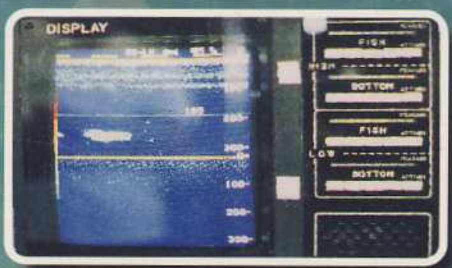
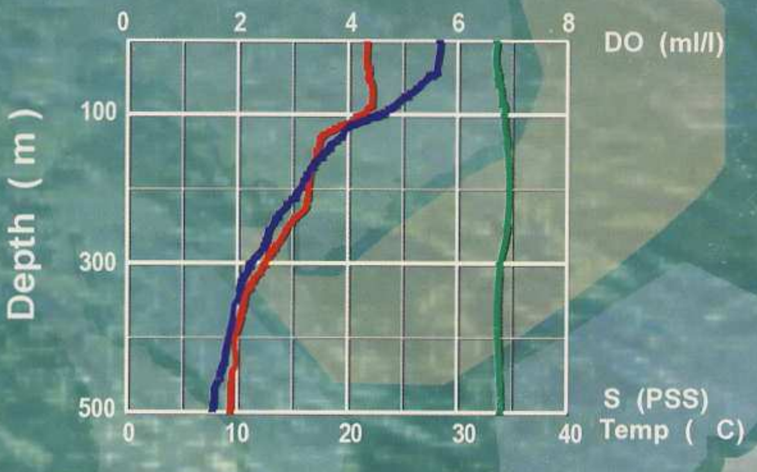
Proceedings of the Third Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area III : Western Philippines





THE SECRETARIAT
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
BANGKOK
FEBRUARY 2000

TD/SP/26

SEAFDEC INTERDEPARTMENTAL COLLABORATIVE RESEARCH PROGRAM

Proceedings of the Third Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area III: Western Philippines

13-15 July 1999

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

BUREAU OF FISHERIES AND AQUATIC RESOURCES,
QUEZON CITY, THE PHILIPPINES

THE SECRETARIAT
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
BANGKOK
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FOREWORD

To provide a forum for scientists from SEAFDEC countries and SEAFDEC Departments who participated in the SEAFDEC Inter-departmental Research Program, the Secretariat organized, on 13 July 1999, the Third Technical Seminar in Metro Manila, Philippines. Like two earlier technical seminars, the Third seminar discussed the results of the fisheries and oceanographic survey covering the waters of western Philippines, designated for the purpose of our survey as Area III. For 46 days at sea from 7 April 1998, our research and training vessel, MV. SEAFDEC, covered an area of 86,400 sq.mi. of the South China Sea that lies between latitudes 11°N and 20°N, and longitudes 117°E and 121°E. By no means a continental shelf, 95% of Area III is more than 1,000 m deep. Certainly, fish and other marine fauna are somewhat different from those of a near-shore area.

The estimate of fish biomass using acoustic survey required a simultaneous verification by a fishing method. Cephalopods inhabiting the waters of western Philippines were sampled by a squid jigging method to assess their potential for commercial exploitation. While other fishing methods could be employed to ascertain the seasonal and geographical distribution of these squids, oceanographic features, e.g. the depth where optimum water temperature for tuna in the thermocline and the upwelling that supports a planktonic bloom need to be corroborated by subsequent studies. Our survey documented for the area four prominent cephalopod species that were collected for morphological studies.

In order to understand the dynamics of fish population and their productivity in the survey area, samples of phyto- and zooplankton were collected for analyses. While ichthyoplankton provided important clues for spawning success of certain species, more samplings would be required to reveal the life-historical information, e.g. on their age and growth. Periodic or large samples of important fish and shellfish species would be necessary for determining their rates of recruitment to a fishable stock. Oceanographic features, such as current and prevailing winds, would help explain their distribution ranges and subsequently the fishing season at a certain ground.

The survey showed negligible number of tuna specimens from its longline experimental fishing. The scientists attributed the poor tuna catch to the depth in the water column where the gear was set, bait size, and surprisingly low DO levels. Clearly, more oceanographic information, particularly the appropriate layers of thermocline associating with the presence of tuna, is required. The prevailing El Niño influences could also be a cause. For another well-known commercial fish, the roundscad was found to have a successful breeding, and Station 16 from where large samples were taken could be its nursery area in the months of April and May. No signs of oil or other pollution were shown in the survey.

