *clevei* Ostenfeld	xx	xx	x
R. clevei var. *communis* Sundström	x	x	xx
R. formosa H. Peragallo	x	x	x
R. hyalina Ostenfeld	x	xx	xx
R. imbricata Brightwell	x	x	x
R. robusta Norman	x	x	x
R. setigera Brightwell	x	xx	xx
R. styliformis Brigthwell	xx	xx	xx
Stephanopyxis palmeriana (Greville) Grunow	x	x	xx
Thalassionema bacillare (Heiden) Kolbe	-	x	x
T. frauenfeldii (Grunow) Hallegraeff	xxx	xxx	xxx
Thalassionema. nitzschioides (Grunow) Mereschkowsky	xxx	xx	xxx
T. pseudonitzschioides (Schuette & Schrader) Hasle	-	x	x
Thalassiothrix longissima Cleve & Grunow	x	xx	xx
T. gibbura Hasle	-	x	x
Thalassiosira eccentrica (Ehrenberg) Cleve	xx	xx	xx
T. leptopus (Grunow) Hasle & G. Fryxell	x	x	-
T. lineata Jouse'	x	x	-
T. oestrupii (Ostenfeld) Hasle	-	x	-
T. subtilis (Ostenfeld) Gran	xx	xx	-
T. thailandica Boonyapiwat	x	-	-
T. spp.	xx	xx	xx
Triceratium favas Ehrenberg	-	x	-
Tropidoneis sp.	-	x	x
Phylum Dinophyceae (Dinoflagellate)			
Alexandrium affine (Inoue & Fukuyo) Balech	x	-	-
A. compressum (Fukuyo, Yoshida & inoue) Balech	-	x	-
A. concavum (Gaarder) Balech	-	-	x
A. fraterculus (Balech) Balech	x	x	-
A. leei Balech	x	x	-
A. tamarense (Lebour) Balech	x	x	-
A. tamiyavanichi Balech	xx	xx	xx
A. spp.	x	x	x
Amphidinium spp.	x	x	-
Amphisolenia bidentata Schroder	xx	xx	xx
A. schauinslandii Lemmermann	x	x	-
A. trinax Schütt	-	x	x
Amylex triacantha (Jörgensen) Sournia	-	x	x
Centrodinium sp.	-	x	x
Ceratium azoricum Cleve	x	x	-
C. belone Cleve	x	-	-
C. biceps Claparede & Lachmann	-	x	x
C. bigelowii Kofoid	-	x	x
C. boehmii Graham & Bronikosky	xx	xx	xx
C. candelabrum (Ehrenberg) Stein	xx	x	x
C. carriense Gourret	xx	xx	xx
C. concillians Jörgensen	x	x	x

Table 2. (Continued).

Specices	Sampling levels		
	S	Th	Ch
C. contortum var. *contortum* (Gourret) Cleve	x	x	-
C. contortum var. *sultans* (Shroder) Jörgensen	x	x	x
C. declinatum var. *declinatum* (Karsten) Jorgensen	x	x	x
C. declinatum var. *angusticornum* (Karsten) Jorgensen	xx	xx	xx
C. deflexum (Kofoid) Jörgensen	x	xx	-
C. dens Ostenfeld & Schmidt	xx	xx	xx
C. falcatum (Kofoid) Jörgensen	x	x	x
C. furca (Ehrenberg) Claparede & Lachmann	xx	xx	xx
C. fusus (Ehrenberg) Dujardin	xx	xx	xx
C. gibberum Gourret	x	x	x
C. gravidum Gourret	-	x	x
C. hexacanthum Gourret	-	x	x
C. horridum (Cleve) Gran	xx	xx	xx
C. humile Jörgensen	xx	xx	xx
C. incisum (Karsten) Jörgensen	x	-	-
C. inflatum (Kofoid) Jörgensen	x	x	x
C. kofoidii Jörgensen	xx	xx	xx
C. longipes (Bailey) Gran	x	-	-
C. limulus Gourret	x	-	-
C. lunula (Schimpe) Jörgensen	x	x	x
C. macroceros (Ehrenberg) Vanholf	xx	x	x
Ceratium massiliense (Gourret) Karsten	x	x	-
C. pentagonum Gourret	x	x	x
C. platycorne Daday	-	-	x
C. praelongum (Lemmermann) Kofoid	-	x	x
C. ranipes Cleve	x	x	xx
C. reflexum (Cleve)	x	-	-
C. schroeteri Schroder	-	x	x
C. symmetricum Pavillard	x	-	-
C. teres Kofoid	xx	xx	xx
C. trichoceros (Ehrenberg) Kofoid	xx	xx	xx
C. tripos (O.F. Muller) Nitzsch	xx	x	x
C. vulture Cleve	x	xx	xx
Ceratocorys armata (Schütt) Kofoid	-	x	-
C. gorretii Paulsen	-	x	x
C. horrida Stein	xx	xx	xx
Citharisthes regius Stein	-	x	x
C. apsteinii Schütt	-	x	-
Corythodinium globosum Jorgensen	-	x	-
C. tesselatum (Stein) Loeblich Jr. & Loeblich	x	xx	xx
Dinophysis acuminata Claparede & Lachmann	-	x	x
D. caudata Saville - Kent	xx	xx	xx
D. hastata Stein	x	x	-
D. infundibula Schiller	x	x	x
D. miles Cleve	x	x	xx
D. recurva Kofoid & Skorgsberg	x	-	-
D. schuettii Murray & Whitting	x	x	x
D. uracantha Stein	x	xx	xx
Diplopsalis lenticulata Berg	x	x	xx
D. spp.	-	x	x
Diplopsalopsis sp.	-	x	x
Fragilidium spp.	x	xx	xx
Goniodoma polyedricum (Pouchet) Jörgensen	xx	xx	xx

Table 2. (Continued).

Specices	Sampling levels		
	S	Th	Ch
Gonyaulax digitale (Pouchet) Jörgensen	x	x	x
G. fragilis (Schütt) Kofoid	-	x	x
G. glyphorhynchus Murry & Whitting	-	x	x
G. hyalina Ostenfeld & Whitting	-	xx	x
G. milneri (Murray & Whitting) Kofoid	-	-	x
G. pacifica Kofoid	-	xx	x
G. polygramma Stein	xx	xx	xx
G. scrippsae Kofoid	-	xx	x
G. spinifera (Claparede & Lachmann) Diesing	xx	xx	xx
G. verior Sournia	-	x	x
G. spp.	xx	xx	xx
Gymnodinium sanguineum Hirasaka	x	x	x
G. spp.	xx	xx	xx
Gyrodinium spp.	-	x	x
Heterocapsa spp.	x	x	x
Heterodinium blackmanii (Murray & Whitting) Kofoid	x	x	-
H. globosum Kofoid	-	-	x
Heterodinium rigdenae Kofoid	-	x	x
Histioneis depressa Schiller	-	-	x
H. pulchra Kofoid	-	x	x
H. spp.	x	x	x
Kofoidnium sp.	x	x	x
Lingulodinium polyedrum (Stein) Dodge	x	x	x
Ornithocercus formosus Kofoid	-	x	-
O. heteroporus Kofoid	-	x	x
O. magnificus Stein	-	x	x
Ornithocercus quadratus Schutt	x	x	x
O. splendidus Schütt	-	x	x
O. steinii Schutt	-	x	-
O. thumii (A. Schmidt) Kofoid & Skogsberg	xx	xx	xx
Oxytoxum parvum Schiller	-	x	x
O. scolopax Stein	xx	xx	xx
O. subulatum Kofoid	x	xx	xx
Phalacroma acutoides Balech	x	x	x
P. argus Stein	x	x	x
P. circumsutum Karsten	x	x	x
P. doryphorum Stein	xx	xx	xx
P. favus Kofoid & Michener	x	x	-
P. parvulum (Schütt) Jörgensen	x	-	x
P. rapa Stein	x	-	-
P. rotundatum (Claparede & Lachmann) Kofoid & Michener	xx	xx	xx
P. rudgei Murry & Whitting	-	x	x
Podolampas bipes Stein	xx	xx	xx
P. palmipes Stein	xx	xx	xx
P. spinifera Okamura	xx	xx	xx
Preperidinium meunieri (Pavillard) Elbachter	x	xx	-
Prorocentrum balticum (Lohmann) Loeblich	-	x	x
P. compressum (Bailey) Abe' & Dodage	xx	xx	xx
P. concavum Fukuyo	-	-	x
P. emarginatum Fukuyo	-	-	xx
P. mexicanum Tafall	-	-	x
P. micans Ehrenberg	x	x	x
P. sigmoides Böhm	x	x	x

Table 2. (Continued).

Specices	Sampling levels		
	S	Th	Ch
Protoceratium spinulosum (Murray & Whitting) Schiller	x	x	x
Protoperidinium abei (Abe') Balech	x	xx	x
P. angustum P. Dangeard	-	-	x
P. cerasus Paulsen	-	x	-
P. claudicans (Paulsen) Balech	-	-	x
P. conicum (Gran) Balech	xx	xx	xx
P. crassipes (Kofoid) Balech	xx	x	-
P. curtipes (Jörgensen) Balech	-	x	-
P. depressum (Baley) Balech	xx	xx	xx
P. diabolus (Cleve) Balech	x	x	x
P. divaricatum (Meunier) Balech	-	x	-
P. divergents (Ehrenberg) Balech	xx	xx	xx
P. elegans (Cleve) Balech	xx	xx	xx
P. grande (Kofoid) Balech	xx	xx	xx
P. hirobis (Abe') Balech	xx	x	-
P. latispinum (Mangin) Balech	x	x	x
P. leonis (Pavillard) Balech	xx	x	-
P. murrayi (Kofoid) Balech	x	x	-
P. minutum Kofoid	x	-	-
P. nipponicum (Abe') Balech	x	-	-
P. oceanicum (Vanholf) Balech	xx	xx	xx
P. okamurai (Abe') Balech	x	x	-
P. ovum (Schiller) Balech	x	x	-
P. pacificum Kofoid & Michener	xx	xx	xx
P. pallidum (Ostenfeld) Balech	x	xx	x
P. pellucidum Bergh	x	x	x
P. pentagonum (Gran) Balech	x	x	-
P. quanerense (Schroder) Balech	x	x	x
P. roseum Balech	-	x	-
P. spinulosum (Schiller) Balech	x	x	x
P. stenii (Jörgensen) Balech	xx	xx	xx
Protoperidinium subinerme (Paulsen) Balech	xx	xx	x
P. subpuriforme P. Dangeard	-	x	-
P. tennuisimum Kofoid	-	-	x
P. thorianuum (Paulsen) Balech	-	x	-
P. trisylum Stein	x	-	-
P. tumidum Okamura	-	x	-
P. spp.	xx	xx	xx
Pyrocystis fusiformis Wyville - Thomson ex Blachman	xx	xx	xx
P. hamulus Cleve	xx	xx	x
P. lunula species complex	xx	xx	xx
P. noctiluca Murray ex Haeckel	xx	xx	xx
Pyrophacus horologium Stein	x	x	x
P. steinii (Schiller) Wall & Dale	x	x	x
Scripsiella trochoidea (Stein) Balech	xx	xx	x
S. spp.	xx	xx	xx
Schuettiella mitra (Schütt) Balech	-	x	x
Sinophysis spp.	x	-	-
Spiraulax kofoidii Graham	-	x	x
Triposolenia truncata Kofoid	x	x	x

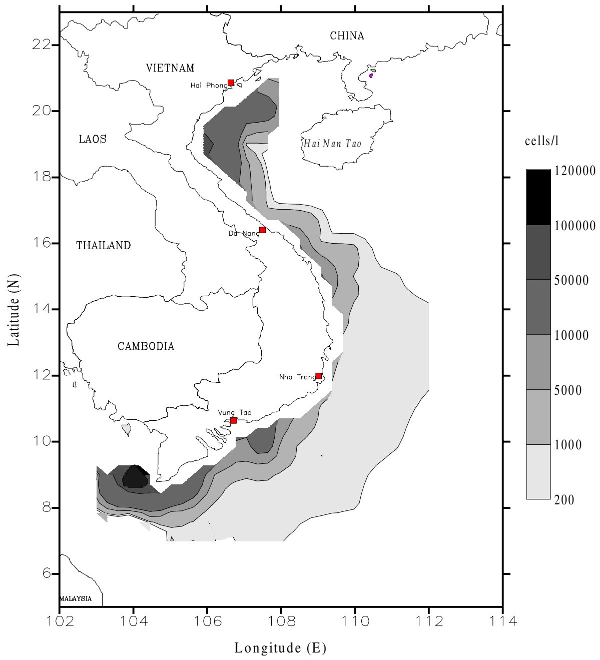


Fig. 2. Phytoplankton abundance at surface.

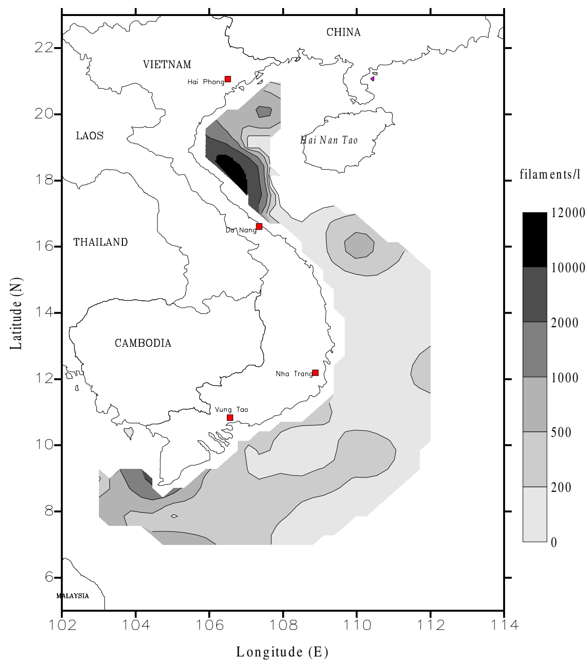


Fig. 3. Abundance of blue green algae at surface.

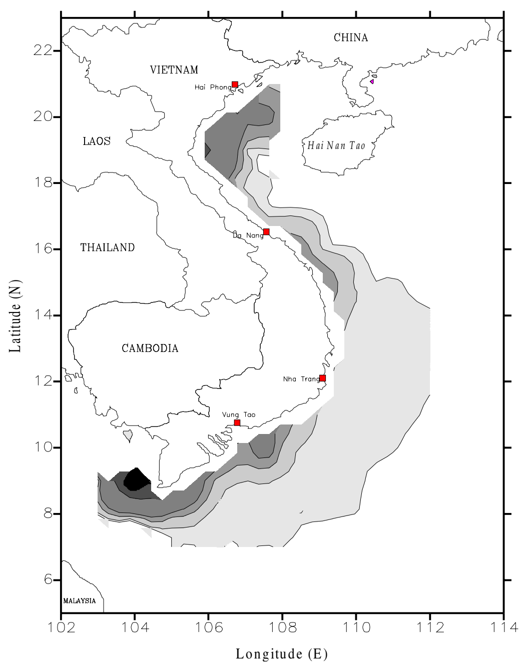


Fig. 4. Abundance of diatom at surface.

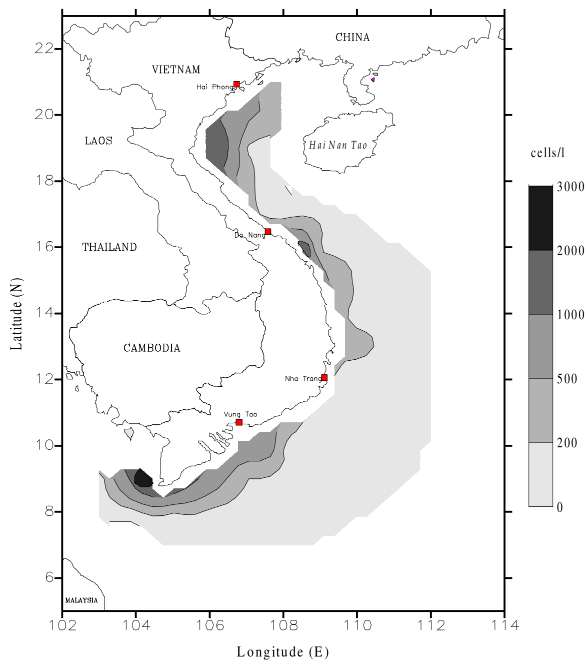


Fig. 5. Abundance of dinoflagellate at surface.

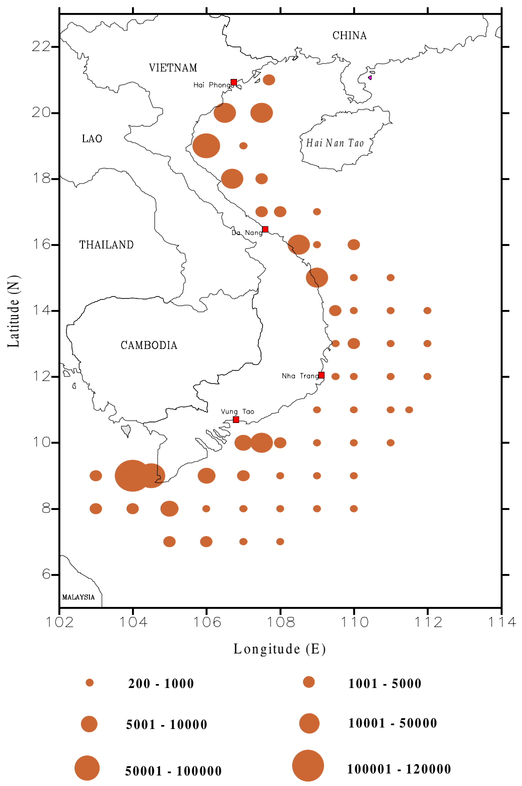


Fig. 6. Phytoplankton densities (cells/l) at surface.

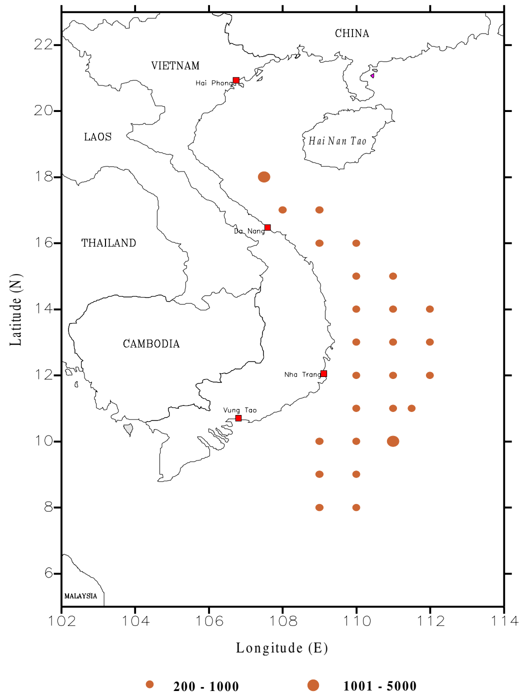
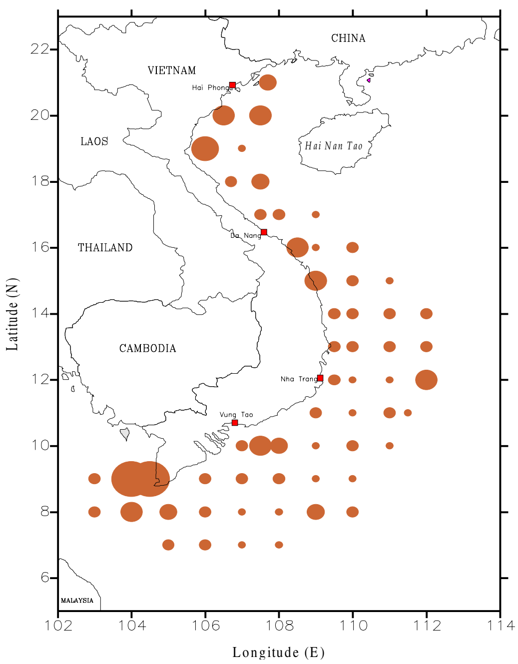


Fig. 7. Phytoplankton densities (cells/l) at thermocline depth.



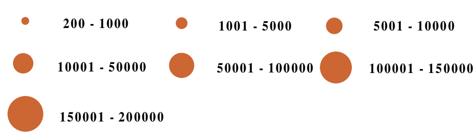


Fig. 8. Phytoplankton densities (cells/l) at chlorophyll maximum depth.

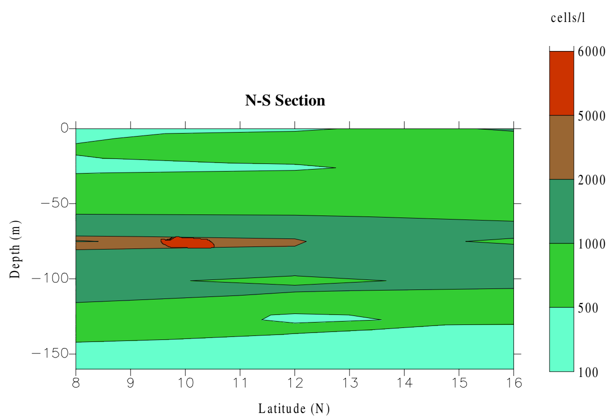


Fig. 9. Vertical cross section of phytoplankton density.

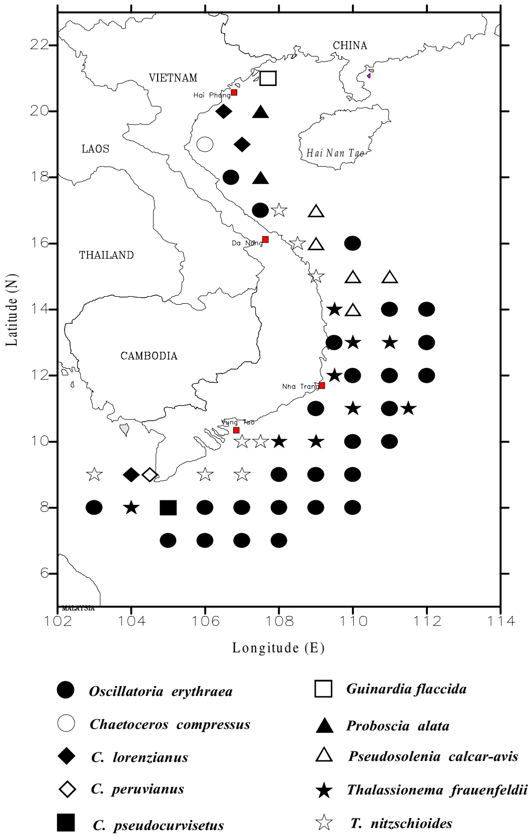


Fig. 10. Dominant species at surface.

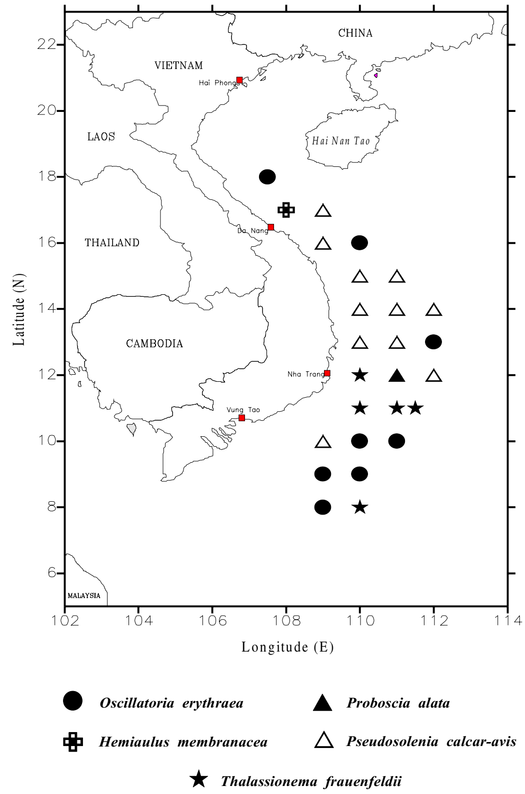


Fig. 11. Dominant species at thermocline depth.

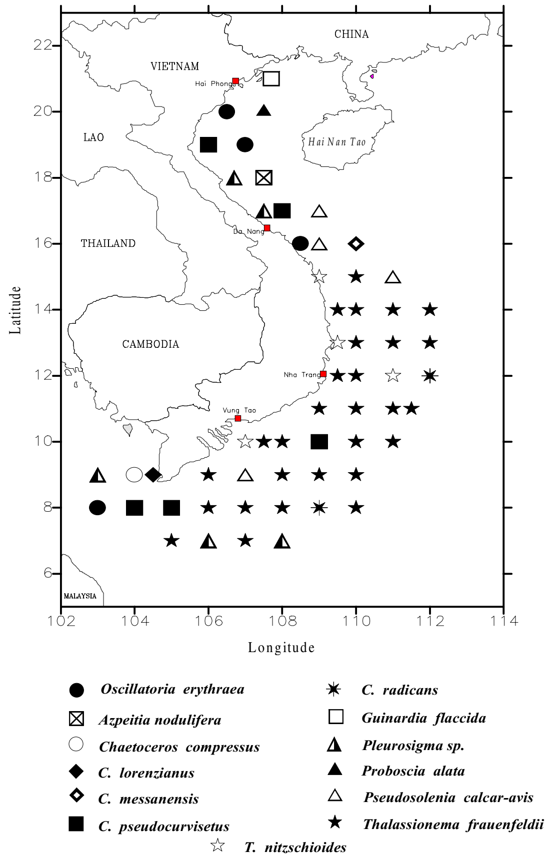


Fig. 12. Dominant species at chlorophyll maximum depth.

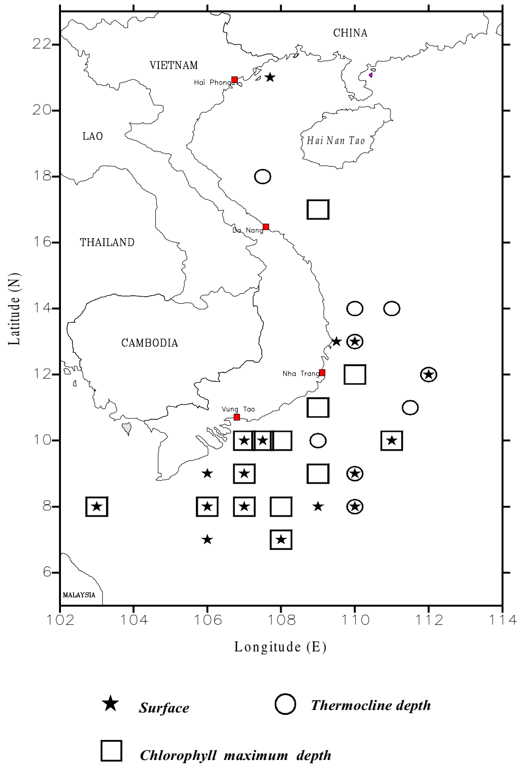


Fig. 13. Distribution of *Alexandrium* spp. at different depths.

Table 3. Phytoplankton species numbers, richness indices (R), diversity indices(H') and evenness indices (E) in 3 parts of study area.

Part	SD	Species number				R		H'		E	
		Diatom		Dinoflagellate							
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
North	S	21-49	35	10-23	17	1.26-3.41	2.47	0.89-3.92	3.05	0.22-0.91	0.75
(Gulf of	Th	20-38	27	14-23	19	1.86-2.82	2.49	2.99-3.42	3.15	0.79-0.83	0.82
Tonkin)	Ch	20-54	37	6-29	17	1.35-2.94	2.27	2.15-3.47	2.98	0.58-0.84	0.76
Central	S	9-45	19	9-33	19	1.45-3.32	2.48	1.55-3.37	2.70	0.43-0.87	0.74
	Th	10-33	18	10-33	20	1.93-3.12	2.67	1.78-3.16	2.77	0.52-0.87	0.78
	Ch	14-53	35	5-26	14	1.37-3.13	2.14	2.12-3.32	2.80	0.60-0.87	0.78
South	S	8-44	22	8-25	13	1.09-3.09	1.97	1.66-3.17	2.44	0.48-0.83	0.68
	Th	7-21	14	11-20	14	1.21-3.12	1.94	0.73-3.05	1.86	0.22-0.82	0.55
	Ch	15-50	30	2-26	11	1.01-2.42	1.68	1.67-3.34	2.58	0.41-0.84	0.70

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Analysis and Pre-Estimation of Nutrients in Vietnamese Waters

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ABSTRACT

The distribution of nutrients (Silica, Phosphate, Ammonium, Nitrate, Nitrite and Sulfate) in the Vietnamese waters was studied in the SEAFDEC Interdepartmental Collaborative Research Survey: Area IV. The samples were collected by M.V. SEAFDEC on the 30 April to 29 May 1999 (post monsoon period). Fifty-eight stations (2m from surface and 100 m from surface) were established in this study. The average of Silica at the surface layer is 25.96µM and at the bottom layer is 30.69µM. The average of Phosphate at the surface layer is 0.890 µM and at the bottom layer is 1.353µM. The average of Ammonium at the surface layer is 2.805µM and at the bottom layer is 2.538µM. The average of Nitrate at the surface layer is 5.593µM and at the bottom layer is 6.810µM. The average of Nitrite at the surface layer is 0.169µM and at the bottom layer is 0.197µM. The average of Sulfate at the surface layer is 26.903 µM and at the bottom layer is 27.831µM. The results indicated that the concentrations of Silica, Phosphate, Nitrate, Nitrite and Sulfate in deep water were higher in the surface water, but the Ammonium is inverse.

Key words: Nutrients, Vietnamese waters, along coastline

Introduction

One of most important problems in the oceanographic study is determination and estimation of nutrient composition and the their relationship in the development, revolution, biotransformation etc. in the seawater and sediments with sea-biologists. Phytoplanktons are primary producer in the sea. They require dissolved inorganic nutrients for their growth. Through photosynthesis, they produce food for supporting all trophic levels in the sea. Phytoplanktons provide food for zooplankton which are then consumed by organisms higher up in the food chain. Based on international and Vietnamese references, focused into six parameters in nutrients: Silicate, Inorganic Phosphate, Ammonia, Nitrate, Nitrite and Sulfate.

Materials and Methods

The present reference method designed to provide the user with reliable techniques for the determination of six chemical parameters of general application to basic oceanographic studies, whether at sea or within coastal lagoons and estuaries. It is interesting to note that, although techniques have existed for these parameters for more than haft a century, the general analytical precision and accuracy of them have been poor. This is partly due to the ease with samples may be contaminated during handling and the tendency (particularly with nutrients) for the analyses to break down or react during storage.

The marine analytical chemist is faced with two major problems. Firstly, to procedure correct analytical results in the rather complicated seawater matrix; and secondly, to obtain representative samples from a highly variable environment over which he has no control. The latter problem is complicated by fact that the constituents (dissolved or dispersed) in the sea have three-dimensional pattern of distribution, i.e. they vary from place to place, with depth and with time because of physical and biogeochemical processes. In addition, the sample itself may drastically change its composition after having been enclosed in the sampler and removed from its natural environment. Therefore, the most refined techniques and skilled work on the part of the analyst will not produce automatically a representative value if the sampling procedure is influenced by significant errors.

Sampling

Fifty-eight stations from offshore of Vietnam from latitude 7°N to 21°N and longitude 103°E to 112°E were established in this study (Plan 1).

M.V. SEAFDEC collected the water samples on 30 April 1999 to 29 May 1999 (post-northeast monsoon period). Water sampler attached to a rosette system collected the water at each station during cruise on two levels (surface and bottom). The water samples were transferred into PE bottles.

The samples were analyzed in laboratory of the Department for Analytical Science and Technique of the Institute of Chemistry, National Center for Natural Science and Technology of Vietnam (NCST).

All bottles, filter membranes and labwares that would be in contact with samples were carefully pre-washed by 10% suprapure HNO_3 acid and Milli-Q water.

Merck standard solutions diluted by Milli-Q water was used as standards.

The concentrations of nutrients were measured using GBC UV-VIS CINTRA 40 Spectrometer and Ion - Chromatograph Metrohm concerning 709 IC Pump, 732 IC Detector and 733 IC Separator.

Analytical methods

Determination of dissolved silicon

The determination of dissolved silicon compounds is based on the formulation of a heteropoly acid when the sample is treated with a molybdate solution. This silicomolybdic acid is then reduced to an intensely blue-colored complex by adding ascorbic acid as a reductant. The color is formed within 30 minute, determined at 810nm wave length, and is stable for several hours.

Measure 50cm^3 of the sample with a graduated cylinder and transfer it into the plastic reaction bottle. Add 1.5cm^3 of the mixed reagent and mix well. After 10-20 minute add 1cm^3 oxalic acid immediately followed by 1cm^3 ascorbic acid. Mix well between the additions. Measure the absorbency after 30-40 minute in a cell of suitable length at 810nm against distilled water as reference.

Determination of dissolved inorganic phosphate

The phosphate ions in the sample react in acidic solution with ammonium molybdate to yield a phospho-molybdate complex. This heteropoly to a blue-coloured complex, the absorbency of which is then measured in a spectrophotometer at 882nm.

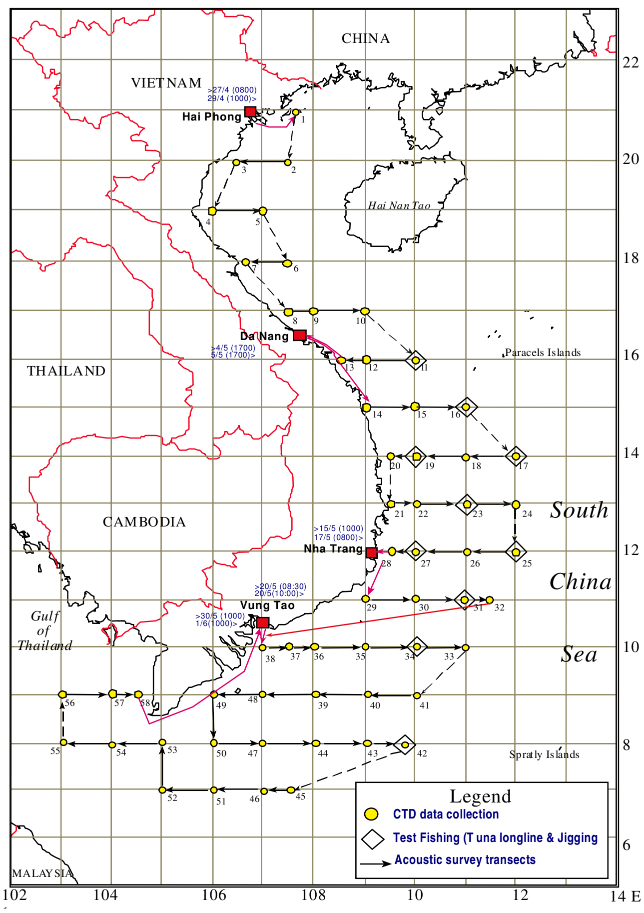
Transfer two 50cm³ portions of the sample to two reaction flasks. One of the portions is regarded as the sample, the other one as the turbidity blank. To each of the portions add 1.5cm³ of the mixed reagent ascorbic acid solution. Mix well between the additions. After 10 minute measure the absorbency of the sample and the turbidity blank at 882nm against acidified distilled water as reference.

Determination of Ammonia

The method is specific for ammonia and is based on the formation of the blue colored indophenol by phenol and hypochlorite in the presence of the NH_4^+ and NH_3 species. The reaction requires an elevated temperature or a catalyst. The colour is measured at 630nm and is stable for at least 30 hours.

Measure 50cm³ of the sample with a graduated cylinder and transfer it into the reaction flasks. Add 2cm³ phenol reagent, 1cm³ buffer solution and 2cm³ hypochlorite reagent. Mix well by swirling between the additions. Close the reaction bottles properly and keep them in a dark place during the reaction time.

Measure the absorbency after 6 hours in a cell of suitable length at 630nm and use a cuvette of similar length filled with distilled water as reference.



Plan 1. The survey stations for the SEAFDEC Area IV: Vietnamese Waters.

Determination of Nitrate

The method generally applied for the determination of nitrate is based on its reduction to nitrite, which is then determined colorimetrically via the formation of an azo dye. Nitrate is reduced to nitrite in a reduction column filled with copper-coated cadmium granules.

Transfer $25cm^3$ of the sample into the reaction flask $100cm^3$, add $25cm^3$ of the buffer solution and mix well. If nitrate concentrations of more than about $15mmol/dm^3$ are expected $25cm^3$ of the sample must be diluted with $75cm^3$ of the buffer solution.

Pass about $20cm^3$ of the mixture through the reduction column in order to rinse the system and to adjust the time of passage. Discard this fraction. Then pass another fraction through the column until the level in the Erlenmeyer flask has reached the $25cm^3$ mark.

Determination of Nitrite

The photometry determination of nitrite is based on the reaction of nitrite with an aromatic amine (sulfanilamide) which leads (at pH 1.5 - 2.0) to the formation of a diazonium compound. This diazo compound then couples with a second aromatic amine N-(1-naphtyl)-ethylenediamine to form the azo dye with a molar absorptivity of about 46,000.

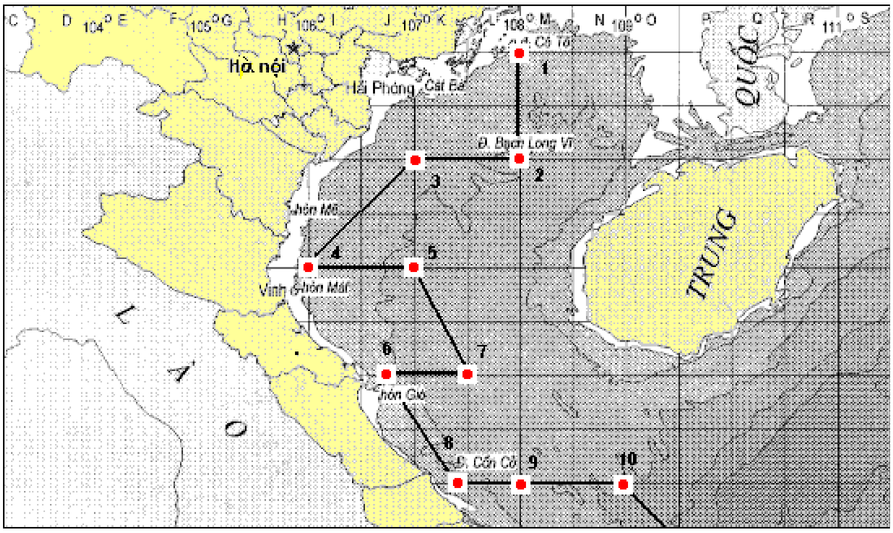
Transfer $50cm^3$ of the sample into reaction bottle and add $1cm^3$ of the sulfanilamide reagent. Then mix well. After reaction time about 1 minute, add $1cm^3$ of the diamine solution. Shake the flask and allow the azo dye to develop for at least 20-30 minute. Measure the absorbance in a cell of suitable length at 540nm against distilled water as reference. The colour intensity is constant for about two hours.

Determination of Sulfate

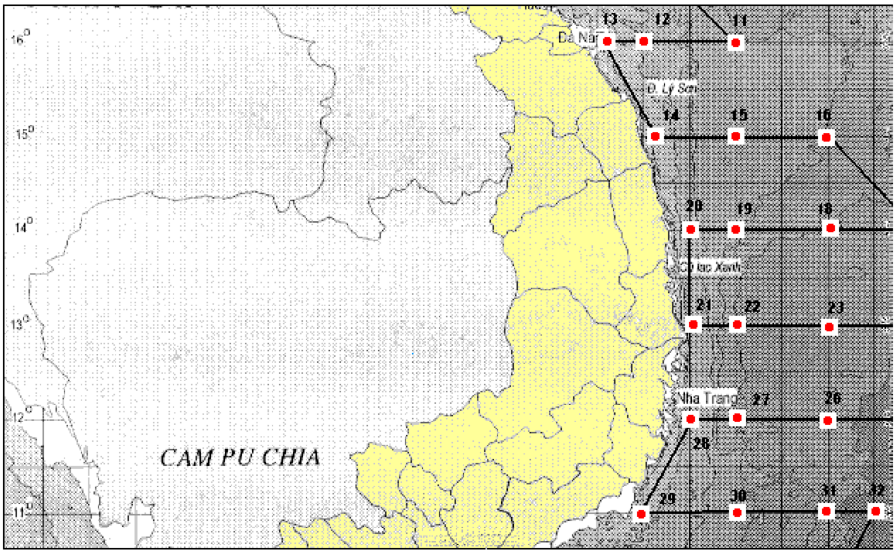
The volume of the water samples to be employed for gravimeter determination of sulfate must be measured so that it contains between 10 and 500mg sulfate ions. Where necessary a larger volume of water must be reduced to 400ml and / or in the case of lower concentrations of sulfate ions to 100ml. Hydrochloric acid is added to this volume until any sediment possibly present or any salt precipitate (calcium sulfate) is redissolved. In principle, the entire contents of the sampling should be used for an analysis. Care should be taken that the hydrochloric acid employed for acidification and / or for dissolving residue and salt precipitates does not comprise more than 1ml per 100ml of the reduced solution. Any precipitates not dissolving (e.g. silicic acid) or other substances remaining undissolved are filtered off before precipitation of sulfate.

The solution prepared for precipitation is heated to boiling point and an excess of hot barium chloride solution added at boiling heat. After completion of precipitation, the sample is allowed to continue to boil for a further 30 minutes and then covered with a watch glass overnight. On the next day, the barium sulfate precipitation is filtered off, either through a paper filter or through a filtering crucible A1 that has been baked at 800^o C and weighed.

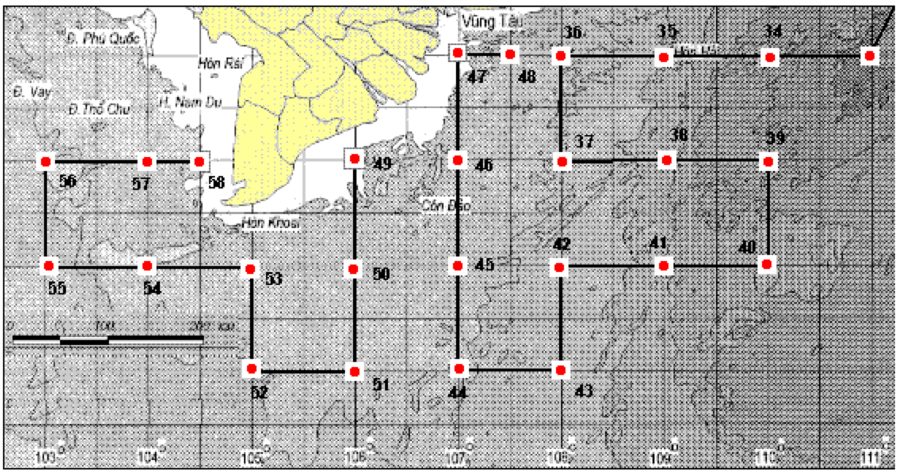
The precipitate is washed with hot water until a negative chloride reaction is detected in the filtrate. 1mg barium sulfate corresponds to 0.4115mg SO_4^{2-}. The sulfate content of the water analyzed is calculated from the quantity of barium sulfate weighed.



Plan 2. The survey stations for the Northern region.



Plan 3. the survey stations for the middle region.



Plan 4. The survey stations for the southern region.

Results and Discussion

With a long coastline (more than 2000 km) and large continental shelf, the marine environment of Vietnam is characterized by a wide range of geomorphological, climatic, hydrological and economical conditions. (Plan 1). In addition, could separated the Vietnamese coastline in three zones (sub-regions): Tonkin gulf (gulf of Northern region), sea of Middle region and sea of Southern region. In the Southern region, could divided into two sub-zone insisting of Southeastern and Southwestern regions. (Plans 2, 3 and 4).

The concentration of determined nutrients of survey cruises at surface (2m from surface of water) and bottom layer (100 m from surface of water) of sampling stations are presented in Tables 1, 2,3,4,5,6,7,8 and 9.

Silica

Table 1.1 and1.2 shows concentrations of silica from 58 sampling stations in surface and bottom layers. Generally, bottom samples have higher concentration than surface samples. Highest concentration of silicate is 55,60µM equals 3.340mg/l in stations 16B and 18B belongs to the middle region. In the seaside of this region there are several mines containing SiO_2, Al_2O_3, $CaCO_3$ etc. Lower concentration is in stations 23B, 24B and 25B with 49.91-51.09µM (2.994 - 3.065mg/l). Especially in station 38B in southern region silicate concentration is rather high - 51.41mM (3.084mg/l). Lowest concentration of silicate is 17.69µM (1.061mg/l) in stations 1S, 2S, 4S and 5S in northern region. Variations of silicate concentration in whole Vietnamese marine region are shown in Fig. 1. Average value in surface layer is 25.96µM (1.557mg/l) and in bottom layer - 30.69µM (1.841 mg/l). Generally, previous results (from 1996-1997) of Vietnam in middle region are compatible.

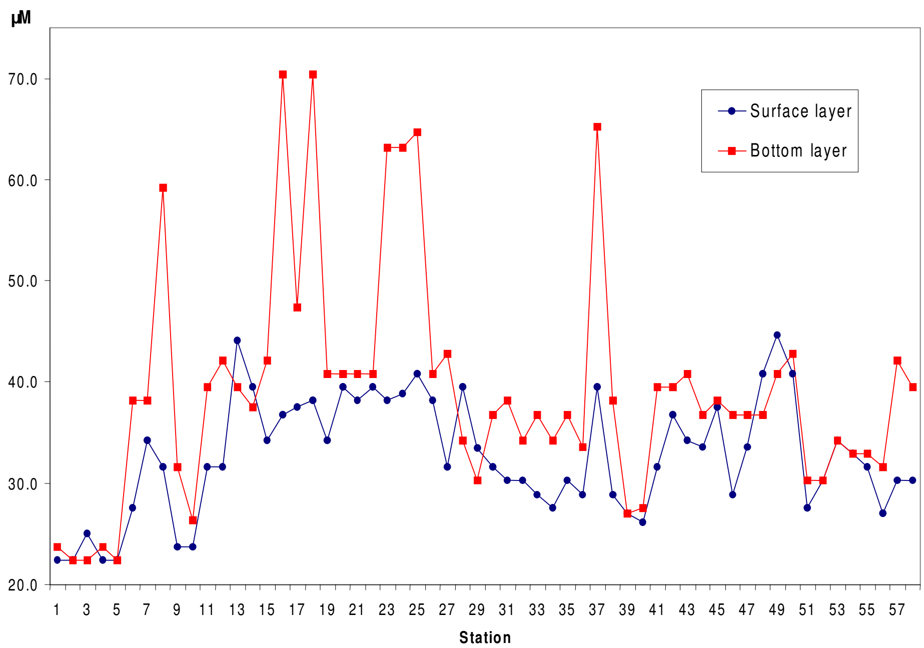


Fig. 1. Concentration of SiO_2 in both surface and bottom layers

Table 1.1. SiO_2 - Concentration(µM).