The information provided in the proceedings of this seminar could serve as a basis for future investigations of fish stocks and oceanographic features in Area III of the South China Sea. It is hoped that, with the necessary support and participation of all our member countries, future investigations would provide additional scientific information to support sustainable fisheries in this fishing ground.

On behalf of SEAFDEC, I would like to express our warm appreciation to all participating scientists for their intellectual and dedicated contributions to science and to fisheries in this region.

(Panu Tavarutmaneegul)
Secretary-General

SPEECH AT OPENING CEREMONY

by

CESAR M. DRILON, JR.

Undersecretary for Fisheries and Legislative Relations and
SEAFDEC Council Director in the Philippines

Honored Guests, SEAFDEC Secretary-General Mr. Panu, Dr. Kato, Dr. Shimomura, Mr. Ismail, Dr. Platon, Director Camacho, Participants, Other Guests, Ladies and Gentlemen, GOOD MORNING!

It is my great honor and privilege to speak before you on this very important significant occasion. The Technical Seminar on the Survey Results of the SEAFDEC/BFAR Interdepartmental Collaborative Research Program on Marine Fisheries Resource and Environmental studies in South China Sea, Area III: Western Philippines was significant event. We appreciate the importance of the various studies for its outcomes will provide relative information which contribute to the proper management of the fishery resources and marine environment protection.

Likewise, the data gathered from the joint survey undertakings of M/V SEAFDEC and M/V Maya-Maya will be of great benefits to the Philippines and other SEAFDEC member countries. It is expected that all the technical data derived from the applied research methodologies will be fruitfully utilized by all concerned Researchers and Participating Nations. The results of the Survey shall confirm if the tuna and tuna like species, squids, various types of plankton resources and other potential species can still be sustainable conserved, managed, utilized, developed and exploited within the optimum economic limits.

Thru the applied scientific approaches using the State of the Art equipment/machineries of M/V SEAFDEC, I am certain that the studies conducted on the biological, ecological aspects of tuna and tuna like species and oceanic squid; multi species assessment thru acoustic methodology; visual observation of fish schools; selective fishing gear explorations using purse seine, squid jig and tuna longline for round scads, oceanic squid and tuna as well as the various plankton studies will provide adequate information to serve as our bases for determining the potential fisheries resources which can be harnessed and exploited in response to the food security program of the government

I am optimistic that the survey results presentation in this Seminar will establish a comprehensive oceanographic and resource assessment data as bases for policy formulation and decision making; program/project planning; identification of the most viable fishing technology methods for introduction and operation in the municipal and offshore waters within ecological and sustainable limits. Ultimately, it is expected that a Comprehensive Fishery Management and Development Plan for Western Philippines waters will also be designed.

In view of the mentioned activities, let us continue the conduct of more collaborative programs; I am recommending another survey in the Northeastern Philippines and other priority areas of concerns using both M/V SEAFDEC and M/V DA/BFAR which shall be commissioned sometime September 1999. I honestly believed that the conduct of a Collaborative Research in Northeastern Philippines would provide information of the available fishery resources and the oceanographic conditions of the Philippine waters. Moreover, I am looking forward that the technical cooperation between BFAR and SEAFDEC will be strengthened.

Corollarily hereto, is my sincere gratitude to the Kingdom of Thailand and the SEADEC Management for their valuable assistance in sharing the services of M/V SEAFDEC during the implementation of the interdepartmental collaborative research programs.

Lastly, may I commend the organizers of this program for the fruitful benefits it extended to the Fishing Industry. I hope that you will have a pleasant stay in Manila. GOOD DAY AND MORE POWER.