Station	Samples	SiO_2 (µM)	Station	Samples	SiO_2 (µM)	Station	Samples	SiO_2 (µM)
1	1S	17.69	**21**	21S	30.17	**41**	41S	24.95
	1B	18.72		21B	32.22		41B	31.19
2	2S	17.69	**22**	22S	31.19	**42**	42S	29.04
	2B	17.69		22B	32.22		42B	31.19
3	3S	19.74	**23**	23S	30.17	**43**	43S	27.01
	3B	17.69		23B	49.91		43B	32.22
4	4S	17.69	**24**	24S	30.64	**44**	44S	26.53
	4B	18.72		24B	49.91		44B	29.04
5	5S	17.69	**25**	25S	32.22	**45**	45S	29.61
	5B	17.69		25B	51.09		45B	30.17
6	6S	21.8	**26**	26S	30.17	**46**	46S	22.82
	6B	30.17		26B	32.22		46B	29.04
7	7S	27.01	**27**	27S	24.95	**47**	47S	26.53
	7B	30.17		27B	33.8		47B	29.04
8	8S	24.95	**28**	28S	31.19	**48**	48S	32.22
	8B	46.75		28B	27.01		48B	29.04
9	9S	18.72	**29**	29S	26.45	**49**	49S	35.3
	9B	24.95		29B	23.93		49B	32.22
10	10S	18.72	**30**	30S	24.95	**50**	50S	32.22
	10B	20.77		30B	29.04		50B	33.8
11	11S	24.95	**31**	31S	23.93	**51**	51S	21.79
	11B	31.19		31B	30.17		51B	23.93
12	12S	24.95	**32**	32S	23.93	**52**	52S	23.93
	12B	33.25		32B	27.01		52B	23.93
13	13S	34.83	**33**	33S	22.82	**53**	53S	27.01
	13B	31.19		33B	29.04		53B	27.01
14	14S	31.19	**34**	34S	21.8	**54**	54S	25.98
	14B	29.61		34B	27.01		54B	25.98
15	15S	27.01	**35**	35S	23.93	**55**	55S	24.95
	15B	33.25		35B	29.04		55B	25.98
16	16S	29.04	**36**	36S	22.82	**56**	56B	21.32
	16B	55.6		36B	26.53		56B	24.95
17	17S	29.61	**37**	37S	31.19	**57**	57S	23.93
	17B	37.43		37B	21.32		57B	33.25
18	18S	30.17	**38**	38S	30.17	**58**	58S	23.93
	18B	55.6		38B	51.41		58B	31.19
19	19S	27.01	**39**	39S	21.32	***Note:***		
	19B	32.22		39B	21.32	***S: Surface layer, 2m***		
20	20S	31.19	**40**	40S	20.61	***B: Bottom layer, ≥ 100m***		
	20B	32.22		40B	21.79			

Table 1.2. SiO_2 – Concentration (mg/l).

Station	Samples	SiO_2 (mg/L)	Station	Samples	SiO_2 (mg/L)	Station	Samples	SiO_2 (mg/L)
1	1S	1.06	**21**	21S	1.81	**41**	41S	1.50
	1B	1.12		21B	1.93		41B	1.87
2	2S	1.06	**22**	22S	1.87	**42**	42S	1.74
	2B	1.06		22B	1.93		42B	1.87
3	3S	1.18	**23**	23S	1.81	**43**	43S	1.62
	3B	1.06		23B	3.00		43B	1.93
4	4S	1.06	**24**	24S	1.84	**44**	44S	1.59
	4B	1.12		24B	3.00		44B	1.74
5	5S	1.06	**25**	25S	1.93	**45**	45S	1.78
	5B	1.06		25B	3.07		45B	1.81
6	6S	1.31	**26**	26S	1.81	**46**	46S	1.37
	6B	1.81		26B	1.93		46B	1.74
7	7S	1.62	**27**	27S	1.50	**47**	47S	1.59
	7B	1.81		27B	2.03		47B	1.74
8	8S	1.50	**28**	28S	1.87	**48**	48S	1.93
	8B	2.81		28B	1.62		48B	1.74
9	9S	1.12	**29**	29S	1.59	**49**	49S	2.12
	9B	1.50		29B	1.44		49B	1.93
10	10S	1.12	**30**	30S	1.50	**50**	50S	1.93
	10B	1.25		30B	1.74		50B	2.03
11	11S	1.50	**31**	31S	1.44	**51**	51S	1.31
	11B	1.87		31B	1.81		51B	1.44
12	12S	1.50	**32**	32S	1.44	**52**	52S	1.44
	12B	2.00		32B	1.62		52B	1.44
13	13S	2.09	**33**	33S	1.37	**53**	53S	1.62
	13B	1.87		33B	1.74		53B	1.62
14	14S	1.87	**34**	34S	1.31	**54**	54S	1.56
	14B	1.78		34B	1.62		54B	1.56
15	15S	1.62	**35**	35S	1.44	**55**	55S	1.50
	15B	2.00		35B	1.74		55B	1.56
16	16S	1.74	**36**	36S	1.37	**56**	56B	1.28
	16B	3.34		36B	1.59		56B	1.50
17	17S	1.78	**37**	37S	1.87	**57**	57S	1.44
	17B	2.25		37B	1.28		57B	2.00
18	18S	1.81	**38**	38S	1.81	**58**	58S	1.44
	18B	3.34		38B	3.09		58B	1.87
19	19S	1.62	**39**	39S	1.28	***Note:***		
	19B	1.93		39B	1.28	***S: Surface layer, 2m***		
20	20S	1.87	**40**	40S	1.24	***B: Bottom layer, ≥ 100m***		

Phosphate

Table 2.1,2.2 and 2.3 are the results for phosphate concentration calculating in PO_4 and P. Generally phosphate concentration as well as Silicate, the samples in bottom layer are higher than surface layer. Highest concentration is found in station 8B, C= 3.84µM PO_4 - 1.25µM P (equivalent 0.364mg/l -0.039 mg/l), then they are stations 1B, C=3.47µM PO_4 -1.13 µM P (0.33 - 0.035mg/l), 2B,C=3.05µM PO_4 - 1.00 µM P (0.289 -0.031mg/l). Lowest concentration 0.51µM PO_4 - 0.16 µM P (equivalent 0.048 - 0.005mg/l) is in station 58S belongs to southern region. Variation of phosphate concentration in two layers of seawater is not much, but comparing to other areas in the region, phosphate concentrations in Vietnam sea are higher . Variation of phosphate concentration in 58 sampling station is shown in Fig. 2. Average concentration of phosphate in surface layer is 0.890µM PO_4 - 0.290µM P (0.084 - 0.009 mg/l) and in bottom layer is 1.353µM PO_4 - 0.442µM P (0.128 - 0.013mgl).

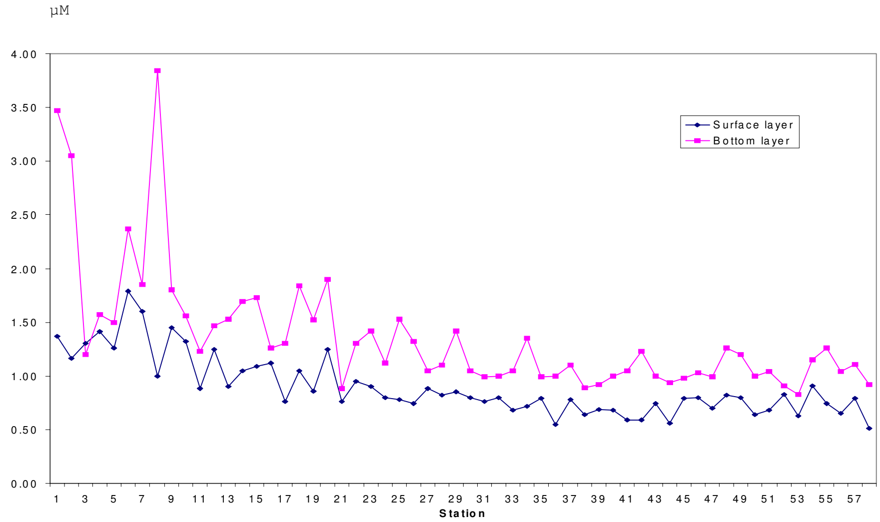


Fig. 2. Concentration of PO_4 (III) in both surface and bottom layers.

After viewing the Fig. 2., we can conclude that, the concentration of phosphate in the North region is higher than in both others. And according to Riley J.P., the dissolved inorganic phosphate is used by all species of phytoplankton. Phosphate is taken up by phytoplankton following photosynthetic activities at the surface layer. This explains for the phenomenon of concentration of phosphate in surface layer higher than in bottom layer.

Ammonium

The results for ammonium concentration in Vietnamese waters are shown in the Table 3.1,3.2 and 3.3. The results have shown that ammonium concentrations in surface layer are higher than in bottom layer. Suggestion reason by the equation between ammonia and ammonium shifts from depth to surface. Highest concentrations 4.44mM NH_4 - 3.45mM N (equivalent 0.080 - 0.0483mg/l) are found in station 29S and 4.43mM NH_4 (0.0789 mg/l) in station 55S. Lowest concentrations are 1.11mM NH_4 - 0.86mM N (0.020 - 0.012mg/l) in stations 7B, 26B and 40B. In middle region, ammonium concentrations are in more variation than other regions. Variation of ammonium concentration in the whole marine environment of Vietnam is shown in the Fig. 3

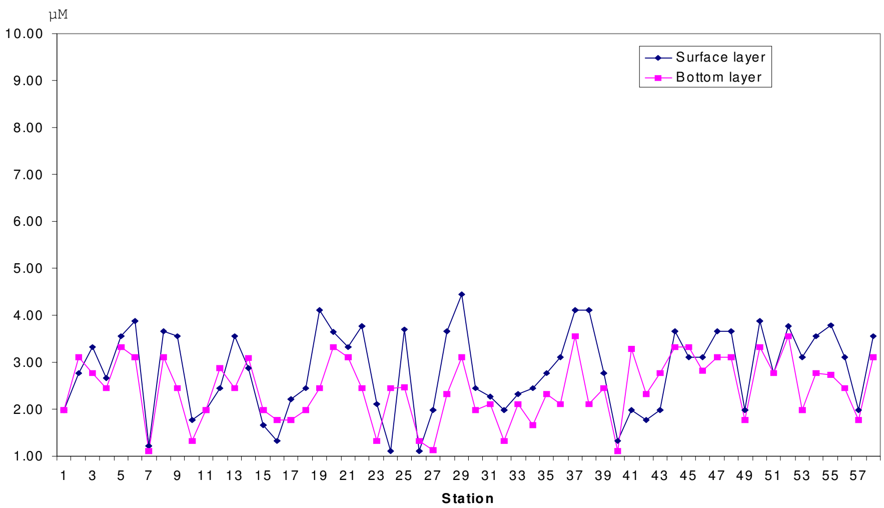


Fig. 3. Concentration of NH_4^+ in both surface and bottom layers.

Average concentration of ammonium in surface samples is 2.805µM NH_4 - 2.182 µM N (0.050 - 0.030 mg/l) and in the bottom is2.538µM NH_4 -1.974µM N (0.0456 - 0.0276mg/l).

Table 2.1. PO_4^{3-} - Concentration(µM).

Station	**Samples**	**PO_4^{3-} (µM)**	**Station**	**Samples**	**PO_4^{3-} (µM)**	**Station**	**Samples**	**PO_4^{3-} (µM)**
1	1S	1.37	**21**	21S	0.76	**41**	41S	0.59
	1B	3.47		21B	0.88		41B	1.05
2	2S	1.16	**22**	22S	0.95	**42**	42S	0.59
	2B	3.05		22B	1.30		42B	1.23
3	3S	1.30	**23**	23S	0.90	**43**	43S	0.74
	3B	1.20		23B	1.42		43B	1.00
4	4S	1.41	**24**	24S	0.80	**44**	44S	0.56
	4B	1.57		24B	1.12		44B	0.94
5	5S	1.26	**25**	25S	0.78	**45**	45S	0.79
	5B	1.50		25B	1.53		45B	0.98
6	6S	1.79	**26**	26S	0.74	**46**	46S	0.80
	6B	2.37		26B	1.32		46B	1.03
7	7S	1.60	**27**	27S	0.88	**47**	47S	0.70
	7B	1.85		27B	1.05		47B	0.99
8	8S	1.00	**28**	28S	0.82	**48**	48S	0.82
	8B	3.84		28B	1.10		48B	1.26
9	9S	1.45	**29**	29S	0.85	**49**	49S	0.80
	9B	1.80		29B	1.42		49B	1.20
10	10S	1.32	**30**	30S	0.80	**50**	50S	0.64
	10B	1.56		30B	1.05		50B	1.00
11	11S	0.88	**31**	31S	0.76	**51**	51S	0.68
	11B	1.23		31B	0.99		51B	1.04
12	12S	1.25	**32**	32S	0.80	**52**	52S	0.83
	12B	1.47		32B	1.00		52B	0.91
13	13S	0.90	**33**	33S	0.68	**53**	53S	0.63
	13B	1.53		33B	1.05		53B	0.83
14	14S	1.05	**34**	34S	0.72	**54**	54S	0.91
	14B	1.69		34B	1.35		54B	1.15
15	15S	1.09	**35**	35S	0.79	**55**	55S	0.74
	15B	1.73		35B	0.99		55B	1.26
16	16S	1.12	**36**	36S	0.55	**56**	56B	0.65
	16B	1.26		36B	1.00		56B	1.04
17	17S	0.76	**37**	37S	0.78	**57**	57S	0.79
	17B	1.30		37B	1.10		57B	1.11
18	18S	1.05	**38**	38S	0.64	**58**	58S	0.51
	18B	1.84		38B	0.89		58B	0.92
19	19S	0.86	**39**	39S	0.69	***Note:***		
	19B	1.52		39B	0.92	***S: Surface layer, 2m***		
20	20S	1.25	**40**	40S	0.68	***B: Bottom layer, ≥ 100m***		
	20B	**1.90**		40B	1.00			

Table 2.2. PO_4^{3-} - Concentration (mg/l).

Station	Samples	PO_4^{3-} (mg/L)	Station	Samples	PO_4^{3-} (mg/L)	Station	Samples	PO_4^{3-} (mg/L)
1	1S	0.130	21	21S	0.072	41	41S	0.056
	1B	0.329		21B	0.084		41B	0.100
2	2S	0.110	22	22S	0.090	42	42S	0.056
	2B	0.299		22B	0.123		42B	0.117
3	3S	0.123	23	23S	0.085	43	43S	0.070
	3B	0.114		23B	0.135		43B	0.095
4	4S	0.134	24	24S	0.076	44	44S	0.053
	4B	0.149		24B	0.106		44B	0.089
5	5S	0.120	25	25S	0.074	45	45S	0.075
	5B	0.142		25B	0.145		45B	0.093
6	6S	0.170	26	26S	0.070	46	46S	0.076
	6B	0.225		26B	0.125		46B	0.098
7	7S	0.152	27	27S	0.084	47	47S	0.066
	7B	0.176		27B	0.100		47B	0.094
8	8S	0.095	28	28S	0.078	48	48S	0.078
	8B	0.365		28B	0.104		48B	0.120
9	9S	0.138	29	29S	0.081	49	49S	0.076
	9B	0.171		29B	0.135		49B	0.114
10	10S	0.125	30	30S	0.076	50	50S	0.061
	10B	0.148		30B	0.100		50B	0.095
11	11S	0.084	31	31S	0.072	51	51S	0.065
	11B	0.117		31B	0.094		51B	0.099
12	12S	0.119	32	32S	0.076	52	52S	0.079
	12B	0.140		32B	0.095		52B	0.086
13	13S	0.085	33	33S	0.065	53	53S	0.060
	13B	0.145		33B	0.100		53B	0.079
14	14S	0.100	34	34S	0.068	54	54S	0.086
	14B	0.160		34B	0.128		54B	0.109
15	15S	0.103	35	35S	0.075	55	55S	0.070
	15B	0.164		35B	0.094		55B	0.120
16	16S	0.106	36	36S	0.052	56	56B	0.062
	16B	0.120		36B	0.095		56B	0.099
17	17S	0.072	37	37S	0.074	57	57S	0.075
	17B	0.123		37B	0.104		57B	0.105
18	18S	0.100	38	38S	0.061	58	58S	0.048
	18B	0.175		38B	0.084		58B	0.087
19	19S	0.082	39	39S	0.066			
	19B	0.144		39B	0.087			
20	20S	0.119	40	40S	0.065			
	20B	0.180		40B	0.095			

Note:
S: Surface layer, 2m
B: Bottom layer, ≥ 100m

Table 2.3. PO_4^{3-} -P: Concentration (µg/l).

St.	Sp	P (µM)	P (µg/l)	St	Sp	P (µM)	P (µg/l)	St	Sp	P (µM)	P (µg/l)
1	1S	0.45	13.86	**21**	21S	0.25	7.69	**41**	41S	0.19	5.97
	1B	1.13	35.10		21B	0.29	8.90		41B	0.34	10.62
2	2S	0.38	11.73	**22**	22S	0.31	9.61	**42**	42S	0.19	5.97
	2B	1.00	30.85		22B	0.42	13.15		42B	0.40	12.44
3	3S	0.42	13.15	**23**	23S	0.29	9.10	**43**	43S	0.24	7.49
	3B	0.39	12.14		23B	0.46	14.36		43B	0.33	10.12
4	4S	0.46	14.26	**24**	24S	0.26	8.09	**44**	44S	0.18	5.66
	4B	0.51	15.88		24B	0.37	11.33		44B	0.31	9.51
5	5S	0.41	12.75	**25**	25S	0.25	7.89	**45**	45S	0.26	7.99
	5B	0.49	15.17		25B	0.50	15.48		45B	0.32	9.91
6	6S	0.58	18.11	**26**	26S	0.24	7.49	**46**	46S	0.26	8.09
	6B	0.77	23.97		26B	0.43	13.35		46B	0.34	10.42
7	7S	0.52	16.19	**27**	27S	0.29	8.90	**47**	47S	0.23	7.08
	7B	0.60	18.71		27B	0.34	10.62		47B	0.32	10.01
8	8S	0.33	10.12	**28**	28S	0.27	8.29	**48**	48S	0.27	8.29
	8B	1.25	38.84		28B	0.36	11.13		48B	0.41	12.75
9	9S	0.47	14.67	**29**	29S	0.28	8.60	**49**	49S	0.26	8.09
	9B	0.59	18.21		29B	0.46	14.36		49B	0.39	12.14
10	10S	0.43	13.35	**30**	30S	0.26	8.09	**50**	50S	0.21	6.47
	10B	0.51	15.78		30B	0.34	10.62		50B	0.33	10.12
11	11S	0.29	8.90	**31**	31S	0.25	7.69	**51**	51S	0.22	6.88
	11B	0.40	12.44		31B	0.32	10.01		51B	0.34	10.52
12	12S	0.41	12.64	**32**	32S	0.26	8.09	**52**	52S	0.27	8.40
	12B	0.48	14.87		32B	0.33	10.12		52B	0.30	9.21
13	13S	0.29	9.10	**33**	33S	0.22	6.88	**53**	53S	0.21	6.37
	13B	0.50	15.48		33B	0.34	10.62		53B	0.27	8.40
14	14S	0.34	10.62	**34**	34S	0.23	7.28	**54**	54S	0.30	9.21
	14B	0.55	17.10		34B	0.44	13.66		54B	0.38	11.63
15	15S	0.36	11.03	**35**	35S	0.26	7.99	**55**	55S	0.24	7.49
	15B	0.56	17.50		35B	0.32	10.01		55B	0.41	12.75
16	16S	0.37	11.33	**36**	36S	0.18	5.56	**56**	56B	0.21	6.58
	16B	0.41	12.75		36B	0.33	10.12		56B	0.34	10.52
17	17S	0.25	7.69	**37**	37S	0.25	7.89	**57**	57S	0.26	7.99
	17B	0.42	13.15		37B	0.36	11.13		57B	0.36	11.23
18	18S	0.34	10.62	**38**	38S	0.21	6.47	**58**	58S	0.17	5.16
	18B	0.60	18.61		38B	0.29	9.00		58B	0.30	9.31
19	19S	0.28	8.70	**39**	39S	0.23	6.98				
	19B	0.50	15.38		39B	0.30	9.31				
20	20S	0.41	12.64	**40**	40S	0.22	6.88				
	20B	0.62	19.22		40B	0.33	10.12				

Note:
S: Surface layer, 2m
B: Bottom layer, ≥ 100m

Table 3.1. NH_4^+ - Concentration (μM) .

Station	Samples	NH_4^+ (μM)	Station	Samples	NH_4^+ (μM)	Station	Samples	NH_4^+ (μM)
1	1S	1.99	**21**	21S	3.33	**41**	41S	1.99
	1B	1.99		21B	3.11		41B	3.29
2	2S	2.77	**22**	22S	3.77	**42**	42S	1.77
	2B	3.11		22B	2.44		42B	2.33
3	3S	3.32	**23**	23S	2.11	**43**	43S	1.99
	3B	2.77		23B	1.33		43B	2.77
4	4S	2.66	**24**	24S	2.44	**44**	44S	3.66
	4B	2.44		24B	1.11		44B	3.32
5	5S	3.55	**25**	25S	3.88	**45**	45S	3.11
	5B	3.32		25B	2.77		45B	3.32
6	6S	3.88	**26**	26S	1.33	**46**	46S	3.11
	6B	3.11		26B	1.11		46B	3.66
7	7S	1.22	**27**	27S	1.99	**47**	47S	3.66
	7B	1.11		27B	1.13		47B	3.11
8	8S	3.66	**28**	28S	3.66	**48**	48S	3.66
	8B	3.11		28B	2.33		48B	3.11
9	9S	3.55	**29**	29S	4.44	**49**	49S	1,99
	9B	2.44		29B	3.11		49B	1.77
10	10S	1.77	**30**	30S	2.44	**50**	50S	3.88
	10B	1.33		30B	1.99		50B	3.32
11	11S	1.99	**31**	31S	2.27	**51**	51S	2.77
	11B	1.99		31B	2.11		51B	2.77
12	12S	2.88	**32**	32S	1.99	**52**	52S	3.77
	12B	2.44		32B	1.33		52B	3.55
13	13S	3.55	**33**	33S	2.33	**53**	53S	3.11
	13B	2.44		33B	2.11		53B	1.99
14	14S	3.55	**34**	34S	2.44	**54**	54S	3.55
	14B	2.88		34B	1.66		54B	2.77
15	15S	1.99	**35**	35S	2.77	**55**	55S	4.43
	15B	1.66		35B	2.32		55B	2.22
16	16S	1.77	**36**	36S	3.11	**56**	56B	3.11
	16B	1.33		36B	2.11		56B	2.44
17	17S	2.22	**37**	37S	4.10	**57**	57S	1.99
	17B	1.77		37B	3.55		57B	1.77
18	18S	2.44	**38**	38S	4.10	**58**	58S	3.55
	18B	1.99		38B	2.11		58B	3.11
19	19S	4.10	**39**	39S	2.77	***Note:***		
	19B	2.44		39B	2.44	***S: Surface layer, 2m***		
20	20S	4.10	**40**	40S	1.33	***B: Bottom layer, ≥100m***		
	20B	3.55		40B	1.11			

Table 3.2. NH_4^+ - Concentration (mg/L).

Station	Samples	NH_4^+ (mg/L)	Station	Samples	NH_4^+ (mg/L)	Station	Samples	NH_4^+ (mg/L)
1	1S	0.036	**21**	21S	0.060	**41**	41S	0.036
	1B	0.036		21B	0.056		41B	0.059
2	2S	0.050	**22**	22S	0.068	**42**	42S	0.032
	2B	0.056		22B	0.044		42B	0.042
3	3S	0.060	**23**	23S	0.038	**43**	43S	0.036
	3B	0.050		23B	0.024		43B	0.050
4	4S	0.048	**24**	24S	0.020	**44**	44S	0.066
	4B	0.044		24B	0.044		44B	0.060
5	5S	0.064	**25**	25S	0.050	**45**	45S	0.056
	5B	0.060		25B	0.070		45B	0.060
6	6S	0.070	**26**	26S	0.020	**46**	46S	0.056
	6B	0.056		26B	0.024		46B	0.066
7	7S	0.022	**27**	27S	0.036	**47**	47S	0.066
	7B	0.020		27B	0.020		47B	0.056
8	8S	0.066	**28**	28S	0.066	**48**	48S	0.066
	8B	0.056		28B	0.042		48B	0.056
9	9S	0.064	**29**	29S	0.080	**49**	49S	0.036
	9B	0.044		29B	0.056		49B	0.032
10	10S	0.032	**30**	30S	0.044	**50**	50S	0.070
	10B	0.024		30B	0.036		50B	0.060
11	11S	0.036	**31**	31S	0.041	**51**	51S	0.050
	11B	0.036		31B	0.038		51B	0.050
12	12S	0.044	**32**	32S	0.036	**52**	52S	0.068
	12B	0.052		32B	0.024		52B	0.064
13	13S	0.064	**33**	33S	0.042	**53**	53S	0.056
	13B	0.044		33B	0.038		53B	0.036
14	14S	0.052	**34**	34S	0.044	**54**	54S	0.064
	14B	0.064		34B	0.030		54B	0.050
15	15S	0.030	**35**	35S	0.050	**55**	55S	0.040
	15B	0.036		35B	0.042		55B	0.080
16	16S	0.024	**36**	36S	0.056	**56**	56B	0.056
	16B	0.032		36B	0.038		56B	0.044
17	17S	0.040	**37**	37S	0.074	**57**	57S	0.036
	17B	0.032		37B	0.064		57B	0.032
18	18S	0.044	**38**	38S	0.074	**58**	58S	0.064
	18B	0.036		38B	0.038		58B	0.056
19	19S	0.074	**39**	39S	0.050	***Note:***		
	19B	0.044		39B	0.044	***S: Surface layer, 2m***		
20	20S	0.064	**40**	40S	0.024	***B: Bottom layer, ≥ 100m***		
	20B	0.074		40B	0.020			

Table 3.3. NH_4^+ - N: Concentration (µg/L).

St	Sp	N (µM)	N(µg/l)	St	Sp	N (µM)	N(µg/l)	St	Sp	N (µM)	N(µg/l)
1	1S	1.55	21.67	**21**	21S	2.59	36.26	**41**	41S	1.55	21.67
	1B	1.55	21.67		21B	2.42	33.86		41B	2.56	35.82
2	2S	2.15	30.16	**22**	22S	2.93	41.05	**42**	42S	1.38	19.27
	2B	2.42	33.86		22B	1.90	26.57		42B	1.81	25.37
3	3S	2.58	36.15	**23**	23S	1.64	22.98	**43**	43S	1.55	21.67
	3B	2.15	30.16		23B	1.03	14.48		43B	2.15	30.16
4	4S	2.07	28.96	**24**	24S	0.86	12.09	**44**	44S	2.85	39.85
	4B	1.90	26.57		24B	1.90	26.57		44B	2.58	36.15
5	5S	2.76	38.66	**25**	25S	2.15	30.16	**45**	45S	2.42	33.86
	5B	2.58	36.15		25B	3.02	42.25		45B	2.58	36.15
6	6S	3.02	42.25	**26**	26S	0.86	12.09	**46**	46S	2.42	33.86
	6B	2.42	33.86		26B	1.03	14.48		46B	2.85	39.85
7	7S	0.95	13.28	**27**	27S	1.55	21.67	**47**	47S	2.85	39.85
	7B	0.86	12.09		27B	0.88	12.30		47B	2.42	33.86
8	8S	2.85	39.85	**28**	28S	2.85	39.85	**48**	48S	2.85	39.85
	8B	2.42	33.86		28B	1.81	25.37		48B	2.42	33.86
9	9S	2.76	38.66	**29**	29S	3.45	48.35	**49**	49S	1.54	21.56
	9B	1.90	26.57		29B	2.42	33.86		49B	1.38	19.27
10	10S	1.38	19.27	**30**	30S	1.90	26.57	**50**	50S	3.02	42.25
	10B	1.03	14.48		30B	1.55	21.67		50B	2.58	36.15
11	11S	1.55	21.67	**31**	31S	1.77	24.72	**51**	51S	2.15	30.16
	11B	1.55	21.67		31B	1.64	22.98		51B	2.15	30.16
12	12S	1.90	26.57	**32**	32S	1.55	21.67	**52**	52S	2.93	41.05
	12B	2.24	31.36		32B	1.03	14.48		52B	2.76	38.66
13	13S	2.76	38.66	**33**	33S	1.81	25.37	**53**	53S	2.42	33.86
	13B	1.90	26.57		33B	1.64	22.98		53B	1.55	21.67
14	14S	2.24	31.36	**34**	34S	1.90	26.57	**54**	54S	2.76	38.66
	14B	2.76	38.66		34B	1.29	18.08		54B	2.15	30.16
15	15S	1.29	18.08	**35**	35S	2.15	30.16	**55**	55S	1.73	24.17
	15B	1.55	21.67		35B	1.80	25.26		55B	3.45	48.24
16	16S	1.03	14.48	**36**	36S	2.42	33.86	**56**	56B	2.42	33.86
	16B	1.38	19.27		36B	1.64	22.98		56B	1.90	26.57
17	17S	1.73	24.17	**37**	37S	3.19	44.64	**57**	57S	1.55	21.67
	17B	1.38	19.27		37B	2.76	38.66		57B	1.38	19.27
18	18S	1.90	26.57	**38**	38S	3.19	44.64	**58**	58S	2.76	38.66
	18B	1.55	21.67		38B	1.64	22.98		58B	2.42	33.86
19	19S	3.19	44.64	**39**	39S	2.15	30.16				
	19B	1.90	26.57		39B	1.90	26.57				
20	20S	2.76	38.66	**40**	40S	1.03	14.48				
	20B	3.19	44.64		40B	0.86	12.09				

Note:
S: Surface layer, 2m
B: Bottom layer, ≥100m

Nitrate

Results for nitrate concentrations are shown in Table 4.1,4.2 and 4.3. Highest concentration of nitrate is 11.16µM NO_3 - 2.52µM N (0.692 - 0.035mg/l) in the station 1B, and then they are 10.19µM NO_3 - 2.30µM N (0.63 - 0.032mg/l) in station 2B, 10.87µM NO_3 - 2.45µM N (0.674 - 0.034mg/l) in station 3B; 10.68µM NO_3 - 2.41µM N (0.66 - 0.033mg/l) in station 11B. Generally, nitrate concentration in northern region is higher to compare to two other regions. Lowest concentration 1.95µM - 0,44 µM (0.120 - 6,16mg/l) is found in station 30S. All the results show that the concentration in bottom layer always higher in the surface layer. It can be explained by the exchanging and/or disintegrating of phytoplankton. It suggests the same phenomena with the phosphate concentration. Average concentration of nitrate in surface layer (2m depth comparing to the sea surface) is 5.59 - 1.26µM and in bottom layer (100m comparing to the sea surface) is 6.81 - 1.39µM. Variation of nitrate concentration along the Vietnamese seaside are shown in Fig. 4.

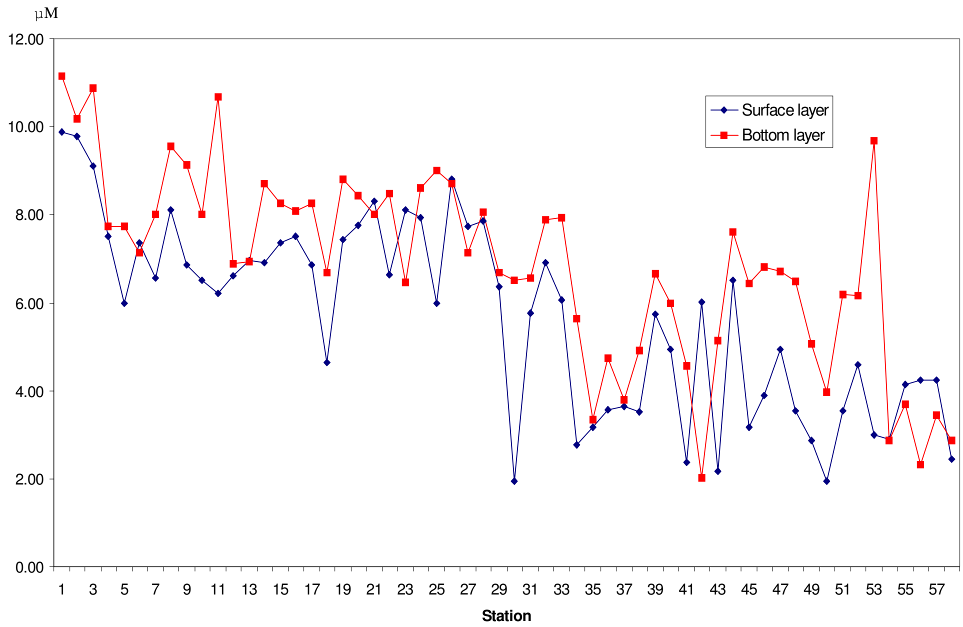


Fig. 4. Concentration of NO_3^- in both surface and bottomlayers.

Nitrite

Nitrite and nitrate concentrations always have the relations, but since the sampling stations are far away from laboratories and they have to transferred by ships, therefore the duration time from sampling to analyses often longer than limitation values of standard. Though it can be considered it is some part of nitrite had been oxidized into nitrate and made the results not correctly. On the other hand, nitrite concentration in seawater usually is low. With these reasons we cannot find out the clear relations between the surface and bottom layers. Highest concentration 0.60µM NO_2 - 0.18µM N (0.0287 - 0.014 mg/l) is found in station 13S and lowest concentrations 0.04µM NO_2- 0.012µM N (0.0019 - 0.00017mg/l) in some stations 41S and 50S (Table 5.1,5.2 and 5.3). As well as nitrate, nitrite concentration in northern region is higher and more variable than in middle and southern regions. Variation of nitrite concentration along Vietnamese seaside is shown in Fig. 5. Average concentration of nitrite in surface layer is 0.169µM NO_2 - 0.051µM N and in the bottom layer is 0.197µM NO_2 - 0.059µM N.

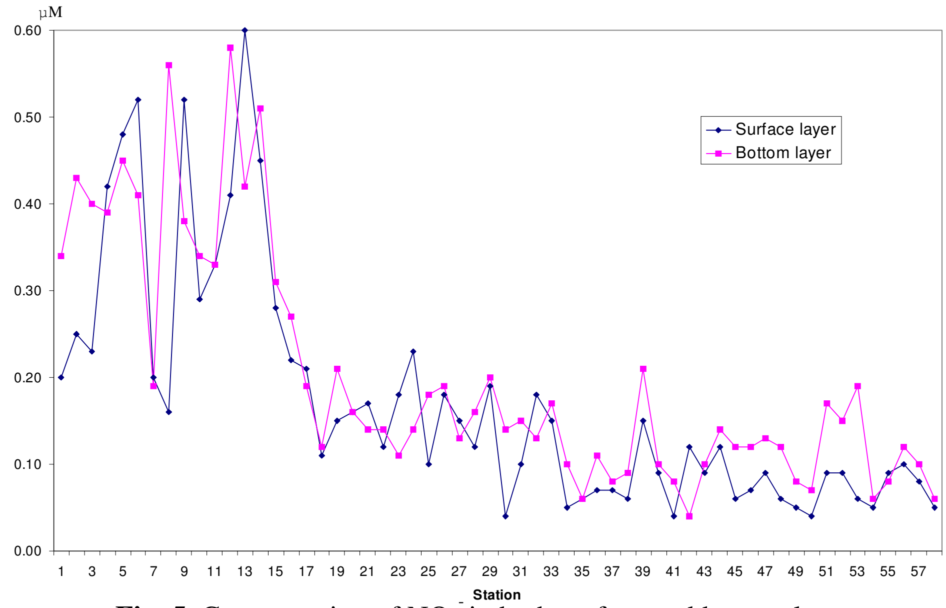


Fig. 5. Concentration of NO_2^- in both surface and bottom layers.

Sulfate

The results for sulfate concentration are shown in Table 6.1 and 6.2. According to molecular mass of sulfate anion high, even though these are sulfate content of dissolved salts, the concentrations in bottom layer are always higher than in surface layer. Highest concentration of sulfate 35.38µM (3.398 mg/l) is found in station 3B in northern region, this is suitable with the results of ammonium, nitrate, nitrite. Lowest concentration is 21.63µM (2.0778mg/l) in station 38S. Variation of sulfate concentration along the Vietnam seaside is shown in the Fig. 6. Average concentration of sulfate in surface layer is 26.903 µM and in bottom layer is 27.831µM.

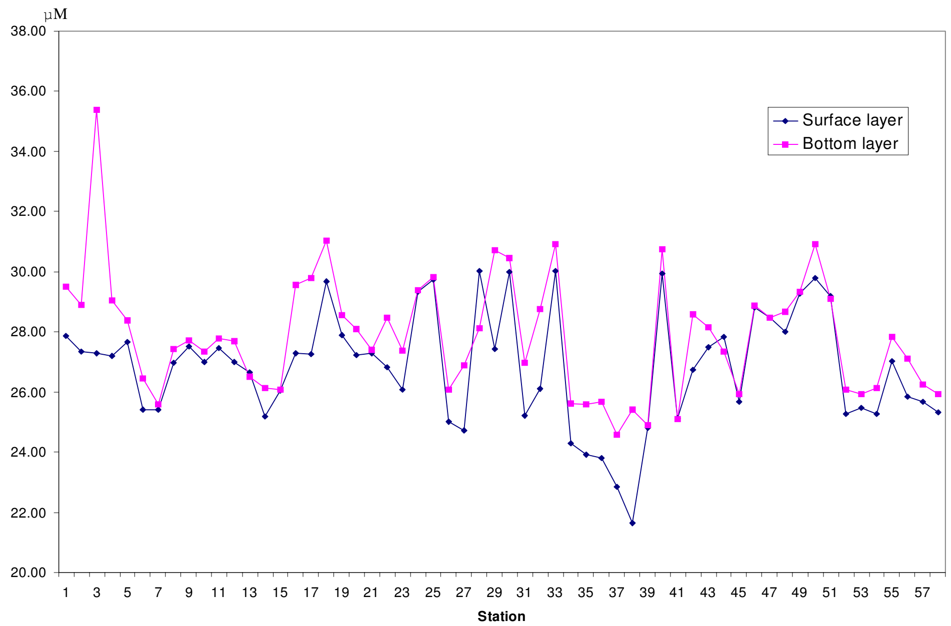


Fig. 6. Concentration of SO_4^{2-} in both surface and bottom layers.

Fig. 7 shows generally the chart of 5 parameters for nutrient along the Vietnamese seaside. Sulfate concentration is in unit of µM therefore it cannot be shown in the same scale.

As said in the introduction of this report, Vietnamese seaside curved as an S, therefore the variation of nutrients is not the same. Specially in northern region with estuary characteristics is characterized by N/P ratios which are likely due to fertilizer applications and sewage discharges in the drainage area. In the estuary, phosphate shows a maximum value probably due to remobilization from solid phases (See Fig. 8.1.)

To compare the concentrations of nutrients more clearly, the results can be shown in Table 7 and in Fig. 8.1, 8.2 and 8.3 as well as in Fig.9.1, 9.2 and 9.3 and also in the tables respectively (Table 8.1, 8.2a,8.2b,8.3a,8.3b,9.1,9.2 and 9.3) for all three regions.

Table 4.1. NO_3^- - Concentration (μM).

Station	Samples	NO_3^- (μM)	Station	Samples	NO_3^- (μM)	Station	Samples	NO_3^- (μM)
1	1S	9.87	**21**	21S	8.32	**41**	41S	2.37
	1B	11.16		21B	8.00		41B	4.56
2	2S	9.79	**22**	22S	6.63	**42**	42S	2.02
	2B	10.19		22B	8.47		42B	6.02
3	3S	9.10	**23**	23S	8.10	**43**	43S	2.16
	3B	10.87		23B	6.47		43B	5.15
4	4S	7.52	**24**	24S	7.94	**44**	44S	6.50
	4B	7.74		24B	8.61		44B	7.60
5	5S	5.98	**25**	25S	6.00	**45**	45S	3.16
	5B	7.74		25B	9.00		45B	6.44
6	6S	7.35	**26**	26S	8.81	**46**	46S	3.90
	6B	7.13		26B	8.71		46B	6.81
7	7S	6.55	**27**	27S	7.74	**47**	47S	4.95
	7B	8.02		27B	7.13		47B	6.71
8	8S	8.10	**28**	28S	7.85	**48**	48S	3.55
	8B	9.55		28B	8.06		48B	6.48
9	9S	6.85	**29**	29S	6.37	**49**	49S	2.87
	9B	9.13		29B	6.68		49B	5.06
10	10S	6.52	**30**	30S	1.95	**50**	50S	1.95
	10B	8.00		30B	6.50		50B	3.97
11	11S	6.21	**31**	31S	5.76	**51**	51S	3.55
	11B	10.68		31B	6.56		51B	6.19
12	12S	6.61	**32**	32S	6.90	**52**	52S	4.60
	12B	6.89		32B	7.89		52B	6.16
13	13S	6.97	**33**	33S	6.05	**53**	53S	3.00
	13B	6.94		33B	7.94		53B	9.69
14	14S	6.92	**34**	34S	2.76	**54**	54S	2.90
	14B	8.71		34B	5.65		54B	2.87
15	15S	7.37	**35**	35S	3.18	**55**	55S	4.15
	15B	8.27		35B	3.34		55B	3.68
16	16S	7.50	**36**	36S	3.56	**56**	56B	4.24
	16B	8.09		36B	4.74		56B	2.31
17	17S	6.87	**37**	37S	3.63	**57**	57S	4.24
	17B	8.27		37B	3.79		57B	3.45
18	18S	4.63	**38**	38S	3.52	**58**	58S	2.45
	18B	6.68		38B	4.92		58B	2.87
19	19S	7.44	**39**	39S	5.73	***Note:***		
	19B	8.81		39B	6.65	***S: Surface layer, 2m***		
20	20S	7.76	**40**	40S	4.95	***B: Bottom layer, ≥ 100m***		
	20B	8.42		40B	6.00			

Table 4.2. NO_3^- Concentration (mg/L).

Station	Sample	NO_3^- (mg/L)	Station	Samples	NO_3^- (mg/L)	Station	Samples	NO_3^- (mg/L)
1	1S	0.612	**21**	21S	0.516	**41**	41S	0.147
	1B	0.692		21B	0.496		41B	0.283
2	2S	0.607	**22**	22S	0.411	**42**	42S	0.373
	2B	0.632		22B	0.525		42B	0.125
3	3S	0.564	**23**	23S	0.502	**43**	43S	0.134
	3B	0.674		23B	0.401		43B	0.319
4	4S	0.466	**24**	24S	0.492	**44**	44S	0.403
	4B	0.480		24B	0.534		44B	0.471
5	5S	0.371	**25**	25S	0.372	**45**	45S	0.196
	5B	0.480		25B	0.558		45B	0.399
6	6S	0.456	**26**	26S	0.546	**46**	46S	0.242
	6B	0.442		26B	0.540		46B	0.422
7	7S	0.406	**27**	27S	0.480	**47**	47S	0.307
	7B	0.497		27B	0.442		47B	0.416
8	8S	0.502	**28**	28S	0.487	**48**	48S	0.220
	8B	0.592		28B	0.500		48B	0.402
9	9S	0.425	**29**	29S	0.395	**49**	49S	0.178
	9B	0.566		29B	0.414		49B	0.314
10	10S	0.404	**30**	30S	0.121	**50**	50S	0.121
	10B	0.496		30B	0.403		50B	0.246
11	11S	0.385	**31**	31S	0.357	**51**	51S	0.220
	11B	0.662		31B	0.407		51B	0.384
12	12S	0.410	**32**	32S	0.428	**52**	52S	0.285
	12B	0.427		32B	0.489		52B	0.382
13	13S	0.432	**33**	33S	0.375	**53**	53S	0.186
	13B	0.430		33B	0.492		53B	0.601
14	14S	0.429	**34**	34S	0.171	**54**	54S	0.180
	14B	0.540		34B	0.350		54B	0.178
15	15S	0.457	**35**	35S	0.197	**55**	55S	0.257
	15B	0.513		35B	0.207		55B	0.228
16	16S	0.465	**36**	36S	0.221	**56**	56B	0.263
	16B	0.502		36B	0.294		56B	0.143
17	17S	0.426	**37**	37S	0.225	**57**	57S	0.263
	17B	0.513		37B	0.235		57B	0.214
18	18S	0.287	**38**	38S	0.218	**58**	58S	0.152
	18B	0.414		38B	0.305		58B	0.178
19	19S	0.461	**39**	39S	0.355	***Note:***		
	19B	0.546		39B	0.412	***S: Surface layer, 2m***		
20	20S	0.481	**40**	40S	0.307	***B: Bottom layer, ≥ 100m***		
	20B	0.522		40B	0.372			

Table 4.3. NO_3^-- N: Concentration.

St	Sp	N (µM)	N(µg/l)	St	Sp	N (µM)	N (µg/l)	St	Sp	N (µM)	N(µg/l)
1	1S	2.23	31.20	**21**	21S	1.88	26.30	**41**	41S	0.54	7.49
	1B	2.52	35.28		21B	1.81	25.29		41B	1.03	14.42
2	2S	2.21	30.95	**22**	22S	1.50	20.96	**42**	42S	1.36	19.03
	2B	2.30	32.21		22B	1.91	26.78		42B	0.46	6.39
3	3S	2.05	28.77	**23**	23S	1.83	25.61	**43**	43S	0.49	6.83
	3B	2.45	34.36		23B	1.46	20.45		43B	1.16	16.28
4	4S	1.70	23.77	**24**	24S	1.79	25.10	**44**	44S	1.47	20.55
	4B	1.75	24.47		24B	1.94	27.22		44B	1.72	24.03
5	5S	1.35	18.90	**25**	25S	1.35	18.97	**45**	45S	0.71	9.99
	5B	1.75	24.47		25B	2.03	28.45		45B	1.45	20.36
6	6S	1.66	23.24	**26**	26S	1.99	27.85	**46**	46S	0.88	12.33
	6B	1.61	22.54		26B	1.97	27.53		46B	1.54	21.53
7	7S	1.48	20.71	**27**	27S	1.75	24.47	**47**	47S	1.12	15.65
	7B	1.81	25.35		27B	1.61	22.54		47B	1.52	21.21
8	8S	1.83	25.61	**28**	28S	1.77	24.82	**48**	48S	0.80	11.22
	8B	2.16	30.19		28B	1.82	25.48		48B	1.46	20.49
9	9S	1.55	21.65	**29**	29S	1.44	20.14	**49**	49S	0.65	9.07
	9B	2.06	28.86		29B	1.51	21.12		49B	1.14	16.00
10	10S	1.47	20.61	**30**	30S	0.44	6.16	**50**	50S	0.44	6.16
	10B	1.81	25.29		30B	1.47	20.55		50B	0.90	12.55
11	11S	1.40	19.63	**31**	31S	1.30	18.21	**51**	51S	0.80	11.22
	11B	2.41	33.76		31B	1.48	20.74		51B	1.40	19.57
12	12S	1.49	20.90	**32**	32S	1.56	21.81	**52**	52S	1.04	14.54
	12B	1.51	21.78		32B	1.78	24.94		52B	1.39	19.47
13	13S	1.57	22.03	**33**	33S	1.37	19.13	**53**	53S	0.68	9.48
	13B	1.57	21.94		33B	1.79	25.10		53B	2.19	30.63
14	14S	1.56	21.88	**34**	34S	0.62	8.73	**54**	54S	0.65	9.17
	14B	1.97	27.53		34B	1.28	17.86		54B	0.65	9.07
15	15S	1.66	23.30	**35**	35S	0.72	10.05	**55**	55S	0.94	13.12
	15B	1.87	26.14		35B	0.75	10.56		55B	0.83	11.63
16	16S	1.69	23.71	**36**	36S	0.80	11.25	**56**	56B	0.96	13.40
	16B	1.83	25.57		36B	1.07	14.98		56B	0.52	7.30
17	17S	1.55	21.72	**37**	37S	0.82	11.48	**57**	57S	0.96	13.40
	17B	1.87	26.14		37B	0.86	11.98		57B	0.78	10.91
18	18S	1.05	14.64	**38**	38S	0.79	11.13	**58**	58S	0.55	7.75
	18B	1.51	21.12		38B	1.11	15.55		58B	0.65	9.07
19	19S	1.68	23.52	**39**	39S	1.29	18.11				
	19B	1.99	27.85		39B	1.50	21.02				
20	20S	1.75	24.53	**40**	40S	1.12	15.65				
	20B	1.90	26.62		40B	1.35	18.97				

Note:
S: Surface layer, 2m
B: Bottom layer, ≥ 100m

Table 5.1. NO_2^- - Concentration (µM).

Station	Samples	NO_2^- (µM)	Station	Samples	NO_2^- (µM)	Station	Samples	NO_2^- (µM)
1	1S	0.20	**21**	21S	0.17	**41**	41S	0.04
	1B	0.34		21B	0.14		41B	0.08
2	2S	0.25	**22**	22S	0.12	**42**	42S	0.12
	2B	0.43		22B	0.14		42B	0.04
3	3S	0.23	**23**	23S	0.18	**43**	43S	0.09
	3B	0.40		23B	0.11		43B	0.10
4	4S	0.42	**24**	24S	0.23	**44**	44S	0.12
	4B	0.39		24B	0.14		44B	0.14
5	5S	0.48	**25**	25S	0.10	**45**	45S	0.06
	5B	0.45		25B	0.18		45B	0.12
6	6S	0.52	**26**	26S	0.18	**46**	46S	0.07
	6B	0.41		26B	0.19		46B	0.12
7	7S	0.20	**27**	27S	0.15	**47**	47S	0.09
	7B	0.19		27B	0.13		47B	0.13
8	8S	0.16	**28**	28S	0.12	**48**	48S	0.06
	8B	0.56		28B	0.16		48B	0.12
9	9S	0.52	**29**	29S	0.19	**49**	49S	0.05
	9B	0.38		29B	0.20		49B	0.08
10	10S	0.29	**30**	30S	0.04	**50**	50S	0.04
	10B	0.34		30B	0.14		50B	0.07
11	11S	0.33	**31**	31S	0.10	**51**	51S	0.09
	11B	0.33		31B	0.15		51B	0.17
12	12S	0.41	**32**	32S	0.18	**52**	52S	0.09
	12B	0.58		32B	0.13		52B	0.15
13	13S	0.60	**33**	33S	0.15	**53**	53S	0.06
	13B	0.42		33B	0.17		53B	0.19
14	14S	0.45	**34**	34S	0.05	**54**	54S	0.05
	14B	0.51		34B	0.10		54B	0.06
15	15S	0.28	**35**	35S	0.06	**55**	55S	0.09
	15B	0.31		35B	0.06		55B	0.08
16	16S	0.22	**36**	36S	0.07	**56**	56B	0.10
	16B	0.27		36B	0.11		56B	0.12
17	17S	0.21	**37**	37S	0.07	**57**	57S	0.08
	17B	0.19		37B	0.08		57B	0.10
18	18S	0.11	**38**	38S	0.06	**58**	58S	0.05
	18B	0.12		38B	0.09		58B	0.06
19	19S	0.15	**39**	39S	0.15	***Note:***		
	19B	0.21		39B	0.21	***S: Surface layer, 2m***		
20	20S	0.16	**40**	40S	0.09	***B: Bottom layer, ≥ 100m***		
	20B	0.16		40B	0.10			

Table 5.2. NO_2^- - Concentration (mg/L).

Station	Samples	NO_2^- (mg/L)	Station	Samples	NO_2^- (mg/L)	Station	Samples	NO_2^- (mg/L)
1	1S	0.010	**21**	21S	0.008	**41**	41S	0.002
	1B	0.016		21B	0.007		41B	0.004
2	2S	0.012	**22**	22S	0.006	**42**	42S	0.006
	2B	0.021		22B	0.007		42B	0.002
3	3S	0.011	**23**	23S	0.009	**43**	43S	0.004
	3B	0.019		23B	0.005		43B	0.005
4	4S	0.020	**24**	24S	0.011	**44**	44S	0.006
	4B	0.019		24B	0.007		44B	0.007
5	5S	0.023	**25**	25S	0.005	**45**	45S	0.003
	5B	0.022		25B	0.009		45B	0.006
6	6S	0.025	**26**	26S	0.009	**46**	46S	0.003
	6B	0.020		26B	0.009		46B	0.006
7	7S	0.010	**27**	27S	0.007	**47**	47S	0.004
	7B	0.009		27B	0.006		47B	0.006
8	8S	0.008	**28**	28S	0.006	**48**	48S	0.003
	8B	0.027		28B	0.008		48B	0.006
9	9S	0.025	**29**	29S	0.009	**49**	49S	0.002
	9B	0.018		29B	0.010		49B	0.004
10	10S	0.014	**30**	30S	0.002	**50**	50S	0.002
	10B	0.016		30B	0.007		50B	0.003
11	11S	0.016	**31**	31S	0.005	**51**	51S	0.004
	11B	0.016		31B	0.007		51B	0.008
12	12S	0.020	**32**	32S	0.009	**52**	52S	0.004
	12B	0.028		32B	0.006		52B	0.007
13	13S	0.029	**33**	33S	0.007	**53**	53S	0.003
	13B	0.020		33B	0.008		53B	0.009
14	14S	0.022	**34**	34S	0.002	**54**	54S	0.002
	14B	0.024		34B	0.005		54B	0.003
15	15S	0.013	**35**	35S	0.003	**55**	55S	0.004
	15B	0.015		35B	0.003		55B	0.004
16	16S	0.011	**36**	36S	0.003	**56**	56B	0.005
	16B	0.013		36B	0.005		56B	0.006
17	17S	0.010	**37**	37S	0.003	**57**	57S	0.004
	17B	0.009		37B	0.004		57B	0.005
18	18S	0.005	**38**	38S	0.003	**58**	58S	0.002
	18B	0.006		38B	0.004		58B	0.003
19	19S	0.007	**39**	39S	0.007	***Note:***		
	19B	0.010		39B	0.010	***S: Surface layer, 2m***		
20	20S	0.008	**40**	40S	0.004	***B: Bottom layer, ≥ 100m***		
	20B	0.008		40B	0.005			

Table 5.3. NO_2^- - N: Concentration.

St	Sp	N(µM)	N(µg/l)	St	Sp	N (µM)	N(µg/l)	St	Sp	N(µM)	N(µg/l)
1	1S	0.50	6.94	**21**	21S	0.05	0.72	**41**	41S	0.01	0.17
	1B	0.84	11.80		21B	0.04	0.60		41B	0.02	0.34
2	2S	0.62	8.67	**22**	22S	0.04	0.51	**42**	42S	0.04	0.51
	2B	1.07	14.92		22B	0.04	0.60		42B	0.01	0.17
3	3S	0.57	7.98	**23**	23S	0.05	0.77	**43**	43S	0.03	0.38
	3B	0.99	13.88		23B	0.03	0.47		43B	0.03	0.43
4	4S	1.04	14.57	**24**	24S	0.07	0.98	**44**	44S	0.04	0.51
	4B	0.97	13.53		24B	0.04	0.60		44B	0.04	0.60
5	5S	1.19	16.65	**25**	25S	0.03	0.43	**45**	45S	0.02	0.26
	5B	1.12	15.61		25B	0.05	0.77		45B	0.04	0.51
6	6S	1.29	18.04	**26**	26S	0.05	0.77	**46**	46S	0.02	0.30
	6B	1.02	14.23		26B	0.06	0.81		46B	0.04	0.51
7	7S	0.50	6.94	**27**	27S	0.05	0.64	**47**	47S	0.03	0.38
	7B	0.47	6.59		27B	0.04	0.55		47B	0.04	0.55
8	8S	0.40	5.55	**28**	28S	0.04	0.51	**48**	48S	0.02	0.26
	8B	1.39	19.43		28B	0.05	0.68		48B	0.04	0.51
9	9S	1.29	18.04	**29**	29S	0.06	0.81	**49**	49S	0.02	0.21
	9B	0.94	13.18		29B	0.06	0.85		49B	0.02	0.34
10	10S	0.72	10.06	**30**	30S	0.01	0.17	**50**	50S	0.01	0.17
	10B	0.84	11.80		30B	0.04	0.60		50B	0.02	0.30
11	11S	0.82	11.45	**31**	31S	0.03	0.43	**51**	51S	0.03	0.38
	11B	0.82	11.45		31B	0.05	0.64		51B	0.05	0.72
12	12S	1.02	14.23	**32**	32S	0.05	0.77	**52**	52S	0.03	0.38
	12B	1.44	20.12		32B	0.04	0.55		52B	0.05	0.64
13	13S	1.49	20.82	**33**	33S	0.05	0.64	**53**	53S	0.02	0.26
	13B	1.04	14.57		33B	0.05	0.72		53B	0.06	0.81
14	14S	1.12	15.61	**34**	34S	0.02	0.21	**54**	54S	0.02	0.21
	14B	1.26	17.69		34B	0.03	0.43		54B	0.02	0.26
15	15S	0.69	9.71	**35**	35S	0.02	0.26	**55**	55S	0.03	0.38
	15B	0.77	10.76		35B	0.02	0.26		55B	0.02	0.34
16	16S	0.55	7.63	**36**	36S	0.02	0.30	**56**	56B	0.03	0.43
	16B	0.67	9.37		36B	0.03	0.47		56B	0.04	0.51
17	17S	0.52	7.29	**37**	37S	0.02	0.30	**57**	57S	0.02	0.34
	17B	0.47	6.59		37B	0.02	0.34		57B	0.03	0.43
18	18S	0.27	3.82	**38**	38S	0.02	0.26	**58**	58S	0.02	0.21
	18B	0.30	4.16		38B	0.03	0.38		58B	0.02	0.26
19	19S	0.37	5.20	**39**	39S	0.05	0.64				
	19B	0.52	7.29		39B	0.06	0.89				
20	20S	0.40	5.55	**40**	40S	0.03	0.38				
	20B	0.40	5.55		40B	0.03	0.43				

Note:
S: Surface layer, 2m
B:Bottom layer, ≥ 100m

Table 6.1. SO_4^{2-} - Concentration (µM).

Station	Samples	SO_4^{2-} (µM)	Station	Samples	SO_4^{2-} (µM)	Station	Samples	SO_4^{2-} (µM)
1	1S	27.87	**21**	21S	27.30	**41**	41S	25.13
	1B	29.51		21B	27.41		41B	25.11
2	2S	27.35	**22**	22S	26.83	**42**	42S	26.73
	2B	28.90		22B	28.48		42B	28.58
3	3S	27.30	**23**	23S	26.07	**43**	43S	27.48
	3B	35.38		23B	27.38		43B	28.14
4	4S	27.19	**24**	24S	29.33	**44**	44S	27.84
	4B	29.05		24B	29.38		44B	27.34
5	5S	27.66	**25**	25S	29.73	**45**	45S	25.67
	5B	28.38		25B	29.83		45B	25.92
6	6S	25.41	**26**	26S	25.02	**46**	46S	28.81
	6B	26.46		26B	26.09		46B	28.87
7	7S	25.42	**27**	27S	24.73	**47**	47S	28.47
	7B	25.60		27B	26.88		47B	28.46
8	8S	26.98	**28**	28S	28.13	**48**	48S	28.02
	8B	27.43		28B	30.02		48B	28.67
9	9S	27.53	**29**	29S	28.30	**49**	49S	29.27
	9B	27.72		29B	30.96		49B	29.32
10	10S	26.99	**30**	30S	30.00	**50**	50S	29.78
	10B	27.34		30B	30.45		50B	30.92
11	11S	27.45	**31**	31S	26,96	**51**	51S	29.18
	11B	27.79		31B	25.20		51B	29.10
12	12S	27.01	**32**	32S	26.10	**52**	52S	25.26
	12B	27.68		32B	28.75		52B	26.08
13	13S	26.65	**33**	33S	30.02	**53**	53S	25.48
	13B	26.51		33B	30.91		53B	25.93
14	14S	25.19	**34**	34S	24.28	**54**	54S	25.27
	14B	26.12		34B	25.63		54B	26.14
15	15S	26.04	**35**	35S	23.93	**55**	55S	27.04
	15B	26.08		35B	25.59		55B	27.84
16	16S	27.30	**36**	36S	23.80	**56**	56B	25.84
	16B	29.56		36B	25.67		56B	27.10
17	17S	27.25	**37**	37S	22.84	**57**	57S	25.66
	17B	29.79		37B	24.58		57B	26.26
18	18S	29.67	**38**	38S	21.63	**58**	58S	25.33
	18B	31.04		38B	25.42		58B	25.92
19	19S	27.89	**39**	39S	24.82			
	19B	28.55		39B	24.90			
20	20S	27.24	**40**	40S	29.95			
	20B	28.10		40B	30.73			

Note:
S: Surface layer, 2m
B: Bottom layer, ≥ 100m

Table 6.2. SO_4^{2-} - Concentration (mg/L).

Station	Samples	SO_4^{2-} (mg/L)	Station	Samples	SO_4^{2-} (mg/L)	Station	Samples	SO_4^{2-} (mg/L)
1	1S	2.68	**21**	21S	2.62	**41**	41S	2.41
	1B	2.83		21B	2.63		41B	2.41
2	2S	2.63	**22**	22S	2.58	**42**	42S	2.57
	2B	2.78		22B	2.74		42B	2.75
3	3S	2.62	**23**	23S	2.50	**43**	43S	2.64
	3B	3.40		23B	2.63		43B	2.70
4	4S	2.61	**24**	24S	2.82	**44**	44S	2.67
	4B	2.79		24B	2.82		44B	2.63
5	5S	2.66	**25**	25S	2.86	**45**	45S	2.47
	5B	2.73		25B	2.87		45B	2.49
6	6S	2.44	**26**	26S	2.40	**46**	46S	2.77
	6B	2.54		26B	2.51		46B	2.77
7	7S	2.44	**27**	27S	2.38	**47**	47S	2.73
	7B	2.46		27B	2.58		47B	2.73
8	8S	2.59	**28**	28S	2.88	**48**	48S	2.69
	8B	2.63		28B	2.70		48B	2.75
9	9S	2.64	**29**	29S	2.97	**49**	49S	2.81
	9B	2.66		29B	2.72		49B	2.82
10	10S	2.59	**30**	30S	2.88	**50**	50S	2.86
	10B	2.63		30B	2.93		50B	2.97
11	11S	2.64	**31**	31S	2.42	**51**	51S	2.80
	11B	2.67		31B	2.59		51B	2.80
12	12S	2.59	**32**	32S	2.51	**52**	52S	2.43
	12B	2.66		32B	2.76		52B	2.51
13	13S	2.56	**33**	33S	2.88	**53**	53S	2.45
	13B	2.55		33B	2.97		53B	2.49
14	14S	2.42	**34**	34S	2.33	**54**	54S	2.43
	14B	2.51		34B	2.46		54B	2.51
15	15S	2.50	**35**	35S	2.30	**55**	55S	2.60
	15B	2.51		35B	2.46		55B	2.67
16	16S	2.62	**36**	36S	2.29	**56**	56B	2.48
	16B	2.84		36B	2.47		56B	2.60
17	17S	2.62	**37**	37S	2.19	**57**	57S	2.46
	17B	2.86		37B	2.36		57B	2.52
18	18S	2.85	**38**	38S	2.08	**58**	58S	2.43
	18B	2.98		38B	2.44		58B	2.49
19	19S	2.68	**39**	39S	2.38	***Note:***		
	19B	2.74		39B	2.39	***S: Surface layer, 2m***		
20	20S	2.62	**40**	40S	2.88	***B: Bottom layer, ≥ 100m***		
	20B	2.70		40B	2.95			

Table 7. Comparison of nutrient concentrations in the Vietnamese Waters.

NORTHERN REGION							
Name		**SiO_2 (μM)**	**PO_4^{3-}(μM)**	**NH_4^+ (μM)**	**NO_3^- (μM)**	**NO_2^- (μM)**	**SO_4^{2-} (μM)**
Surface	Average	20.16	1.37	2.84	7.76	0.32	26.97
	Max	27.00	1.79	3.88	9.87	0.52	27.87
	Min	17.68	1	1.22	5.98	0.16	25.41
Bottom	Average	24.32	2.22	2.47	8.95	0.39	28.58
	Max	46.74	3.84	3.32	11.16	0.56	35.38
	Min	17.68	1.2	1.11	7.13	0.19	25.6
MIDDLE REGION							
Name		**SiO_2 (μM)**	**PO_4^{3-}(μM)**	**NH_4^+ (μM)**	**NO_3^- (μM)**	**NO_2^- (μM)**	**SO_4^{2-} (μM)**
Surface	Average	28.63	0.91	2.60	6.85	0.21	27.41
	Max	34.82	1.25	4.44	8.81	0.60	30.96
	Min	23.92	0.74	1.11	1.95	0.04	24.73
Bottom	Average	35.90	1.35	2.34	7.90	0.22	28.15
	Max	55.58	1.9	4.10	10.68	0.58	31.04
	Min	23.92	0.88	1.13	6.47	0.11	26.08
SOUTHERN REGION							
Name		**SiO_2 (μM)**	**PO_4^{3-}(μM)**	**NH_4^+ (μM)**	**NO_3^- (μM)**	**NO_2^- (μM)**	**SO_4^{2-} (μM)**
Surface	Average	25.96	0.70	2.92	3.84	0.08	26.44
	Max	35.29	0.91	4.10	6.5	0.15	30.02
	Min	20.61	0.51	1.33	1.95	0.04	21.63
Bottom	Average	28.87	1.05	2.70	5.19	0.11	27.27
	Max	51.39	1.35	4.43	9.69	0.21	30.92
	Min	21.32	0.83	1.11	2.02	0.04	24.58

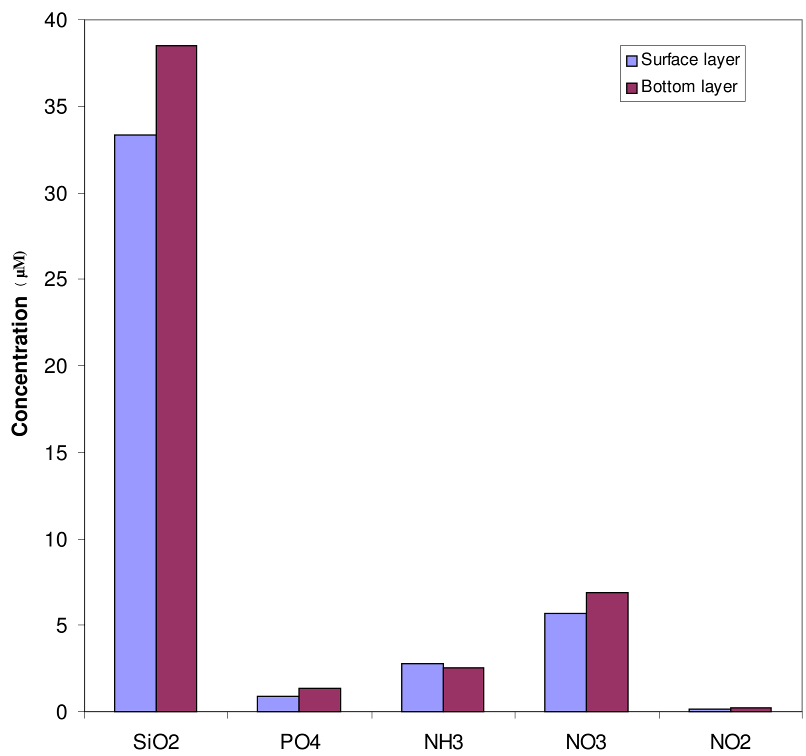


Fig. 7. Variation of 5 nutrient parameters.

Table 8.1. Comparison of nutrients in seawater.

NORTH REGION

SURFACE LAYER

Colors	**PO_4(µM)**		**SiO2(µM)**		**NO_3(µM)**		**NO_2(µM)**		**NH_4(µM)**	
Low (yellow)	2S	1.16	1S	17.69	5S	5.98	1S	0.20	1S	1.99
	8S	1.00	2S	17.69	7S	6.55	2S	0.25	7S	1.22
			4S	17.69	10S	6.52	3S	0.23	10S	1.77
			5S	17.69			7S	0.20		
			9S	18.72			8S	0.16		
			10S	18.72						
Medium (green)	1S	1.37	3S	19.74	4S	7.52	10S	0.29	2S	2.77
	3S	1.30	6S	21.8	6S	7.35			4S	2.66
	4S	1.41			9S	6.85				
	5S	1.26								
	9S	1.45								
	10S	1.32								
High (rose)	6S	1.79	7S	27.01	1S	9.87	4S	0.42	3S	3.32
	7S	1.60	8S	24.95	2S	9.79	5S	0.48	5S	3.55
					3S	9.10	6S	0.52	6S	3.88
					8S	8.10	9S	0.52	8S	3.66
									9S	3.55

BOTTOM LAYER

Colors	**PO_4(µM)**		**SiO_2(µM)**		**NO_3(µM)**		**NO_2(µM)**		**NH_4(µM)**	
Low (yellow)	3B	1.20	1B	18.72	4B	7.74	7B	0.19	7B	1.11
	4B	1.57	2B	17.69	5B	7.74			10B	1.33
	5B	1.50	3B	17.69	6B	7.13				
	10B	1.56	4B	18.72	7B	8.02				
			5B	17.69	10B	8.00				
Medium (green)	7B	1.85	6B	30.17	8B	9.55	1B	0.34	1B	1.99
	9B	1.80	7B	30.17	9B	9.13	3B	0.40	4B	2.44
			9B	24.95			4B	0.39	9B	2.44
							6B	0.41		
							9B	0.38		
							10B	0.34		
High (rose)	1B	3.47	8B	46.75	1B	11.16	2B	0.43	2B	3.11
	2B	3.05	10B	55.60	2B	10.19	5B	0.45	3B	2.77
	6B	2.38			3B	10.87	8B	0.56	5B	3.32
	8B	3.84							6B	3.11
									8B	3.11

Table 8.2a. Comparison of nutrients in seawater.

MIDDLE REGION

SURFACE LAYER										
Colors	**PO_4(μM)**		**SiO2(μM)**		**NO_3(μM)**		**NO_2(μM)**		**NH_4(μM)**	
Low (yellow)	17S	0.76	11S	24.95	18S	4.63	18S	0.11	15S	1.66
	19S	0.86	12S	24.95	30S	1.95	19S	0.15	16S	1.33
	21S	0.76	27S	24.95	31S	5.76	20S	0.16	24S	1.11
	24S	0.80	30S	24.95			21S	0.17	26S	1.11
	25S	0.78	31S	23.93			22S	0.12		
	26S	0.74	32S	23.93			23S	0.18		
	28S	0.82					25S	0.10		
	29S	0.85					26S	0.18		
	30S	0.80					27S	0.15		
	31S	0.76					28S	0.12		
	32S	0.80					30S	0.04		
							31S	0.10		
							32S	0.18		
Medium (green)	13S	0.90	15S	27.01	11S	6.21	11S	0.33	11S	1.99
	14S	1.05	16S	29.04	12S	6.61	12S	0.41	12S	2.44
	15S	1.09	17S	29.61	13S	6.97	15S	0.28	14S	2.88
	18S	1.05	18S	30.17	14S	6.92	16S	0.22	17S	2.22
	22S	0.95	19S	27.01	17S	6.87	17S	0.21	18S	2.44
	23S	0.90	21S	30.17	22S	6.63	24S	0.23	23S	2.11
	27S	0.88	23S	30.17	25S	6.00	29S	0.19	25S	2.77
			24S	30.64	29S	6.37			27S	1.99
			26S	30.17	32S	6.90			30S	2.44
			29S	26.45					31S	2.27
									32S	1.99
High (rose)	12S	1.25	13S	34.83	15S	7.37	13S	0.60	13S	3.55
	16S	1.12	14S	31.19	16S	7.50	14S	0.45	19S	4.10
	20S	1.25	20S	31.19	19S	7.44			20S	3.55
			22S	31.19	20S	7.76			21S	3.33
			25S	32.22	21S	8.32			22S	3.77
			28S	31.19	23S	8.10			28S	3.66
					24S	7.94			29S	4.44
					26S	8.81				
					27S	7.74				
					28S	7.85				

Table 8.2b. Comparison of nutrients in seawater.

MIDDLE REGION

BOTTOM LAYER

Colors	PO_4(µM)		SiO_2(µM)		NO_3(µM)		NO_2(µM)		NH_4(µM)	
Low (yellow)	21B	0.88	28B	27.01	12B	6.89	18B	0.12	16B	1.77
	30B	1.05	29B	23.93	13B	6.94	20B	0.16	17B	1.77
	31B	0.99	32B	27.01	18B	6.68	21B	0.14	23B	1.33
	32B	1.00			23B	6.47	22B	0.14	26B	1.33
					27B	7.13	23B	0.11	27B	1.33
					29B	6.68	24B	0.14	32B	1.33
					30B	6.50	25B	0.18		
					31B	6.56	27B	0.13		
							28B	0.16		
							30B	0.14		
							31B	0.15		
							32B	0.13		
Medium (green)	11B	1.23	11B	31.19	15B	8.27	11B	0.33	11B	1.99
	12B	1.47	12B	33.25	16B	8.09	15B	0.31	12B	2.88
	13B	1.53	13B	31.19	17B	8.27	16B	0.27	13B	2.44
	14B	1.69	14B	29.61	20B	8.42	17B	0.21	15B	1.99
	15B	1.73	15B	33.25	21B	8.00	19B	0.19	18B	1.99
	16B	1.26	17B	37.43	22B	8.47	26B	0.19	19B	2.44
	17B	1.30	19B	32.22	24B	8.61	29B	0.20	22B	2.44
	19B	1.52	20B	32.22	28B	8.06			24B	2.44
	20B	1.90	21B	32.22	32B	7.89			28B	2.33
	22B	1.30	22B	32.22					30B	1.99
	23B	1.42	26B	32.22					31B	2.11
	24B	1.12	27B	33.80						
	25B	1.53	30B	29.04						
	26B	1.32	31B	30.17						
	27B	1.05								
	28B	1.10								
	29B	1.42								
High (rose)	15B	1.73	16B	55.60	11B	10.68	12B	0.58	14B	3.55
	18B	1.84	18B	55.60	14B	9.00	13B	0.42	20B	4.10
			23B	49.91	19B	8.81	14B	0.51	21B	3.11
			24B	49.91	25B	8.71			25B	3.88
			25B	51.09	26B	8.71			29B	3.11

Table 8.3a . Comparison of nutrients in seawater.

SOUTH REGION

SURFACE LAYER										
Colors	**PO_4(μM)**		**SiO2(μM)**		**NO_3(μM)**		**NO_2(μM)**		**NH_4(μM)**	
Low (yellow)	36S	0.55	33S	22.82	34S	2.76	34S	0.05	40S	1.33
	38S	0.64	34S	21.80	41S	2.37	41S	0.04	41S	1.99
	41S	0.59	36S	22.82	43S	2.16	49S	0.05	42S	1.77
	42S	0.59	39S	21.32	49S	2.87	50S	0.04	43S	1.99
	44S	0.56	40S	20.61	50S	1.95	54S	0.05	49S	1.99
	50S	0.64	46S	22.82	54S	2.90	58S	0.05	57S	1.99
	53S	0.63	51S	21.79	58S	2.45				
	56S	0.65	56S	21.32						
	58S	0.51								
Medium (green)	33S	0.68	35S	23.93	35S	3.18	35S	0.06	33S	2.33
	34S	0.72	41S	24.95	36S	3.56	36S	0.07	34S	2.44
	35S	0.79	42S	29.04	37S	3.63	37S	0.06	35S	2.77
	37S	0.78	43S	27.01	38S	3.52	38S	0.06	36S	3.11
	39S	0.69	44S	26.53	45S	3.16	45S	0.06	39S	2.77
	40S	0.68	45S	29.61	46S	3.90	46S	0.07	51S	2.77
	43S	0.74	47S	26.53	48S	3.55	48S	0.06	53S	3.11
	45S	0.79	52S	23.93	51S	3.55	53S	0.06	55S	2.22
	46S	0.80	53S	27.01	52S	4.60	57S	0.08	56S	3.11
	47S	0.70	54S	25.95	53S	3.00				
	48S	0.82	55S	24.95	55S	4.15				
	49S	0.80	57S	23.93	56S	4.24				
	51S	0.68	58S	23.93	57S	4.24				
	52S	0.83								
	55S	0.74								
	57S	0.79								
High (rose)	54S	0.91	37S	31.19	33S	6.05	33S	0.15	37S	4.10
			38S	30.17	39S	5.73	39S	0.15	38S	4.10
			48S	32.22	40S	4.95	40S	0.09	44S	3.66
			49S	35.30	42S	6.02	42S	0.12	45S	3.11
			50S	32.22	44S	6.50	43S	0.09	46S	3.11
					47S	4.95	44S	0.12	47S	3.66
							47S	0.09	48S	3.66
							51S	0.09	50S	3.88
							52S	0.09	52S	3.77
							55S	0.09	54S	3.55
							56S	0.10	58S	3.55

Table 8.3b. Comparison of nutrients in seawater.

SOUTH REGION

BOTTOM LAYER										
Colors	**PO_4(μM)**		**SiO_2(μM)**		**NO_3(μM)**		**NO_2(μM)**		**NH_4(μM)**	
Low (yellow)	38B	0.89	37B	21.32	35B	3.34	35B	0.06	34B	1.66
	39B	0.92	39B	21.32	37B	3.79	42B	0.04	40B	1.11
	53B	0.83	40B	21.79	42B	2.02	50B	0.07	49B	1.77
			51B	23.93	50B	3.97	54B	0.06	53B	1.99
			52B	23.93	54B	2.87	58B	0.06	57B	1.77
			54B	24.98	55B	3.68				
			55B	25.98	56B	2.31				
			56B	24.95	57B	3.45				
					58B	2.87				
Medium (green)	33B	1.05	33B	29.04	34B	5.65	34B	0.10	33B	2.11
	35B	0.99	34B	27.01	36B	4.74	36B	0.11	35B	2.32
	36B	1.00	35B	29.04	38B	4.92	37B	0.08	36B	2.11
	37B	1.10	36B	26.53	39B	6.65	38B	0.09	38B	2.11
	40B	1.00	41B	31.10	40B	6.00	40B	0.10	39B	2.44
	41B	1.05	42B	31.19	41B	4.56	41B	0.08	42B	2.33
	43B	1.00	43B	32.22	43B	5.15	43B	0.10	43B	2.77
	44B	0.94	44B	29.04	45B	6.44	44B	0.14	47B	3.11
	45B	0.98	45B	30.17	48B	6.48	45B	0.12	48B	3.11
	46B	1.03	46B	29.04	49B	5.06	46B	0.12	51B	2.77
	47B	0.99	47B	29.04	51B	6.19	47B	0.13	54B	2.77
	50B	1.00	48B	29.04	52B	6.16	48B	0.12	56B	2.44
	51B	1.04	49B	32.22			49B	0.08		
	52B	0.91	50B	33.80			55B	0.08		
	54B	1.15	53B	27.01			56B	0.12		
	56B	1.04	57B	33.25			57B	0.10		
	57B	1.11	58B	31.25						
	58B	0.92								
High (rose)	34B	1.35	38B	51.41	33B	7.94	33B	0.17	37B	3.55
	42B	1.23			44B	7.60	39B	0.21	41B	3.29
	48B	1.28			46B	6.81	51B	0.17	44B	3.32
	49B	1.20			47B	6.71	52B	0.15	45B	3.32
	55B	1.26			53B	9.69	53B	0.19	46B	3.66
									50B	3.32
									52B	3.55
									55B	4.43
									58B	3.11

Table 9.1. Comparison of SO_4 concentration.

NORTH REGION

	Surface layer		Bottom layer	
	Position	*Concentration*	*Position*	*Concentration*
Low (yellow)	6S	25.41	6B	26.46
	7S	25.42	7B	25.60
			8B	27.43
			9B	27.72
			10B	27.34
Medium (green)	8S	26.98	2B	28.90
	10S	26.99	5B	28.38
			4B	29.05
High (Rose)	1S	27.87	1B	29.51
	2S	27.35	3B	35.38
	3S	27.30		
	4S	27.19		
	5S	27.66		
	9S	27.53		

Table 9.2. Comparison of SO_4 concentration.

MIDDLE REGION

	Surface layer		Bottom layer	
	Position	*Concentration*	*Position*	*Concentration*
Low (yellow)	13S	26.65	11B	27.79
	14S	25.19	12B	27.68
	15S	26.04	13B	26.51
	22S	26.88	14B	26.12
	23S	26.07	15B	26.08
	26S	26.02	21B	27.41
	27S	24.73	23B	27.38
	31S	25.30	26B	26.09
	32S	26.10	27B	26.88
			31B	26.96
Medium (Green)	11S	27.45	19B	28.55
	12S	27.01	20B	28.10
	16S	27.30	22B	28.48
	17S	27.25	32B	28.75
	19S	27.89		
	20S	27.24		
	21S	27.30		
High (Rose)	18S	29.67	16B	29.56
	24S	29.33	17B	29.79
	25S	29.73	18B	31.04
	28S	28.13	24B	29.38
	29S	28.30	25B	29.83
	30S	30.00	28B	30.02
			29B	30.96
			30B	30.45

Table 9.3. Comparison of SO_4 concentration.

SOUTH REGION

	Surface layer		Bottom layer	
	Position	*Concentration*	*Position*	*Concentration*
Low (yellow)	34S	24.28	34B	26.63
	35S	23.93	35B	25.59
	36S	23.80	36B	25.67
	37S	22.84	37B	24.58
	38S	21.63	38B	24.90
	39S	24.82	39B	25.13
	41S	25.13	41B	25.13
	42S	26.73	44B	27.34
	45S	25.67	45B	25.92
	52S	25.26	52B	26.08
	53S	25.48	53B	25.93
	54S	25.27	54B	26.14
	56S	25.84	55B	27.84
	57S	25.66	56B	27.10
	58S	25.33	57B	26.26
			58B	25.92
Medium (Green)	43S	27.48	42B	28.52
	44S	27.84	43B	28.14
	46S	28.81	46B	28.47
	47S	28.47	47B	28.46
	48S	28.02	48B	28.67
	55S	27.04	49B	29.32
			51B	29.18
High (Rose)	33S	30.02	33B	30.91
	40S	29.95	40B	30.73
	49S	29.27	50B	30.92
	50S	29.78		
	51S	29.10		

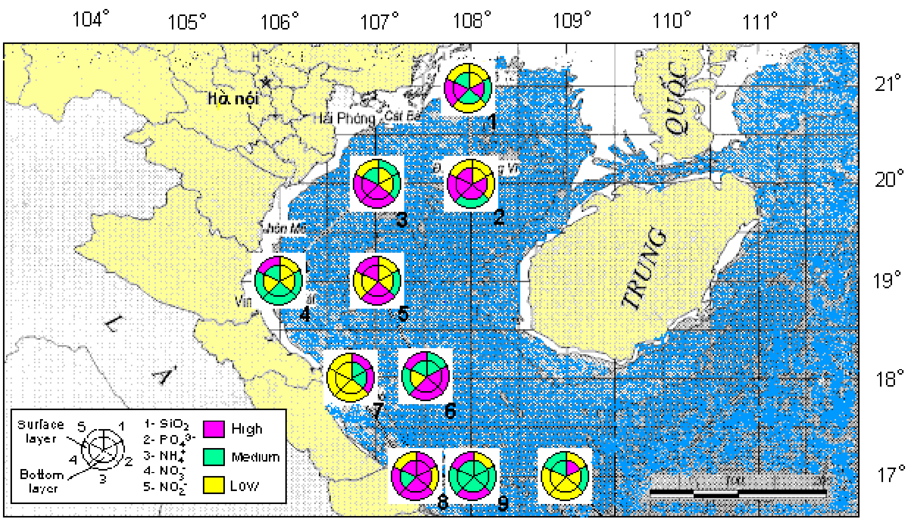


Fig. 8.1. Comparison of nutrient concentration in the northern region.

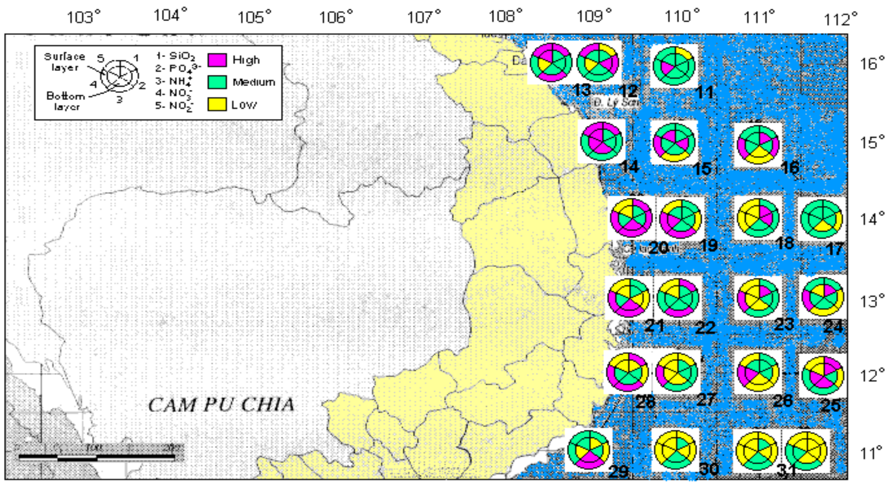


Fig. 8.2. Comparison of nutrient concentration in the middle region.

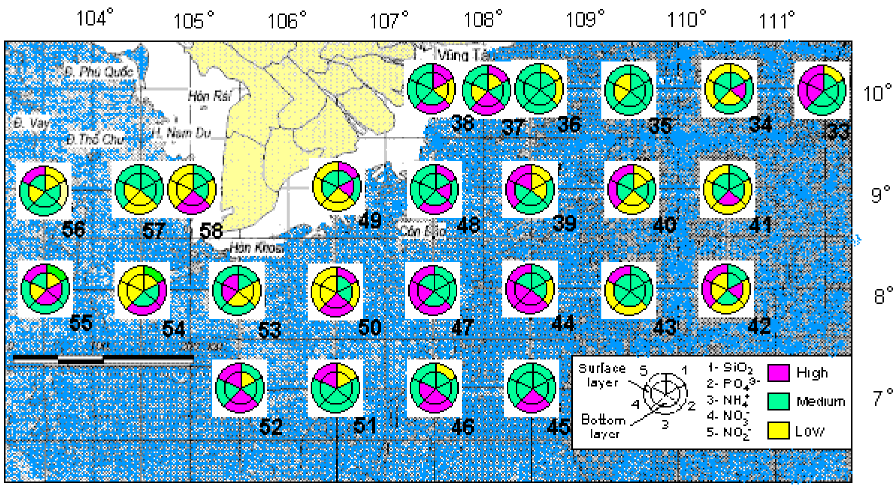


Fig. 8.3. Comparison of nutrient concentration in the southern region.

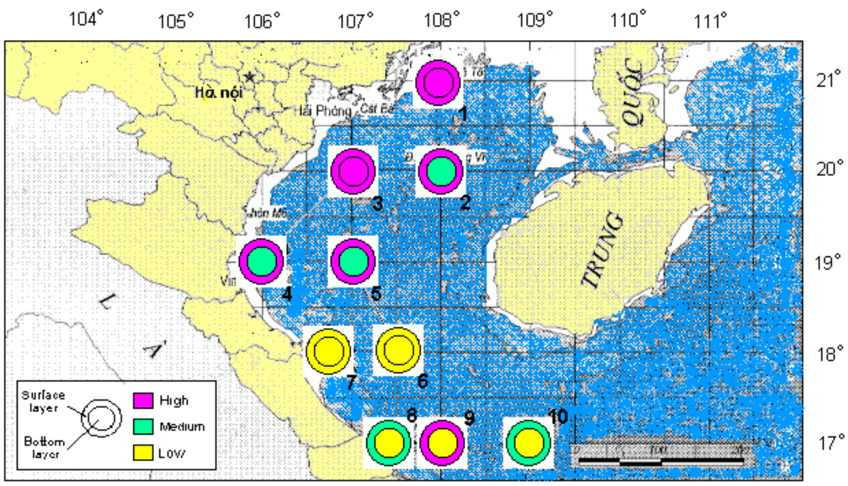


Fig. 9.1. Comparison of SO_4^{2-} concentration in the northern region.

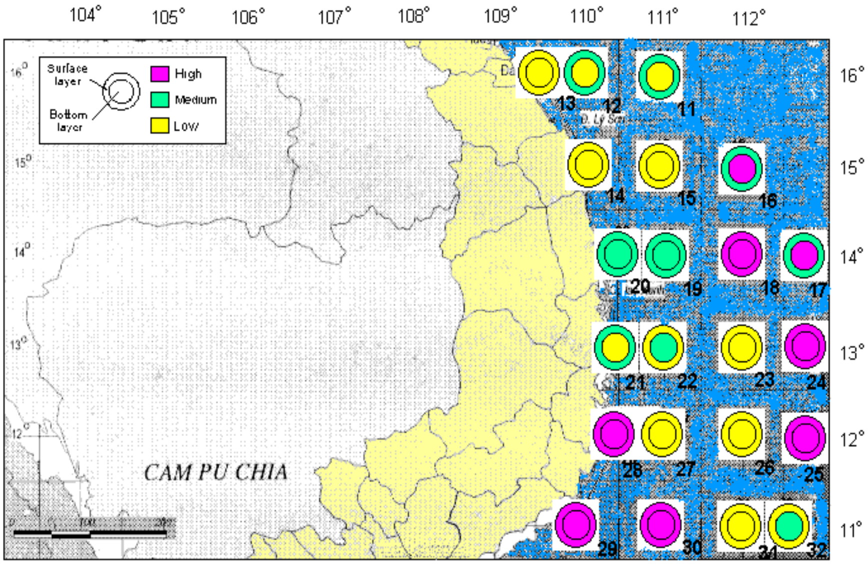


Fig. 9.2. Comparison of SO_4^{2-} concentration in the middle region.

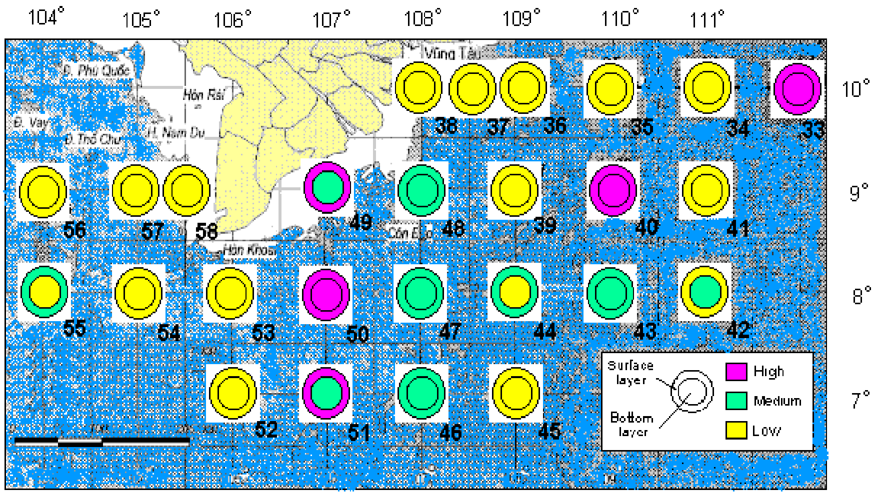


Fig. 9.3. Comparison of SO_4^{2-} concentration in the southern region.

Conclusion

This is the first result we have got through the sampling procedure in summer of 1999. Higher silica, nitrate and phosphate concentrations are found in deeper water than surface water. The same observation of nutrients was found in several areas in the South China Sea. All most all of nutrients are fit to Vietnam Standard TCVN –1995 for marine- and aquaculture and in some stations it also fit the standard for swimming beach.

Studies on the relationship between nutrient concentration and other oceanographic parameters and then the fisheries resources in this study area are needed.

The coming sampling time is expected in the year of 2000 for further results to update the data in this report.

Acknowledgements

The Authors would like to thank sincerely the Director, Ph.D. Dao Manh Son - Research Institute of Marine Products Hai Phong for useful documents and Ph.D. Nguyen Kien Cuong for report manuscript preparation as well as all colleagues in the Department of Analytical Science and Technology (Institute of Chemistry, NCST of Vietnam).

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Temperature, Salinity, Dissolved Oxygen and Water Masses of Vietnamese Waters

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ABSTRACT

During April and May 1999, An MV SEAFDEC cruise was carried out in Vietnamese waters for the SEAFDEC Interdepartmental Collaborative Research Program on Marine Fishery Resources. Data on temperature, salinity and dissolved oxygen concentration of water in the area were collected using the Integrated CTD instrument. The survey period was in April to May which is the transition period between the Northeast monsoon to the Southwest monsoon, the feature from the study seem to mix under the influence of both monsoon seasons. The Northern part of the survey was still under the influence of the Northeast Monsoon as shown by the lower temperatures and higher salinity water of water along the coast from Da Nang to Nha Trang than those off shore. In the southern part of the area, the Southwest monsoon started to prevail as shown by the occurrence of weak upwelling off the Nha Trang coast, the shallow mix layer and the covering of mixed layer of the outer Gulf of Thailand station by the Thailand Gulf mixed layer water. The runoff from the Red and the Mekong River also plays an important role in the characteristics of the water in the study area, as shown from the distribution of low salinity and low oxygen off coast near the river. There was an intrusion of subsurface water (10-15 m) from off the Mekong River station to the subsurface water of station no.56 and 57 in the outer Gulf of Thailand. Temperatures between 29.5-30°C and salinity of about 33.2-33.5 PSU characterize the water.

Six water masses, Continental shelf water, Open sea water, Maximum salinity water, Seasonal thermocline water, Permanent thermocline water and Deep water, were found during the survey period.

Key words: Vietnamese water ,Temperature, Salinity, Dissolved Oxygen, Water Masses, SW Monsoon, NE Monsoon

Introduction

This study is the forth area in the series of the Interdepartmental Collaborative Research Program on the Marine Fisheries Resources in the South China Sea, which has been continuously carried out since 1995. The program aims to collect and analyze the information necessary for management through collaboration among Southeast Asian Fisheries Development member countries and other organizations concerned.

The survey was conducted off Vietnam by MV.SEAFDEC between 30 April and 29 May 1999. The study area covers from latitude 7 °N to 21 °N and Longitude 103 °E to 112 °E. in the western part of the South China Sea (SCS).

The seasonally reversing monsoon winds play an important role in the hydrological features and the general circulation of the SCS. (Uu and Brankart, 1997, Shaw and Chao, 1994,etc.) The beginning of northeast monsoon (winter season) is in September in the sea north of 20 °N while south of that latitude, the southwest monsoon still prevails. In October, the northeast monsoon expands southward to diminish the southwest monsoon. The northeast monsoon reaches its maximum strength and covers the entire area in December finishing in April. The first appearance of the southwest monsoon in the central South China Sea basin is in May and expands to cover the entire basin during July and August. Ocean circulation off the coast of Vietnam is the most significant in response to the changing wind. During the northeast monsoon, a strong southerly current develops along the coast of Vietnam with the main thermocline deeper nearer the coast than offshore, during the southwest monsoon the current of the area become northeasterly (Shaw and Chao, 1994).

Materials and Methods

Data were collected at Fifty-eight oceanographic stations (Fig.1) measuring conductivity, temperature and dissolved oxygen using the onboard Falmouth Integrated CTD instrument. At station no. 42-44, there were no CTD data, because of a problem with the connection between the sensor and the winch. According to the manufacturer's specification, the instrument has an accuracy of ±0.003mmhn. , ±0.003 °c, ±0.03% and ±100 ppm for conductivity, temperature, pressure, and dissolved oxygen respectively. The CTD was equipped with twelve 2.5 liter bottles for *in situ* water sampling. Water samples were determined for dissolved oxygen by a modification of the Winkler procedure (Parsons, Maita and Lilli, 1984) for validating with oxygen sensor data. The CTD unit was last sent for calibration and deck testing by the manufacturer in April 1997.

The maximum depth for CTD casting was about 1500 meters depth, because of the limitation of the length of armored sea cable. The efficiency of the oxygen sensor is limited in shallow water, the lowest dissolved oxygen data collecting depth was not reached nor the depth for temperature and salinity.

Raw counts of each variable were calculated and raw data were average at every 1 dbar interval, for reducing data noise, using the FSI post acquisition data analysis software. All CTD data were checked using quality control methods by the excessive gradient checks method of the National Oceanographic data center.

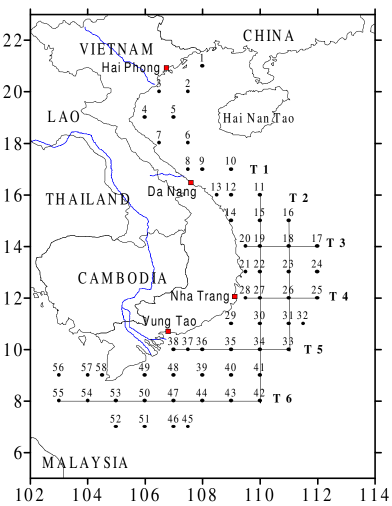

Fig. 1. Oceanographic stations location and six selected transects.

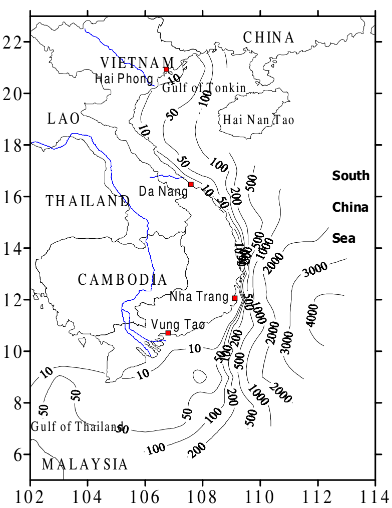

Fig. 2. Bottom topography of the study area.