Program for the Third Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area III: Western Philippines

Manila Midtown Hotel, Metro Manila, The Philippines

(13-15 July 1999)

July 13(Tue.) Day 1

0830-0900 :	Registration
0900-0910 :	Welcome address by ***Director Arsenio S. Camacho, BFAR***
0910-0920 :	Keynote address by SEAFDEC Council Director for the Philippines, ***Undersecretary Cesar M. Drilon, DG***
0920-0930 :	Address by the Secretary-General of SEAFDEC ***Mr. Panu Tavarutmaneegul***
0930-0940 :	Introduction of the Interdepartmental Collaborative Research Program ***Mr. Aussanee Munprasit, TD/Technical Coordinator, ICRP***

Session I: Fishery Resources

Moderator : Mr. Somsak Chullasorn

0940-1000 :	Multi species stock assessment by acoustic method ***Mr. Raja Bidin Bin Raja Hassan (SEAFDEC/MFRDMD)***
1000-1020 :	Visual observation on fishes schooling and fishing activities on the survey area ***Mr. Aussanee Munprasit (SEAFDEC/TD)***
1020-1040 :	Catch rate of oceanic squid by jigging method ***Ms. Ludivina L. Labe (BFAR)***
1040-1100 :	Refreshment/Coffee break

Moderator : Dr. Glenn D. Aguilar

1100-1120 :	Diamondback squid *Tysanoteuthis rhombus* exploration ***Mr. Jonathan O. Dickson (BFAR)***
1120-1140 :	Tuna resource exploration by longlining ***Mr. Jonathan O. Dickson (BFAR)***
1140-1200 :	Round scad exploration using purse seining ***Mr. Prospero Pastoral (BFAR)***
1200-1220 :	Catch of experimental longline, purse seine and handline ***Dr. Noel C. Barut (BFAR)***
1220-1420 :	**Lunch**

Session II: Fishery Biology

Moderator : Mr. Geronimo Silvestre

1420-1440 :	The systematic and distribution of oceanic cephalopod ***Dr. Anuwat Nateewathana (TD/DOF)***
1440-1500 :	Ecological aspects of oceanic squid, *Sthenoteuthis oualaniensis* ***Dr. Somboon Siriraksophon (SEAFDEC/TD)***
1500-1520 :	Age and growth studies of tuna and squid using scale and otoliths ***Mr. Zaidi bin Zakaria (MFRDMD/UPM)***
1520-1540 :	Biological features of oceanic squids, *Symplectoteuthis oualaniensis* ***Mr. Samsudin bin Basir (MFRDMD/FRI)***

1540-1600 : Refreshment/coffee break

Moderator : Dr. Suchin Deetae

1600-1620 : Composition, abundance and distribution of ichthyophankton
Dr. Chongkolnee Chamchang (TD/DOF)

1620-1640 : Abundance and distribution of Zooplankton
Mr. Juan R. Relox (BFAR)

1640-1700 : Distribution of planktonic malacostraca and cephalopod paralarvae
Ms. Jutamas Jivaluk (TD/DOF)

1830-2100 : Welcome party hosted by the Secretary-General of SEAFDEC

July 14 (Wed.) Day 2

Session III : Primary Production

Moderator : Prof. Dr. Law Ah Theem

0900-0920 : Species composition, abundance and distribution of phytoplankton in thermocline layer *Ms. Sopana Boonyapiwat (TD/DOF)*

0920-0940 : Subthermocline chloroplyll maxima
Dr. Suchin Deetae (TD/KU)

0940-1000 : Phytoplankton in the surface layers
Ms. Fefarida A. Bajarias (BFAR)

1000-1020 : Refreshment/Coffee break

Moderator : Prof. Dr. Gil S. Jacinto

1020-1040 : The primary production of the survey area
Ms. Elsa F. Furio (BFAR)

1040-1100 : A profile of dissolved nutrient in the survey area
Mr. Ulysses M. Montojo (BFAR)

1100-1120 : Species composition, abundance and distribution of nanoplankton
Prof. Dr. Lokman Shamsudin (MFRDMD/UPM)

Session IV& V : Fishery Oceanography and Marine Pollution

Moderator : Dr. Manuwadi Hungspreugs

1120-1140 : Physical characteristics of watermass in the survey area
Ms. Penjan Rojana-anawat (SEAFDEC/TD)

1140-1200 : Geostrophic and residual current in survey area
Dr. Anond Snidvongs (TD/CU)

1200-1220 : Assessment of petroleum hydrocarbon level in water
Mr. Suriyan Saramun (TD/CU)