Results and Discussions

The topography of the area, which interpolated from echo sounding data, was as shown in Fig. 2. with board shelves shallower than 100 m, the maximum depth reaching about 4000 m.

The Distribution of Temperature, Salinity and Dissolved Oxygen

Temperature, salinity and dissolved oxygen of surface water (5 m) was between 24.04 to 30.31 °C, 30.35 to 33.97 PSU and 3.71 to 4.63 ml/l with the average about 28.21 °C, 33.04 PSU and 4.01 ml/l respectively. Low temperatures were found in the high latitude area from latitude 20 to 21 °N. Water temperature increases following the decrease of latitude (Fig. 3). Low salinity water was found near the Red and the Mekong River mouth (Fig.4), these are influenced by river run off.

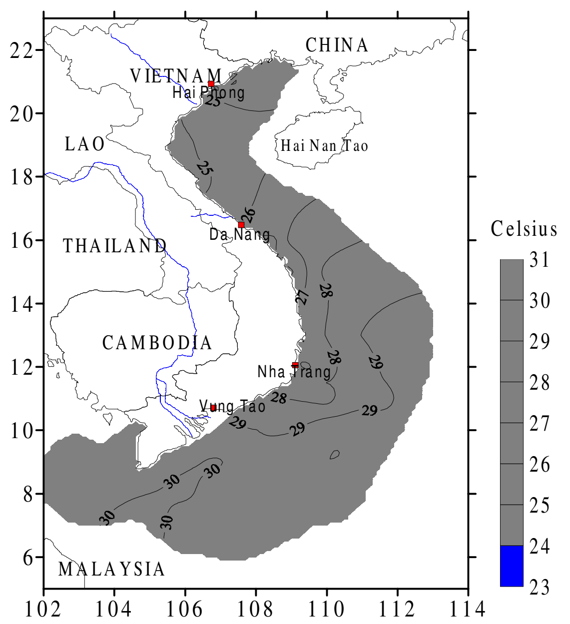

Fig. 3. Temperature at 5 m depth.

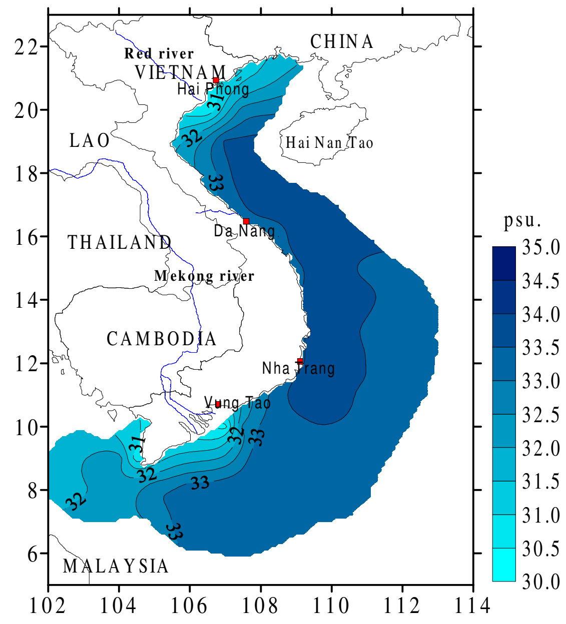

Fig. 4. Salinity at 5 m depth.

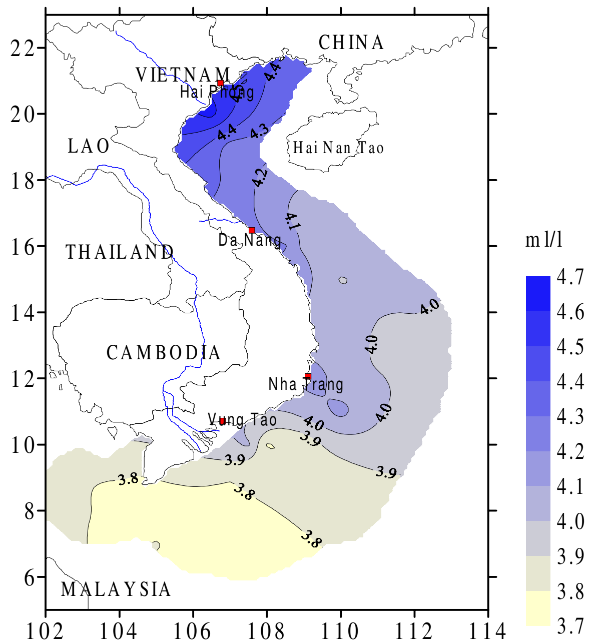

Fig. 5. Dissolved oxygen at 5 m depth.

Water temperatures in the coastal area from Da Nang to Nha Trang from the surface to 50 meters depth were lower than off shore by 0.5-2.5 °C (Fig.3 and 6 Transect 4), while salinity distribution shows a pattern like a tongue of more saline water from north of Da Nang to the coast of Nha Trang (Fig.4). The 33.5 PSU isohaline and 29 °C isotherm at the surface closely matched (Fig.3 and 4), this shows the area of the water mass that is distributed from the North under the influence of the latter period of the Northeast monsoon wind. Generally, the Northeast monsoon will induce some colder water to flow from the north into the coastal area (Lafond, 1963 and Marine Resources Study in Vietnam, Main Report, 1998). This coastal water contains more dissolved oxygen, more nutrient and dissolved organic substances and commonly has a higher concentration of plankton, benthos and fish than off shore water (Lafond, 1963)

The cross section plot (Fig.6 and 7) presents a pattern of weak upwelling in the area of off Nha Trang with lower temperatures and higher salinity than the nearby areas. This is the same as that found by Uu and Brankart, 1997 and Lafond, 1963 that during the Southwest monsoon season the occurrence of upwelling is at a maximum at the coast of Vietnam near Nha Trang province (from 11 ° to 15 ° N and westward of 110 °E). This upwelling carries high salinity and low temperature water rising from the seasonal thermocline. At the same time, surface current flow offshore and the continental shelf water from the Thailand Gulf mixing with low salinity waters from the Mekong river moves along the coastal line of Vietnam to 10 °30-11 °N. The hydrological front formed between those two waters determines a high level of biological production and fish stocks in the southern shelf of Vietnam.

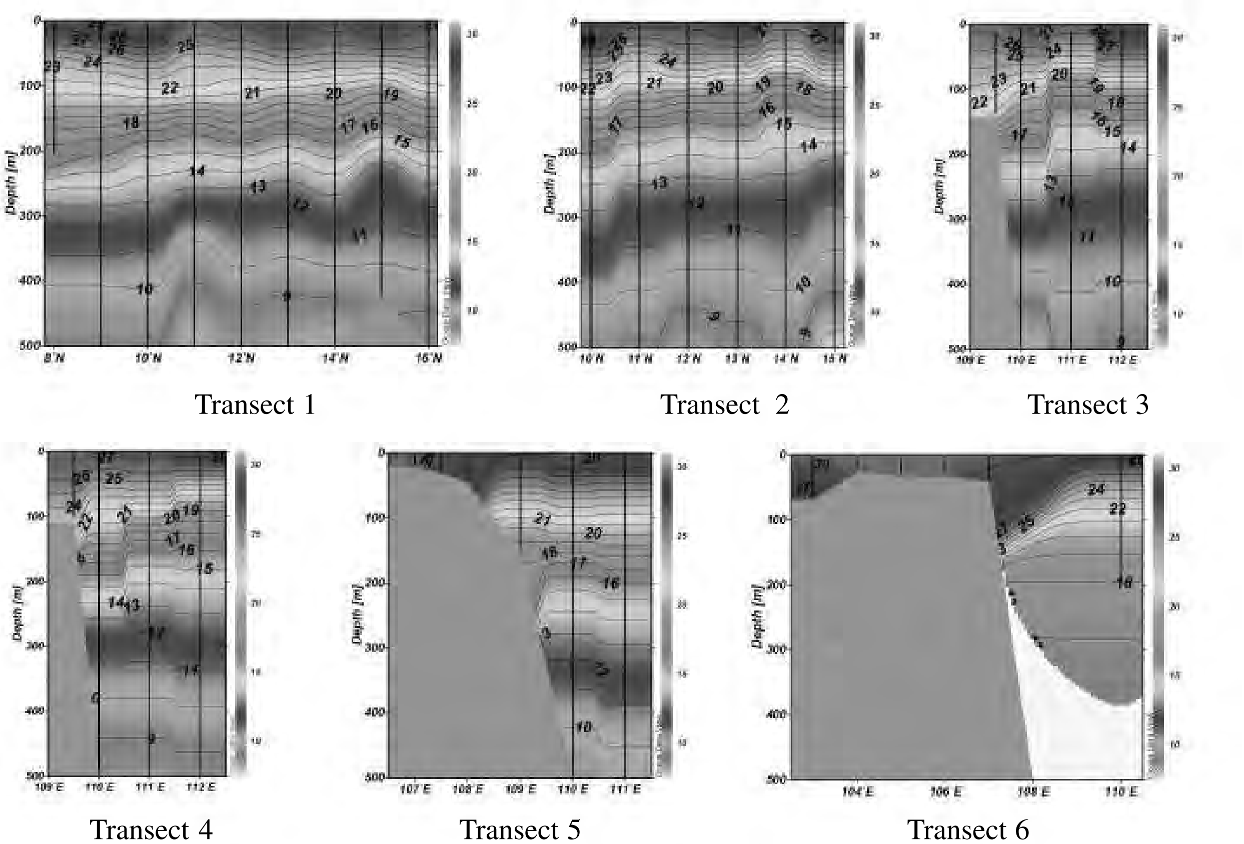

Fig. 6. Temperature (°C) along a section of transect 1 to 6.

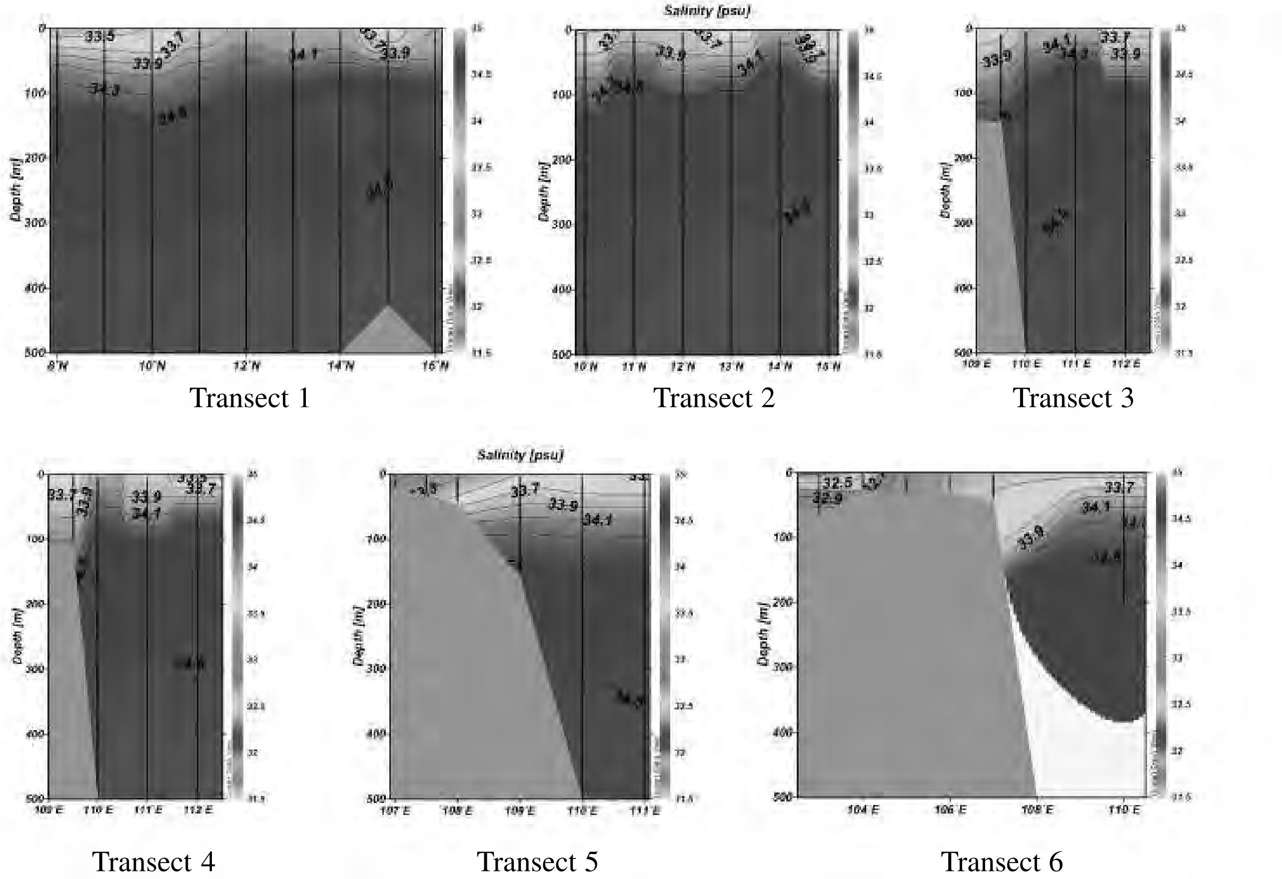

Fig. 7. Salinity (PSU) along a section of transect 1 to 6.

The most prominent features of dissolved oxygen distribution in the upper ocean waters were the highest concentration at the northern part and the lowest concentration in front of Mekong River mouth from the surface down to the 25-meter depth (Fig.5 and 8). The highest dissolved oxygen concentration area coincide with the low temperature area while low dissolved oxygen concentrations were found in front of the Mekong Delta which should be an influence of the high decomposition rate of organic matter and nutrient from the river.

Vertical profiles of temperature, salinity and dissolved oxygen show that the mixed layers of the area were shallow, between 15-50 m from surface (The catalogue of Oceanographic Data in the South China Sea: Vietnamese Water, 2000). This shallow homogeneous layer was found only during the southwest monsoon. During the Northeast monsoon, the homogeneous layer is at 70 to 90 m.

The profile of station no.56 and 57 were different from the usual (st. 53 show as a common pattern). The temperatures were increasing at a depth of about 25 m and 20 m for st. 56 and 57 respectively (Fig. 9). The characteristics of this higher temperature subsurface water and also high salinity are similar to the water that is found at 10-15 m of st. 49 and 5-10 m of st. 48, that near the Mekong River mouth, with temperatures between 29.5-30°C and salinity about 33.2-33.5 PSU (Fig. 9 and 10). The upper layer and lower layer of the high temperature subsurface water are similar to the waters of the Gulf of Thailand (Saadon *et al*, 1998). These occurrences show that water from the Mekong River mouth still has an influence on the outer Gulf of Thailand at the subsurface layer. The mixed layer of the outer Gulf of Thailand station (st 54,55,56 and 57) is above the Thailand Gulf mixed layer which is the feature of the early period of Southwest monsoon season.

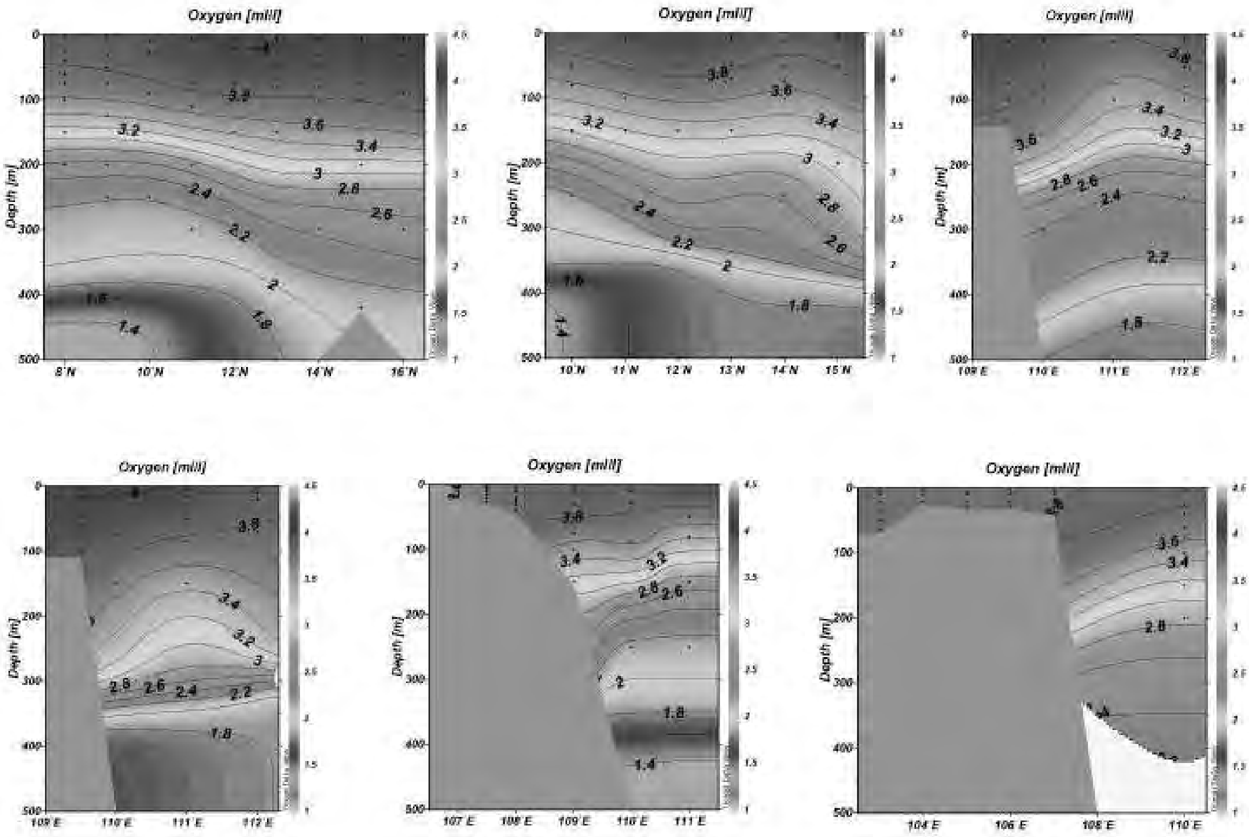

Fig. 8. Dissolved oxygen (ml/l) along a section of transect 1 to 6.

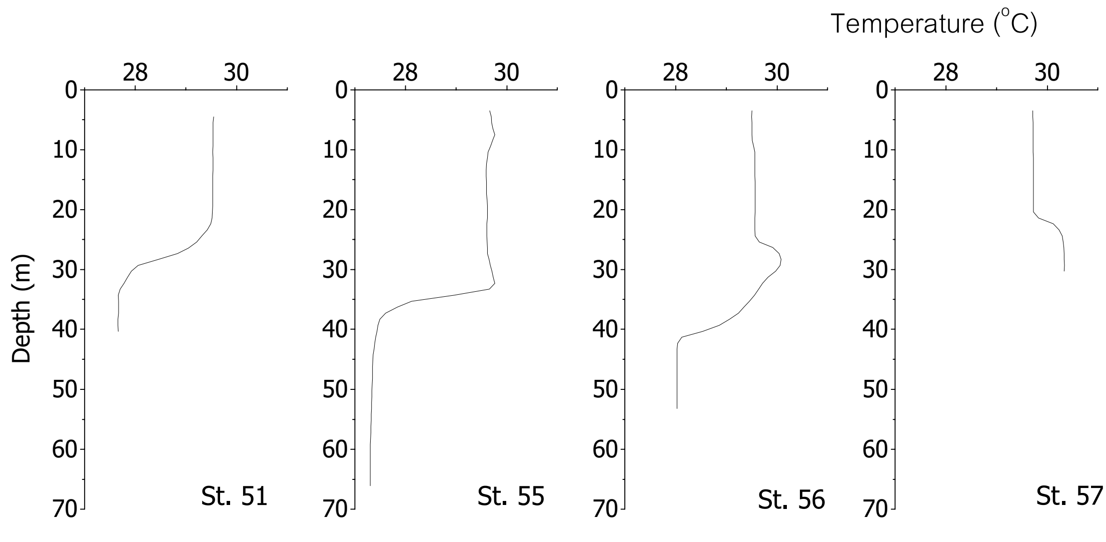

Fig. 9. Vertical profiles of temperature st.48 (near Mekong river mouth), st.51(common pattern temperature profile), st.56 and 57 (the irregular pattern temperature profile).

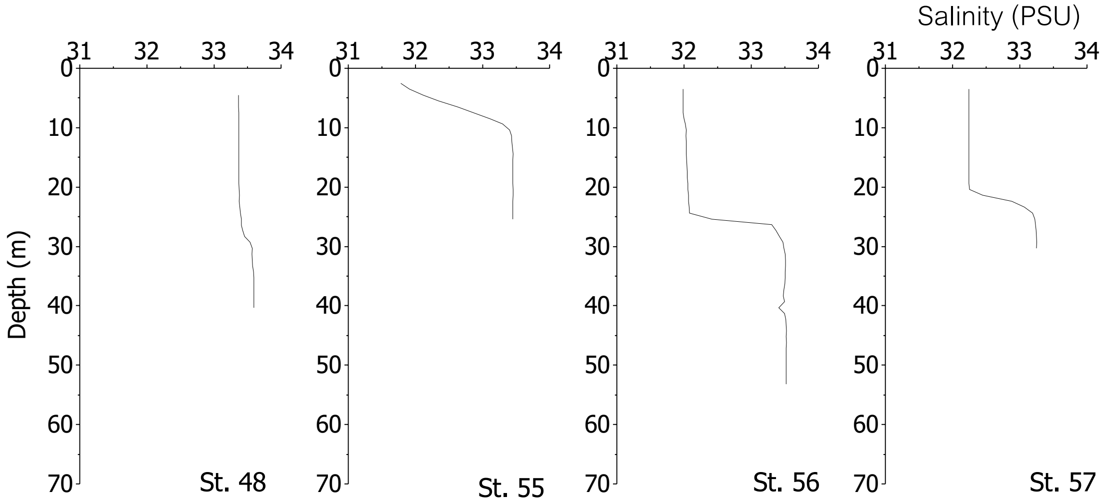

Fig. 10. Vertical profile of salinity st.48 , st. 51, st.56 and st. 57 **.**

Water Mass

The following water masses were obtained from the T-S diagram plot. The upper waters (0-50 meter depth) were covered by two distinct water masses: continental shelf water (CSW) and open seawater (OSW). The continental shelf water was characterized by temperatures between 23 to 27 °C and salinity between 31 to 33 PSU for the northern part and temperatures between 29 to 31°C and salinity between 27 to 33 PSU for the southern part (Fig.11 and 12). This water occupied the coastal area that is shallower than 30 meters with a thickness from 10 to 30 meter depending on the area. The continental shelf water of the southern part is the top layer, both in the Gulf of Thailand and in the water off the Mekong River mouth. This shows the exchange between these two areas.

The open sea waters, in the region where the depth is greater than 40 m, are characterized by temperatures between 25 to 29 °C and salinity between 33 to 34 PSU. This water mass occupies about 70% of the upper layer of the survey area (Fig. 12) and from the surface down to about 50 meters.

There are the other four water masses: the seasonal thermocline water, the maximum salinity water (MSW) , the permanent thermocline water and deep water. Seasonal thermocline water occupied the levels between 50 to 150 meter depth of the entire region that is deeper than 100 meters. The temperatures of this water is vast varying from 20 to 27 °C at different depths while the salinity is stable in the range of 34 to 35 PSU. The maximum salinity water was characterized by temperatures between 15-20 °C and salinity greater than 34.5 PSU. This water is located under the seasonal thermocline, varying in the range of 100 to 200 meter depth. The permanent thermocline water was under the MSW at 180 to 400 meter depth, with temperatures between 10 to 15 °C and the salinity between 34 to 35 PSU (Fig.11).

The last water mass is deep water (DW), located at a depth greater than 900 meter, its temperature was between 2.5 to 5 °C with a salinity between 34 to 35 PSU (Fig.11).

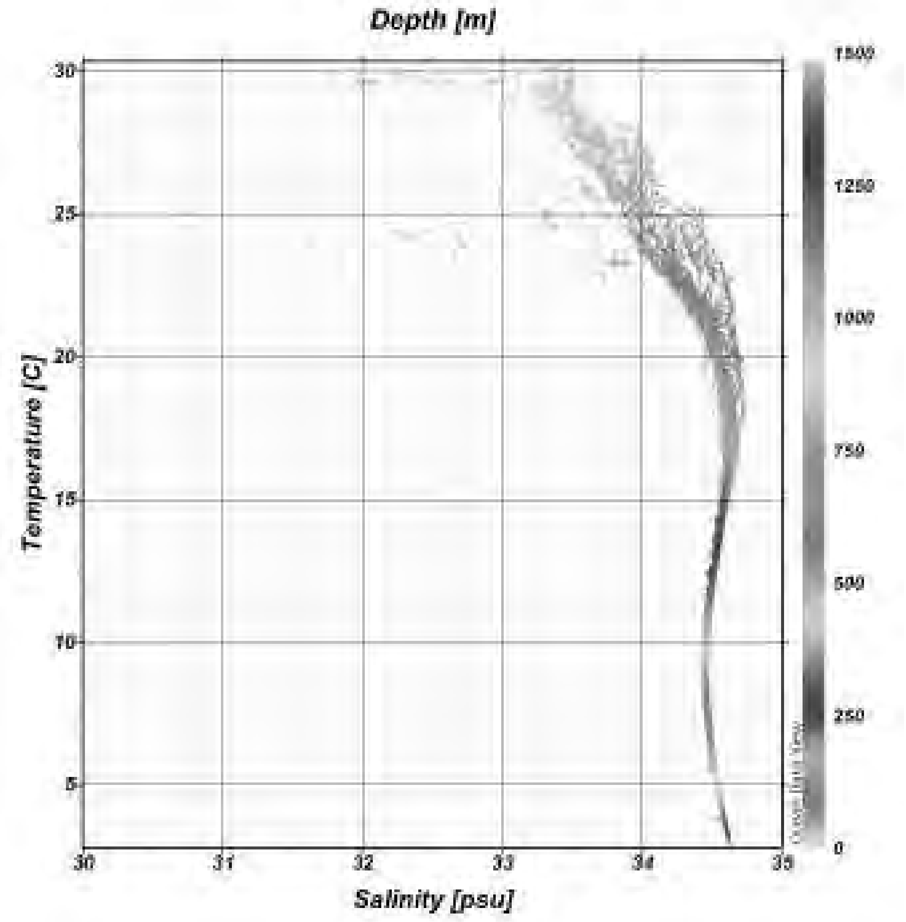

Fig. 11. TS-diagram of all stations.

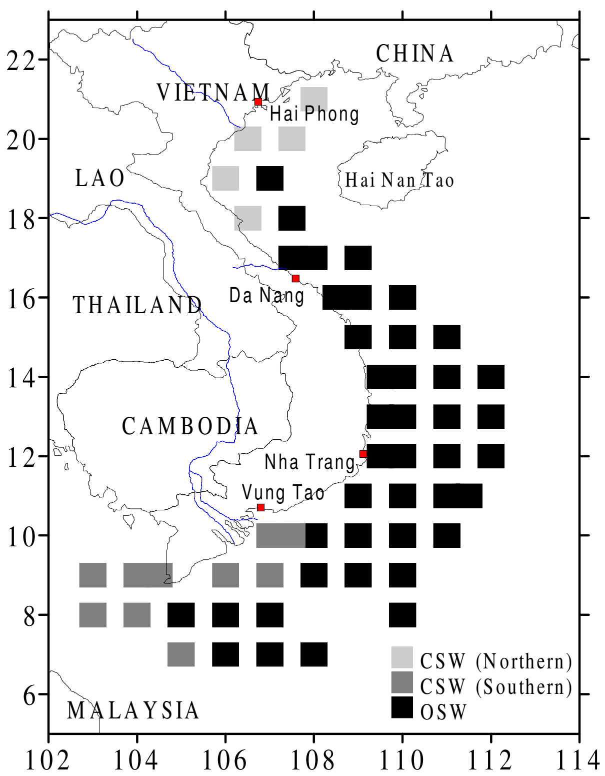

Fig. 12. Distribution of water mass in the upper area.

Conclusion

Since the survey period is in April to May which is the transition period from Northeast monsoon to Southwest monsoon winds in the area, the feature of the study seem to mix under the influence of both monsoon seasons. In this survey, the Northern part of the survey still had an influence from the Northeast Monsoon as shown by the lower temperatures and higher salinity water along the coast from Da Nang to Nha Trang than those off shore. The relative surface current plot from acoustic Doppler current indicator as installed on board MV. SEAFDEC also confirm the current direction of the northern area still flowing southward (Fig.13). The southern part, the Southwest monsoon started to prevail as shown by the occurrence of upwelling off Nha Trang, the shallow mixed layer and the covering of mixed layer of the outer Gulf of Thailand station by the Thailand Gulf mixed layer water.

The runoff from the Red and the Mekong Rivers are another factor that influences the water characteristics off Vietnam, as shown from the low salinity water off the coasts of the Red and Mekong River mouths (Fig.4) and low dissolved oxygen in front of Mekong Delta which is probably an influence of the high decomposition rate of organic matter and nutrient from the river.

The characteristics of upper layer water (0-50 meter) of southern Vietnam and in the outer Gulf of Thailand was quite similar that shows an exchange between the Gulf of Thailand water and the South China Sea water. For this survey there was an intrusion of subsurface water (10-15 m) from the Mekong River station to the subsurface water of station no.56 and 57. The water characterized by temperatures between 29.5-30°C and salinity about 33.2-33.5 PSU.

Six water masses, Continental shelf water, Open sea water, Maximum salinity water, Seasonal thermocline water, Permanent thermocline water and Deep water, were found during the survey period.

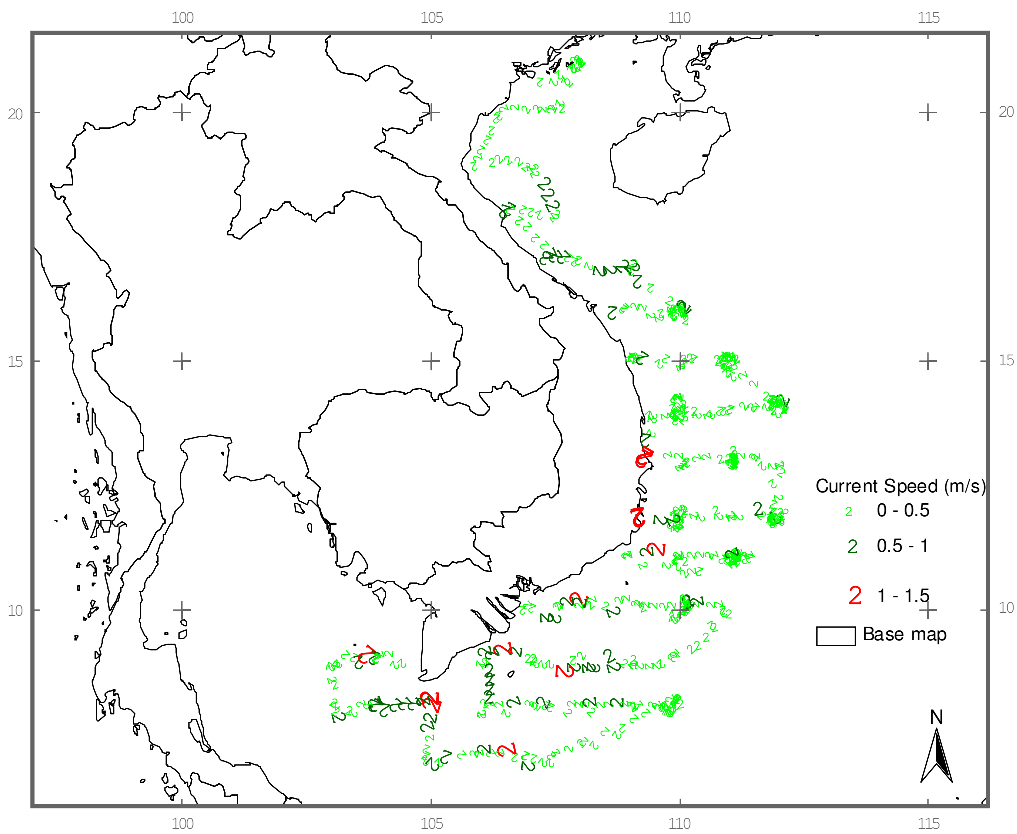

Fig. 13. Surface current along the cruise track from dropper current indicator.

Acknowledgments

We thank the captain and crew of MV. SEAFDEC for their professional and enthusiastic support during the cruise. Thanks Pattarajit Kaewnuratchadasorn for doing quality control to the Oceanographic data . We also thank Mr. W.R.B. Elstow for his comment and English correction.

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Climatological Regime and Weather Condition Occurred on the Cruise Expedition (May 1999) on Vietnam Continental Shelf

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ABSTRACT

The report is considered in two parts as climatological regime in which the most of meteorological parameters are summarized in its climatological conditions based on long time series of data and the exact weather phenomenon occurred on the area during the time of the expedition. In doing such study we have used two kinds of data, one is climatological data collected during the recent 30 years on the stations located along the Vietnam coast and islands, another is data collected during the time of present cruise expedition. The final consideration will reveal the variation of the weather condition in comparison with the climatological characteristics of each meteorological parameters.

The cruise crossing expedition comprises 58 points expanding throughout on Vietnam continental shelf. The study area can be divided into 6 areas depending on the geographical and hydro- meteorological features of each region. We try to describe the climatological regime in each region in particular and the weather condition of the whole area during the time of cruise exploitation.

Key words: Climatological regime: The average conditions of the weather
Meteorological features: The Atmospheric Characters, Areas: Zoning regions

Introduction

During 30 April-29 May 1999 the Cruise of Southeast Asian Fisheries Development Center carried out an joint expedition on continental shelf of Vietnam. In doing description of weather conditions occurred on the area of expedition, we therefore have some comparisons with the basic climatological data. 58 oceanographic survey stations cover almost Vietnam continental shelf from latitude 6^0 N to 20^0 N and 103^0 E to 112^0 E. The mention area is characterized by coastal climate regime. In general the climate features of Vietnam are dominated by monsoon regime and typhoon that occurred in average 6 times in the year. Based on climatological data with number of norms, the coastal area is zoning into 6 regions, each region brings itself with specific climate regime. We do not hope to describe all the characters in term of climate mention. The characters are composed with air temperature, humidity, wind and typhoon frequency .

Materials and Methods

Data are collected from the meteorological stations located along coast and islands of Vietnam. The figures are quoted from time series of 30 years. The climate state here is determined over an agreed time interval computed for the areas. Some of the parameters are computed by higher statistics such as variance that can often be more useful in characterizing a climatic state than the mean.

A. Main climatological features of the cruise expedition area

1. Area 1 comprises 1-3 Cruise expedition stations:

In side the area there are 4 national fixed meteorological stations namely, CuaOng, HongGai, HonDau and CoTo.

Air temperature

The area located on the north Vietnam suffering by two seasonal monsoons: Northeast monsoon with cold dried air and Southwest Monsoon with hot humid air. Air temperature is presented in the Table 1.

Table 1. The air temperature (^{0}C) representative for the 1-3 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Cuaong	15.1	22.8	28.6	24.1	22.5	38.8 (July)	4.6 (Jan.)
Coto	15.1	21.8	28.6	25.1	22.7	36.2 (July)	4.4 (Jan.)
Honggai	15.8	22.9	28.5	24.5	22.9	37.9 (Aug.)	5.0 (Jan.)
Hondau	16.8	22.8	29.0	25.8	23.6	38.6 (Aug.)	6.5 (Jan.)

The humidity.

Table 2. The relative humidity (%).

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Coto	84	90	86	79	84	90(Apr.)	20(Jan.)
Honggai	82	87	83	80	84	88 (Mar.)	18(Jan.)
Hondau	83	90	85	84	85	91(Mar.)	19 (Jan.)

The annual average air temperature varies from 22.5 ^{0}C to 23.6 ^{0}C. In winter time air temperature dropped in an interval from 15.0 ^{0}C to 17.0 ^{0}C . At the same time of winter the minimum air temperature is 4.4 ^{0}C observed at Coto station. The maximum air temperature 38.6 ^{0}C is observed in summer time at HonDau station.

In the area of stations 1,2 and 3 of the cruise expedition the relative humidity gets maximum value of 90- 91% in February and March and minimum value of 73- 77% in December and January of next year (Table 2).

Wind

Table 3. The wind speed (m/s).

Station	Average					Maximum
	January	April	July	October	Year	
Cuaong	3.4	2.5	3.2	3.6	3.1	40 N,NE (July, Sept)
Coto	4.5	3.2	4.7	4.9	4.2	40* (Aug.,Sept)
Honggai	2.8	2.3	3.2	3.5	2.8	45sw (July)
Hondau	4.8	4.7	6.0	5.0	5.0	40* (July,Aug.)

(*) That occurs in various time and directions

In the area wind speed is not strong due to existing in the area a system of small islands, along coast the average wind speed is about 3 m/s, while in the offshore this value gets up to 4-5 m/s. As it is shown in the Table 3 the maximum wind speed is 45 m/s occurred at Hongai station.

Fig. 1-4 presented wind roses of representative months for seasons.

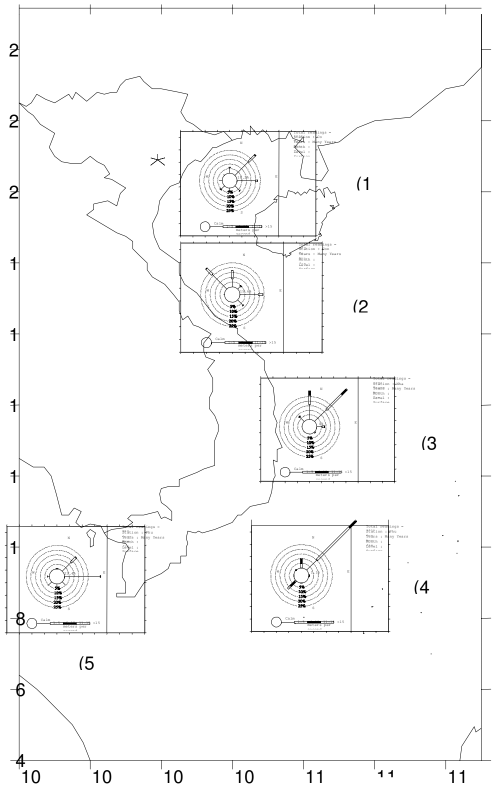

Fig. 1. Wind Rose January (1)Coto, (2)Conco (3)Nhatrang, (4)Phuquy, (5)Phuquoc.

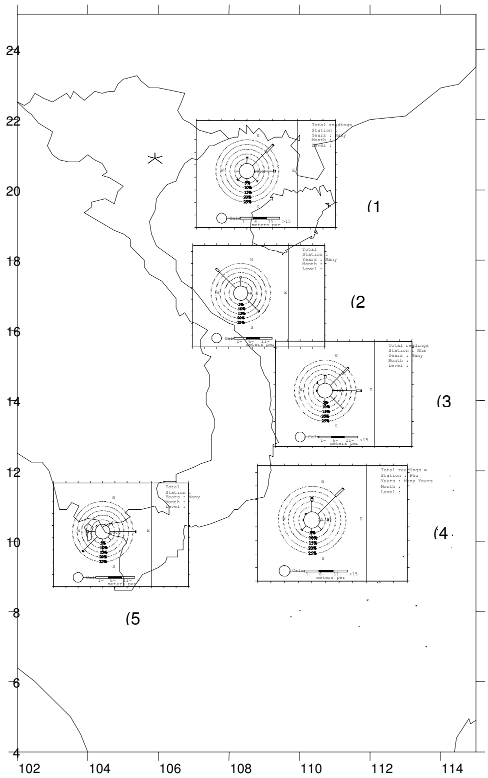

Fig. 2. Wind Rose April (1)Coto, (2)Conco (3)Nhatrang, (4)Phuquy, (5)Phuquoc.

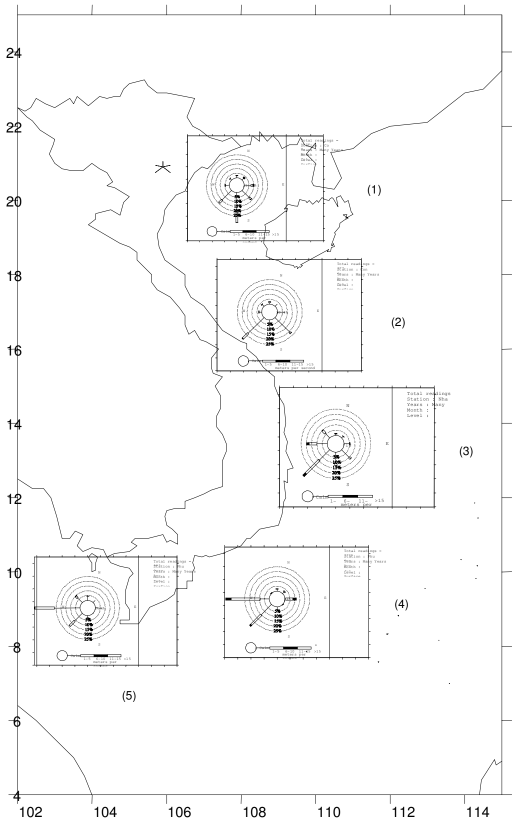

Fig. 3. Wind Rose July (1)Coto, (2)Conco (3)Nhatrang, (4)Phuquy, (5)Phuquoc.

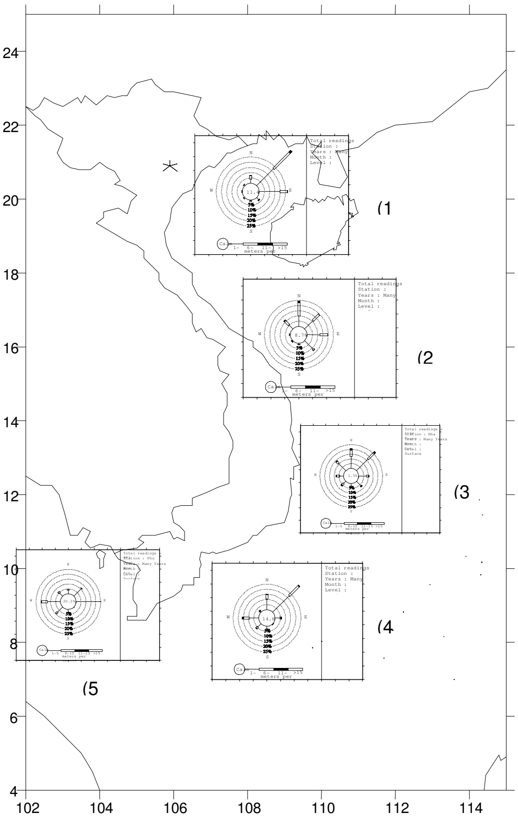

Fig. 4. Wind Rose October (1)Coto, (2)Conco (3)Nhatrang, (4)Phuquy, (5)Phuquoc.

Typhoon

Table 4. The typhoon activity in the whole expedition area.

Latitudes ^{0} N	Total number of Typhoon	Frequency	Annual average (number of Typhoon)
21-22	33	13.2	.82
20-21	33	13.2	.82
19-20	27	10.8	.67
18-19	21	8.4	.52
17-18	32	12.8	.80
16-17	21	8.4	.52
15-16	12	4.8	.30
1-15	14	5.6	.35
13-14	15	6.0	.37
12-13	16	6.4	.40
11-12	13	5.2	.32
10-11	1	0.4	.02
9-10	4	1.6	.10
8-9	7	2.8	.17
Total	250	100	6.25

The typhoon data is collected for 40 years (1954- 1993). The number typhoon landfalling in to this area is about 14 % and every year the area is suffering by 6 typhoons occurred here.

2. Area 2 comprises stations 4, 5, 6 and 7:

Air temperature

Table 5. Air temperature (^{0}C) representative for the stations 4,5, 6 and 7 Cruise expedition.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Hongu	16.8	23.0	29.1	24.1	23.2	39.9 (Aug.)	6.9 (Jan.)
Kyanh	18.1	24.5	29.6	24.4	24.1	39.5 (May)	7.5 (Jan.)

Humidity

Table 6. Relative humidity (%) of the stations 4,5,6 and 7.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Vinh	90.0	89.0	73.0	89.0	85.0	93.0 (Feb.)	33.0 (Dec.)
Ky anh	91.0	88.0	72.0	90.0	85.0	96.0 (Feb.)	30.0 (Mar.)
Honngu	83.4	89.9	82.2	81.3	84.2	97.0 (Feb.)	19.1 (Apr.)

As it is shown in the Table 6 that the humidity gets highest value in comparison with other coastal areas.

Wind

Table 7. The wind speed (m/s) of stations 4, 5,6 and 7.

Station	Average					Maximum
	January	April	July	October	Year	
Vanly	4.0	4.1	5.3	4.2	4.4	48*
Honngu	4.0	3.2	4.2	4.6	3.9	56*
Kyanh	2.1	1.8	3.3	2.4	2.3	54 NE (Aug.)

(*)That occurs in various time and directions

The area comprising stations 4, 5, 6, and 7 belongs to the area of monsoons and typhoon activities. The average wind speed (about 4m/s) is not so high but the strong wind speed is often observed during the time of typhoon with maximum wind speed of 56 m/ s (Table 7). Typhoon occupied about 32 % of the total typhoon number occurs in this area every year.

3. Area 3 comprises stations 8,9,10

Temperature

Table 8. The air temperature (^{0}C) representative for the 8-10 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Conco	20.5	24.6	29.6	26.6	25.3	38.6 (May)	11.1 (Dec.)
Sontra	21.3	26.2	29.1	25.7	25.7	40.9 (May)	10.2 (Jan.)

The annual average air temperature in this area is changing in an interval 25^{0}C - 26^0 C. The lowest air temperature was observed at Sontra station in January with the value of 10.2 ^{0}C, while the maximum air temperature was also occurred at the same place in May with the value of 40.9 ^{0}C. (Table 8).

Humidity

Table 9. The relative humidity (%) representative for the 8-10 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Conco	88	91	81	82	85	94 (Feb.)	37 (Dec.)
Danang	84	82	75	84	81	85 (Dec.)	18 (Apr.)

As it is shown in the Table 9 that there are differences by the values of humidity between the two parts in the area. In the north (Conco Station) the humidity is higher than the south part (Danang Station).

Wind

Table 10. The wind speed (m/s) representative for the 8-10 Cruise expedition stations.

Station	Average					Maximum
	January	April	July	October	Year	
Conco	4.6	2.7	3.7	4.6	3.9	38 (Oct.)
Cua tung	3.4	2.4	3.1	3.1	3.0	40 *
Sontra	1.8	1.9	1.5	1.9	1.8	31 (Oct.)

(*) That occurs in various time or directions

According to the Fig. 1-4 and the above table it is recognized that the northeast wind is dominated in the winter in the area with frequency of 85 - 90% (Conco Station) while in the summer the southwest wind occupied only 60% (Sontra Station) (Table 10).

Typhoon

The number of typhoon occurred in the area occupied 26 % of the total landfalling on Vietnam coast every year. In other word every year there are 1.5 typhoons landfalling in this area.

4. Area 4 comprises 11- 32 Cruise expedition stations

Temperature

Table 11. The air temperature (^{0}C) representative for the 11-32 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Quynhon	23.3	27.4	30.0	27.0	26.8	39.9 (May)	21.8 (Jan.)
Nha trang	23.5	27.2	28.3	26.5	26.5	37.4 (June)	22.7 (Jan.)
Phuqui	24.6	28.3	28.8	27.3	27.1	34.3 (June)	20.7 (Mar.)
Phanthiet	24.6	28.3	27.1	26.9	26.7	37.2 (May)	23.5 (Jan.)

The air temperature in the north and south part of the expedition area is almost identical. Phu qui station is representative for the offshore area (Table 11).

Humidity (Table 12).

Table 12. The relative humidity (%) representative for the 11-32 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Quinhon	84	83	71	82	80	84 (Feb.)	36 (May)
Nhatrang	79	80	77	83	79	83 (Oct.)	37 (July)
Phathiet	75	77	83	84	79	84 (Oct.)	35 (Dec)

Wind

Table 13. The wind speed (m/s) representative for the 11-32 Cruise expedition stations.

Station	Average					Maximum
	January	April	July	October	Year	
Quynhon	3.2	3.5	3.5	3.5	3.4	40* (Nov.)
Nhatrang	4.1	3.1	2.3	3.3	3.2	30* (Nov.)
Phuqui	8.6	3.3	7.2	4.3	6.2	34* (Nov.)