1220-1230 : Closing address by the Secretary-General of SEAFDEC

1230-1400 : **Lunch**

1400-1800 : Excursion in Manila

1400-1600 : Comments and suggestions compilation by secretariat staff

July 15 (Thu.) Day 3

0900-1200 : Discussion and conclusion by Peer Reviewer/Commentator Committee

1200-1400 : **Lunch**

1400-1500 : Steering Committee Meeting

Technical Papers

Multi Species Stock Assessment by Acoustic Method in the South China Sea Area III: Western Philippines

Raja Bidin bin Raja Hassan [1] Rosidi bin Ali [1] Valeriano Borja[2], Homerto A. Riomalos[2], Nadzri bin Seman[1] , Shunji Fujiwara[1] and Kunimune Shiomi[1]

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2 BFAR, 860 Quezon Ave., Quezon City, Metro Manila 3008, Philippines

ABSTRACT

An acoustic resource survey off western Philippines waters from April 18 to May 07, 1998 was conducted by MFRDMD in collaboration with BFAR by using M/V SEAFDEC. A scientific echosounder FQ-70 developed by the Furuno Electric Co. of Japan was used to collect the SV data along the transects of 60 nautical miles apart. The raw data of backscattering strength (SV) collected from the 200 kHz transducer were carefully corrected and filtered to eliminate the influence of noises such as planktons. The corrected SV values were used to estimate the biomass of multi-species pelagic fish. *Decapterus macrosoma* was selected as representative species based on catch composition caught by M/V MAYA-MAYA during fishing operations. From the catch, the standard length (SL) and average weight of *Decapterus macrosoma* were obtained. Then the target strength (TS) of the representative species was calculated using formula, TS=20log (SL) - 66. The distribution of the SV values showed geographical difference. SV values were higher in the northern area and the southern waters of Manila. TS was estimated at -45.8 dB with the standard length of 10.2 cm. The estimated density and biomass of multi-species pelagics along the coastal waters were 18.9 tonnes/km^2 and 1.672 million tonnes respectively. Meanwhile the total area and depth layer used were 88,362 km^2 and 190 m resprectively.

Key words: acoustic survey, FQ70, SV value, biomass estimation, fish density

Introduction

South China Sea is one of the major fishing grounds in the Philippines from where the country depend, on fisheries for export , livelihood and other economic benefits. However, fishing activities off western Philippines are limited due to climatic conditions. During southwest and northeast monsoon seasons, only few large scale fishermen operate in offshore area while the artisanal fishermen concentrate along the coastal waters. Western Philippines, therefore is not considered as productive fishing grounds. However, it might be necessary to assess the potential of the fish resources before they are being exploited.

Fish stock assessment is a growing necessity in many countries in Southeast Asian countries. In the Philippines, stock assessment is only based on landed catch data. However, there is a need to adopt a new method in determining fish stocks i.e hydro-acoustic. As in other tropical regions, western coast of Philippines waters has a similar biological characteristics such as the distribution and abundance of multi-species and all year round spawning. The inherent characteristics of fisheries hinder the collection of reliable landing statistics throughout the area. Suitable fish stock assessment methods are not readily available in this region. SEAFDEC has been making efforts to develop appropriate methods using hydro-acoustics (Rosidi *et al*., 1998). Application of scientific hydro-acoustic equipments in assessing fish population seems to be a more appropriate means among others to meet overall goal of the rapid fish resources assessment, although the method does not give a complete answer for the tropical multi-species condition. But, it is an effective way to assess new fishing grounds where statistics are not sufficient and to provide baseline information for the fishery management.

In April-May 1998, the interdepartmental collaborative research program in the South China Sea (Area III) off western Philippines commenced through SEAFDEC/MFRDMD coordination. The study was conducted with the inclusion of ocenographic and other activities. This is the first ever acoustic survey done in Philippines waters. This report examines the distributions of volume backscattering strength (SV) collected by the scientific echosounder FQ-70 off western Philippines waters and presents the outputs for fish stock assessemnt including biomass estimation off Philippines.

Materials and Methods

The hydro-acoustic survey using the scientific echosounder FQ-70 (Furuno Electric Co.) was carried out simultaneously with oceanographic studies, tuna longline fishing and automatic squid jigging by M/V SEAFDEC off western coast of Philippines waters from April 18 – May 07, 1998.