The north and northeast wind 11 - 15 m/s occupied only 10% in the winter (Fig. 1- 4) while the weak north and northeast occupied 50- 60 % at the same time. In the summer time the southwest and west wind 11- 15 m/s occupied about 20%. It is emphasized that during the time of summer the number of calm is dominant (37%) (Table 13).

Typhoon

The number of typhoon occurred in the area occupied 23.2 % of the total landfalling on Vietnam coast every year.

5. Area 5 comprises 33- 50 Cruise expedition stations

Air temperature

Table 14. The air temperature (^{0}C) representative for the 11- 32 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Vungtau	25.2	28.9	27.4	27.1	27.2	35.8 (Apr.)	15.0 (Dec.)
Condao	25.2	28.2	27.5	26.9	27.0	36.0 (Apr.)	17.7 (Feb.)

The air temperature distribution shows an identical character from the coastal to the offshore stations. The maximum air temperature was observed in the April appeared to be not looked like as usual in other areas (Table 14).

Humidity

Table 15. The relative humidity (%) representative for the 11- 32 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Vungtau	76	76	81	83	79	84 (Sept.)	42 (Jan.)
Camau	81	80	86	88	84	88 (Oct.)	35 (Mar.)

In general the humidity of Vungtau station is lower than it is observed in Camau station while the minimum value of Camau station is lower 7% in comparison with its value in Vungtau station (Table 15).

Wind

Table 16. The wind speed (m/s) representative for the 33- 50 Cruise expedition stations.

Station	Average					Maximum
	January	April	July	October	Year	
Vungtau	3.2	3.8	2.8	2.0	3.1	26* (Apr.)
Condao	3.7	1.6	2.5	1.7	2.6	42* (Apr.)

(*) That occurs in various time or directions.

The east wind is dominated at Vungtau area in the winter with 60% in frequency while the number of calm occupied 24% here at the same time. In the offshore the northeast wind is prominent during the winter time. In the summer the system of west and southwest wind is prevailing with frequency of 80%(Condao station) and 70% (Vungtau station). The number of calm in summer is less than its number occurred in winter time at the same area (Fig.1-4) (Table 16).

Typhoon

Typhoon v5 The number of typhoon occurred in the area occupied 4.8 % of the total landfalling on Vietnam coast every year (Table 4).

6. Area 6 comprises 52- 57 Cruise expedition stations

Air Temperature

Table 17. Air temperature (^{0}C) representative for 52- 57 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Rachgia	27.7	28.9	28.0	27.5	27.4	37.9 (Apr.)	24.9 (Jan.)
Phuquoc	25.6	28.6	27.4	26.8	27.2	38.1 (July)	16.0 (Jan.)

The temperature in this area is warm almost a whole year (Table 17). The season time is not identified.

Humidity

Table 18. Relative humidity (%) representative for 52-57 Cruise expedition stations.

Station	Average					Maximum	Minimum
	January	April	July	October	Year		
Rachgia	78	78	84	84	81	85 (Aug.)	38 (Feb.)
Phuquoc	76	80	86	88	82	88 (Oct.)	34 (Jan.)

The humidity in this area is not high. The highest humidity value is observed in October at Phuquoc station with the value of 88% (Table18) .

Wind

Table 19. The wind speed (m/s) representative for 52- 57 Cruise expedition stations.

Station	Average					Maximum
	January	April	July	October	Year	
Rachgia	1.6	2.6	4.0	1.7	2.6	20 (June)
Phuquoc	1.8	2.2	4.2	2.2	2.9	40 (Oct.)

The wind is light for the whole year. The maximum wind speed is occurred in October with the value of 40 m/s at Phquoc station (Table 19).

Typhoon

The number of typhoon occurred in the area occupied 5 % of the total landfalling on Vietnam coast every year (Table 4).

B. Main weather conditions occurred on the Cruise expedition area during the time of May 1999

During the time of May 1999 the whole Vietnam territory was effected by the internal tropical convergence zone (ITCZ) in joining with north cold front going down to the south. This situation causes rainfall in may places, especially in the north and central part coastal of Vietnam the precipitation gets values higher than climatological data for these regions. The small late flood originated from upper rivers and rainfall do not change so much the coastal hydrological regime, in general saying the weather condition covered whole expedition area was in favorite for the sea activities.

1. The mass of cold air

During the time of May there were 3 times emerging mass of cold air at 4, 18 and 26 May 1999. The mass of cold air brought rainfall along coastal and offshore areas of the South China Sea. The mass of cold air occurred on 18 May was strongest causing low air temperature down to 9- 12 ^{0}C and northeast wind gearing up to 17 m/s offshore.

2. Typhoon and low tropical depression

During the time of expedition only one typhoon occurred on the area. The typhoon named Leo-9902 appearing on 27 April at north of South China sea. The 1 May 1999 center of the typhoon was at 19^0 9N and 115 ^{0} 4 E, the strongest wind speed was measured with 36 m/s. The next day the typhoon was merging into low depression and landfalling on Quangdong coastal area (China). The next 3 days after typhoon Leo-9902 the expedition area was dominated by large swell with S and SW directions and wave high of 3 m at Vungtau, Condao and Spratley islands.

3. Air temperature

The air temperature at the time of expedition was lower 0.3 - 2.0 ^{0}C in comparison with climatological data.

4. Rainfall

The monthly average total precipitation taken for May 1999 in the expedition area is lower than climatological data for the same area. During the time of May 1999 the maximum total precipitation gets value of 203 mm occurred 21 May 1999 at north area of the South China Sea. At Nha trang station the precipitation gets minimum value of 18 mm which is lower 27 mm in comparison with climatological data.

Acknowledgments

I would like to thank Dr. B.D.Chung and Dr. D.M.Son for their giving me a chance to join SEAFDEC working. Thank you many people, who help me in data collecting and reviewing this article.

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Geostrophic and Drift Current in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

The water circulation in area IV was calculated by 2 methods. The circulation for the area where water depth exceeded 600m was calculated by the geostrophic balance method. In a shallow water area effect of wind absolutely surpasses geostrophic balance, so wind induced drift current is greater than geostrophic current many times. So, for the whole area (shallow deep) the drift current was calculated by two-dimensional nonlinear shallow water equation based on typical monsoon fields. The results of 2 methods showed common picture of the circulation with divergence and convergence changing by season.

Introduction

The water circulation is one of the most essential characters in the marine hydrodynamical regime. They are always very important factors for the management of fisheries and living resources in the Ocean. There are some methods to determine currents in the sea. The net current can be determined directly by the observation data measuring the direction and speed of the current at each station. This method requires observation duration of at least 25 hours at each station in a study area in order to obtain separately tidal components and remainder current (non-periodic or stable components). Clearly that, the observation data of the Survey Cruise (30 April - 29 May 1999) of SEAFDEC in Vietnamese sea (Area IV) don't satisfy the requirements of a direct method for current calculation.

The indirect methods to determine the net movement of sea water are enough abundant now. The classical geotrophic balance is one of widely used indirect methods in Oceanography. It is somewhat appropriate under the conditions of this survey. It requires accurate temperature, salinity and pressure data which could be measured by CTD at each station. The current obtained from this geostrophic balance method will be relative current between 2 layers. It is necessary to choose a deep water layer which can be assumed to be the level of no motion. The absolute current at any levels above the level of no motion can be then calculated. This procedure can be realized only in deep ocean, where the current speed at a sufficiently deep water layer is usually very slow relatively to the surface current (less than 1 cm/s). So the method of classical geotrophic balance is calculated suitably only for deep ocean. In a shallow water the level of no motion couldn't be chosen, the results calculated by this method will be incorrect. On the other hand, in a shallow water the effect of wind always surpasses absolutely geostrophic balance and wind induced drift current always is dominant in the remainder current.

The drift current will be calculated by numerical method from two dimensional nonlinear shallow water equation system with the typical wind fields taken into account.

Thus, combining two methods (calculation from geostrophic balance and numerical modelling), it is possible to obtain the common picture of water circulation in the study area: in the deep water the current abides by the laws of geostropic balance, in the shallow water the current has an essence of drift current.

Materials and Methods

The Study Area

The study area is the surrounding Vietnam sea included the Gulf of Tonkin and the continental shelf of Central and Southern Part of Vietnam. The study area is spreading from 6° to 22°N latitude and from 105° to 112°E longitude. The shallow water zone occupied most of area. Among the total of 58 survey stations of Cruise from 30 April to 29 May 1999, only 16 stations had bottom depth exceeded 600 meter and at these station there level of no motion can be assumed.

The location of these stations and the bottom topography of the study area are shown in Fig.1.

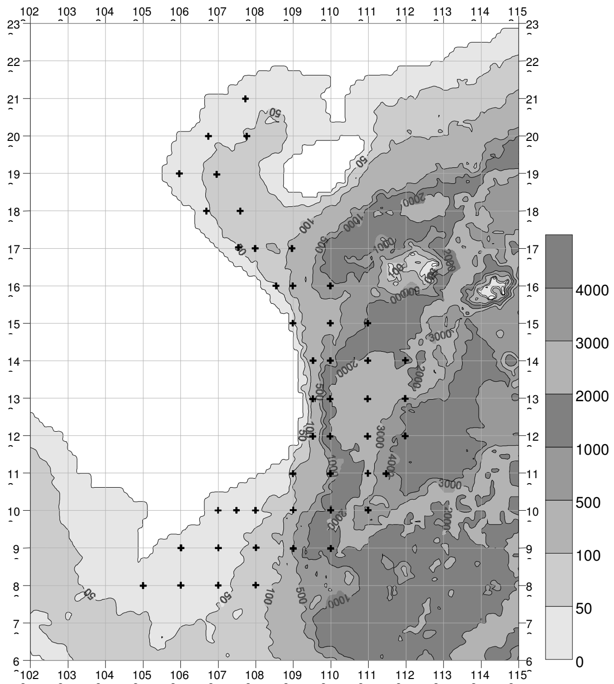

Fig. 1. Depth contours (m) of the study area and the location of stations (+).

Geostrophic Current

The geostrophic balance method has been used widely for deep ocean and it can be said that probably most of the subsurface circulation of the World Ocean up to now was obtained by this approach. The basic assumption of this method is that in the case of an isobaric surface, for example, sea surface, to maintain an unequal level then the horizontal pressure gradient force due to gravity must be balanced by Coriolis force due the movement of water.

The general expression of the classical dynamic method is following:

$$fu = \frac{DYNH_1 - DYNH_2}{L} \tag{3.1}$$

where f - Coriolis factor,
u - Current speed in the direction perpendicular to the pressure gradient,
L - Distance (m) between the 2 stations,
DYNH1,2 - Dynamic height (in dyn.m). Subscript refers to station.

For each station, dynamic height was calculated following.

$$DYNH = gz \tag{3.2}$$

where g - gravitational acceleration,
z - vertical distance between the interested surface and the reference surface (in m).

A lot of observation data on temperature, salinity and pressure for many years in the study area has been collected. These are data in the summer period and the winter period. The summer consists of May, June, July and August. The winter consists of December, January, February and March. The data were collected for each square with one degree size. Based on the data collected during the Cruise 30 April - 29 May 1999 with these available data the picture of geostrophic current in the deep sea has been calculated for each season (summer and winter).

Wind Induced Drift Current

In order to simulate circulation and sea water level oscillation caused by wind stress, the TIDE-2D software developed in Center for Marine Environment Survey, Research, Consultation (CMESRC) was used. The calibration and verification of this model were implemented rather carefully by observation data for several coastal and offshore zones of Vietnam sea, for example Ha Long Bay, Hai Hau, Thanh Hoa, the mouth of the Gulf of Tonkin, Dinh An, Ca Mau... This software has been used to calculate the current regime in many coastal areas of Vietnam sea. This model is based on the two - dimensional nonlinear shallow water equations:

Conservation of mass:

$$\frac{\partial z}{\partial t} + \frac{\partial}{\partial x}(ud) + \frac{\partial}{\partial y}(vd) = 0 \tag{4.1}$$

Conservation of momentum:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -g\frac{\partial z}{\partial x} - f\frac{u\sqrt{u^2+v^2}}{d} + \Omega v + \gamma\frac{\tau_x\sqrt{\tau_x^2+\tau_y^2}}{d} + D(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2})$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -g\frac{\partial z}{\partial y} - f\frac{v\sqrt{u^2+v^2}}{d} - \Omega u + \gamma\frac{\tau_y\sqrt{\tau_x^2+\tau_y^2}}{d} + D(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}) \tag{4.2}$$

where: u, v - Depth averaged components of velocity in the x - direction and y - direction (m/s),
z - Water surface elevation above reference level (m),
h - Water depth below reference level (m),
d - Total water depth (d = h + z),
W - Coriolis parameter (S^{-1}),
g - Acceleration of gravity (m/s^2),
t_x, t_y - The components of wind stress in x - and y - direction with the wind velocity taken at 10m above the Mean Sea Level,
f - The friction coefficient,
g - The wind drag coefficient,
D - The horizontal turbulent coefficient.

The above equations are solved using implicit different scheme and alternating direction method in space (not in time).

Because the study area is influenced strongly by the Monsoons: the North-Eastern wind in winter and the South-Western Wind in summer, the circulation regime also has the characters changing in accordance with seasons. The drift current in the study area has been calculated by model TIDE-2D for two season - winter and summer - in correspondence with two wind fields: NE and SW. The chosen wind fields are the average wind in the typical month in winter and in summer (January and June).

Results and Discussion

Geostrophic Current in the Deep Sea

The data of temperature, salinity and pressure in the study area were collected for the winter (from December to March) and the summer (from May to August) at each square with one degree size from oceanographic database. In addition the summer data also were supplemented by the observation data of the survey cruise (May 1999).

Based on the collected data the dynamic height was calculated and corrected to 600 dbar level, the assumed level of no motion. From the obtained dynamic height the dynamic topography map was established for each isobaric level: sea surface, 50, 150 and 500 dbar. After that these results were used to calculate velocity components u and v for each grid cell at each isobaric level.

Fig.2–Fig.5 show dynamic height and current vectors at different isobaric level in summer.

Fig.6–Fig.9 present dynamic height and current vectors and different isobaric level in winter.

Some characteristics of circulation calculated from geostrophic balance at the deep water are following:

In Summer (the period of Survey Cruise)

On the maps for dynamic topography and geostropic current at isobaric level 0, 50, 150 and 500 dbar it can be noted that in general the isolines of dynamic height were parallel to the coastal line. The current has Northern and North-Eastern direction (N and NE). There are two rather large and strong eddies at the Southern zone: anticyclonic eddy near Vietnam shelf and cyclonic eddy near Kalimantan Island. The current in anticyclonic eddy was strengthened at the South Central Part of Vietnam zone with maximum speed over 30cm/s.

Near the Central Part of Vietnam there exist the cyclonic eddy at the area zone from 13^{o}N to 16^{o}N latitude with maximum speed about 25-30cm/s.

Generally spreading the system of eddies, general direction and tendency of the circulation are similar from sea surface to deep levels, only the value of speed is quickly decreased with depth. Example, of maximum speed at the surface was over 30cm/s then at 500 dbar level that is less than 5cm/s.

In correspondence with the cyclonic and anticyclonic eddies there exist the divergence zone and the convergence zone. In the divergence zone the upwelling process occurs usually and on the contrary in the convergence zone there is a downwelling process. These vertical processes could be very important for fishery because it relates to fishing grounds in the sea.

Thus in the summer there exists the upwelling at offshore zone of the Central Part of Vietnam about 13^{o}N - 16^{o}N latitude and the downwelling at South - Eastern zone about 300 km far from the coast.

In Winter

From Fig.6–Fig.9 presenting dynamic height and geostrophic current at different levels (0, 50, 150 and 500 dbar) it would be possible to recognize that the system of dynamic height isolines on the whole is oriented North-East (NE) to South-West (SE) direction similar to that in summer, although these isolines in winter are more complicated.

There are two large and strong eddies: the cyclonic eddy in the Central Part of Vietnam zone from 9°N to 16°N latitude and anticyclonic eddy in the South Part from 5°N to 8°N latitude. In the cyclonic eddy zone the current is strengthened at the zone near to the South-Eastern coast of Hai Nam Island and along the shore of Central Part of Vietnam from Da Nang to Phan Thiet. The speed can reach 30 cm/s at the surface. In the anticyclonic eddy zone the current is strengthened at the zone along the shelf of South Vietnam. The speed is over 30 cm/s at the surface.

Thus along the Vietnam shoreline over the area of 200 km width from Central Part to South Part there exist the cold water current flowing from North to South in winter.

As in summer the eddies and tendency of circulation are somewhat similar from sea surface to deep levels in winter, only the speed value quickly decrease with depth.

In correspondence with the cyclonic and anticyclonic eddies there exist divergence and convergence zones. Specially, the divergence zone in winter is very large.

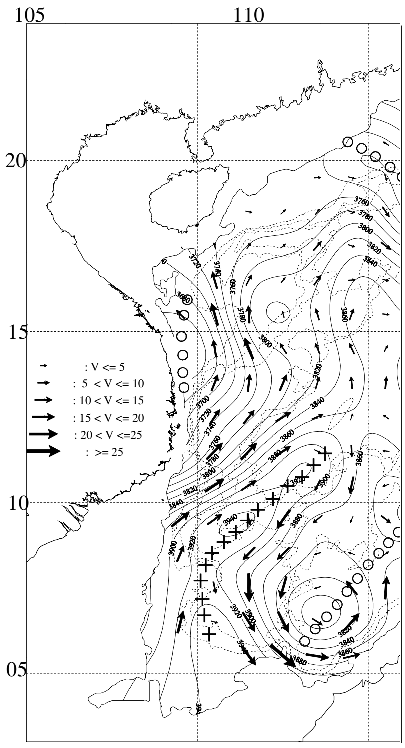

Fig. 2. Dynamic height (dyn.mm) and geostrophic current at sea surface (0 dbar) in summer.

~ isolines of dynamic height

o o o divergence zone

+ + + + convergence zone

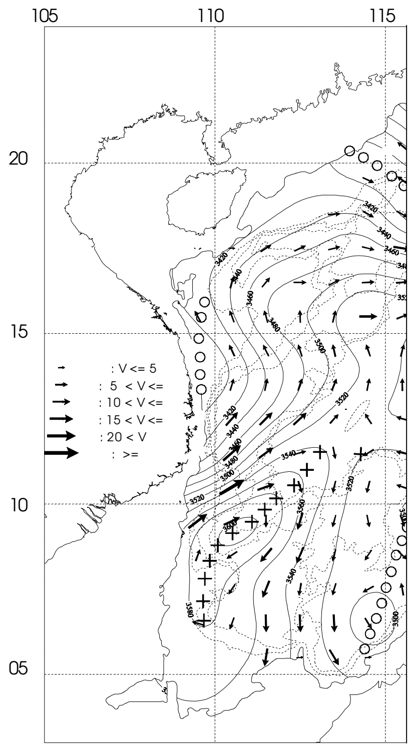

Fig. 3. Dynamic height (dyn.mm) and geostrophic current at 50 dbar in summer.

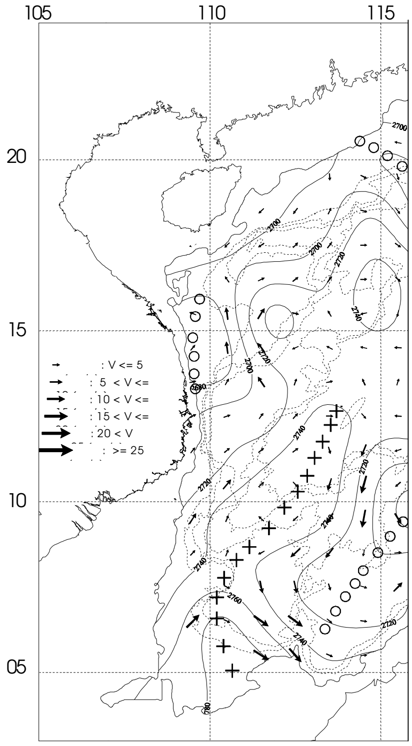

Fig. 4. Dynamic height (dyn.mm) and geostrophic current at 150 dbar in summer.

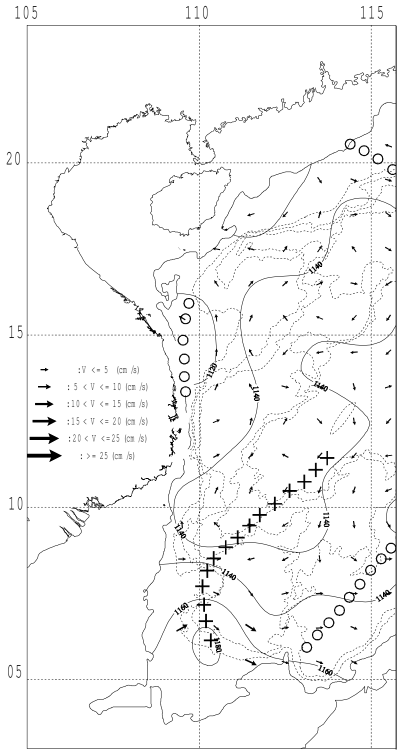

Fig. 5. Dynamic height (dyn.mm) and geostrophic current at 500 dbar in summer.

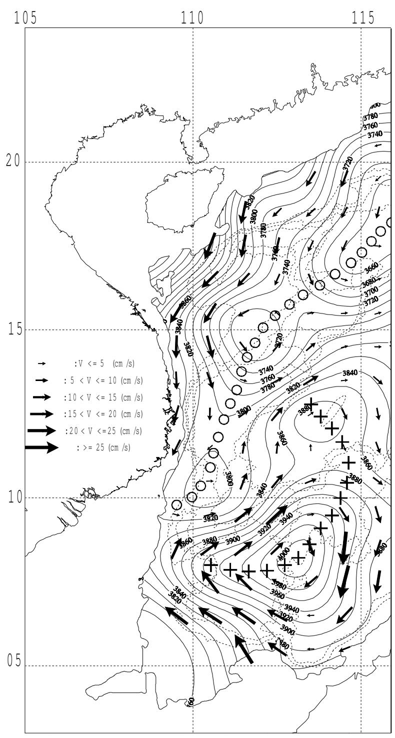

Fig. 6. Dynamic height (dyn.mm) and geostrophic current at sea surface 0 dbar in winter.

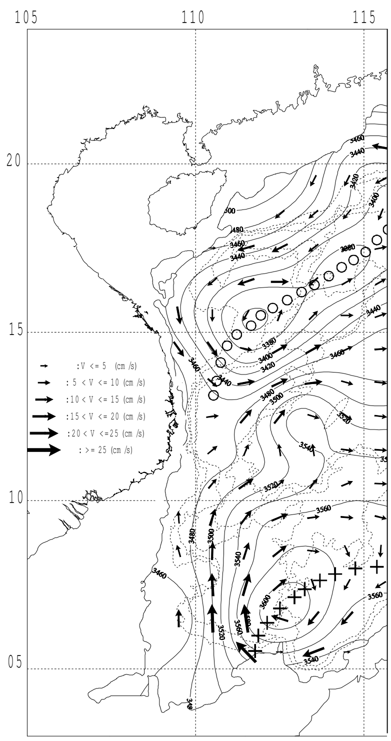

Fig. 7. Dynamic height (dyn.mm) and geostrophic current at 50 dbar in winter.

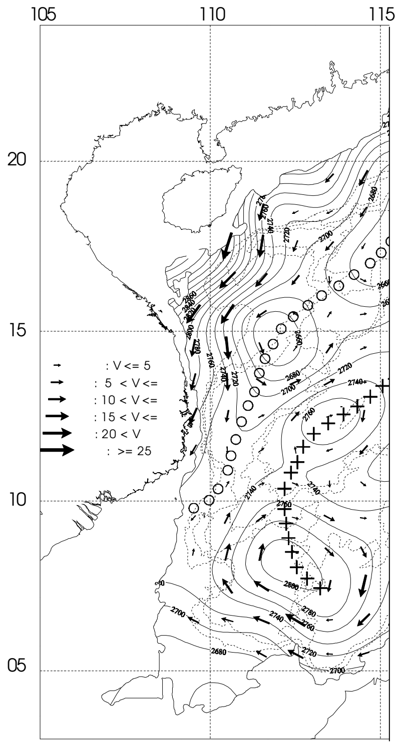

Fig. 8. Dynamic height (dyn.mm) and geostrophic current at 150 dbar in winter.

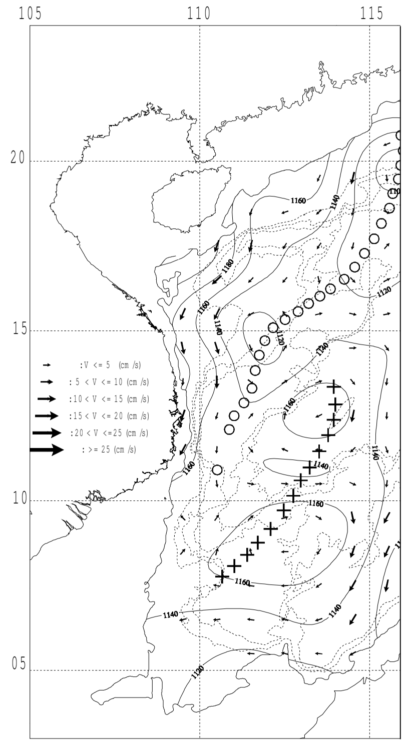

Fig. 9. Dynamic height (dyn.mm) and geostrophic current at 500 dbar in winter.

The Drift Current in the Shallow Water

The model TIDE-2D was used to calculate the depth averaged current induced by wind stress. As above said that in the shallow sea the effect of wind is more important in comparison with geostrophic balance. So it is necessary to calculate the drift current in a shallow water area. Together with the geostrophic current in the deep water the drift current in the shallow water establishes the picture of circulation in whole study area.

In correspondence with averaged monthly wind field (see Fig.10–Fig.12) the averaged drift current fields are calculated as follows:

- The drift current field averaged for May (coincidence with the period of the Survey Cruise)
- The drift current field averaged for June (typical for Summer)
- The drift current field averaged for January (typical for Winter)

The Fig.13–Fig.15 shows the averaged current fields for May, Jun and January respectively. The picture of drift current changes by season has some characteristics as follows:

In Summer

At first it would be possible to realize that the averaged drift current manifests itself clearly only in shallow water zone such as the Gulf of Tonkin or coastal zone along shore from North to South. In the Gulf of Tonkin there exist the large and strong cyclonic eddy, the center of which is in the middle of the Gulf. Thus along Vietnam shoreline from 21°N to 15°N latitude the current always flows to the South. The depth averaged speed can reach 20 cm/s over there. In the North part of Gulf the current is rather weak.

In the Coastal zone of the Central and Southern Parts of Vietnam from 8°N to 15°N latitude there exist the current flowing along shoreline to the North, the value of the depth averaged speed is over 20 cm/s in the Southern coastal zone.

In Winter

It would be possible to say that in winter the drift current is stronger than in summer in the whole coastal zone. Almost everywhere in the coastal zone from North to South the value of the depth averaged speed is about 20 cm/s.

The drift current flowed along the shoreline to the South everywhere. Whole the Gulf of Tonkin is a half of big eddy. The Cold water from the South China Coastal zone flows into the Gulf of Tonkin by strait Quynh Chau and around Hai Nam Island, after that the current continued to flow along the Vietnam shoreline to the South.

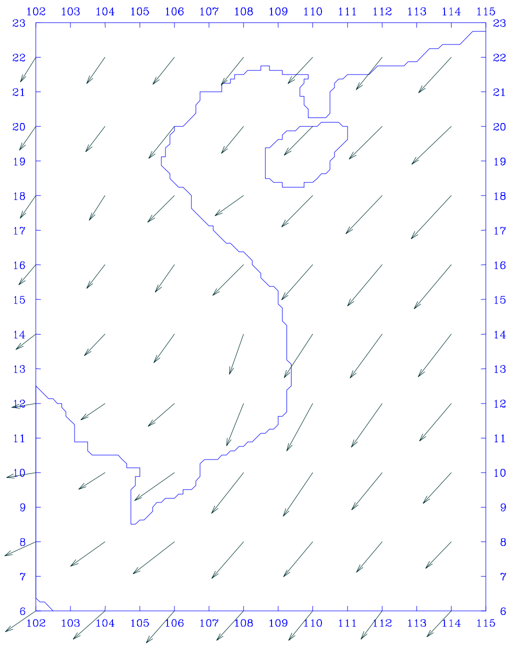

Fig. 10. The wind field averaged for January.

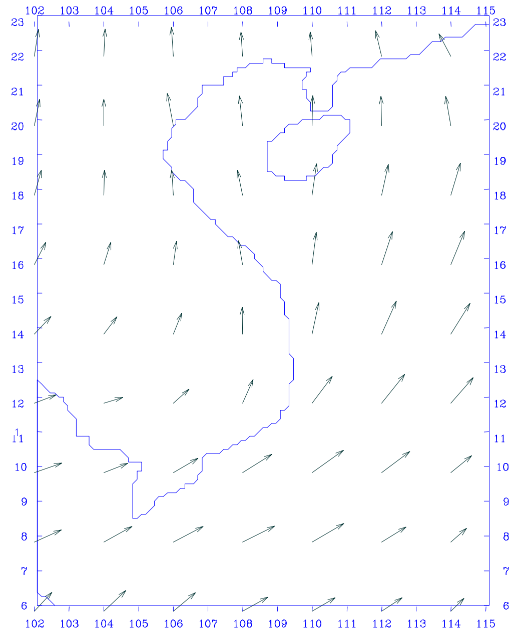

Fig. 11. The wind field averaged for June.

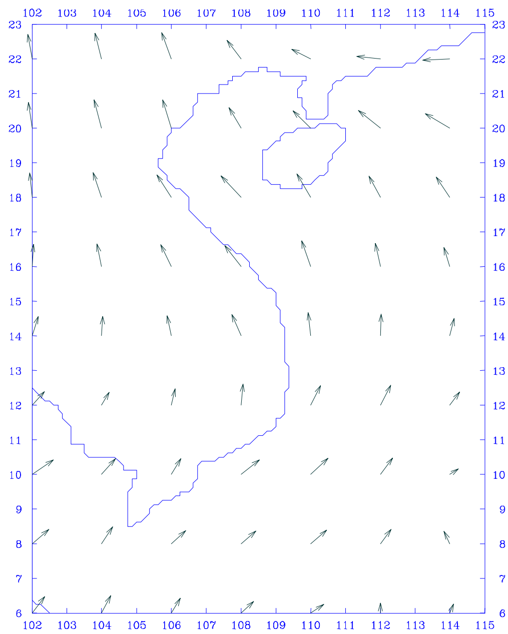

Fig. 12. The wind field averaged for May.

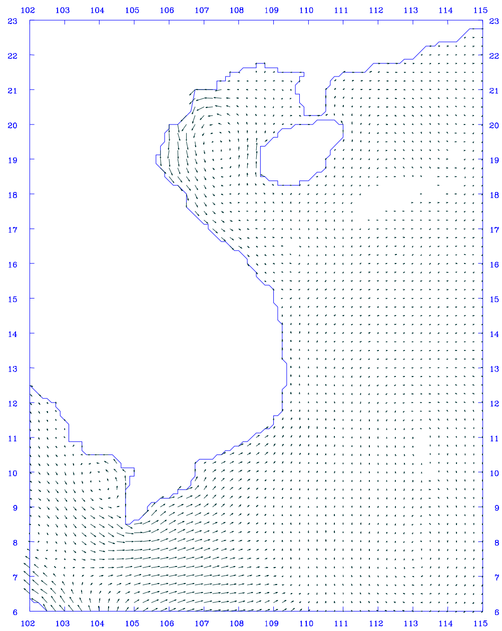

Fig. 13. The depth averaged drift current for May.

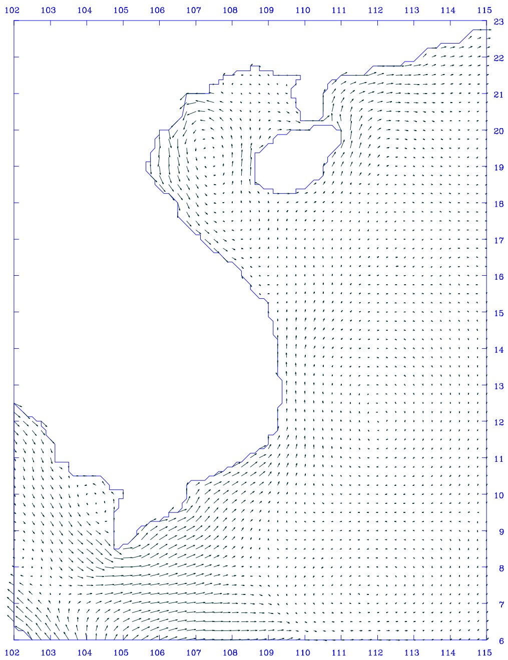

Fig. 14. The depth averaged drift currentfor June.

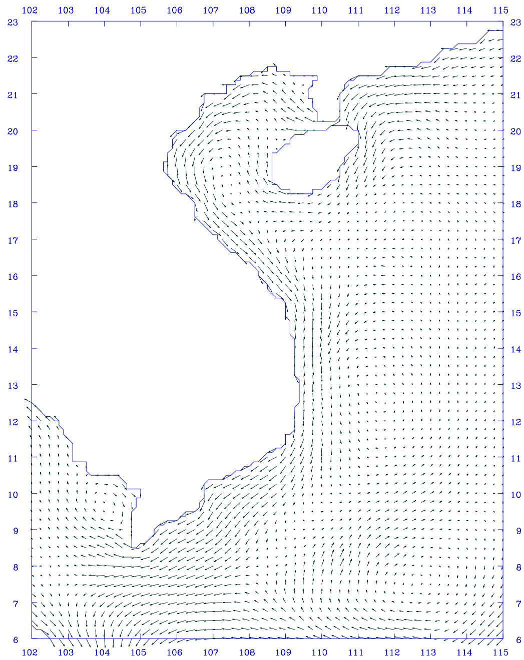

Fig. 15. The depth averaged drift current for January.

Conclusion

The study area consists of the shallow water and the deep sea. The system of the circulation there includes correspondingly the wind induced drift current and geostrophic current.

The circulation in study area changes clearly by seasons. The pictures of the circulation in summer and winter have contrary characters.

There existed the divergence and convergence zones in correspondence with the upwelling and downwelling processes, which could be important for fisheries purposes.

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Analysis and Estimation of Trace Metals in Seawater and Sediment in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

Water samples from off shore of Vietnam from latitude 6°N to 21°N and longitude 103°C to 112°E were collected on 30 April 1999 to 29 May 1999 and analyzed for copper (Cu), lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), chromium (Cr), arsenic (As) and mercury (Hg). The concentration of metals Cu, Pb, Cd, Zn, Ni and Cr was measure using flameless atomic absorption spectroscopy. The total concentration of all eight metals was in concentration ranges of unpolluted coastal water. The results indicated that the concentration of metals in bottom layer higher than in surface layer. Also, trace metal contents in the surface sediment were studied in off shore of Vietnam during this cruise. Total metals content were measured. The range of concentration of metals were 10.3 - 71.0 $mg.g^{-1}$ for Cu, 12.9 - 33.7 $mg.g^{-1}$ for Pb, 1.29 - 18.72 $mg.g^{-1}$ for Cd, 45.8 - 164.8 $mg.g^{-1}$ for Zn, 21.2 - 93.6 $mg.g^{-1}$ for Cr, 5.7 - 45.8 $mg.g^{-1}$ for Ni, 1.64 - 3.80 $mg.g^{-1}$ for As, and 0.104 - 0.493 $mg.g^{-1}$ for Hg. The levels found in the present study are similar to data from other marine.

Key words: Trace metals, Seawater, Surface sediment, South China Sea, Off shore of Vietnam

Introduction

Aquatic systems such as the seawater, inland water etc. are important stages in the biogeochemical cycle. Although dissolved levels are usually in the trace range of 10^{-6}-10^{-9} Ml^{-1} they remain significant, because they entry into the food chain and interactions with suspended particulate and sediments largely occur via the dissolve state.

The various heavy metals as Cd, Ni, As, Hg, etc. in seawater become toxic if present in excessive quantities and pose a potential threat to the ecosystem. Therefore, there has been constant effort to measure the impact of these metals on fauna [De Silva].

In environmental research and protection toxic metal, particularly Cd, Pb, Hg, As, Ni, Cr, etc. are becoming increasingly signification owing their biological nondergradability and chromic toxicity resulting from their accumulation in vital organs of man. As part of the SEAFDEC Cooperative Program in the Study of Fisheries Oceanography of the South China Sea, a Research on trace heavy metals in seawater was made.

The first analyses of seawater were performed just prior the beginning to the 19^{th} century in laboratories. However, problems arising from changes in chemical composition through evanosation, biological activity, or chemical interactions with the containing vessel, forced the marine chemist to transfer his laboratory from land to ships. Herman Walterberg, the chemist on the famous "Meteor Expedition" in 1925, pioneered this change. Today, there is a strong and necessary trend toward instrumental techniques, as opposed to the classical methods, especially when assaying very small amounts of materials.

General comparative considerations suggest atomic absorption spectroscopy and modern voltametric methods, particularly differential pulse stripping voltammetry with high sensitivity, precision, and accuracy also a simple sample preparation and treatment to be the most promising chose for the determination and characterization of toxic heavy metal traces in seawater.

Material and Methods

Analytical methods

The concentrations of metals: Cu, Pb, Cd, Zn, Ni, Cr, As and Hg in Vietnamese waters were studied in the SEAFDEC interdepartmental collaborative research survey. The samples were analyzed in laboratory of the Department for Analytical Science and Technique of the Institute of Chemistry, National Center for Natural Science and Technology of Vietnam, NCST.

All bottles, filter membranes and lab wares that would be contact with samples were carefully pre-washed by 10% suprapure HNO_3 acid and Mili-Q water. Merck standard solutions diluted by Mili-Q water was use as standard.

The concentrations of metals Cu, Pb, Cd, Zn, Cr, Ni were measured using graphite furnace atomic absorption spectrometer PE AAS 3300, USA and As by using hydride AAS technique with MHS-10, Hg by using coldvapour method with MHS-10, and 746 VA Trace Analyzer Metrohm, Switzerland. Polyethylene containers, which have been previously cleaned with nitric acid then rinse with water, shall be used for sampling.

Sampling

Fifty-eight stations from offshore of Vietnam from latitude 6°N to 21°N and longitude 103°E to 112°E were established in this study (Fig.1)

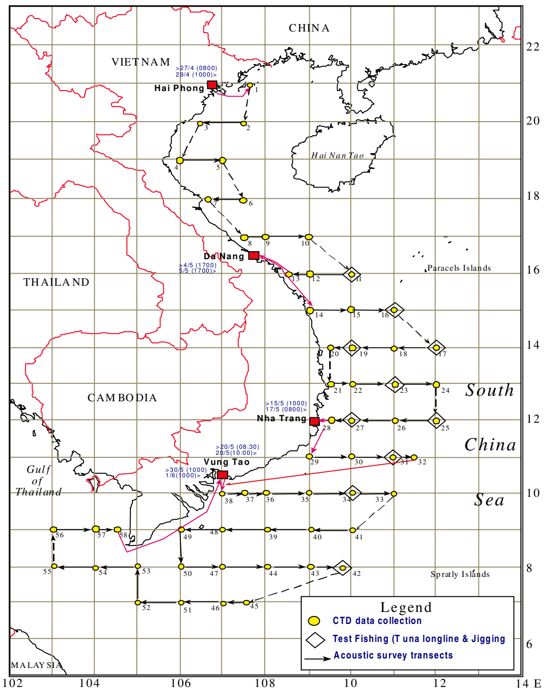

Fig. 1. Oceanographic Survey Station.

MV SEAFDEC collected the water samples on 30 April 1999 to 29 May 1999. The water was collected at each station during cruise at least two depth (surface and bottom) by water sampler attached to a rosette system. The water samples were transferred into acidic washed PE bottles and acidified to pH 1 with suprapure nitric acid for determination of Cu, Pb, Cd, Zn, Ni, Cr and As and with 1ml 10% $K_2Cr_2O_7$ solution to 1 liter for determination of Hg. Glass or other inert materials should be used if there is a risk of interaction of the sample with the container.

Determination of Cu, Pb, Cd, Zn, Ni and Cr

This method describes the determination of soluble copper, lead, cadmium, zinc, chromium and nickel in seawater and other saline waters by the simultaneous extraction of their complexes with ammonium pyrirolidine dithiocarbanate in to methyl isobutyl ketone and by the atomic absorption spectrophotometer with the graphite tube technique. Place 750ml aliquot of the sample, acidified seawater and each of the calibration solutions into series of 1 liter separating funnels fitted with polytetrafluoroethylene (PTFE) taps.

Add 35 ml of MIBK followed by 7ml of 1% APDC. Shake vigorously for 30 min. separate the organic layer in a polypropylene bottle and store for analysis. Allow the mixture to settle for at least 1h away from light or heat in the stoppered funnel. The settling time shall be strictly the same for all the solutions. Collect the organic layer taking care to avoid any trace of the aqueous phase (centrifuge if necessary) carry out a blank test in parallel with the determination by the same procedure, using the same quantities of all the reagents as in the sampling and chelation and extraction, but replacing the test portion by water.

Proceed as follows for each metal being determined. Before carrying out the spectrometric measurement, set up spectrometer according to the manufacturer's instructions by aspirating the organic extract of calibration solution of the metal being determined and using information in Table1.

Optimize the aspiration and conditions. Adjust the response of the instrument to zero absorbance with MIBK. For each metal being determined, aspirate the set of organic extracts of the calibration solutions. Plot a graph having the metal contents, in micrograms per liter, of the calibration solutions as abscissas and the corresponding values of absorbance as ordinates for example by measuring the absorbance of a calibration solution every five samples. Aspirate the organic extract of the test portion. Measure the absorbance of the metal being determined and after each measurement aspirate MIBK in order to rinse the nebulizer system.

Table 1. Wavelength (nm) used to determine metal element.

Element to be determined	Wavelength (nm)
Nickel	232.0
Copper	324.7
Zinc	213.8
Cadmium	228.8
Chromium	357.9
Lead	283.3 217.0

Determination of Mercury

Mercury ions are reduced to metallic mercury by $NaBH_4$, entrancement of the mercury in a current of inert gas at ambient temperature and determination of the mercury, by flameless atomic absorption spectrometry at a wavelength of 253.7nm

Take a test portion of 100 ml from the previously mixed sample containing not more than 0.5 mg of mercury. Prepare, just before use, using the standard mercury solutions at least five calibration solutions, covering the range of concentrations which can be measured with the apparatus to be used.

Treat each of these solutions immediately after their preparation in exactly the same way as the test portion on which the determination is to carry out. Also, proceed in exactly the same way on a solution in which the standard mercury solution is replaced with water.

Set up the instrument in accordance with the manufacturer's introductions. Transfer a volume of sample solution into aeration flask in accordance with the manufacturer's introductions with on the entrainment gas supply and let the developed mercury vapour flow through the absorption cell and measure the absorption of atoms in the beam of the PE - AAS - 3300 by using of MHS - 10 carry out a blank test with each batch of samples, but replacing the test portion with water and using the same volume of reagents as for the determination prefer.

Determination of Arsenic

The method is based on the atomic absorption measurement of arsenic generated by the thermal decomposition of arsenic (III) hydride. As (III) is reduced to gaseous arsenic (III) hydride (AsH_3) by reaction with sodium tetrahydroborate in a hydrochloric acid medium.

The absorbance is determined at a wavelength of 193.7nm. Set all instrumental parameters of the atomic absorption spectrometer in accordance with the manufacturer's operating manual and optimize the position of the absorption cell in order to obtain maximum transmission of the light beam.

Pass a stream of argon through the system and set the instrument to zero. Measure the absorption given by the solutions in the following order:

- Blank solution,
- Calibration solutions,
- Samples, prepared as follows,

Depending on the hydride system used, transfer an appropriate volume of the sample solution to the reaction vessel (MHS - 10). Connect the reaction vessel to the hydride system pass argon through the solution until the absorption signal of atomic absorption spectrometer returns to zero. For 20 ml of the sample solution add 5ml ± 0.1ml of sodium tetrahydroborate solution to the solution and record the signal. Repeat the procedure using separate portions of each solution. Use the mean of these results. Establish the calibration curve using means of values obtained with the blank and calibration solutions.

Results and Discussion

Certified Reference Seawater Probe CASS-3 of the Institute for Environmental Chemistry, Canada, were included in sample preparation and analysis as quality control samples to ensure the accuracy of the results. The percentage recovery of copper was 102.5%, lead was 116.6%, cadmium was 116,6%, zinc was 108.9%, nickel was 104.1% and chromium was 109.8%. The result of analysis indicated good recoveries of all determined metals (Table 2).

Table 2. Analytical performance based on Reference Seawater. (µg/l).

	Cu	Pb	Cd	Zn	Ni	Cr
CASS-3	0.517	0.012	0.030	1.24	0.386	0.092
Our result	0.530	0.014	0.035	1.35	0.402	0.101

The concentration of the determined metals in seawater of survey cruise at surface and bottom layer of sampling are presented in the Tables 3, 4, 5, 6, 7, 8, 9, and 10 in nM and Tables11, 12, 13, 14, 15, 16, 17 and 18 in µg/l

Table 3. Cu-Concentration in seawater.

Station	Samples	Cu (nM)	Station	Samples	Cu (nM)	Station	Samples	Cu (nM)
1	1S	**76.64**	21	21S	**65.16**	41	41S	**59.49**
	1B	**90.34**		21B	**80.11**		41B	**79.16**
2	2S	**73.81**	22	22S	**75.23**	42	42S	**58.07**
	2B	**87.19**		22B	**72.71**		42B	**78.06**
3	3S	**74.59**	23	23S	**72.71**	43	43S	**64.99**
	3B	**75.38**		23B	**67.83**		43B	**75.86**
4	4S	**79.00**	24	24S	**78.85**	44	44S	**60.12**
	4B	**76.48**		24B	**79.16**		44B	**83.57**
5	5S	**62.32**	25	25S	**75.07**	45	45S	**64.05**
	5B	**80.58**		25B	**76.48**		45B	**79.48**
6	6S	**67.99**	26	26S	**67.83**	46	46S	**58.07**
	6B	**67.20**		26B	**80.58**		46B	**78.22**
7	7S	**65.78**	27	27S	**76.01**	47	47S	**60.91**
	7B	**67.83**		27B	**78.06**		47B	**76.02**
8	8S	**58.86**	28	28S	**72.71**	48	48S	**64.99**
	8B	**74.59**		28B	**79.16**		48B	**58.54**
9	9S	**60.43**	29	29S	**75.07**	49	49S	**67.04**
	9B	**67.04**		29B	**92.22**		49B	**64.05**
10	10S	**60.75**	30	30S	**72.71**	50	50S	**61.85**
	10B	**72.23**		30B	**85.30**		50B	**81.52**
11	11S	**58.39**	31	31S	**62.01**	51	51S	**64.21**
	11B	**72.55**		31B	**77.75**		51B	**76.17**
12	12S	**51.93**	32	32S	**62.64**	52	52S	**78.85**
	12B	**61.85**		32B	**81.05**		52B	**79.16**
13	13S	**67.04**	33	33S	**67.99**	53	53S	**60.12**
	13B	**72.71**		33B	**75.86**		53B	**73.81**
14	14S	**61.85**	34	34S	**58.86**	54	54S	**58.07**
	14B	**75.70**		34B	**74.91**		54B	**60.90**
15	15S	**64.84**	35	35S	**64.84**	55	55S	**64.99**
	15B	**80.58**		35B	**66.26**		55B	**80.74**
16	16S	**60.43**	36	36S	**59.17**	56	56B	**63.74**
	16B	**62.48**		36B	**61.06**		56B	**80.89**
17	17S	**64.05**	37	37S	**67.83**	57	57S	**61.69**
	17B	**74.13**		37B	**77.43**		57B	**78.37**
18	18S	**59.17**	38	38S	**73.02**	58	58S	**70.50**
	18B	**75.86**		38B	**58.86**		58B	**74.28**
19	19S	**62.01**	39	39S	**69.09**			
	19B	**74.91**		39B	**76.64**			
20	20S	**60.91**	40	40S	**59.96**			
	20B	**76.80**		40B	**80.58**			

Note:

- *S: Surface layer, 2m*
- *B: Bottom layer, ≥ 100m*

Table 4. Pb-Concentration in seawater.