Calibration of FQ-70 was done prior to survey cruise off Subic Bay (14 ° 39.05'N, 120 ° 15.98'E) before the vessel proceeded to oceanographic station no. 1 (20 ° 20.02'N, 110 ° 00.04'E) located off northwest of Philippines waters. The source level, receiving sensitivity, and the gain of amplifier were measured by means of a hydrophone. Parameter settings of the acoustic system based on the calibration results, were shown in Table 1.

The survey transect was set between the oceanographic stations. Both surveys were conducted along the same transect as shown in Figure 1. Innitially a total of 31 transects were planned, but the last transect between station 31-32 was cancelled due to bottom topographical condition. Each transect was approximately 60 nautical miles apart. The vessel cruised along the transect line at a speed of approximately 10 knots.

Data Collection

The hydro-acoustic system was set up to process echo and produce outputs of the volume backscattering strength (SV in dB/m^2) in real time from depth of 10m to 200m at horizontal intervals of 0.1 nautical mile. The depths were set into 10 layers as shown in Table 2. Layers 1 to 8 were set between 10m and 200m from the surface, while layers 9 and 10 were set between 1 and 10m from the bottom.

The SV values from the low frequency (50kHz) and the high frequency (200kHz) transducers were both recorded. However, only the values from the high frequency transducer were used in data processing and consequently in the fish biomass estimation. The data were recorded in multiple format media as follows:

Table 1. Parameters settings after calibration work of the scientific echo-sounder FQ-70 for the survey off the western coast of Philippines in April and May 1998.

Parameters	Frequency	
	50 khz	200 khz
Source Level (dB)	214.4	211.7
Pulse Duration(ms)	1.2	1.2
Beam Width(dB)	-14.5	-16.1
Absorption Coefficient(dB)	10.8	89.9
Receiving Sensitivity(dB)	-186.9	-200.8
Amplifier Gain(dB)	49.0	50.2

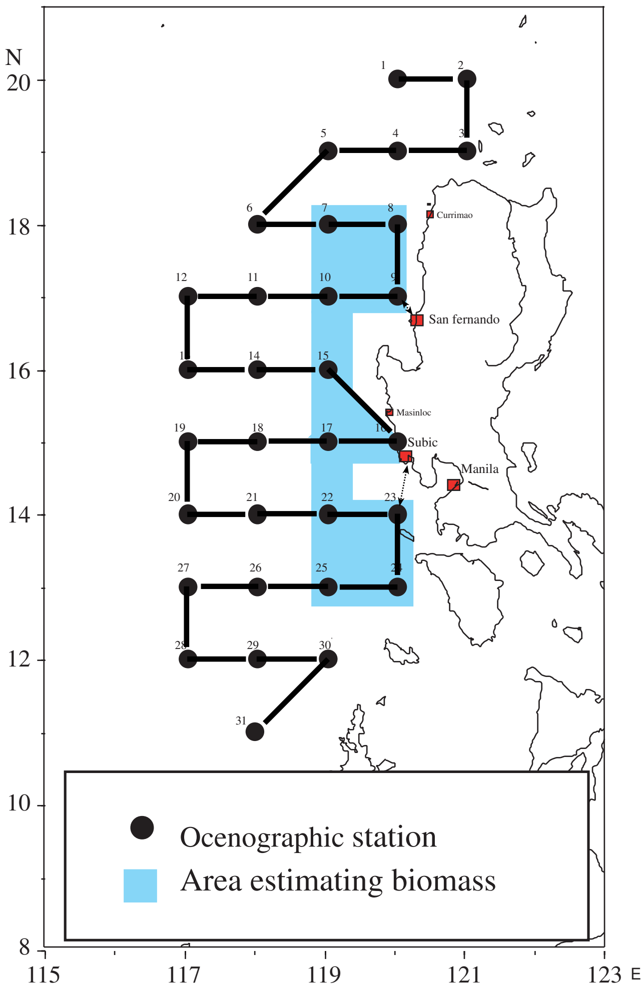

Fig. 1. Survey transects for the acoustic off the western coast of Philippines in April/May 1998. Numbers indicate the oceanographic survey stations.

1. Numeric data from integration results of echo signals were recorded in a floppy disk through data analyser FQ-770

2. Results of the echoes integration were also produced in print-out format (This output was also recorded simultaneously in a floppy disk).

3. Echo signals including echoes of the vertical distribution curve, were also produced on recording paper through the recorder unit FQ-706.