Station	Samples	Pb (nM)	Station	Samples	Pb (nM)	Station	Samples	Pb (nM)
1	1S	9.56	21	21S	8.73	41	41S	9.75
	1B	10.52		21B	9.85		41B	8.49
2	2S	9.79	22	22S	8.40	42	42S	8.11
	2B	13.18		22B	9.03		42B	8.59
3	3S	8.40	23	23S	8.16	43	43S	9.22
	3B	9.51		23B	9.27		43B	11.29
4	4S	10.23	24	24S	7.63	44	44S	8.59
	4B	11.15		24B	10.33		44B	9.75
5	5S	8.49	25	25S	9.80	45	45S	7.58
	5B	10.81		25B	9.07		45B	15.01
6	6S	9.07	26	26S	9.51	46	46S	7.82
	6B	8.97		26B	11.29		46B	11.87
7	7S	8.49	27	27S	10.23	47	47S	9.80
	7B	11.25		27B	13.61		47B	9.56
8	8S	8.30	28	28S	10.52	48	48S	8.78
	8B	8.83		28B	14.38		48B	11.25
9	9S	7.58	29	29S	9.75	49	49S	9.46
	9B	9.85		29B	10.62		49B	8.83
10	10S	8.83	30	30S	8.49	50	50S	8.25
	10B	10.96		30B	11.25		50B	9.70
11	11S	9.27	31	31S	7.14	51	51S	8.16
	11B	11.82		31B	11.63		51B	9.46
12	12S	9.70	32	32S	8.40	52	52S	8.69
	12B	9.60		32B	11.29		52B	11.92
13	13S	8.54	33	33S	7.82	53	53S	7.34
	13B	10.28		33B	11.97		53B	14.07
14	14S	8.11	34	34S	9.22	54	54S	7.14
	14B	7.78		34B	8.64		54B	9.27
15	15S	8.88	35	35S	8.78	55	55S	8.56
	15B	7.82		35B	11.48		55B	7.87
16	16S	7.58	36	36S	9.70	56	56B	7.53
	16B	6.95		36B	10.23		56B	9.60
17	17S	9.75	37	37S	8.40	57	57S	8.40
	17B	6.66		37B	6.47		57B	8.45
18	18S	6.37	38	38S	8.11	58	58S	10.52
	18B	7.53		38B	10.81		58B	10.52
19	19S	7.05	39	39S	8.74			
	19B	8.78		39B	9.51			
20	20S	9.70	40	40S	8.30			
	20B	8.54		40B	8.40			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 5. Cd-Concentration in seawater.

Station	Samples	Cd (nM)	Station	Samples	Cd (nM)	Station	Samples	Cd (nM)
1	1S	**1.86**	**21**	21S	**2.05**	**41**	41S	**1.25**
	1B	**2.14**		21B	**1.33**		41B	**2.31**
2	2S	**1.95**	**22**	22S	**1.60**	**42**	42S	**1.42**
	2B	**2.31**		22B	**2.05**		42B	**2.40**
3	3S	**1.69**	**23**	23S	**1.42**	**43**	43S	**1.07**
	3B	**2.05**		23B	**1.60**		43B	**2.58**
4	4S	**1.51**	**24**	24S	**1.33**	**44**	44S	**1.16**
	4B	**1.42**		24B	**1.42**		44B	**2.14**
5	5S	**1.78**	**25**	25S	**1.86**	**45**	45S	**0.98**
	5B	**1.51**		25B	**1.69**		45B	**2.22**
6	6S	**1.60**	**26**	26S	**1.69**	**46**	46S	**2.67**
	6B	**1.96**		26B	**1.95**		46B	**2.40**
7	7S	**1.51**	**27**	27S	**1.51**	**47**	47S	**2.49**
	7B	**1.16**		27B	**2.31**		47B	**2.58**
8	8S	**1.42**	**28**	28S	**1.60**	**48**	48S	**1.25**
	8B	**1.33**		28B	**2.76**		48B	**2.67**
9	9S	**1.60**	**29**	29S	**2.31**	**49**	49S	**1.86**
	9B	**1.33**		29B	**2.85**		49B	**1.60**
10	10S	**1.33**	**30**	30S	**1.51**	**50**	50S	**2.31**
	10B	**2.05**		30B	**2.76**		50B	**2.05**
11	11S	**1.07**	**31**	31S	**1.69**	**51**	51S	**1.78**
	11B	**2.14**		31B	**2.49**		51B	**2.31**
12	12S	**0.98**	**32**	32S	**1.95**	**52**	52S	**1.51**
	12B	**2.40**		32B	**2.14**		52B	**3.38**
13	13S	**1.16**	**33**	33S	**1.25**	**53**	53S	**1.42**
	13B	**2.76**		33B	**2.31**		53B	**3.91**
14	14S	**1.60**	**34**	34S	**1.16**	**54**	54S	**1.25**
	14B	**1.25**		34B	**1.07**		54B	**3.11**
15	15S	**1.07**	**35**	35S	**1.33**	**55**	55S	**1.07**
	15B	**1.42**		35B	**1.51**		55B	**2.14**
16	16S	**1.25**	**36**	36S	**1.51**	**56**	56B	**2.55**
	16B	**1.25**		36B	**2.14**		56B	**2.49**
17	17S	**1.69**	**37**	37S	**1.80**	**57**	57S	**0.98**
	17B	**1.86**		37B	**2.67**		57B	**2.85**
18	18S	**1.42**	**38**	38S	**1.95**	**58**	58S	**2.05**
	18B	**1.95**		38B	**1.69**		58B	**5.05**
19	19S	**1.86**	**39**	39S	**2.67**	***Note:***		
	19B	**1.16**		39B	**3.39**	• ***S: Surface layer, 2m***		
20	20S	**2.67**	**40**	40S	**1.51**	• ***B: Bottom layer, ≥ 100m***		
	20B	**1.07**		40B	**2.14**			

Table 6. Zn-Concentration in seawater.

Station	Samples	Zn (nM)	Station	Samples	Zn (nM)	Station	Samples	Zn (nM)
1	1S	**156.52**	**21**	21S	**156.68**	**41**	41S	**136.96**
	1B	**188.38**		21B	**118.45**		41B	**147.73**
2	2S	**149.36**	**22**	22S	**134.38**	**42**	42S	**146.97**
	2B	**180.65**		22B	**155.31**		42B	**133.17**
3	3S	**133.32**	**23**	23S	**120.43**	**43**	43S	**134.08**
	3B	**181.11**		23B	**134.38**		43B	**154.86**
4	4S	**145.91**	**24**	24S	**158.95**	**44**	44S	**133.17**
	4B	**162.90**		24B	**138.63**		44B	**168.06**
5	5S	**152.13**	**25**	25S	**132.56**	**45**	45S	**172.00**
	5B	**150.46**		25B	**135.59**		45B	**158.05**
6	6S	**150.46**	**26**	26S	**145.91**	**46**	46S	**161.83**
	6B	**147.27**		26B	**157.14**		46B	**147.73**
7	7S	**127.10**	**27**	27S	**152.73**	**47**	47S	**163.96**
	7B	**132.87**		27B	**170.02**		47B	**146.82**
8	8S	**127.71**	**28**	28S	**150.00**	**48**	48S	**132.56**
	8B	**137.57**		28B	**188.38**		48B	**150.76**
9	9S	**133.59**	**29**	29S	**151.22**	**49**	49S	**131.65**
	9B	**149.85**		29B	**174.27**		49B	**156.53**
10	10S	**162.75**	**30**	30S	**156.37**	**50**	50S	**136.96**
	10B	**156.38**		30B	**182.92**		50B	**167.91**
11	11S	**133.47**	**31**	31S	**146.06**	**51**	51S	**133.17**
	11B	**158.05**		31B	**198.99**		51B	**203.55**
12	12S	**141.36**	**32**	32S	**147.43**	**52**	52S	**140.45**
	12B	**135.59**		32B	**173.82**		52B	**161.99**
13	13S	**115.42**	**33**	33S	**134.53**	**53**	53S	**150.16**
	13B	**138.63**		33B	**164.11**		53B	**150.46**
14	14S	**133.47**	**34**	34S	**142.42**	**54**	54S	**126.04**
	14B	**131.50**		34B	**176.24**		54B	**134.08**
15	15S	**141.97**	**35**	35S	**140.15**	**55**	55S	**150.46**
	15B	**131.05**		35B	**148.49**		55B	**156.53**
16	16S	**133.32**	**36**	36S	**157.44**	**56**	56B	**150.64**
	16B	**139.81**		36B	**172.00**		56B	**167.75**
17	17S	**123.31**	**37**	37S	**134.54**	**57**	57S	**152.13**
	17B	**140.45**		37B	**148.95**		57B	**173.82**
18	18S	**154.86**	**38**	38S	**150.61**	**58**	58S	**102.53**
	18B	**163.50**		38B	**146.97**		58B	**187.17**
19	19S	**150.15**	**39**	39S	**139.08**			
	19B	**155.01**		39B	**156.53**			
20	20S	**167.14**	**40**	40S	**133.32**			
	20B	**138.21**		40B	**161.98**			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥100m***

Table 7. Ni-Concentration in seawater.

Station	Samples	Ni (nM)	Station	Samples	Ni (nM)	Station	Samples	Ni (nM)
1	1S	**20.61**	**21**	21S	**17.54**	**41**	41S	**13.29**
	1B	**36.62**		21B	**25.89**		41B	**29.47**
2	2S	**27.59**	**22**	22S	**28.62**	**42**	42S	**27.93**
	2B	**33.73**		22B	**24.87**		42B	**21.80**
3	3S	**25.21**	**23**	23S	**22.82**	**43**	43S	**29.64**
	3B	**39.35**		23B	**27.59**		43B	**24.19**
4	4S	**23.34**	**24**	24S	**21.63**	**44**	44S	**22.14**
	4B	**34.41**		24B	**28.96**		44B	**22.65**
5	5S	**19.08**	**25**	25S	**19.76**	**45**	45S	**21.46**
	5B	**29.47**		25B	**32.19**		45B	**36.45**
6	6S	**17.20**	**26**	26S	**25.21**	**46**	46S	**22.31**
	6B	**29.98**		26B	**27.59**		46B	**34.41**
7	7S	**33.73**	**27**	27S	**34.24**	**47**	47S	**20.09**
	7B	**24.53**		27B	**27.93**		47B	**33.38**
8	8S	**19.07**	**28**	28S	**24.18**	**48**	48S	**19.08**
	8B	**25.21**		28B	**25.89**		48B	**32.02**
9	9S	**14.82**	**29**	29S	**27.59**	**49**	49S	**17.20**
	9B	**27.59**		29B	**28.96**		49B	**29.64**
10	10S	**16.01**	**30**	30S	**25.04**	**50**	50S	**30.83**
	10B	**30.83**		30B	**41.05**		50B	**35.09**
11	11S	**21.46**	**31**	31S	**23.51**	**51**	51S	**29.13**
	11B	**30.49**		31B	**39.69**		51B	**36.28**
12	12S	**23.51**	**32**	32S	**21.97**	**52**	52S	**17.54**
	12B	**22.82**		32B	**42.24**		52B	**37.13**
13	13S	**22.82**	**33**	33S	**24.02**	**53**	53S	**16.86**
	13B	**21.46**		33B	**36.96**		53B	**39.86**
14	14S	**24.19**	**34**	34S	**29.47**	**54**	54S	**31.68**
	14B	**21.80**		34B	**39.86**		54B	**33.72**
15	15S	**15.33**	**35**	35S	**27.59**	**55**	55S	**22.31**
	15B	**34.58**		35B	**30.99**		55B	**32.70**
16	16S	**18.90**	**36**	36S	**22.82**	**56**	56B	**26.92**
	16B	**18.90**		36B	**29.98**		56B	**31.85**
17	17S	**18.39**	**37**	37S	**15.67**	**57**	57S	**21.12**
	17B	**19.42**		37B	**30.83**		57B	**34.41**
18	18S	**20.27**	**38**	38S	**16.52**	**58**	58S	**19.25**
	18B	**20.10**		38B	**34.58**		58B	**31.34**
19	19S	**20.44**	**39**	39S	**23.80**			
	19B	**23.34**		39B	**29.97**			
20	20S	**19.25**	**40**	40S	**16.86**			
	20B	**24.87**		40B	**39.86**			

Note:

- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 8. Cr-Concentration in seawater.

Station	Samples	Cr (nM)	Station	Samples	Cr (nM)	Station	Samples	Cr (nM)
1	1S	**23.08**	**21**	21S	**16.54**	**41**	41S	**16.73**
	1B	**22.12**		21B	**13.08**		41B	**27.31**
2	2S	**19.80**	**22**	22S	**15.19**	**42**	42S	**17.69**
	2B	**24.23**		22B	**14.23**		42B	**16.73**
3	3S	**18.85**	**23**	23S	**14.23**	**43**	43S	**24.42**
	3B	**18.85**		23B	**15.19**		43B	**26.35**
4	4S	**18.46**	**24**	24S	**21.73**	**44**	44S	**16.54**
	4B	**16.15**		24B	**21.35**		44B	**27.30**
5	5S	**15.96**	**25**	25S	**20.00**	**45**	45S	**34.81**
	5B	**25.38**		25B	**19.04**		45B	**24.23**
6	6S	**18.65**	**26**	26S	**22.31**	**46**	46S	**25.00**
	6B	**27.12**		26B	**23.66**		46B	**22.69**
7	7S	**19.42**	**27**	27S	**18.85**	**47**	47S	**24.23**
	7B	**20.77**		27B	**20.77**		47B	**25.38**
8	8S	**16.35**	**28**	28S	**14.62**	**48**	48S	**21.15**
	8B	**30.77**		28B	**21.54**		48B	**23.65**
9	9S	**21.54**	**29**	29S	**25.39**	**49**	49S	**14.82**
	9B	**15.77**		29B	**24.23**		49B	**24.04**
10	10S	**14.62**	**30**	30S	**17.31**	**50**	50S	**15.19**
	10B	**23.46**		30B	**25.00**		50B	**35.00**
11	11S	**17.69**	**31**	31S	**16.54**	**51**	51S	**16.54**
	11B	**18.08**		31B	**21.35**		51B	**26.73**
12	12S	**16.73**	**32**	32S	**13.85**	**52**	52S	**15.38**
	12B	**26.16**		32B	**16.92**		52B	**23.37**
13	13S	**21.35**	**33**	33S	**16.15**	**53**	53S	**20.58**
	13B	**23.85**		33B	**19.04**		53B	**28.46**
14	14S	**18.46**	**34**	34S	**15.77**	**54**	54S	**21.54**
	14B	**25.19**		34B	**25.58**		54B	**25.00**
15	15S	**26.54**	**35**	35S	**15.19**	**55**	55S	**18.85**
	15B	**20.96**		35B	**23.85**		55B	**33.85**
16	16S	**14.23**	**36**	36S	**25.77**	**56**	56B	**15.92**
	16B	**22.18**		36B	**16.73**		56B	**30.39**
17	17S	**14.82**	**37**	37S	**22.31**	**57**	57S	**15.00**
	17B	**16.73**		37B	**17.69**		57B	**37.31**
18	18S	**23.27**	**38**	38S	**17.31**	**58**	58S	**20.38**
	18B	**15.19**		38B	**25.58**		58B	**25.38**
19	19S	**25.00**	**39**	39S	**25.19**			
	19B	**16.92**		39B	**24.23**			
20	20S	**17.69**	**40**	40S	**25.77**			
	20B	**18.08**		40B	**25.19**			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥100m***

Table 9. As-Concentration in seawater.

Station	Samples	As (nM)	Station	Samples	As (nM)	Station	Samples	As (nM)
1	1S	**21.22**	**21**	21S	**20.82**	**41**	41S	**23.62**
	1B	**17.22**		21B	**18.55**		41B	**21.49**
2	2S	**22.29**	**22**	22S	**19.22**	**42**	42S	**22.02**
	2B	**20.15**		22B	**16.68**		42B	**23.89**
3	3S	**17.48**	**23**	23S	**20.28**	**43**	43S	**21.76**
	3B	**21.49**		23B	**19.35**		43B	**23.62**
4	4S	**27.76**	**24**	24S	**24.56**	**44**	44S	**23.22**
	4B	**21.75**		24B	**22.82**		44B	**26.83**
5	5S	**23.89**	**25**	25S	**18.15**	**45**	45S	**21.36**
	5B	**17.61**		25B	**19.22**		45B	**21.36**
6	6S	**20.55**	**26**	26S	**22.56**	**46**	46S	**24.16**
	6B	**20.55**		26B	**20.02**		46B	**28.83**
7	7S	**32.70**	**27**	27S	**20.83**	**47**	47S	**27.76**
	7B	**21.88**		27B	**18.15**		47B	**19.09**
8	8S	**21.22**	**28**	28S	**19.75**	**48**	48S	**25.09**
	8B	**21.49**		28B	**18.01**		48B	**22.02**
9	9S	**30.96**	**29**	29S	**23.09**	**49**	49S	**23.49**
	9B	**21.62**		29B	**20.82**		49B	**29.09**
10	10S	**26.29**	**30**	30S	**21.22**	**50**	50S	**23.22**
	10B	**18.82**		30B	**20.42**		50B	**22.96**
11	11S	**33.37**	**31**	31S	**17.75**	**51**	51S	**26.96**
	11B	**19.09**		31B	**78.95**		51B	**20.28**
12	12S	**21.16**	**32**	32S	**21.22**	**52**	52S	**21.89**
	12B	**20.95**		32B	**24.16**		52B	**23.22**
13	13S	**21.22**	**33**	33S	**22.69**	**53**	53S	**20.42**
	13B	**20.15**		33B	**19.22**		53B	**24.69**
14	14S	**21.49**	**34**	34S	**23.09**	**54**	54S	**19.62**
	14B	**20.28**		34B	**19.75**		54B	**24.96**
15	15S	**19.62**	**35**	35S	**20.42**	**55**	55S	**21.89**
	15B	**21.36**		35B	**23.49**		55B	**24.16**
16	16S	**19.22**	**36**	36S	**26.03**	**56**	56B	**23.36**
	16B	**18.68**		36B	**38.03**		56B	**19.35**
17	17S	**23.89**	**37**	37S	**19.88**	**57**	57S	**19.89**
	17B	**16.82**		37B	**19.49**		57B	**26.43**
18	18S	**17.88**	**38**	38S	**16.42**	**58**	58S	**20.55**
	18B	**19.62**		38B	**19.49**		58B	**18.82**
19	19S	**23.49**	**39**	39S	**21.22**	***Note:***		
	19B	**19.62**		39B	**20.55**	• ***S: Surface layer, 2m***		
20	20S	**21.76**	**40**	40S	**19.62**	• ***B: Bottom layer, ≥ 100m***		
	20B	**20.82**		40B	**21.08**			

Table 10. Hg-Concentration in seawater.

Station	Samples	Hg (nM)	Station	Samples	Hg (nM)	Station	Samples	Hg (nM)
1	1S	**0.60**	**21**	21S	**0.85**	**41**	41S	**0.79**
	1B	**0.55**		21B	**0.35**		41B	**0.89**
2	2S	**0.55**	**22**	22S	**0.45**	**42**	42S	**0.85**
	2B	**0.69**		22B	**0.35**		42B	**0.89**
3	3S	**0.59**	**23**	23S	**0.45**	**43**	43S	**0.85**
	3B	**0.69**		23B	**1.24**		43B	**0.89**
4	4S	**0.40**	**24**	24S	**0.49**	**44**	44S	**0.85**
	4B	**0.40**		24B	**0.49**		44B	**0.80**
5	5S	**0.59**	**25**	25S	**0.45**	**45**	45S	**0.49**
	5B	**0.85**		25B	**0.41**		45B	**0.82**
6	6S	**0.75**	**26**	26S	**0.49**	**46**	46S	**0.60**
	6B	**0.55**		26B	**0.45**		46B	**0.45**
7	7S	**0.75**	**27**	27S	**0.45**	**47**	47S	**0.49**
	7B	**0.55**		27B	**0.35**		47B	**0.60**
8	8S	**6.48**	**28**	28S	**0.35**	**48**	48S	**0.60**
	8B	**0.49**		28B	**0.49**		48B	**3.60**
9	9S	**1.54**	**29**	29S	**0.99**	**49**	49S	**0.70**
	9B	**0.89**		29B	**0.89**		49B	**1.05**
10	10S	**0.59**	**30**	30S	**0.45**	**50**	50S	**2.09**
	10B	**0.60**		30B	**0.75**		50B	**1.45**
11	11S	**0.70**	**31**	31S	**0.65**	**51**	51S	**0.60**
	11B	**0.70**		31B	**0.65**		51B	**0.55**
12	12S	**0.75**	**32**	32S	**0.89**	**52**	52S	**0.55**
	12B	**0.45**		32B	**0.60**		52B	**0.55**
13	13S	**0.55**	**33**	33S	**0.80**	**53**	53S	**0.65**
	13B	**0.45**		33B	**3.09**		53B	**0.65**
14	14S	**0.40**	**34**	34S	**1.69**	**54**	54S	**0.60**
	14B	**0.80**		34B	**0.85**		54B	**0.49**
15	15S	**0.41**	**35**	35S	**0.60**	**55**	55S	**0.80**
	15B	**0.65**		35B	**0.70**		55B	**0.49**
16	16S	**0.35**	**36**	36S	**0.75**	**56**	56B	**0.60**
	16B	**0.49**		36B	**089**		56B	**7.13**
17	17S	**0.35**	**37**	37S	**0.45**	**57**	57S	**1.20**
	17B	**0.41**		37B	**0.75**		57B	**0.89**
18	18S	**0.55**	**38**	38S	**0.60**	**58**	58S	**0.60**
	18B	**0.89**		38B	**0.75**		58B	**2.46**
19	19S	**0.45**	**39**	39S	**0.70**			
	19B	**0.41**		39B	**0.95**			
20	20S	**0.55**	**40**	40S	**0.60**			
	20B	**0.90**		40B	**2.59**			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 11. Cu-Concentration in seawater.

Station	Samples	Cu (µg/l)	Station	Samples	Cu (µg/l)	Station	Samples	Cu (µg/l)
1	1S	4.87	**21**	21S	4.14	**41**	41S	3.78
	1B	5.74		21B	5.09		41B	5.03
2	2S	4.69	**22**	22S	4.78	**42**	42S	3.69
	2B	5.54		22B	4.62		42B	4.96
3	3S	4.74	**23**	23S	4.62	**43**	43S	4.13
	3B	4.79		23B	4.31		43B	4.82
4	4S	5.02	**24**	24S	5.01	**44**	44S	3.82
	4B	4.86		24B	5.03		44B	5.31
5	5S	3.96	**25**	25S	4.77	**45**	45S	4.07
	5B	5.12		25B	4.86		45B	5.05
6	6S	4.32	**26**	26S	4.31	**46**	46S	3.69
	6B	4.27		26B	5.12		46B	4.97
7	7S	4.18	**27**	27S	4.83	**47**	47S	3.87
	7B	4.31		27B	4.96		47B	4.83
8	8S	3.74	**28**	28S	4.62	**48**	48S	4.13
	8B	4.74		28B	5.03		48B	3.72
9	9S	3.84	**29**	29S	4.77	**49**	49S	4.26
	9B	4.26		29B	5.86		49B	4.07
10	10S	3.86	**30**	30S	4.62	**50**	50S	3.93
	10B	4.59		30B	5.42		50B	5.18
11	11S	3.71	**31**	31S	3.94	**51**	51S	4.08
	11B	4.61		31B	4.94		51B	4.84
12	12S	3.30	**32**	32S	3.98	**52**	52S	5.01
	12B	3.93		32B	5.15		52B	5.03
13	13S	4.26	**33**	33S	4.32	**53**	53S	3.82
	13B	4.62		33B	4.82		53B	4.69
14	14S	3.93	**34**	34S	3.74	**54**	54S	3.69
	14B	4.81		34B	4.76		54B	3.87
15	15S	4.12	**35**	35S	4.12	**55**	55S	4.13
	15B	5.12		35B	4.21		55B	5.13
16	16S	3.84	**36**	36S	3.76	**56**	56B	4.05
	16B	3.97		36B	3.88		56B	5.14
17	17S	4.07	**37**	37S	4.31	**57**	57S	3.92
	17B	4.71		37B	4.92		57B	4.98
18	18S	3.76	**38**	38S	4.64	**58**	58S	4.48
	18B	4.82		38B	3.74		58B	4.72
19	19S	3.94	**39**	39S	4.39			
	19B	4.76		39B	4.87			
20	20S	3.87	**40**	40S	3.81			
	20B	4.88		40B	5.12			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 12. Pb-Concentration in seawater.

Station	Samples	Pb (μg/l)	Station	Samples	Pb (μg/l)	Station	Samples	Pb (μg/l)
1	1S	**1.98**	**21**	21S	**1.81**	**41**	41S	**2.02**
	1B	**2.18**		21B	**2.04**		41B	**1.76**
2	2S	**2.03**	**22**	22S	**1.74**	**42**	42S	**1.68**
	2B	**2.73**		22B	**1.87**		42B	**1.78**
3	3S	**1.74**	**23**	23S	**1.69**	**43**	43S	**1.91**
	3B	**1.97**		23B	**1.92**		43B	**2.34**
4	4S	**2.12**	**24**	24S	**1.58**	**44**	44S	**1.78**
	4B	**2.31**		24B	**2.14**		44B	**2.02**
5	5S	**1.76**	**25**	25S	**2.03**	**45**	45S	**1.57**
	5B	**2.24**		25B	**1.88**		45B	**3.11**
6	6S	**1.88**	**26**	26S	**1.97**	**46**	46S	**1.62**
	6B	**1.86**		26B	**2.34**		46B	**2.46**
7	7S	**1.76**	**27**	27S	**2.12**	**47**	47S	**2.03**
	7B	**2.33**		27B	**2.82**		47B	**1.98**
8	8S	**1.72**	**28**	28S	**2.18**	**48**	48S	**1.82**
	8B	**1.83**		28B	**2.98**		48B	**2.33**
9	9S	**1.57**	**29**	29S	**2.02**	**49**	49S	**1.96**
	9B	**2.04**		29B	**2.20**		49B	**1.83**
10	10S	**1.83**	**30**	30S	**1.76**	**50**	50S	**1.71**
	10B	**2.27**		30B	**2.33**		50B	**2.01**
11	11S	**1.92**	**31**	31S	**1.48**	**51**	51S	**1.69**
	11B	**2.45**		31B	**2.41**		51B	**1.96**
12	12S	**2.01**	**32**	32S	**1.74**	**52**	52S	**1.80**
	12B	**1.99**		32B	**2.34**		52B	**2.47**
13	13S	**1.77**	**33**	33S	**1.62**	**53**	53S	**1.52**
	13B	**2.13**		33B	**2.48**		53B	**2.91**
14	14S	**1.68**	**34**	34S	**1.91**	**54**	54S	**1.48**
	14B	**1.61**		34B	**1.79**		54B	**1.92**
15	15S	**1.84**	**35**	35S	**1.82**	**55**	55S	**1.77**
	15B	**1.62**		35B	**2.38**		55B	**1.63**
16	16S	**1.57**	**36**	36S	**2.01**	**56**	56B	**1.56**
	16B	**1.44**		36B	**2.12**		56B	**1.99**
17	17S	**2.02**	**37**	37S	**1.74**	**57**	57S	**1.74**
	17B	**1.38**		37B	**1.34**		57B	**1.76**
18	18S	**1.32**	**38**	38S	**1.68**	**58**	58S	**2.18**
	18B	**1.56**		38B	**2.24**		58B	**2.18**
19	19S	**1.46**	**39**	39S	**1.81**			
	19B	**1.82**		39B	**1.97**			
20	20S	**2.01**	**40**	40S	**1.72**			
	20B	**1.77**		40B	**1.74**			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 13. Cd-Concentration in seawater.

Station	Samples	Cd (μg/l)	Station	Samples	Cd (μg/l)	Station	Samples	Cd (μg/l)
1	1S	**0.21**	**21**	21S	**0.23**	**41**	41S	**0.14**
	1B	**0.24**		21B	**0.15**		41B	**0.26**
2	2S	**0.22**	**22**	22S	**0.18**	**42**	42S	**0.16**
	2B	**0.26**		22B	**0.23**		42B	**0.27**
3	3S	**0.19**	**23**	23S	**0.16**	**43**	43S	**0.12**
	3B	**0.23**		23B	**0.18**		43B	**0.29**
4	4S	**0.17**	**24**	24S	**0.15**	**44**	44S	**0.13**
	4B	**0.16**		24B	**0.16**		44B	**0.24**
5	5S	**0.20**	**25**	25S	**0.21**	**45**	45S	**0.11**
	5B	**0.17**		25B	**0.19**		45B	**0.25**
6	6S	**0.18**	**26**	26S	**0.19**	**46**	46S	**0.30**
	6B	**0.22**		26B	**0.22**		46B	**0.27**
7	7S	**0.17**	**27**	27S	**0.17**	**47**	47S	**0.28**
	7B	**0.13**		27B	**0.26**		47B	**0.29**
8	8S	**0.16**	**28**	28S	**0.18**	**48**	48S	**0.14**
	8B	**0.15**		28B	**0.31**		48B	**0.30**
9	9S	**0.18**	**29**	29S	**0.26**	**49**	49S	**0.21**
	9B	**0.15**		29B	**0.32**		49B	**0.18**
10	10S	**0.15**	**30**	30S	**0.17**	**50**	50S	**0.26**
	10B	**0.23**		30B	**0.31**		50B	**0.23**
11	11S	**0.12**	**31**	31S	**0.19**	**51**	51S	**0.20**
	11B	**0.24**		31B	**0.28**		51B	**0.26**
12	12S	**0.11**	**32**	32S	**0.22**	**52**	52S	**0.17**
	12B	**0.27**		32B	**0.24**		52B	**0.38**
13	13S	**0.13**	**33**	33S	**0.14**	**53**	53S	**0.16**
	13B	**0.31**		33B	**0.26**		53B	**0.44**
14	14S	**0.18**	**34**	34S	**0.13**	**54**	54S	**0.14**
	14B	**0.14**		34B	**0.12**		54B	**0.35**
15	15S	**0.12**	**35**	35S	**0.15**	**55**	55S	**0.12**
	15B	**0.16**		35B	**0.17**		55B	**0.24**
16	16S	**0.14**	**36**	36S	**0.17**	**56**	56B	**0.29**
	16B	**0.14**		36B	**0.24**		56B	**0.28**
17	17S	**0.19**	**37**	37S	**0.20**	**57**	57S	**0.11**
	17B	**0.21**		37B	**0.30**		57B	**0.32**
18	18S	**0.16**	**38**	38S	**0.22**	**58**	58S	**0.23**
	18B	**0.22**		38B	**0.19**		58B	**0.57**
19	19S	**0.21**	**39**	39S	**0.30**	***Note:***		
	19B	**0.13**		39B	**0.38**	• ***S: Surface layer, 2m***		
20	20S	**0.30**	**40**	40S	**0.17**	• ***B: Bottom layer, ≥ 100m***		
	20B	**0.12**		40B	**0.24**			

Table 14. Zn-Concentration in seawater.

Station	Samples	Zn (μg/l)	Station	Samples	Zn (μg/l)	Station	Samples	Zn (μg/l)
1	1S	**10.32**	**21**	21S	**10.33**	**41**	41S	**9.03**
	1B	**12.42**		21B	**7.81**		41B	**9.74**
2	2S	**9.85**	**22**	22S	**8.86**	**42**	42S	**9.69**
	2B	**11.91**		22B	**10.24**		42B	**8.78**
3	3S	**8.79**	**23**	23S	**7.94**	**43**	43S	**8.84**
	3B	**11.94**		23B	**8.86**		43B	**10.21**
4	4S	**9.62**	**24**	24S	**10.48**	**44**	44S	**8.78**
	4B	**10.74**		24B	**9.14**		44B	**11.08**
5	5S	**10.03**	**25**	25S	**8.74**	**45**	45S	**11.34**
	5B	**9.92**		25B	**8.94**		45B	**10.42**
6	6S	**9.92**	**26**	26S	**9.62**	**46**	46S	**10.67**
	6B	**9.71**		26B	**10.36**		46B	**9.74**
7	7S	**8.38**	**27**	27S	**10.07**	**47**	47S	**10.81**
	7B	**8.76**		27B	**11.21**		47B	**9.68**
8	8S	**8.42**	**28**	28S	**9.89**	**48**	48S	**8.74**
	8B	**9.07**		28B	**12.42**		48B	**9.94**
9	9S	**8.81**	**29**	29S	**9.97**	**49**	49S	**8.68**
	9B	**9.88**		29B	**11.49**		49B	**10.32**
10	10S	**10.73**	**30**	30S	**10.31**	**50**	50S	**9.03**
	10B	**10.31**		30B	**12.06**		50B	**11.07**
11	11S	**8.80**	**31**	31S	**9.63**	**51**	51S	**8.78**
	11B	**10.42**		31B	**13.12**		51B	**13.42**
12	12S	**9.32**	**32**	32S	**9.72**	**52**	52S	**9.26**
	12B	**8.94**		32B	**11.46**		52B	**10.68**
13	13S	**7.61**	**33**	33S	**8.87**	**53**	53S	**9.90**
	13B	**9.14**		33B	**10.82**		53B	**9.92**
14	14S	**8.80**	**34**	34S	**9.39**	**54**	54S	**8.31**
	14B	**8.67**		34B	**11.62**		54B	**8.84**
15	15S	**9.36**	**35**	35S	**9.24**	**55**	55S	**9.92**
	15B	**8.64**		35B	**9.79**		55B	**10.32**
16	16S	**8.79**	**36**	36S	**10.38**	**56**	56B	**9.93**
	16B	**9.22**		36B	**11.34**		56B	**11.06**
17	17S	**8.13**	**37**	37S	**8.87**	**57**	57S	**10.03**
	17B	**9.26**		37B	**9.82**		57B	**11.46**
18	18S	**10.21**	**38**	38S	**9.93**	**58**	58S	**6.76**
	18B	**10.78**		38B	**9.69**		58B	**12.34**
19	19S	**9.90**	**39**	39S	**9.17**	***Note:***		
	19B	**10.22**		39B	**10.32**	• ***S: Surface layer, 2m***		
20	20S	**11.02**	**40**	40S	**8.79**	• ***B: Bottom layer, ≥ 100m***		
	20B	**9.11**		40B	**10.68**			

Table 15. Ni-Concentration in seawater.

Station	Samples	Ni (μg/l)	Station	Samples	Ni (μg/l)	Station	Samples	Ni (μg/l)
1	1S	**1.21**	**21**	21S	**1.21**	**41**	41S	**0.78**
	1B	**2.15**		21B	**2.15**		41B	**1.73**
2	2S	**1.62**	**22**	22S	**1.62**	**42**	42S	**1.64**
	2B	**1.98**		22B	**1.98**		42B	**1.28**
3	3S	**1.48**	**23**	23S	**1.48**	**43**	43S	**1.74**
	3B	**2.31**		23B	**2.31**		43B	**1.42**
4	4S	**1.37**	**24**	24S	**1.37**	**44**	44S	**1.30**
	4B	**2.02**		24B	**2.02**		44B	**1.33**
5	5S	**1.12**	**25**	25S	**1.12**	**45**	45S	**1.26**
	5B	**1.73**		25B	**1.73**		45B	**2.14**
6	6S	**1.01**	**26**	26S	**1.01**	**46**	46S	**1.31**
	6B	**1.76**		26B	**1.76**		46B	**2.02**
7	7S	**1.98**	**27**	27S	**1.98**	**47**	47S	**1.18**
	7B	**1.44**		27B	**1.44**		47B	**1.96**
8	8S	**1.12**	**28**	28S	**1.12**	**48**	48S	**1.12**
	8B	**1.48**		28B	**1.48**		48B	**1.88**
9	9S	**0.87**	**29**	29S	**0.87**	**49**	49S	**1.01**
	9B	**1.62**		29B	**1.62**		49B	**1.74**
10	10S	**0.94**	**30**	30S	**0.94**	**50**	50S	**1.81**
	10B	**1.81**		30B	**1.81**		50B	**2.06**
11	11S	**1.26**	**31**	31S	**1.26**	**51**	51S	**1.71**
	11B	**1.79**		31B	**1.79**		51B	**2.13**
12	12S	**1.38**	**32**	32S	**1.38**	**52**	52S	**1.03**
	12B	**1.34**		32B	**1.34**		52B	**2.18**
13	13S	**1.34**	**33**	33S	**1.34**	**53**	53S	**0.99**
	13B	**1.26**		33B	**1.26**		53B	**2.34**
14	14S	**1.42**	**34**	34S	**1.42**	**54**	54S	**1.86**
	14B	**1.28**		34B	**1.28**		54B	**1.98**
15	15S	**0.90**	**35**	35S	**0.90**	**55**	55S	**1.31**
	15B	**2.03**		35B	**2.03**		55B	**1.92**
16	16S	**1.11**	**36**	36S	**1.11**	**56**	56B	**1.58**
	16B	**1.11**		36B	**1.11**		56B	**1.87**
17	17S	**1.08**	**37**	37S	**1.08**	**57**	57S	**1.24**
	17B	**1.14**		37B	**1.14**		57B	**2.02**
18	18S	**1.19**	**38**	38S	**1.19**	**58**	58S	**1.13**
	18B	**1.18**		38B	**1.18**		58B	**1.84**
19	19S	**1.20**	**39**	39S	**1.20**	*Note:*		
	19B	**1.37**		39B	**1.37**	• *S: Surface layer, 2m*		
20	20S	**1.13**	**40**	40S	**1.13**	• *B: Bottom layer, ≥ 100m*		
	20B	**1.46**		40B	**1.46**			

Table 16. Cr-Concentration in seawater.

Station	Samples	Cr (μg/l)	Station	Samples	Cr (μg/l)	Station	Samples	Cr (μg/l)
1	1S	**1.20**	**21**	21S	**0.86**	**41**	41S	**0.87**
	1B	**1.15**		21B	**0.68**		41B	**1.42**
2	2S	**1.03**	**22**	22S	**0.79**	**42**	42S	**0.92**
	2B	**1.26**		22B	**0.74**		42B	**0.87**
3	3S	**0.98**	**23**	23S	**0.74**	**43**	43S	**1.27**
	3B	**0.98**		23B	**0.79**		43B	**1.37**
4	4S	**0.96**	**24**	24S	**1.13**	**44**	44S	**0.86**
	4B	**0.84**		24B	**1.11**		44B	**1.42**
5	5S	**0.83**	**25**	25S	**1.04**	**45**	45S	**1.81**
	5B	**1.32**		25B	**0.99**		45B	**1.26**
6	6S	**0.97**	**26**	26S	**1.16**	**46**	46S	**1.30**
	6B	**1.41**		26B	**1.23**		46B	**1.18**
7	7S	**1.01**	**27**	27S	**0.98**	**47**	47S	**1.26**
	7B	**1.08**		27B	**1.08**		47B	**1.32**
8	8S	**0.85**	**28**	28S	**0.76**	**48**	48S	**1.10**
	8B	**1.60**		28B	**1.12**		48B	**1.23**
9	9S	**1.12**	**29**	29S	**1.32**	**49**	49S	**0.77**
	9B	**0.82**		29B	**1.26**		49B	**1.25**
10	10S	**0.76**	**30**	30S	**0.90**	**50**	50S	**0.79**
	10B	**1.22**		30B	**1.30**		50B	**1.82**
11	11S	**0.92**	**31**	31S	**0.86**	**51**	51S	**0.86**
	11B	**0.94**		31B	**1.11**		51B	**1.39**
12	12S	**0.87**	**32**	32S	**0.72**	**52**	52S	**0.80**
	12B	**1.36**		32B	**0.88**		52B	**1.22**
13	13S	**1.11**	**33**	33S	**0.84**	**53**	53S	**1.07**
	13B	**1.24**		33B	**0.99**		53B	**1.48**
14	14S	**0.96**	**34**	34S	**0.82**	**54**	54S	**1.12**
	14B	**1.31**		34B	**1.33**		54B	**1.30**
15	15S	**1.38**	**35**	35S	**0.79**	**55**	55S	**0.98**
	15B	**1.09**		35B	**1.24**		55B	**1.76**
16	16S	**0.74**	**36**	36S	**1.34**	**56**	56B	**0.83**
	16B	**1.15**		36B	**0.87**		56B	**1.58**
17	17S	**0.77**	**37**	37S	**1.16**	**57**	57S	**0.78**
	17B	**0.87**		37B	**0.92**		57B	**1.94**
18	18S	**1.21**	**38**	38S	**0.90**	**58**	58S	**1.06**
	18B	**0.79**		38B	**1.33**		58B	**1.32**
19	19S	**1.30**	**39**	39S	**1.31**			
	19B	**0.88**		39B	**1.26**			
20	20S	**0.92**	**40**	40S	**1.34**			
	20B	**0.94**		40B	**1.31**			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 17. As-Concentration in seawater.

Station	Samples	As (μg/l)	Station	Samples	As (μg/l)	Station	Samples	As (μg/l)
1	1S	**1.59**	**21**	21S	**1.56**	**41**	41S	**1.77**
	1B	**1.29**		21B	**1.39**		41B	**1.61**
2	2S	**1.67**	**22**	22S	**1.44**	**42**	42S	**1.65**
	2B	**1.51**		22B	**1.25**		42B	**1.79**
3	3S	**1.31**	**23**	23S	**1.52**	**43**	43S	**1.63**
	3B	**1.61**		23B	**1.45**		43B	**1.77**
4	4S	**2.08**	**24**	24S	**1.84**	**44**	44S	**1.74**
	4B	**1.63**		24B	**1.71**		44B	**2.01**
5	5S	**1.79**	**25**	25S	**1.36**	**45**	45S	**1.60**
	5B	**1.32**		25B	**1.44**		45B	**1.60**
6	6S	**1.54**	**26**	26S	**1.69**	**46**	46S	**1.81**
	6B	**1.54**		26B	**1.50**		46B	**2.16**
7	7S	**2.45**	**27**	27S	**1.56**	**47**	47S	**2.08**
	7B	**1.64**		27B	**1.36**		47B	**1.43**
8	8S	**1.59**	**28**	28S	**1.48**	**48**	48S	**1.88**
	8B	**1.61**		28B	**1.35**		48B	**1.65**
9	9S	**2.32**	**29**	29S	**1.73**	**49**	49S	**1.76**
	9B	**1.62**		29B	**1.56**		49B	**2.18**
10	10S	**1.97**	**30**	30S	**1.59**	**50**	50S	**1.74**
	10B	**1.41**		30B	**1.53**		50B	**1.72**
11	11S	**2.50**	**31**	31S	**1.33**	**51**	51S	**2.02**
	11B	**1.43**		31B	**5.92**		51B	**1.52**
12	12S	**1.59**	**32**	32S	**1.59**	**52**	52S	**1.64**
	12B	**1.57**		32B	**1.81**		52B	**1.74**
13	13S	**1.59**	**33**	33S	**1.70**	**53**	53S	**1.53**
	13B	**1.51**		33B	**1.44**		53B	**1.85**
14	14S	**1.61**	**34**	34S	**1.73**	**54**	54S	**1.47**
	14B	**1.52**		34B	**1.48**		54B	**1.87**
15	15S	**1.47**	**35**	35S	**1.53**	**55**	55S	**1.64**
	15B	**1.60**		35B	**1.76**		55B	**1.81**
16	16S	**1.44**	**36**	36S	**1.95**	**56**	56B	**1.75**
	16B	**1.40**		36B	**2.85**		56B	**1.45**
17	17S	**1.79**	**37**	37S	**1.49**	**57**	57S	**1.49**
	17B	**1.26**		37B	**1.46**		57B	**1.98**
18	18S	**1.34**	**38**	38S	**1.23**	**58**	58S	**1.54**
	18B	**1.47**		38B	**1.46**		58B	**1.41**
19	19S	**1.76**	**39**	39S	**1.59**	*Note:*		
	19B	**1.47**		39B	**1.54**	• *S: Surface layer, 2m*		
20	20S	**1.63**	**40**	40S	**1.47**	• *B: Bottom layer, ≥ 100m*		
	20B	**1.56**		40B	**1.58**			

Table 18. Hg-Concentration in seawater.

Station	Samples	Hg (μg/l)	Station	Samples	Hg (μg/l)	Station	Samples	Hg (μg/l)
1	1S	**0.12**	21	21S	**0.17**	41	41S	**0.16**
	1B	**0.11**		21B	**0.07**		41B	**0.18**
2	2S	**0.11**	22	22S	**0.09**	42	42S	**0.17**
	2B	**0.14**		22B	**0.07**		42B	**0.18**
3	3S	**0.12**	23	23S	**0.09**	43	43S	**0.17**
	3B	**0.14**		23B	**0.25**		43B	**0.18**
4	4S	**0.08**	24	24S	**0.10**	44	44S	**0.17**
	4B	**0.08**		24B	**0.10**		44B	**0.16**
5	5S	**0.12**	25	25S	**0.09**	45	45S	**0.10**
	5B	**0.17**		25B	**0.08**		45B	**0.16**
6	6S	**0.15**	26	26S	**0.10**	46	46S	**0.12**
	6B	**0.11**		26B	**0.09**		46B	**0.09**
7	7S	**0.15**	27	27S	**0.09**	47	47S	**0.10**
	7B	**0.11**		27B	**0.07**		47B	**0.12**
8	8S	**1.30**	28	28S	**0.07**	48	48S	**0.12**
	8B	**0.10**		28B	**0.10**		48B	**0.72**
9	9S	**0.31**	29	29S	**0.20**	49	49S	**0.14**
	9B	**0.18**		29B	**0.18**		49B	**0.21**
10	10S	**0.12**	30	30S	**0.09**	50	50S	**0.42**
	10B	**0.12**		30B	**0.15**		50B	**0.29**
11	11S	**0.14**	31	31S	**0.13**	51	51S	**0.12**
	11B	**0.14**		31B	**0.13**		51B	**0.11**
12	12S	**0.15**	32	32S	**0.18**	52	52S	**0.11**
	12B	**0.09**		32B	**0.12**		52B	**0.11**
13	13S	**0.11**	33	33S	**0.16**	53	53S	**0.13**
	13B	**0.09**		33B	**0.62**		53B	**0.13**
14	14S	**0.08**	34	34S	**0.34**	54	54S	**0.12**
	14B	**0.16**		34B	**0.17**		54B	**0.10**
15	15S	**0.08**	35	35S	**0.12**	55	55S	**0.16**
	15B	**0.13**		35B	**0.14**		55B	**0.10**
16	16S	**0.07**	36	36S	**0.15**	56	56B	**0.12**
	16B	**0.10**		36B	**0.17**		56B	**1.43**
17	17S	**0.07**	37	37S	**0.09**	57	57S	**0.24**
	17B	**0.08**		37B	**0.15**		57B	**0.18**
18	18S	**0.11**	38	38S	**0.12**	58	58S	**0.12**
	18B	**0.18**		38B	**0.15**		58B	**0.49**
19	19S	**0.09**	39	39S	**0.14**			
	19B	**0.08**		39B	**0.19**			
20	20S	**0.11**	40	40S	**0.12**			
	20B	**0.18**		40B	**0.52**			

Note:
- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

The results are shown that concentrations of Cu, Pb, Cd, Zn, Ni, Cr and As in every samples were low and well within the range found in near shore as well as open ocean seawater elsewhere (Table 19). One attention point is that relatively Hg concentrations in the study area are found as compared with those in other marine areas. The highest concentration of Hg was observed at the station 8, which was located, offshore (Fig. 9). The average concentration of Hg appears to be considerably higher than open ocean value but same range obtained in semi-enclosed unpolluted seas.

Comparison of determined metals at different areas of world indicated that concentrations of Cu, Pb, Cd, Zn, Ni, Cr and As in Vietnamese Sea, South China Sea, Baltic Sea, Pacific Ocean and South African Coast were in the same concentration range.

The concentration values for all determined trace metals at the most stations were near placed average values. (Fig. 2, 3, 4, 5, 6, 7 and 8)

Table 19. Comparison of the concentration of Cu, Pb, Cd, Zn, Cr, Ni, As and Hg in Vietnamese waters with other areas of the World (nM) [Utoomprurkporn (1997), Utoomprurkporn (1998), Brugman (1977), Bruland (1983), Millins(1964), Brugman (1977), Gian (1987), Jacinto (1996)].

Trace Metals	Cu	Pb	Cd	Zn	Ni	Cr	As	Hg
South African Coast	4.7-23.6		0.3-1.4		10.2-66.4			
	468.18	20.67	2.58	424.9				
Sea of Japan	4.72		0.98		17.03			
China sea	6.3-36.2		0.4-1.1		11.9-85.2			
Gulf of Thailand	1.5-9.0	0.03-1.00	0.01-0.17		0.5-9.0			
Gulf of Thailand and East Coast of Peninsular Malaysia	1.6-14.2	0.05-0.87	0.001-0.10		1.7-8.5			
Off Sabah, Sarawak and Brunei Darussalam	2.9-20.5	0.02-1.50	0.01-1.37		1.3-14.1			
Ocean	47.24	14.49	0.89	152.9	8.82	0.96	40	0.15
Pacific Ocean	2.36	0.48	0.13	9.94	21.5		1.33	0.08
Atlantic Ocean		4.06	0.27	121.1				
Baltic Sea	111.8	3.86	2.58	125.38				
South China Sea	7.9-100	2.4-26	4.4-30	7.6-650.0				
This Study (Surface Layer)	65.67	10.04	1.61	142.6	22.69	19.26	22.35	0.775

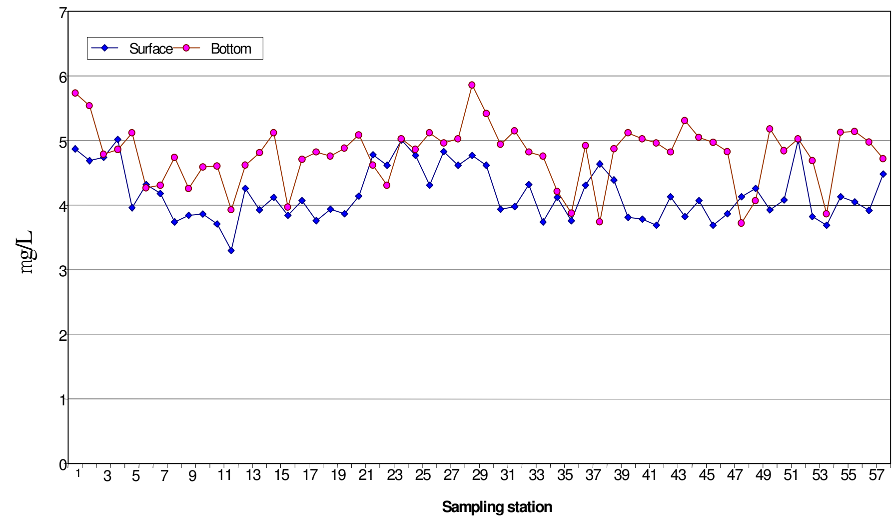

Fig. 2. Cu-Concentration in seawater.

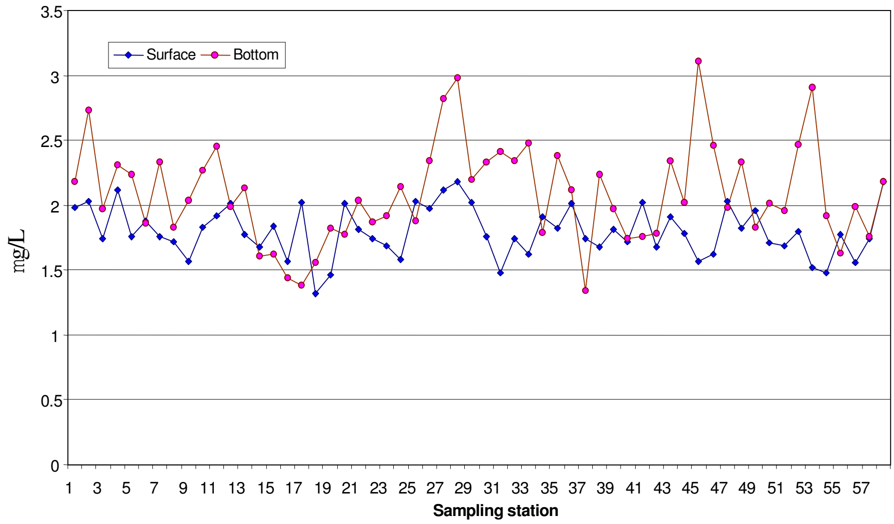

Fig. 3. Pb-Concentration in seawater.

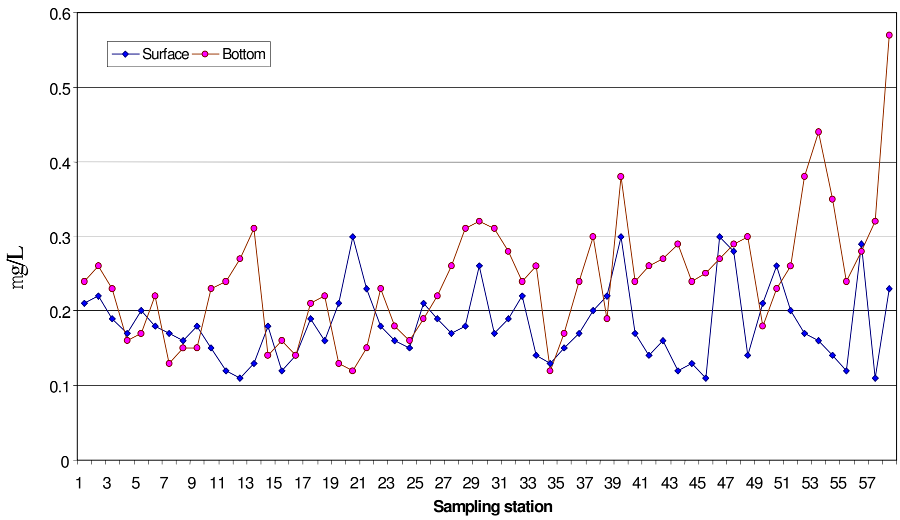

Fig. 4. Cd-Concentration in seawater.

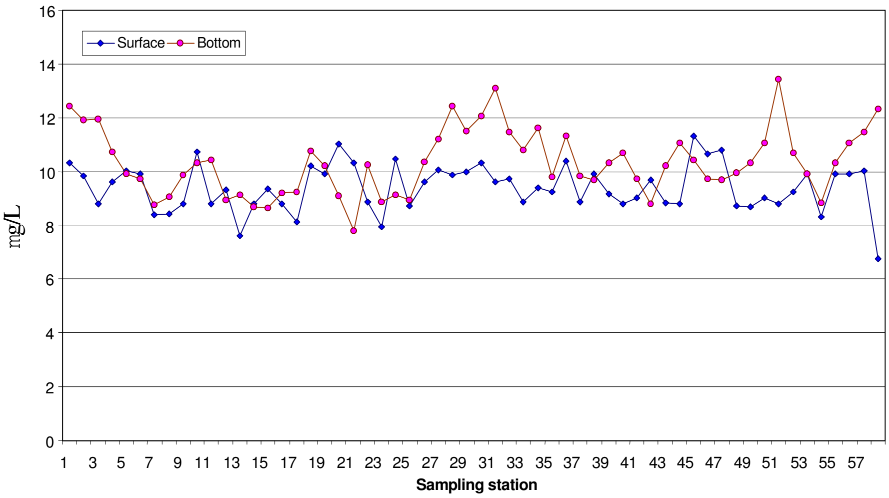

Fig. 5. Zn-Concentration in seawater.

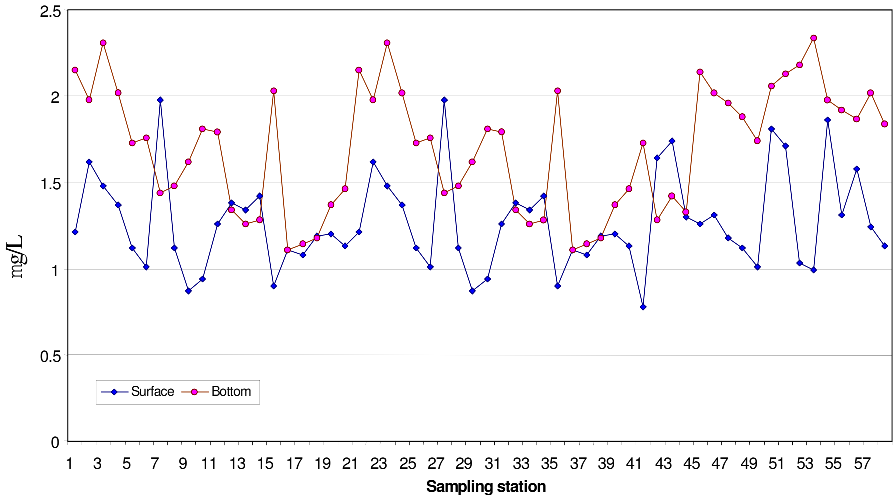

Fig. 6. Ni-Concentration in seawater.

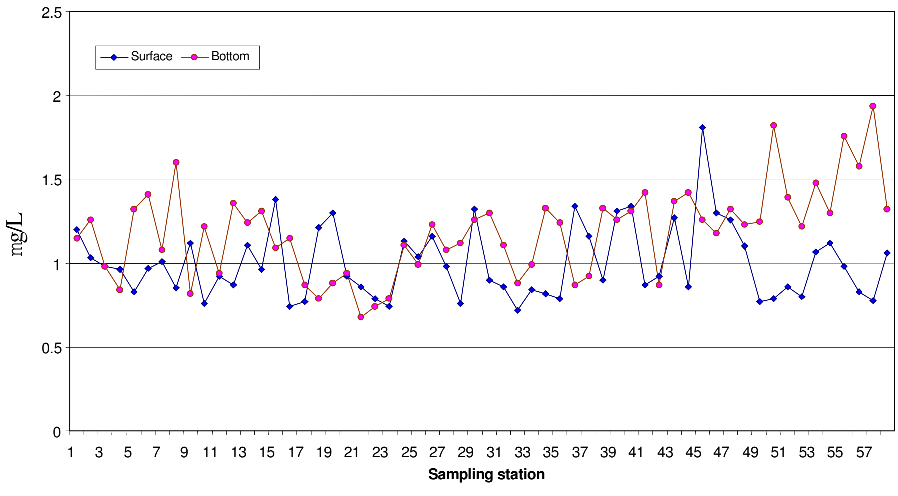

Fig. 7. Cr-Concentration in seawater.

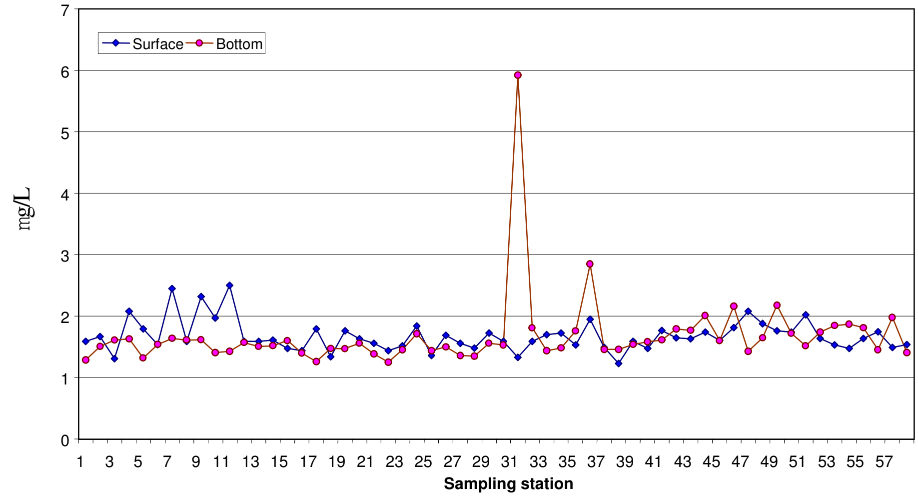

Fig. 8. As-Concentration in seawater.

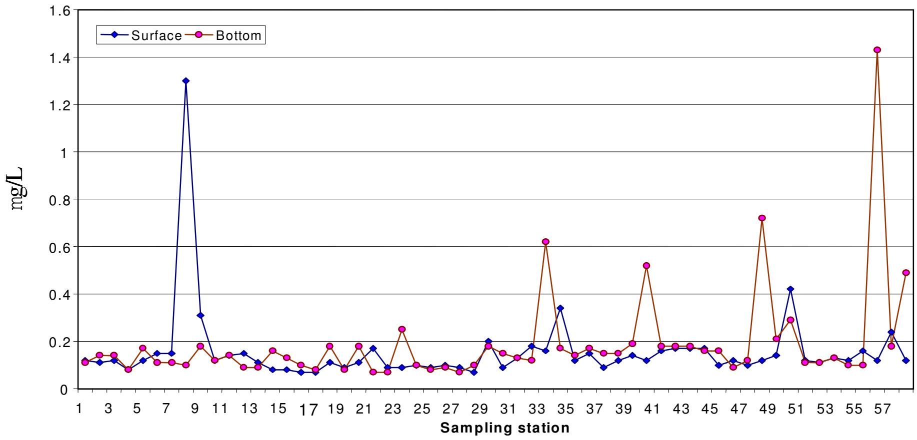

Fig. 9. Hg-Concentration in seawater.

ANALYSIS OF SEA-SEDIMENT

Sediment is known to be the key to ancient and historian environments. A sequence of sedimentary layers can tell us about environmental changes over time [Hallberg (1992)]. The geophysical properties of ocean sediments have been used as environmental indicators. Studies on ocean sediments have begun since the early 1900s. [Folk (1966), Krumbrein (1996)]

The recent sedimentary record can reveal cultural impacts on the environments during the industrial era. During formation and digenesis, the sediments also take an active part in the biogeochemical cycles of the elements, which affect the overlying water column.

Assessment of sediment contaminants has become increasingly import over the past several years. These assessments must be predictive of pollutant transport and of potential biological effects.

The bottom sediments logical properties not only play a major role in determining the richness of benthic life and productivity i.e. the diversity of benthic organisms but are also an important parameter that closely relates to pollution and mineral resources in the oceans.

It was carried as one subproject under the Collaborative Research Project. Objective of this research was to collect up - to -data sediment information concerning on the marine fishery resource and present oceanographic conditions in the sea area for suitable development of fishery resource scheme of the South China Sea.

Samples Collection and preparation

Surface sediment samples from offshore of Vietnam are collected using a Smith McIntyre grab on board of the M.V. SEAFDEC.

Out of the 58 stations, a total of 38 stations were sampled on 30 April 1999 to 29 May 1999 during the cruise (Fig. 1)

20 stations were not sampled due to technician problems (too deep).

A portion of sediment were carefully collected with a clean plastic spatula, kept in acid cleaned PE bottles, then stored at -20^{o}C until ready for analysis.

The sediment samples were dried at 85^{o}C then lightly ground to break up the particles. The sediment was achieved homogeneity and sieved through a 65 mm.

All equipment used for homogenization should be cleaned to minimize the potential of cross-contamination.

Analytical method

About 1 gram homogenized prepared sediment was totally digested in a Teflon decomposition vessel under pressure with a mixture of nitric, hydrochloric, perchloric and hydrofluoric acid. The Teflon bomb was placed inside a plastic pressure cooker, which was this. Then inside an ordinary household microwave over with the power turned on full for 1.5h at 150^{o}C.

After cooling, the digest was than made up to 50ml with Mili-Q water.

The sediment samples were analyzed in laboratory of the Department for Analytical Science and Technique of the Institute of Chemistry, NCST.

Results and Discussion

This report focuses only on the information gathered and data analyzed from the surface sediment samples collected during cruise.

The metal concentrations of Cu, Pb, Cd, Zn, Cr and Ni were determined with the same

The contents of trace heavy metals in sediments of the South China Sea, nevertheless, are not well documented.

For quality assurance standard reference materials (MESS-1 Gulf of sea Miramichi River) from National Research Council, Marine Analytical Chemistry Standards program, Ottawa, Canada were digested as above and analyzed for metals with same above described methods. (Table 20)

The total contents of determined metals in surface sediment are shown in Tables 21, 22, 23, 24, 25, 26, 27 and 28 respectively.

The average concentration of metals in surface layer were found 65.57 nM for Cu, 10.04 nM for Pb, 1.61 nM for Cd, 142.65 nM for Zn, 22.35 nM for As, 0.775 nM for Hg, 22.39 nM for Ni and 19.26 nM for Cr.

Comparison of concentration of determined metals reported by different papers are difficult to compare because of different method for samples sampling, preparation and determining used.

The range of concentration of metals were 10.3 - 71.0 $\mu g.g^{-1}$ for Cu, 12.9 - 33.7 $\mu g.g^{-1}$ for Pb, 1.29 - 18.72 $\mu g.g^{-1}$ for Cd, 45.8 - 164.8 $\mu g.g^{-1}$ for Zn, 21.2 - 93.6 $\mu g.g^{-1}$ for Cr, 5.7 - 45.8 $\mu g.g^{-1}$ for Ni, 1.64 - 3.80 $\mu g.g^{-1}$ for As, and 0.104 - 0.493 $\mu g.g^{-1}$ for Hg. The levels found in the present study are similar to data from other marine. [Shazili (1986), Shazili (1997), Shazili (1998), Brugman (1982)]

The highest contents of metals were 71.0 $\mu g.g^{-1}$ for Cu at station 2, 32.0 $\mu g.g^{-1}$ for Pb at station 3, 18.72 $\mu g.g^{-1}$ for Cd at station 40, 169.8 $\mu g.g^{-1}$ for Zn at station 2, 41.0 $\mu g.g^{-1}$ for Ni at station 3, 93.6 $\mu g.g^{-1}$ for Cr at station 58, 3.8 $\mu g.g^{-1}$ for As at station 5 and 0.493 $\mu g.g^{-1}$ for Hg at station 57. (Fig. 10, 11, 12, 13, 14, 15, 16 and 17)

Table 20. Analysis of certified reference materials.

MESS - 1	Certified Value (μg.g^{-1})	Measured Value (μg.g^{-1})	% Mean Recovery
Cu	25.1	26.15	104.2
Pb	34.0	36.18	92.8
Cd	0.59	0.63	106.4
Zn	191	203.99	106.8
Cr	71	66.39	93.5
Ni	29.5	28.62	97.0
Co	10.8	10.23	94.7
Hg	0.171	0.187	109.4

Table 21. Cu-Content in surface Sediment.

No.	Station	Cu (μg.g^{-1})	No.	Station	Cu (μg.g^{-1})
1	1	30.0	20	37	16.2
2	2	71.0	21	38	28.0
3	3	50.5	22	39	25.7
4	4	31.1	23	40	20.9
5	5	26.2	24	44	10.3
6	6	31.4	25	45	14.3
7	7	36.6	26	46	16.0
8	8	22.3	27	47	10.7
9	9	36.1	28	48	17.6
10	10	32.3	29	49	11.1
11	11	29.0	30	50	18.8
12	12	35.8	31	51	22.5
13	13	24.1	32	52	28.1
14	14	24.9	33	53	28.0
15	20	35.0	34	54	23.5
16	21	34.9	35	55	28.7
17	29	17.6	36	56	25.1
18	35	28.1	37	57	33.2
19	36	15.7	38	58	31.4

Table 22. Pb-Content in surface Sediment.

No.	Station	Pb (μg.g^{-1})	No.	Station	Pb (μg.g^{-1})
1.	1	19.3	20	37	16.1
2.	2	18.3	21	38	16.3
3.	3	32.2	22	39	15.6
4.	4	13.8	23	40	17.1
5.	5	17.4	24	44	14.0
6.	6	13.5	25	45	15.3
7.	7	17.8	26	46	17.5
8.	8	19.6	27	47	18.4
9.	9	14.4	28	48	18.6
10.	10	12.9	29	49	20.48
11.	11	13.9	30	50	16.8
12.	12	20.9	31	51	15.4
13.	13	17.8	32	52	12.9
14.	14	19.3	33	53	19.3
15.	20	18.3	34	54	14.4
16.	21	18.5	35	55	17.2
17.	29	19.4	36	56	14.2
18.	35	21.6	37	57	12.9
19.	36	33.7	38	58	21.0

Table 23. Cd-Content in surface Sediment.

No.	Station	Cd (μg.g^{-1})	No.	Station	Cd (μg.g^{-1})
1.	1	2.52	20	37	3.02
2.	2	1.29	21	38	5.56
3.	3	3.99	22	39	4.37
4.	4	1.52	23	40	18.72
5.	5	4.07	24	44	2.88
6.	6	4.26	25	45	3.67
7.	7	3.91	26	46	3.53
8.	8	3.26	27	47	3.70
9.	9	3.73	28	48	4.28
10.	10	3.13	29	49	3.69
11.	11	3.75	30	50	3.40
12.	12	3.44	31	51	4.23
13.	13	2.45	32	52	4.12
14.	14	3.46	33	53	6.63
15.	20	3.64	34	54	3.41
16.	21	4.36	35	55	4.27
17.	29	2.87	36	56	4.17
18.	35	4.42	37	57	4.53
19.	36	5.57	38	58	3.61

Table 24. Zn-Content in surface Sediment.

No.	Station	Zn ($\mu g.g^{-1}$)	No.	Station	Zn ($\mu g.g^{-1}$)
1.	1	102.7	20	37	56.7
2.	2	164.8	21	38	88.1
3.	3	163.7	22	39	74.3
4.	4	118.8	23	40	51.8
5.	5	86.6	24	44	75.4
6.	6	140.0	25	45	76.5
7.	7	132.2	26	46	71.3
8.	8	86.0	27	47	45.8
9.	9	139.3	28	48	51.4
10.	10	123.9	29	49	60.1
11.	11	102.5	30	50	51.0
12.	12	145.1	31	51	58.1
13.	13	115.6	32	52	107.7
14.	14	119.9	33	53	87.5
15.	20	141.1	34	54	106.2
16.	21	133.4	35	55	126.3
17.	29	79.8	36	56	71.3
18.	35	116.0	37	57	91.0
19.	36	74.9	38	58	115.2

Table 25. Ni-Content in surface Sediment

No.	Station	Ni ($\mu g.g^{-1}$)	No.	Station	Ni ($\mu g.g^{-1}$)
1.	1	11.9	20	37	23.9
2.	2	5.7	21	38	38.1
3.	3	41.0	22	39	29.6
4.	4	21.4	23	40	27.1
5.	5	19.3	24	44	27.8
6.	6	26.8	25	45	29.5
7.	7	35.0	26	46	29.5
8.	8	17.0	27	47	19.2
9.	9	40.8	28	48	27.3
10.	10	32.1	29	49	29.4
11.	11	28.7	30	50	27.9
12.	12	37.8	31	51	31.3
13.	13	22.8	32	52	41.5
14.	14	34.9	33	53	38.3
15.	20	45.8	34	54	29.5
16.	21	45.4	35	55	40.0
17.	29	26.4	36	56	29.4
18.	35	37.6	37	57	31.7
19.	36	30.9	38	58	33.8

Table 26. Cr-Content in Surface Sediment.

No.	Station	Cr (μg.g^{-1})	No.	Station	Cr (μg.g^{-1})
1.	1	43.1	20	37	50.1
2.	2	21.2	21	38	63.9
3.	3	74.8	22	39	54.0
4.	4	54.2	23	40	45.7
5.	5	45.4	24	44	53.5
6.	6	72.0	25	45	59.4
7.	7	56.6	26	46	58.3
8.	8	40.7	27	47	55.3
9.	9	71.0	28	48	58.5
10.	10	41.4	29	49	61.1
11.	11	56.5	30	50	58.5
12.	12	82.5	31	51	61.8
13.	13	70.5	32	52	82.1
14.	14	67.4	33	53	63.5
15.	20	81.5	34	54	89.7
16.	21	78.4	35	55	93.1
17.	29	42.1	36	56	75.1
18.	35	73.0	37	57	89.3
19.	36	47.2	38	58	93.6

Table 27. As-Content in surface Sediment.

No.	Station	As (μg.g^{-1})	No.	Station	As (μg.g^{-1})
1.	1	3.21	20	37	2.26
2.	2	3.21	21	38	2.62
3.	3	1.64	22	39	2.52
4.	4	2.86	23	40	3.62
5.	5	3.80	24	44	3.28
6.	6	2.78	25	45	2.00
7.	7	2.96	26	46	2.65
8.	8	1.76	27	47	2.16
9.	9	3.66	28	48	2.46
10.	10	2.98	29	49	3.26
11.	11	2.84	30	50	2.96
12.	12	2.64	31	51	3.44
13.	13	3.72	32	52	2.78
14.	14	2.92	33	53	3.12
15.	20	2.94	34	54	2.18
16.	21	2.40	35	55	2.46
17.	29	3.10	36	56	3.24
18.	35	2.86	37	57	2.78
19.	36	3.00	38	58	2.04

Table 28. Hg-Content in surface Sediment.

No.	Station	Hg (μg.g^{-1})	No.	Station	Hg (μg.g^{-1})
1.	1	0.160	20	37	0.159
2.	2	0.181	21	38	0.168
3.	3	0.338	22	39	0.158
4.	4	0.170	23	40	0.139
5.	5	0.155	24	44	0.141
6.	6	0.142	25	45	0.164
7.	7	0.152	26	46	0.132
8.	8	0.107	27	47	0.120
9.	9	0.155	28	48	0.151
10.	10	0.394	29	49	0.139
11.	11	0.161	30	50	0.268
12.	12	0.133	31	51	0.162
13.	13	0.127	32	52	0.480
14.	14	0.141	33	53	0.211
15.	20	0.188	34	54	0.266
16.	21	0.127	35	55	0.169
17.	29	0.130	36	56	0.158
18.	35	0.178	37	57	0.493
19.	36	0.107	38	58	0.104

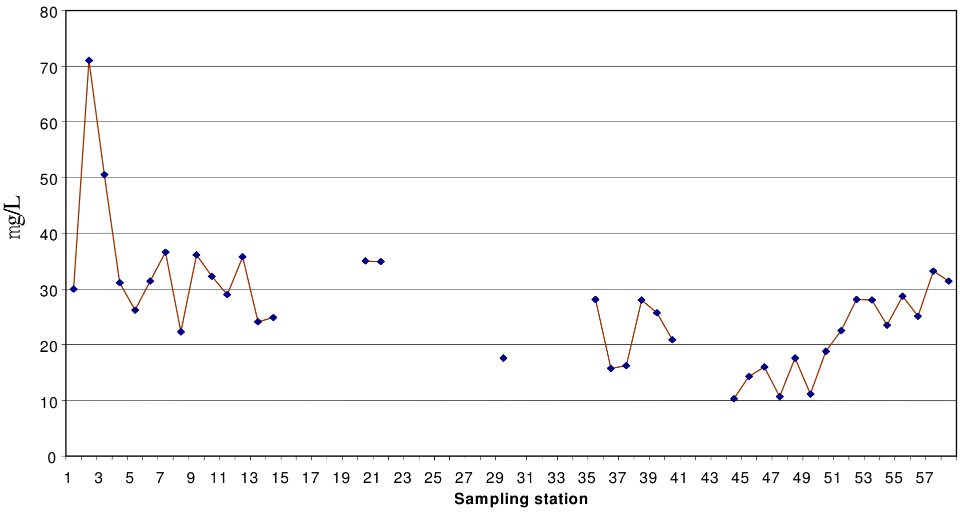

Fig. 10. Cu-Concentration in Sediment.

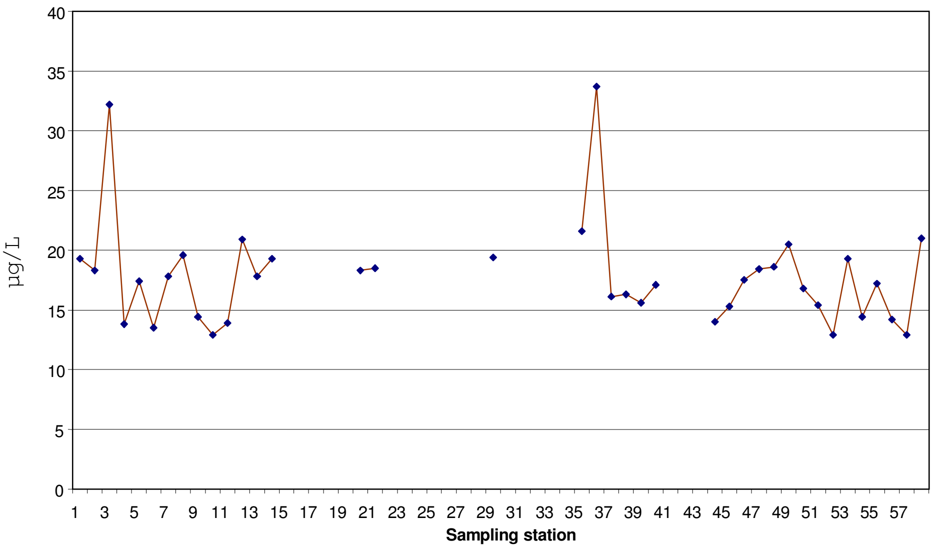

Fig. 11. Pb-Concentration in Sediment.

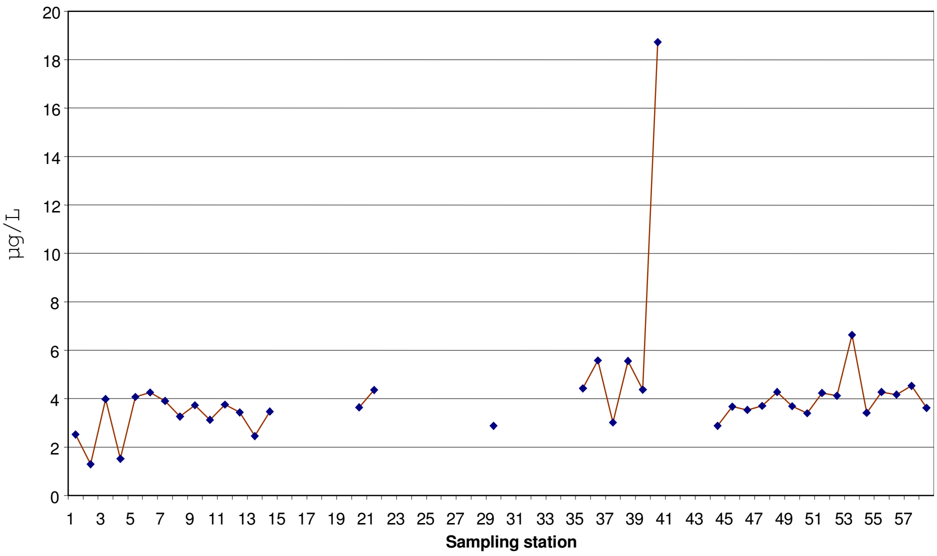

Fig. 12. Cd-Concentration in Sediment.

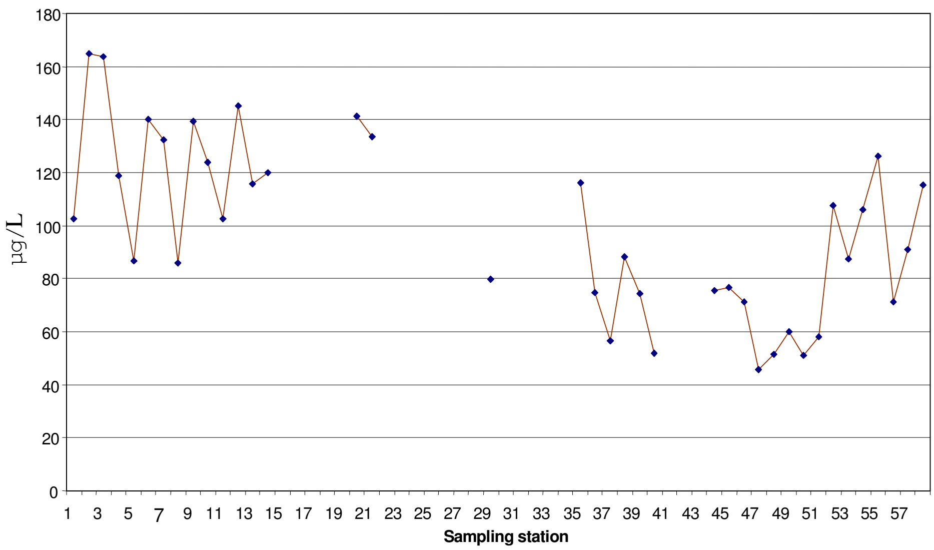

Fig. 13. Zn-Concentration in Sediment.

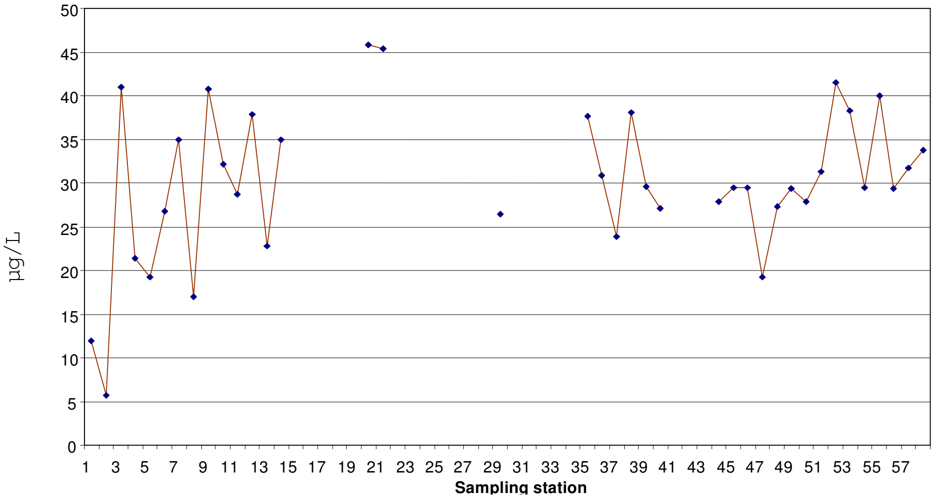

Fig. 14. Ni- Concentration in Sediment.

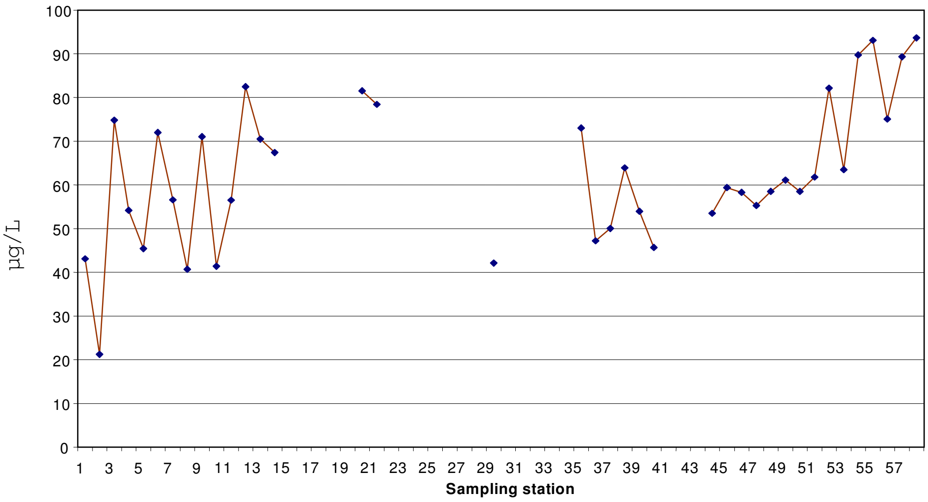

Fig. 15. Cr-Concentration in Sediment.

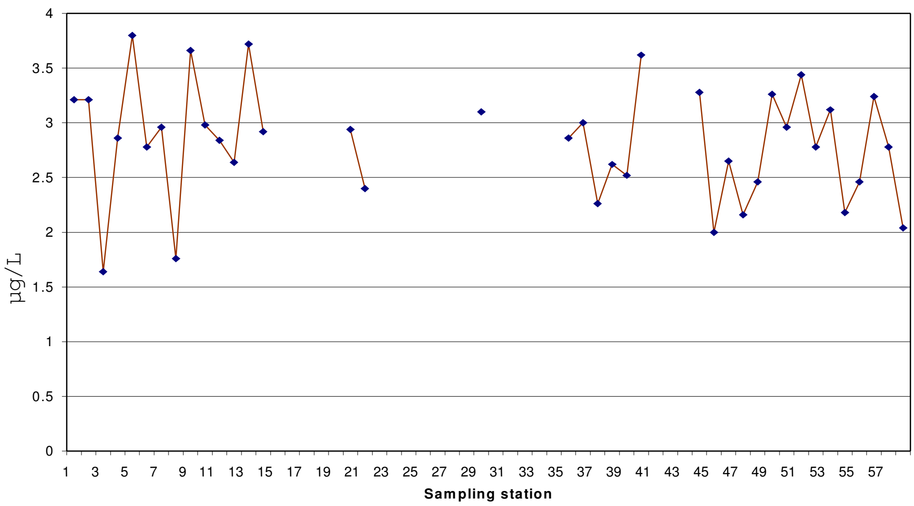

Fig. 16. As-Concentration in Sediment.

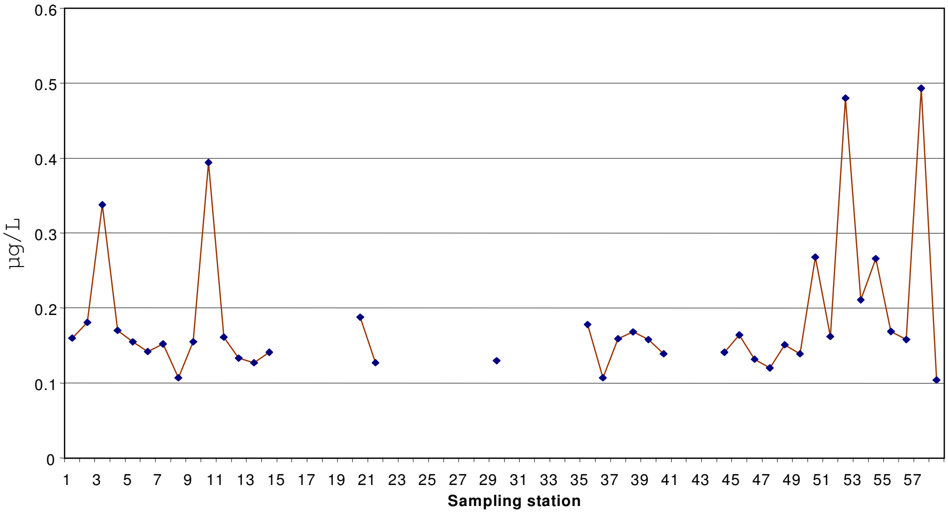

Fig. 17. Hg-Concentration in Sediment.

Conclusions

This research study was the first attempt, which covered largest surveyed areas of Vietnamese Sea.

The trace metal levels determined in this cruise is among the first reported values for trace heavy metals in seawater and sediments.

There is a meed to obtain other published data on trace metals at different areas of world.

It is now well know that trace metals are present in seawater and sediment in various chemical forms.

The determination and speciation of trace heavy metals in seawater and sediment for environmental research is of great significance for their interactions with suspended matter, sediment and their uptake by aquatic organimus and has become an area of key interest in present aquatic metal chemistry.

Data for distribution of trace metals between the water column, sediment and the suspended particulate material were important and necessary.

Studies on the relationship between metal concentration and other oceanography parameters and then fisheries resources in this study area are needed.

The coming sampling time is expected in the year of 2000 for further results to update the data in this report.

Acknowledgements

The Authors would like to thank Dr. Vu Van Trieu, Prof. Dr. Bui Dinh Chung, Dr. Dao Manh Son, the Research Institute of Marine Products - Vietnam, for their kind help and co-operation in this research. We give a special thank to the captain and crew of R.V. SEAFDEC for assisting in sample collection.

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Sedimentological Characteristic of Bottom Sediment of Vietnamese Coastline

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ABSTRACT

During survey of SEAFDEC vessel in May, 1999, 39 samples of bottom sediments of Vietnamese coastline were collected. The samples were analyzed for their sedimentological, micropaleontological characteristics as well as for their total organic matter and mineralogical composition of sediments. The study area can be divided into three parts: northern, central and southern part. Northern and southern parts are characterized by a wide, shallow continental shelf, while central part has very narrow continental shelf.

Generally, in the southern part sand is more spread, especially in the front of the Maekong river mouth (25.64% of total sediments), sediments is coarser than in others (average mean size is 0.162mm), better sorted, less skewed. In the northern part, clayish silts, clayish, sandy silts are most spread, sediments are poor sorted, moderate skewed. Average mean size is 0.088mm. In the central part, clayish, silty sand is dominant. Average mean size is 0.1507mm. Sediments are poor sorted.

Result of study revealed an occurrence of 98 foraminifers species in the bottom sediments, 19 of them are plankton and 79 are benthos.

A content of total organic matter in the study area varies from 0.125% to 1.344%. High content of TOM is observed in the central part, as well as in the south western part.

A study on mineralogical composition has pointed out a presence of 35 minerals in bottom sediment.

Introduction

Continental shelf of Vietnam has been studied since 1970. During 1970-1980 these studies were focused mainly on biological aspect, geological aspects were not concerned. After 1980, study of continental shelf of Vietnam was put forward. Some marine projects were carried out and works dealing with bottom sediment were published [Nguyen Huu Cu,, 1991, Nguyen Van Tac, 1996, Nguyen The Tiep, 1995, Tran Duc Thanh, 1991, Trinh The Hieu, 1996]. Since 1991 geological mapping scale of 1:500,000 of nearshore shallow marine water (0-30 m water depth) has being carried out.

Implementing a collaboration between Southeast Asia Fisheries Development Center and Research Institute for Marine Products, in May 1999 researchers from Japan, Thailand, Malaysia and Vietnam have gathered on the vessel SEAFDEC to conduct research on the South China Sea- zone IV (Fig.1). One of the objectives of program is to study bottom sediments. This work focused only on information gathered and a result of analyses of bottom sediments collected during cruise in May, 1999.

Description of study area

Study area is stretched from 103^0 E to 112^0E and from 21^0N to 7^0N (Fig.1). This area can be divided into 3 parts: Northern, Central and Southern.

Northern part is from 21^0N to 17^0N and characterized by shallow, wide continental shelf.

Water depth is from 10m-15m to 25m-30m. Central part is from 17^0N to 11^0N and characterized by a narrow continental shelf. Its width is of 40km-50 km. After that the water depth is abruptly reached 1000m-2000m. Southern part is characterized by wide continental shelf. The water depth is from 20m-30m to 50m-60m

Materials and Methods

Sampling process was carried out by corer and grab. From 58 surveyed stations, sampling was success only at 39 stations (Fig.1). Because of technical problems, bottom sediments were not taken at 19 stations, mainly in the Central part, where water depth is too deep, exceeds over 200m. From 39 stations, samples taken by corer only at 27 stations, at others process sampling was carried out by grab. Upon retrieval of core or grab, some parameters of bottom sediments were recorded: color, stratification, texture and length of collected sediment.

In laboratory, 5cm of sample was cut from top of core and 200 gr. from grab were taken for different analyses.

Following analyses were implemented in the Institute of Geology:

Grainsize analysis

Total organic matter analysis

Micropaleontological analysis

Mineralogical analysis

For grainsize analysis, depending on texture of sediments two methods were chosen for analysis: sieving and pipette methods. If a content of coarse fraction (> 0.063mm) is less than 20 %, then a pipette method was applied. This method determines the concentration of a suspension at a series of predetermined depths as a function of settling time. A pipette was used to withdraw a solution at intervals from 30s to 24 h depending on a fractions. The solid concentration from each fraction is determined by evaporation. Sand-size particles in sample are separated by wet sieving, then mechanically classed by dry sieving. In the case if a content of fine fraction (< 0.063mm) is less than 20 %, then sieving method is applied. Sediments are reported in mm.

For sieving method, 100grams of splited sample were taken for analysis. A standard sieves with an interval of ^{10}ö10 was used. Sediments were sieved using a sieve shaker for 15 minutes. After that each fraction was weighed, recorded and used for making cumulative curve and determination of sediment parameters: Md, So, Sk and K.

For pipette analysis, carbonate and organic matters were removed from sediments using HCL and H_2O_2 respectively. Then a dispersing agent such as sodium hexametaphosphate was added to sediment solution. This solution is put into one litre cylinder and filled up with distilled water. Using the Stocks law, at different time and distance, from this solution, fractions of 0.1-0.05, 0.05-0.01, 0.01 -0.005, 0.005-0.001 and less than 0.001mm were taken by pipette. After that, samples were dried and weighed for calculation percentage of each fraction. Using percentage of fractions to make a cumulative curve. From the cumulative curve (Fig.2), sedimentological parameters were calculated as follow [Petijohn, 1975].

$$So = \sqrt{\frac{Q_1}{Q_3}} \qquad Sk = \sqrt{\frac{Q_1 * Q_3}{Md^2}} \qquad K = \frac{Q_1 - Q_3}{2(P10-P90)}$$

Where Q1-grainsize corresponds to 25 % on the curve, Q3 – grainsize corresponds to 75%,

P10- grainsize corresponds to 10% and P90- Grainsize corresponds to 90% (Fig.2)
Md- is a grainsize of sample that corresponds to 50% on the curve

For micropaleontological analysis, 50 grams of sample was taken for analysis. Using microscope MBC-10 for determining foraminifer species. Each species was determined and established its abundance in sample according to 3 categories: High, intermediate and low.

For mineralogical analysis, fraction 0.1mm - 0.125mm was chosen for analyze. Determine mineral and its abundance in sample using microscope MBC-10.

Method Thurin was used for determination total organic matter of bottom sediment. $K_2Cr_2O_7$ was used for oxidation of organic matter as follow:

$$3C + 2Cr_2O_7^{2-} + 16H^+ \longrightarrow 3CO_2 + 4Cr_3+ + 8H_2O$$

Diphenylamine was used as color indicator during titration, obstacle of Fe^{3+} is surmounted using H_3PO_4.

Result and Discussion

Grainsize composition (Table1, Fig. 3, 4, 5, 6)

In general, the study area can be divided into 3 parts: Northern, Central and Southern with its particular features, so grainsize characteristic will be reported separately for each region.

Northern part

For this area an average medium size (Md) of bottom sediment is 0.088mm (very fine sand). The lowest value is 0.0041mm (clay) and the highest is 0.25mm (medium sand). Two of ten stations (St.2, 8) have highest value of Md (0.25mm and 0.23mm respectively). Three other stations (St.3, 6, 9) have low value of Md (from 0.0041 to 0.0046mm). From analyses one conclusion can be made that sediment in Northern part is poor sorted. An average value of sorting coefficient (So) is 3.46. The best sorted sediments are at station 2, where So is 1.16. The worst sorted sediments is at station 1 with a value of So of 5.35. At station 5, some gravels of 0.5cm are present in clayish silt . These are old tidal channel deposits.

Skewness (Sk) of sediments in the Northern part is not too high. The average value of Sk is 0.832. The lowest value is 0.32 (St.8) and the highest is 1.03 (St.9). The average value of kurtosis of sediments in the Northern part is 0.229, varies from 0.332 to 0.055.

Central part

In general, sediments in central part are coarser than in the northern part. The average value of Md is 0.1507mm (medium sand). The highest value of Md is 0.45mm and the lowest is 0.0082mm. Bottom sediments in the central part are poor sorted, more skewed compared with sediments in the North and South. Average value of So is 5,29. The highest value of So is 18.46 (worst sorted) and the lowest is 1,2 (well sorted). Skewness of sediments in the Central part varied from 0.98 to 0.48. An average value is 0.758. Kurtosis of sediments is from 0.229 to 0.084, average value is 0.187.

Southern part

The range of Md in the Southern part is quite wide, with an average value is 0.162mm. The highest value of Md is 0.5mm at station 38 and the lowest value is 0.0028mm at station 55. Sediments in the front of the Maekong River mouth are coarser, mainly sand and silty sand. In opposite, in the western part (Gulf of Thailand) sediments are finer, mainly silty clay and clayish silts. Bottom sediments in the Southern part are better sorted compared with others regions. Their average value of So is 2.57.

Maximum value is 7.63 and minimum is 1,1. In general, sediments in the front of the Maekong river mouth are very well sorted (So is of 1.1 to 1.5). In the west (Gulf of Thailand), sediments are poorer sorted (So is of 2.89 to 7.63). The average skewness value of sediments is 1.02, ranging from 1.53 to 0.31. Average kurtosis is 0.194, varies from 0.493 to 0.055.