4. Analog and echo signals data including log data were recorded in VHS videotape.

However, during SV data processing only the numeric data in floppy disk and print out formats were used. The traced echo signals on recording papers were used only for verification of fish signals and planktons. Meanwhile the analog data in video tapes were not utilized due to the absence of the post data analyser.

SV correction

Noise produced from other electric devices and unlocked bottom echoes due to rough sea conditions might result in errors to the collected raw SV values. Besides noise and bottom unlocked echoes, plankton and other dense micronecton might also affect the raw SV values. Therefore, these raw SV values need to be corrected earlier before further analysis.

Graph of SV values against the integration numbers were plotted to detect the extreme values, which were probably produced, by fish, plankton layer or noise. The graph would indicate SV characteristic from layer 1 to 8 and bottom layers 9 to 10. By removing the extreme values due to the noise, the graph would automatically change accordingly, following trend similar to that of the data. These values were termed as the *Corrected SV* values.

The corrected SV values were further filtered to select the values produced by fish, using five-point moving average. These filtered SV values would be called the *Calculated SV* values.

The calculated SV values for each transect were averaged vertically from depth layer 1 to 8 for each integration number, and horizontally from the first integration number to the end. The calculated SV were sorted out into pelagic and demersal fish. Average SV values from layer 9 and 10 were considered as demersal fish. Pelagic fish was calculated from the remaining value of layer 2 to 8 after subtracting the SV values of layers 9 and 10. The overall averaged calculated SV values for all transects within the specified area were used for pelagic and demersal fish biomass estimation.

Biomass estimation

The pelagic particularly tuna and tuna like fishes as well as roundscad off western Philippines waters were estimated based on information available. Biomass for roundscads group in particular was based on limited area and information collected by M/V MAYA MAYA. The area considered for biomass estimation is shown in Figure 1. The following expression is used to estimate the fish biomass.

$$\mathbf{Q = (sv / ts).w.a.d} \quad \text{.................... (1)}$$

where Q = Biomass

sv = $10^{(sv/10)}$: Backscattering strength

ts = $10^{(ts/10)}$: Target strength

w = average fish weight (g)

a = survey area (m^2)

d = layer depth (m)

Target strength (TS) was estimated using the Furusawa (1990) equation

$$\mathbf{TS = 20 \log SL - 66} \quad \text{............. (2)}$$

Where, TS = Target strength (dB)

SL = Fish Standard length (cm)

A single TS value from the representative species was used for biomass estimation in this report. The representative species for pelagic was determined based on the actual catch of M/V MAYA-MAYA (by purse seine). It was also compared with the catch statistics by major fishing gears operating along the area off western Philippines.

Maximum Sustainable Yield (MSY) Estimation Based on Biomass

MSY is one of the important indicators used for fishery management. MSY could be estimated from the catch and effort data, available from fishery statistics. One of the typical procedures is to use surplus production models devised by Schaefer (1954) or Fox (1970). In Philippines, historical statistics are not readily available to fit these models to estimate MSY. However, the Cadima's empirical equation (Troadec, 1977), modifed from Gulland's model (1971), may applicable to estimate MSY using biomass estimated from the hydro-acoustic method.

$$\mathbf{MSY = 0.5MB_o} \quad \text{......................(3)}$$

where M = Annual natural mortality

Bo = Biomass for unexploited fish stocks

M is estimated by using empirical equation developed by Pauly (1980)

$$\ln \mathbf{M} = -0.0152 - 0.279 \ln \mathbf{L_\infty} + 0.6543 \ln \mathbf{K} + 0.463 \ln \mathbf{T} \quad (4)$$

where M = Annual natural mortality

L_∞ = maximum length

K = Growth coefficient

T = Average annual temperature at the surface (°C).

The surface water temperatute in tropical waters are relatively constant at approximately 27-28°C (Chua and Charles, 1980; Sverdrup et al. 1947). In this analysis, T was set at 28 °C.

Results

Fish Echoes

Figure 2 shows an example of echogram with SV vertical distribution curves for both high and low frequency. Normally a large fish echo would appear on the echo-sounder screen and record a relatively higher SV value. In ideal situation, the same level of SV values are observed for high and low frequency echogram. However, the low frequency sometimes produce a continuous SV from -70 to –60 dB especially at the depth layer of 20 to 80m. Under such circumstances, SV values from high frequency only is used for further treatment and analysis.