Generally, an average value of Md for whole area is 0.1335mm, the maximum value is 0.5mm and the minimum is 0.0028mm (from coarse sand to clay). The average value of So is 3.773 and varied from 1.1 (the best sorted) to 18.46 (the worst sorted). Bottom sediments in the Central part are poorer sorted. Sediments in the Southern part, especially in the front of the Maekong river mouth are very well sorted. An average skewness value for whole area is 0.87, varied from 0.31 to 1.53. An average kurtosis of sediments for whole area is 0.203.

Texture (Table 2, 3, Fig.7, 8, 9, 10, 12)

Generally, in the study area can be distinguished 6 types of bottom sediments: sand, silty sand, clayish-silty sand, clayish silt, clayish-sandy silt, and silty clay. Sand is the most spread in the study area. Its occurrence frequency is 35.89%. This is concerned with sand formation in the front of the Maekong river mouth, where sand occupied 33.33% of total bottom sediment in the study area. In the Northern part, sand occupied only 2.56% and it is absent in the Central part. Clayish-silty sand is quite spread in the study area followed sand. Its occurrence frequency is 20.49%. It is more spread in the Central and Southern parts, where its occurrence frequency is 7.68%. Silty sand is less spread in the area. It occupied only 17.93% of total bottom sediments. Its high content is observed in the Central part (average value is 7.68%). The occurrence frequency of clayish silt in the study area is 10.24%, concentrates mainly in the North (5.12%), in other regions its content is quite low (2.56% for both areas). Silty clay and clayish-sandy silt have the same occurrence frequency in the study area (7.68%). They are widely spread in the southwestern part and absent in the Central part. In the Northern part, a content of clayish-sandy silt is higher than in the south (5.12 compared 2.56%).

From Table 3, it is clear that sand is the most spread in the study area. Its average percentage is 57.39% for whole area. Its highest value is observed in the South, where it reached 72.55%. Maximum content of sand is 100% and minimum is 0%. In the Central part the content of sand is lower (only 56.82%), with maximum content is 88.4% and minimum is 4.8%. For the Northern part the content of sand still much lower, reached only 42.8% in an average, varied from 100% to 0%.

Silt is composed 26.55% for whole area. It is more spread in the North, where it content reached 33.5%. In the Central area it decreases to 29.25% and is still lower in the South, only 16.9% in average. Maximum value of silt content is observed in the South, reached 70.2 %, while in the North and Central only 54.3% and 59.5% respectively.

In the study area, clay occupied only 16.05%, more spread in the Northern area and in the south western part, where its average content is 23.68%. It decreases in the Central and South eastern parts (13.9% and 10.58% respectively).

Color of sediments (Table 5)

Overall 5 colors of sediments can be distinguished: Greenish grey, dull grey, brownish grey, light grey and dull yellow. For whole area the most popular color is dull yellow (28.2%), followed by dull grey (25.64%) and light grey (23.07%). The greenish and brownish grey colors are less spread (15.78 and 7.69% respectively). For the Northern part, a greenish grey color is dominant (10.25%), while others are less than 5%. In the Central part a dull grey is the most popular (10.25%) compared with others only 2.56%. The picture of color is different for the Southern part, where dull yellow color is the most spread, occupied 23.07%. Light grey color is of 15.38% and dull grey occupied only 10.25%. Greenish grey and brownish grey have very low occurrence (5.12% and 2.56% respectively).

Total organic matter (TOM) (Table 4, Fig. 11)

Average value of total organic matter in Vietnamese coastline is 0.77276%, varies from 0.125% to 1.344%. Maximum value is observed at station 55 and 13, minimum value is at station 44. Generally, in the front of the Maekong river mouth, where sand is dominant, the value of TOM is very low (0.12% - 0.14%). This value is higher in the Northern part, where minimum value is 0.48% and maximum is 1.326%. Average value of TOM for the Northern part is 0.8755%.

For the Central part, the average value of TOM reached 0.778%, varies from 0.395 to 1.34% In the Southern part, the value of TOM is very low in the front of the Maekong river mouth, (a content of TOM is of 0.125%). It increases in the western part, where silty clay and clayish silt are dominant (content of TOM is from 0.238 to 1.344%).

Micropaleontological characteristic. (Table 6)

Total of 98 species of benthos and plankton foraminifers were found in bottom sediments of Vietnamese coastline, from which 19 species are plankton and 79 species are benthos foraminifer (Table 6, In general can be distinguished 3 regions:

1. Northern part from Mong Cai to Deo Ngang. Beside most common species such as *Quinqueloculina akneriata, Quinqueloculina elongata, Quinqueloculina oblonga, Pseudorotalia indopacifica, Globorotalia menadii....*, some special temperate species are present in this area: *Buccella* sp., *Ammonia beccarii, Trochammina inflata, Trochammina nitida,* especially *Bruccella* sp. is present only in the Northern part. They are rich in clayish silt, sandy silt.

2. Central part from Deo Ngang to Vung Tau

This region is characterised by a presence of complex of foraminifer, which are typical species of shallow, warm ocean with high content of salt (over 33%0). Following species have a high occurrence: *Calcarina hispida, Calcarina spengneri, Marginopora vertebralis, Elphidium crispum, Elphidium hispidulum, Quinqueloculina parkerii.* Especially *Calcarina hispida, Marginopora vertebralis, Amphistegina madagaskariensis* are present only in the Central part.

3. Southern part , from Vung Tau to Ha Tien

Sediments in the southern part are rich of foraminifers. Especially at station 51, about 30-35% of bottom sediment consists of foraminifers. Here, foraminifers have a big size (0.5-2 mm). These are *Globigerinoides trilobus* and *Globigerinoides sacclifer*. A result of study has revealed 94 foraminifers species in the southern part, most of them are benthos (75%). Plankton foraminifers occupied only around 25%. Some species are more abundant in this area such as *Amphistegina madagascariensis, Asiarotalia holocenia, Asiarotalia mekongensis, Asiarotalia multispinosa, Quinqueloculina* sp, *Operculina complanata.* A complex of foraminifers in the southern part is characterzied for tropical, warm sea.

Mineralogical characteristic

Study area is characterised by a wide spectrum of minerals. Mineral composition of bottom sediments in the study area varies in different parts. There are 30 minerals in a sand fraction (Table7). For fine silt and clay fraction, according to previous study (Nguyen Van Tac, 1996), following minerals are present: Kaolinite, montmorillonite, hydromica, chlorite and calcite.

In sand fraction, quartz is dominant in sediments. In most samples, quartz composed 95-98% of sediments. Following quartz, in the study area, muscovite, feldspar, ilmenite and limonite are the most abundant in bottom sediments. The others have a low occurrence, varies from 0.001 to 0.1%. Central part is characterized by a high content of ilmenite, monazite, cassiterite and zircon, while in the northern part, ilmenite, garnet, actinolite, limonite are dominant in a heavy fraction.

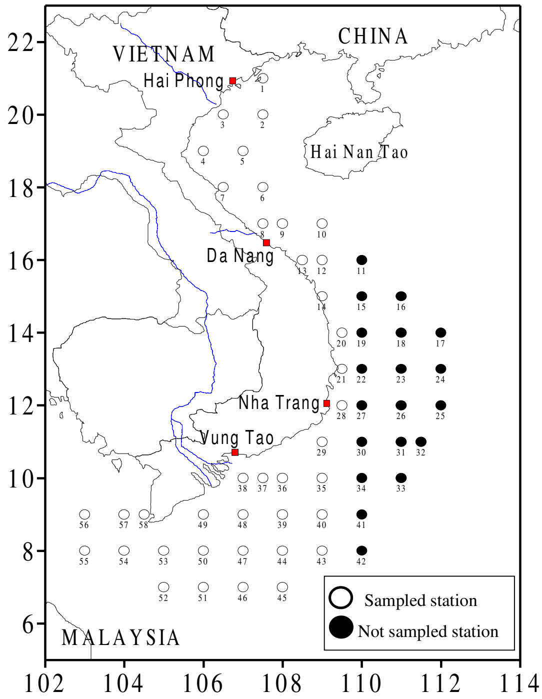

Fig. 1. Sampling location in Vietnamese coastline.

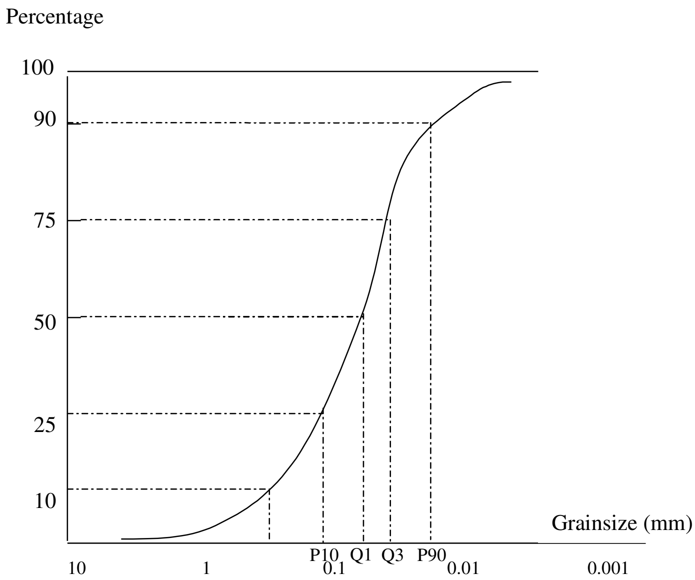

Fig. 2. Cumulative curve.

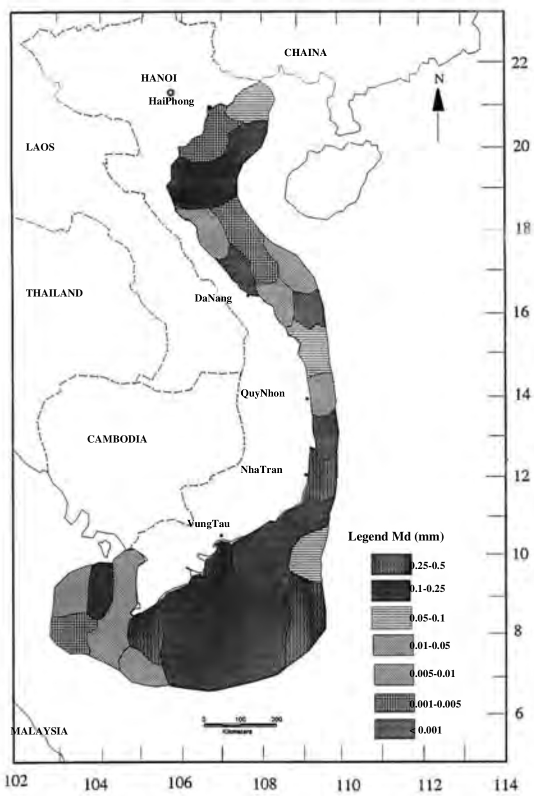

Fig. 3. Pattern of sediment mean size distribution in Vietnamese coastline.

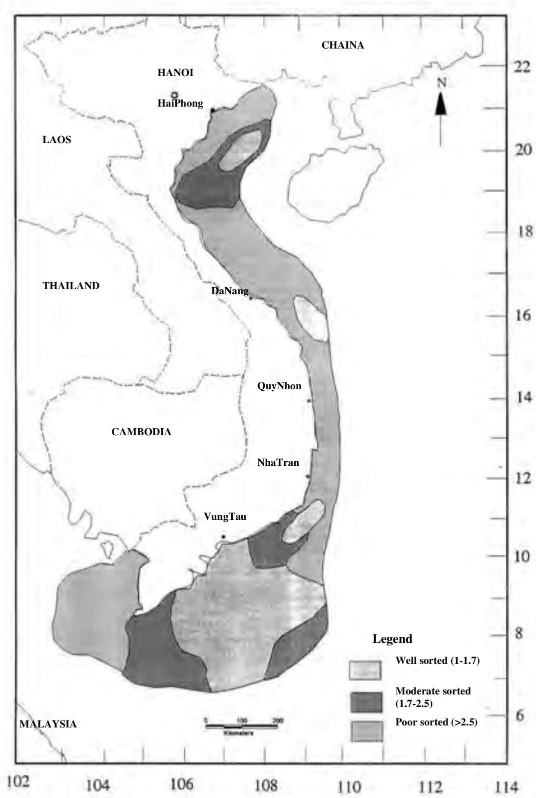

Fig. 4. Pattern of sediment sorting distribution of Vietnamese coastline.

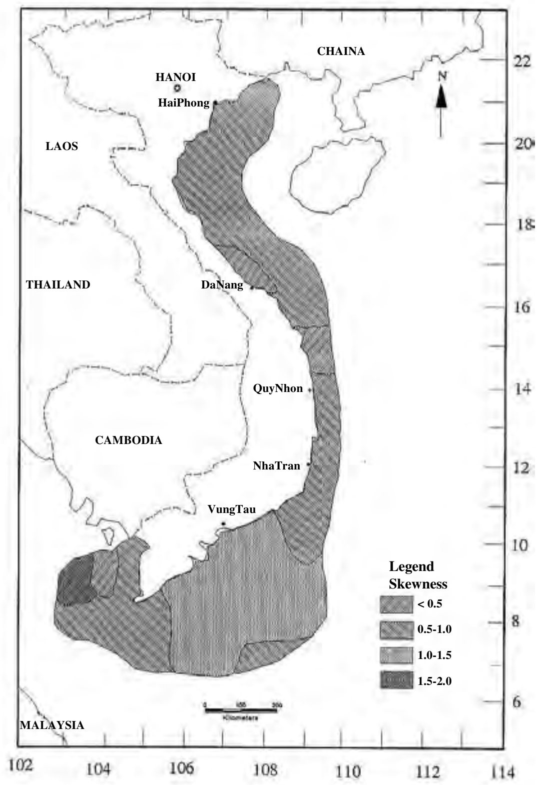

Fig. 5. Pattern of sediment skewness distribution in Vietnamese coastline.

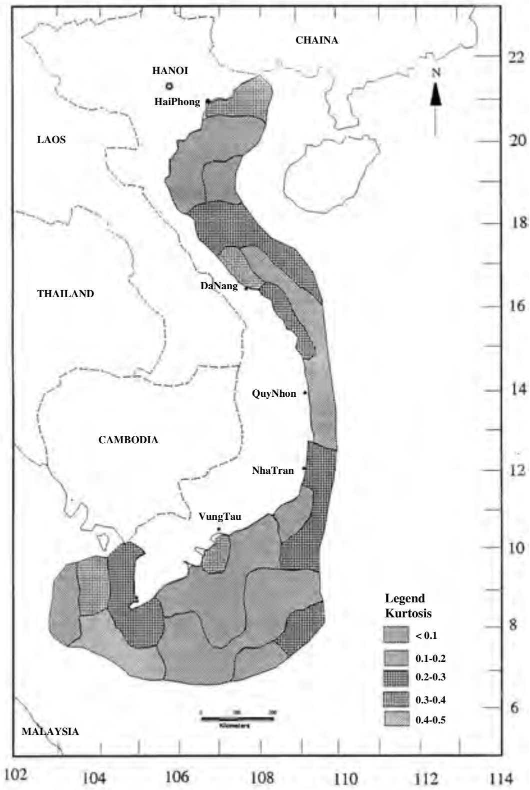

Fig. 6. Pattern of sediment kurtosis in Vietnamese coastline.

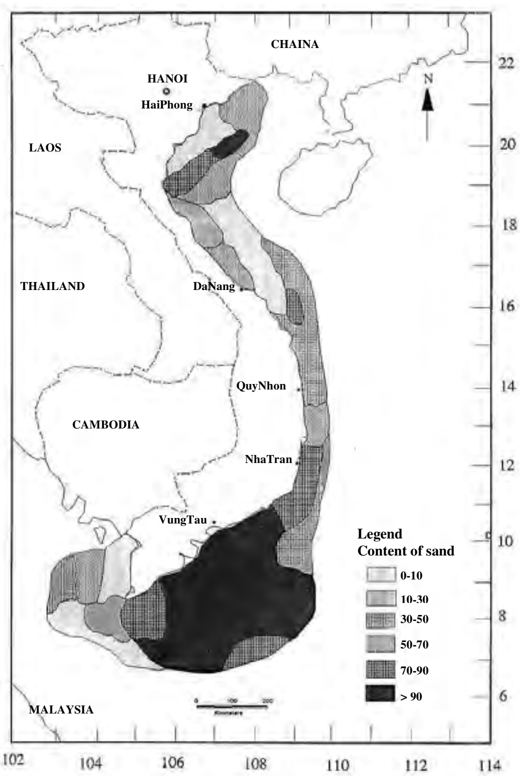

Fig. 7. Sand content distribution of Vietnames coastline.

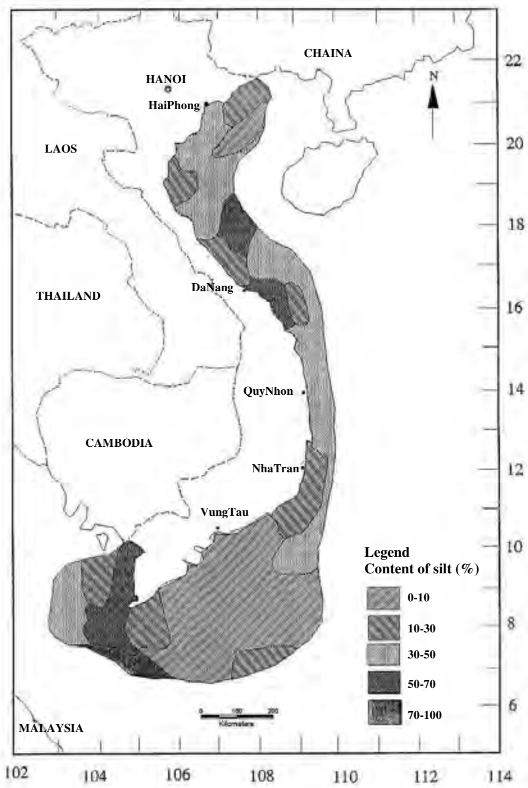

Fig. 8. Silt content distribution of Vietnamese coastline.

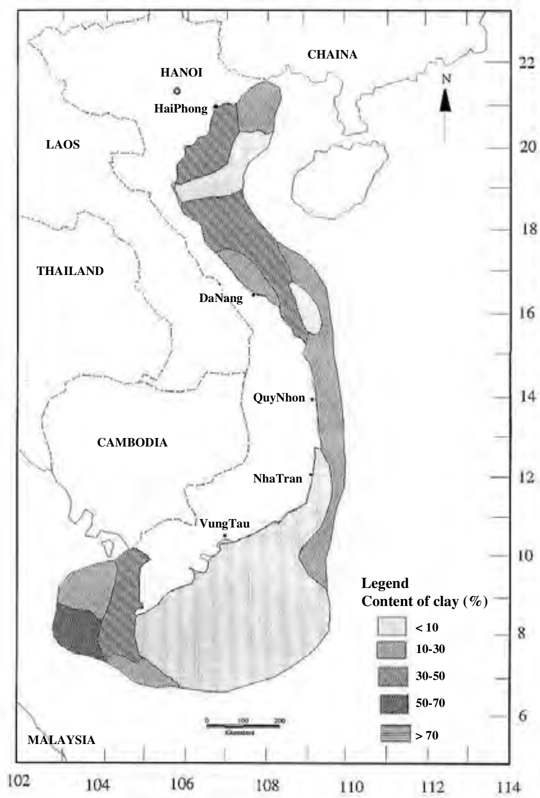

Fig. 9. Clay content distribution of Vietnamese coastline.

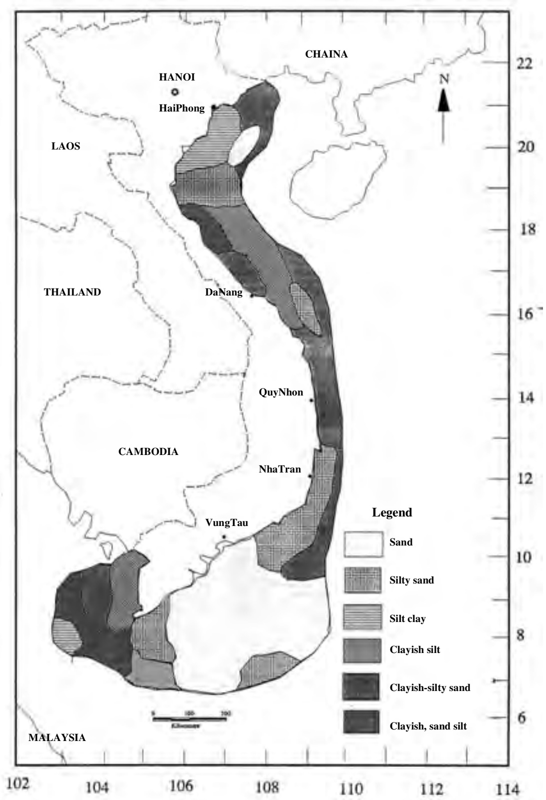

Fig. 10. Pattern of sediment distribution in Vietnamese coastline.

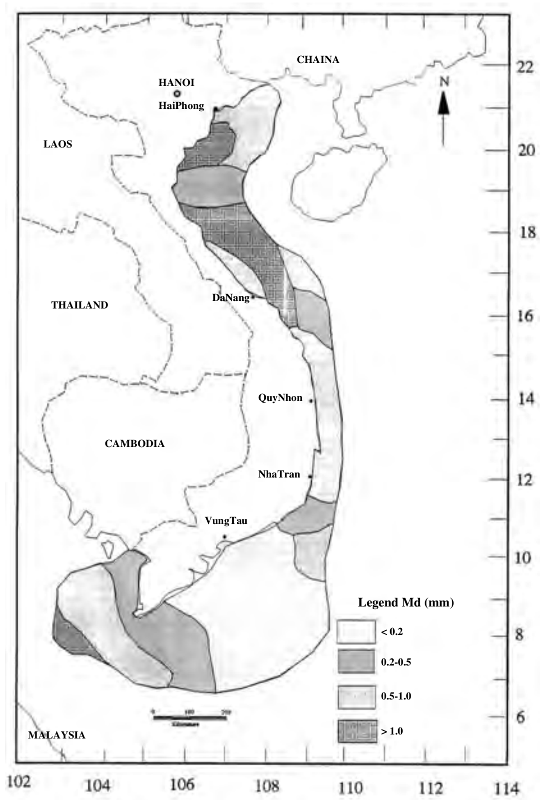

Fig. 11. Distribution of organic matter in bottom sediment of Vietnamese coastline.

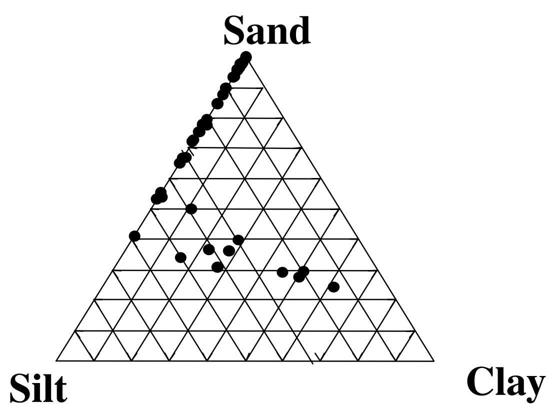

Fig. 12. Diagram distribution of sediment.

Table 1. Statistical sedimentological parameters of bottom sediments in Vietnamese coastline.

	Md (mm)				So				Sk				K			
	Average	Max	Min	Range	Average	Max	Min	Range	Average	Max	Min	Range	Average	Max.	Min.	Range
Northern part	0.088	0.25	0.0041	0.2459	3.46	5.35	1.16	4.19	0.832	1.03	0.32	0.71	0.229	0.332	0.055	0.277
Central part	0.1507	0.45	0.0082	0.4418	5.29	18.46	1.2	17.26	0.785	0.98	0.48	0.5	0.187	0.229	0.084	0.145
Southern part	0.162	0.5	0.0028	0.4972	2.574	7.63	1.1	6.47	1.02	1.53	0.31	1.22	0.194	0.493	0.055	0.338
For whole area	0.1335	0.5	0.0028	0.4972	3.773	18.46	1.1	17.35	0.87	1.53	0.31	1.22	0.203	0.493	0.055	0.338

Table 2. Percentage of sediment in Vietnamese coastline.

	Sand (%)	Silty sand(%)	Silty clay (%)	Clayish silt (%)	Clayish-silty sand(%)	Clayish-sandy silt(%)
Whole area	35.89	17.93	7.68	10.24	17.93	10.24
Northern part	2.56	5.12	2.56	5.12	5.12	5.12
Central part	0	7.69	0	2.56	5.12	2.56
Southern part	33.33	5.12	5.12	2.56	7.69	2.56

Table 3. Percentage of sand, silt and clay in Vietnamese coastline.

	Sand (%)				Silt (%)				Clay (%)			
	Average	Max.	Min.	Range	Average	Max.	Min.	Range	Average	Max.	Min.	Range
Northern part	36.6	100	0	100	28.36	50.07	0	50.07	35.0	72.82	0	72.82
Central part	47.68	79.8	0.98	78.82	30.93	44.91	20.2	24.71	21.38	54.11	0	54.11
Southern part	66.45	100	0	100	17.96	58.53	0	58.53	15.69	80.0	0	80.0
Whole area	50.24	100	0	100	25.75	58.53	0	58.53	24.01	80.0	0	80.0

Table 4. Distribution of total organic matter in Vietnamese coastline.

	Whole area(%)	Northern part(%)	Central part(%)	Southern part(%)
Maximum	1.344	1.326	1.344	1.344
Minimum	0.125	0.48	0.395	0.125
Average	0.772	0.8755	0.7787	0.6864
Range	1.219	0.846	0.949	1.219

Table 5. Color distribution of bottom sediments in Vietnamese coastline (in percent).

	Greenish grey (%)	Dull grey (%)	Brownish grey (%)	Light grey (%)	Dull yellow (%)
Whole area	15.38	25.64	7.69	23.07	28.20
Northern part	10.25	5.12	2.56	5.12	2.56
Central part	0	10.25	2.56	2.56	2.56
Southern part	5.12	10.25	2.56	15.38	23.07

Table 6. Occurrence of foraminifera in Vietnamese coastline.

No	Species	North part	Central part	Southern part
1	*Adelosina pulchella*	+	+	+
2	*A. philipinensis*	+	+	+
3	*Ammonia annectens*	+	+	+
4	*A. beccarii*	+++	+	+
5	*A. japonica*	+++	+	+
6	*Amphistegina lessonii*	+	+	+++
7	*A. madagascariensis*			+++
8	*Articulina sulcata*	+	+	+
9	*A.pacifica*	+	+	+
10	*Asiarotalia holocenia*			+++
11	*A. mekongensis*			+++
12	*A. multispinosa*			+++
13	*Asterorotalia pulchella*			+++
14	*A.multispinosa*			+++

Table 6. (Continued).

No	Species	North part	Central part	Southern part
15	*Bigenerina nodosaria*	+	+	+
16	*Bigenerina sp.*	+	+	+
17	*Bolivina dinatata*	++	++	++
18	*B.nitida*	+	+	+
19	*B. punctata*	++	++	++
20	*Bucella sp.*	++		
21	*Casidulina globosa*	+	+	+
22	*Calcarina hispida*		+++	
23	*Cellanthus craticulatus*	++	++	++
24	*Cibicides lobatus*	+	+	+
25	*Calcarina spengneri*		+++	
26	*Cibicides sp.*	+	+	+
27	*Dentalina communis*	+	+	+
28	*D. elongata*	+	+	+
29	*Discorbis sp.*	+	+	+
30	*D.procerus*	+	+	+
31	*Elphidiella indopacifica*		+	
32	*Elphidium advenum*	+	+	+
33	*E. hispidulum*		++	
34	*E. crispum*		+++	
35	*E. macellum*	+	+	+
36	*Eponides sp.*	+	+	+
37	*E. praeccinctus*	+	+	+
38	*E. procerus*	+	+	+
39	*Gladulina laevigata*	+	+	+
40	*Hauerina sp.*	+	+	+
41	*H. ornatisima*	+	+	+
42	*Lagena costata*	+	+	+
43	*L.crenata*	+	+	+
44	*L. elongata*	+	+	+
45	*L. sulcata*	+	+	+
46	*Marginopora vertebralis*		++	
47	*Nonion sp.*	+	+	+
48	*N. japonicum*	+	+	+
49	*Nonioninella sp.*	+	+	+
50	*Operculina ammonoides*	+	+	++
51	*O. complanata*	+	+	+++
52	*O. venosa*	+	+	+
53	*Peneroplis pertusus*	+	+	+
54	*P. planatus*	+	+	+
55	*Pseudorotalia indopacifica*	++	++	++
56	*P.papuanensis*	+	+	+
57	*P. schroeteriana*	+	+	+
58	*Quinqueloculina akneriata*	++	++	++
59	*Q. bouenana*	++	++	++
60	*Q. elongata*	++	++	++
61	*Q. lamarckiana*	++	+	++
62	*Q. oblonga*	++	++	++
63	*Q. parkerii*		+++	
64	*Q.philippinensis*	++	++	++
65	*Q. seminulina*	++	++	++
66	*Q. reticulata*	+	+	+
67	*Reussella spengnerii*	+	+	+
68	*R. spinulosa*	+	+	+
69	*Reophax sp.*	+	+	+
70	*Robulus sp.*	+	+	+
71	*Sigomoidella pacifica*	+	+	+
72	*Spiroloculina communis*	++	++	++
73	*S. manifesta*	+	+	+
74	*S. spengnerii*	+	+	+
75	*Trochammina inflata*	+++	+	+

Table 6. (Continued).

No	Species	North part	Central part	Southern part
76	*T. nitida*	+++	+	+
77	*Triloculina tricarinata*	+	+	+
78	*T. trigonula*	+	+	+
79	*Textularia conica*	++	++	++
80	*T. foliacea*	++	++	++
81	*Uvigerina proboscidea*	+	+	+
82	*Globogerina bulloides*	++	++	++
83	*Globigerina sp.*	+	+	+
84	*Globigerinoides conglobatus*	++	++	++
85	*G. obliqus extremus*	+	+	+
86	*G. obliqus oblicus*	+	+	+
87	*G. ruber*		+	+
88	*G.saculifer*	++	++	++
89	*G. trilobus*	++	++	++
90	*Globoquadrina altispida*	+	+	+
91	*G.dutertrei*	+	+	+
92	*Globorotalia acostaensis*	+	+	+
93	*G. cultrata*	+	+	+
94	*G.menardi*	+	+	+
95	*G. tumida*	+	+	+
96	*Hastigerina siphonifera*	+	+	+
97	*Neogloboquadrine dutertrei*	+	+	+
98	*Orbulina universsa*	+	+	+

* Occurrence
+++ High ++ Intermediate + Low

Table 7. Occurrence of minerals in bottom sediments of Vietnamese coastline.

No.	Mineral	North part	Central part	Northern part	Remark
1	Quartz	+++	+++	+++	
2	Muscovite	+++	+++	+++	
3	Feldspar	++	++	++	
4	Limonite	+++	+++	+++	
5	Ilmenite	+++	+++	+++	
6	Leucoxene	++	+	++	
7	Actinolite	++	+	+	
8	Tremolite	+	+	+	
9	Rutile	+	+	+	
10	Siderite	+	+	+	
11	Pyrite	+	+	+	
12	Anatase	+	+	+	
13	Disthen	+	+	+	
14	Epidote	++	+	+	
15	Olivine	+	+	+	
16	Pyroxene	+	+	+	
17	Garnet	+++	++	+	
18	Magnetite	++	++	++	
19	Zircon	++	++	++	
20	Monazite	+	++	++	
21	Caxiterite	+	+	+	
22	Apatite	+	+	+	
23	Topaz	+	+	+	
24	Sillimanite	+	+	+	
25	Chromite	+	+	+	
26	Hematite	+	+	+	
27	Tourmaline	++	++	++	
28	Sphene	+	+	+	
29	Glauconite	+	+	+	
30	Biotite	++	++	++	

Conclusion

In the study area can be distinguished six types of bottom sediments: sand, silty sand, clayish-silty sand, silty clay, clayish silt and clayish-sandy silt. In general, sand, silty sand and clayish silty sand are dominant in the study area. Fine sediments: clayish silt, clayish-sandy silt and silty clay are abundant in the northern part and in the south western part (Gulf of Thailand). In the south eastern part, especially in the front of the Maekong River mouth, sands are dominated and spread over a large area as a sand field. Bottom sediments in the South are better sorted, less skewed

Mineralogical, grainsize composition and texture of sediments prove that bottom sediments of vietnamese coastline are mainly terrestrially dirived.

Acknowledgements

We would like to express our sincere thanks to the autorities of Institute of Geology-NCST for their support and permission to participate in this project.

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Oil Pollution in the Vietnamese Waters

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ABSTRACT

Enumeration of hydrocarbon-degrading microorganisms (HDM) and their degradative capacity studies were carried out in area IV of South China Sea (Vietnamese water). Microbial most probable number (MPN) varied from 10^1 to 10^5 cell/ ml of surface seawater or gram of sediment. Some microbial communities and bacterial strains isolated from 97 collected samples show high hydrocarbon degradation and surfactant producing abilities. Preliminary results of our microbial study indicated that oil pollution in IV area was not found in 30 research stations. Slight oil contamination was observed in 28 survey stations.

Key words: hydrocarbon-degrading microorganism, marine microorganisms, oil pollution, polycyclic aromatic hydrocarbon

Introduction

Petroleum-based products are the major source of energy for industry and daily life. Petroleum is also the raw material for many chemical products such as plastics, paints, and cosmetics. The petroleum transport across the world is frequent, and the amounts of petroleum stocks in developed countries are enormous. Consequently, the potential for oil spills is significant, and research on the fate of petroleum in a marine environment is important to evaluate the environmental threat of oil spills, and to develop biotechnology to scope with them since half of world oil production is transported by sea (Shigeaki Harayama, *et al*. 1999) .

The Interdepartmental Collaborative Research Program has been carried out since 1995 with the main objective of collecting and analyzing data and necessary information for the management of fishery resources and the protection of the environment through collaborative research member countries and organization concerned. With the agreement of Vietnamese Government, the Collaborative Research Program in Vietnamese waters, as area IV, has been carried out from 29th April to 30th May 1999.

Our project in the program is to conduct petroleum hydrocarbon pollution study with the following objective:

- *Detection of total petroleum hydrocarbon level.*
- *Investigation of number of HDM.*
- *Study of biodegradative capacity of isolated hydrocarbon-degrading microbial communities in laboratory condition.*

Materials and Methods

Sampling procedures

Surface water and sediment samples for microbial and total oil analysis were collected on cruise. Enumeration of hydrocarbon degraders was carried out immediately after the sample collection. For evaluation of oil biodegradation capacity and oil concentration, the samples were transported to the laboratory in presterilized glassed bottles. Total oil level was detected by Infra red-spectrophotometry (IRS) method.

Microbial enumeration

Improved most probable number method (MPN) was used for direct count of oil-degrading microorganisms(Ronald Atlas and Rechard Bartha,1974).Serial dilution of samples were inoculated into mineral salt medium (MSM) (Brushnell-Haas medium supplemented with 3% NaCl and adjusted to pH 7.8) in 10 ml tubes with 5% diesel oil as sole carbon and energy source. The results were scored after inoculating from 15 to 20 days at room temperature.

Biodegradative capacity

50 ml of MSM in cornical flasks containing 5% of DO were inoculated with 1 ml of preculture of isolated hydrocarbon-degrading microbial community that collected from sediment of stations No 3, 12, 40, 29, 38, 7, 52, 58, 48, 21 and incubated at 28^0C for 7 days and shaking at 200 rpm.

Aromatic hydrocarbon degradation by purified cultures that isolated from stations No 2 and 57 was also studied. For this experiments, MSM containing 50 ppm/ L phenanthrene as sole carbon and energy sources was used. Shaking culture was incubated at 30^oC for 4 days.

The residual oil was determined by weight and by gas chromatography (GC) method.

Result and Discussion

After finishing the cruise, 97 samples have been collected that including 39 sediment samples and 58 surface water samples. In general, the sediment samples can be divided into four groups such as mud, sandy mud, muddy sands, and sand.

Total hydrocarbon concentration

Only 11 samples (No 1, 2, 3, 4, 8, 10, 13, 27, 40, 43, and 48) from 58 research stations were investigated. Among them only in stations No 1 and No 2 oil concentration 0.095 mg/L and 0.017 mg/L respectively was detected (Table 1). In other research stations the oil concentration was under detected level of IRS detector (< 0.01 mg/L).

These results indicated that in these samples no oil contamination was observed. This data can not be used for the conclusion of oil pollution level in seawater because of several technical reasons that concerning to the method used for these chemical analysis.

Microbial investigation

The enumeration result of hydrocarbon-degrading microorganisms was illustrated in Table 2 and Table 3. According to obtained results HDM number is in the range from 10^1 to 10^5 cell/ml or cell/g of sample. Number of microorganisms in sediment samples was normally higher than in surface water samples. Number of HDM in the surface water samples was higher than in the sediment samples, it was found only in two stations No 2 and 38. There are 12 stations in which the number of hydrocarbon-degraders was equal in both sediment and surface(Fig. 1) water samples such as stations No 3, 4, 5, 12, 13 (10^5 cell/ml); stations No 47, 50, 56 (10^4 cell/ml); stations No 8, 9 (10^3 cell/ml), and stations No 29, 40 (10^2 cell/ml)

In 18 samples (6 from surface and 12 from sediment) number of HDM was 10^5 cell/ml, in 22 samples (8 from surface and 14 from sediment) bacterial number was 10^4 cell/ml, in 32 samples (23 from surface and 9 from sediment) number of HDM was 10^3 cell/ml and in the last 23 sample (19 from surface and 4 from sediment) number of HDM 10^2 cell/ml was detected only (Table 2). According to colony morphology of all isolated bacteria, they can be belonged to about 20 groups. In almost far from shore samples, including stations No 2, 6, 10, 15, 16, 17, 24, 25, 32, 33, 34, 41, number of HDM was lowest, except in stations No 42, 45, 46, 51, 52, 55.

According to the number of HDM (indirect indication), oil contamination was not detected in 30 stations, and light oil contamination was detected in other 28 stations. In almost stations in the South Sea (from No 43 to 58) light oil contamination was observed (Table 2).

Microbial community of hydrocarbon- degraders in different research stations showed different oil degradative capacity (Table 4). The strongest community in diesel oil degradation was found in two stations No 21 and 48, about 94 % oil was reduced during 7 day shaking cultivation. The weakest communities in oil degradation study detected in stations No 3, 12, 43, 29, only 15.8 – 26.4 % oil was reduced. In stations No 38, 37, 52, 58 the microbial communities were able to degrade 31.6 – 47.4 % oil.

Surfactant producing bacteria were isolated from 8 stations (Fig. 2). Isolated bacteria and their products play an important role in the process of cleaning up oil contamination (Oberbremer A. et al., 1990).

Study of polycyclic aromatic hydrocarbon degradative capacity by purified culture was also carried out. The result showed that some bacterial strains isolated from different stations degraded rapidly phenanthrene. For example, after 4 day cultivation, strain I-572 that isolated from sediment of research station No 57 (Fig. 3) could degrade 99 % of added phenanthrene in MSM (Fig. 4).

Table 1. Hydrocarbon concentration in sea water at some research stations.

Research stations	Oil concentration (mg/L)
1	0.095
2	0.017
3	< 0.01
4	< 0.01
8	< 0.01
10	< 0.01
13	< 0.01
27	< 0.01
40	< 0.01
43	< 0.01
48	< 0.01

Table 2. Number of hydrocarbon- degrading microorganisms in survey stations.

Station No	Number of HDM (cell per ml)		Station No	Number of HDM (cell per ml)	
	Surface water	Sediment		Surface water	Sediment
1	10^4	10^3	30	ND	10^3
2	10^2	10^3	31	ND	10^3
3	10^5	10^5	32	ND	10^3
4	10^5	10^5	33	ND	10^1
5	10^5	10^5	34	ND	10^1
6	10^3	10^2	35	10^3	10^2
7	10^3	10^2	36	10^3	10^2
8	10^3	10^3	37	10^3	10^2
9	10^3	10^3	38	10^2	10^3
10	10^3	10^2	39	10^3	10^2
11	ND	10^5	40	10^2	10^2
12	10^5	10^5	41	ND	10^2
13	10^5	10^5	42	ND	10^4
14	10^4	10^2	43	10^5	10^4
15	ND	10^2	44	10^4	10^3
16	ND	10^2	45	10^5	10^3
17	ND	10^3	46	10^5	10^3
18	ND	10^3	47	10^4	10^4
19	ND	10^3	48	10^4	10^3
20	10^4	10^2	49	10^4	10^3
21	10^4	10^2	50	10^4	10^4
22	ND	10^3	51	10^4	10^3
23	ND	10^3	52	10^5	10^4
24	ND	10^3	53	10^5	10^4
25	ND	10^3	54	10^4	10^2
26	ND	10^2	55	10^4	10^3
27	ND	10^2	56	10^4	10^4
28	10^5	10^2	57	10^4	10^3
29	10^2	10^2	58	10^5	10^4

ND: not detected

Table 3. Distribution of samples according to the number of HDM.

Samples	Number of HDM (cells per ml)					Total of samples
	10^1	10^2	10^3	10^4	10^5	
Surface	2	19	23	8	6	58
Sediment	0	4	9	14	12	39

Table 4. Oil degradative capacity of microbial communities isolated from sediment in some research stations.

Station	Residual oil (mg/L)	Degraded oil (%)
Control	38	0
3	32	15.8
12	30	21.1
40	28	26.4
29	28	26.4
38	26	31.6
7	26	31.6
52	24	33.9
58	20	47.4
48	2.4	93.7
21	2.2	94.2

A B

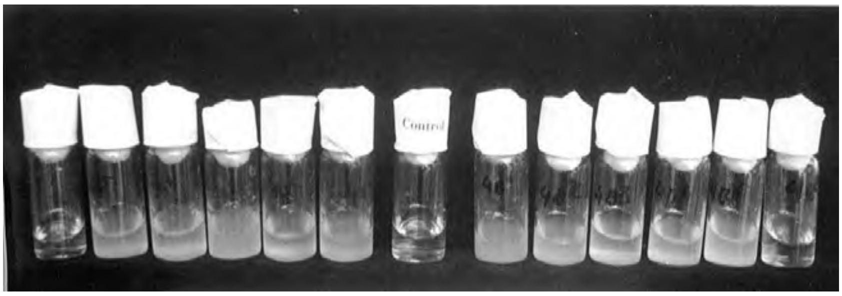

Fig.1. Hydrocarbon degrading microorganism from (A) surface and (B) sediment samples determined by improved MPN method.

A B

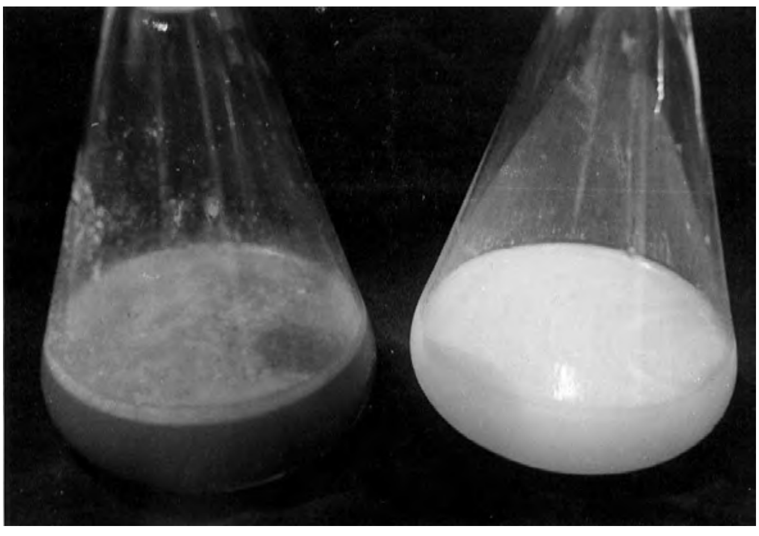

Fig. 2. Biosurfactant produced by two different isolates from stations No.13 (A) and No. 21 (B).

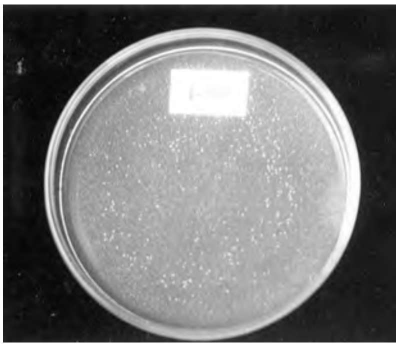

Fig. 3. Polycyclic aromatic hydrocarbon degrading microorganism strain isolated from research station No. 57.

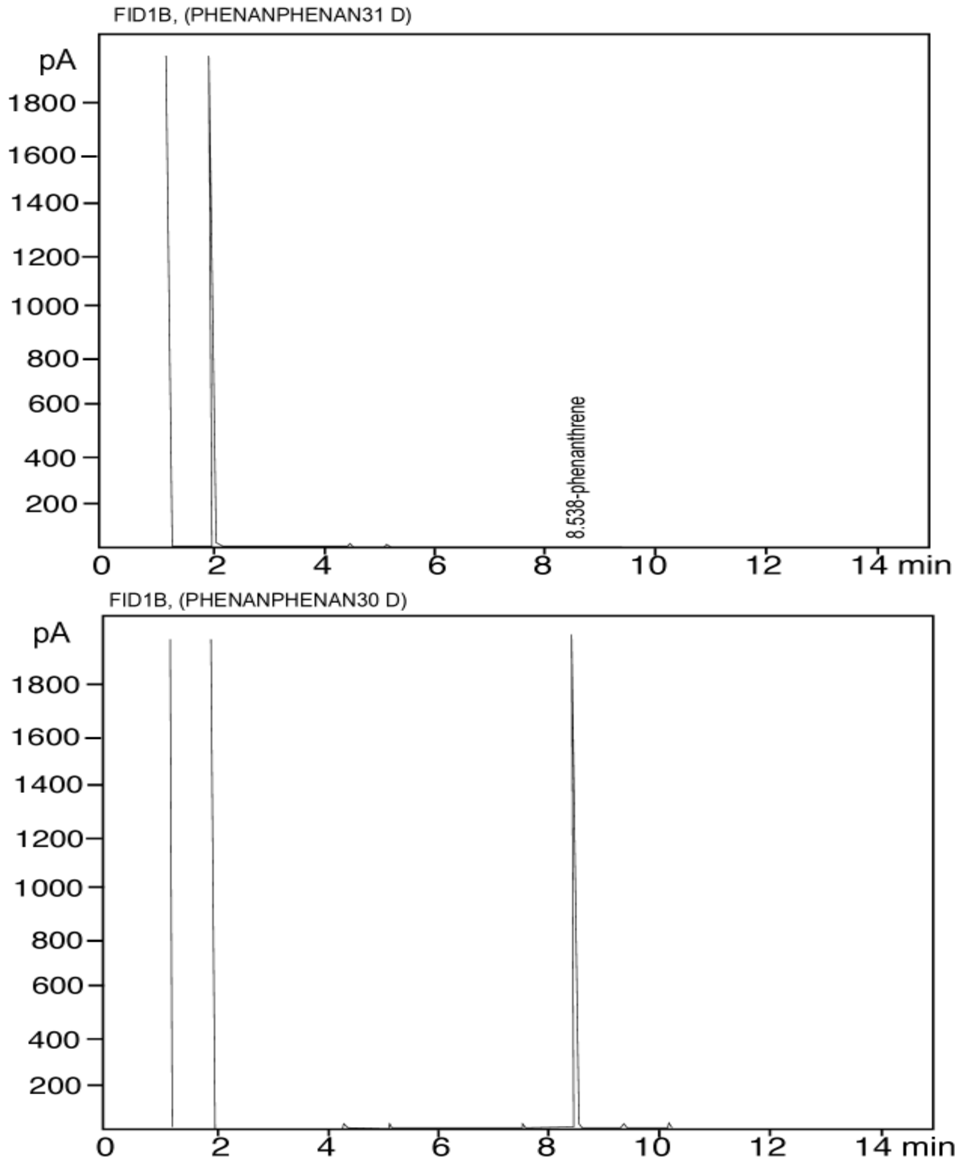

Fig. 4. Gas chromatograms of residual phenanthrene in shaking culture inoculated with I-572 (A) and without (B) after 4 days.

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