SV Distribution

Distribution of the calculated SV values of pelagics is shown in Figures 3. These figures show that there are relatively higher SV values in depth layer between 100 and 200m on the continental shelf along the shore. There are significant differences for SV recorded along the coastal area with higher SV values appearing in the north and south of Manila.

Biomass Estimation

Fishing activities in the survey area are limited to the coastal waters up to 60 nm. It is difficult to obtain fishing information further off shore due to the capacity of the fishing boats. Fishing operation is pre determined to verify the echoes of dominant species. Then the biomass estimation is made based on representative species. In this study, roundscad of *Decapterus macrosoma* species was selected as representative species for biomass estimation. The parameter used for this species is indicated in Table 3. In this report, the biomass produced is only for coastal waters. Detailed results of biomass estimation for pelagic fish off the western coast of the Philippines bordering the South China Sea area is shown in Table 4. The estimated density and biomass of pelagic fish were 18.9 tonnes/km ^{2} and 1.672 million tonnes respectively.

MSY Estimation

Von Bertalanffy growth model was used to determine the annual natural mortality (M) for *Decapterus macrosoma* as obtained from Mohsin (1996). Other parameters were also derived, including L_{inf} and K at 33cm and 0.9 per year respectively. M was estimated at 1.62 for the surface temperature at 28 ^{o} C. Using the above parameters, MSY was estimated at 1.356 million tonnes (Gulland's equation) or 904,000 tonnes at 2/3 MSY (Table 5).

Discussion

This paper presents one of the approaches for multi-species stock assessment by hydro-acoustic method. This survey only collected SV values without proper echo identification as required for ideal biomass estimation. Future study should strongly emphasize on the echo identification by using appropriate fishing methods, such as the high-speed mid-water trawl, purse seine or vertical longline.

The present survey estimated the average pelagic fish density at 18.9 tonnes/km ^{2} based on roundscad fish as representative species. This figure is relatively higher in the region as

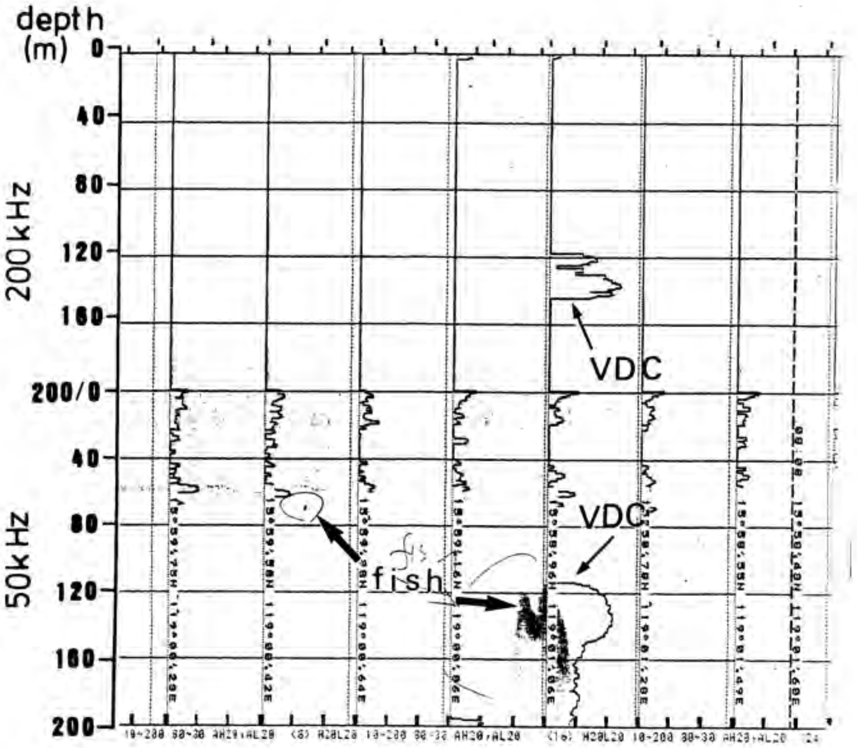

Fig. 2. An example of large fish school observed during the survey cruise at station no 15-16(1) in April 28, 1998.

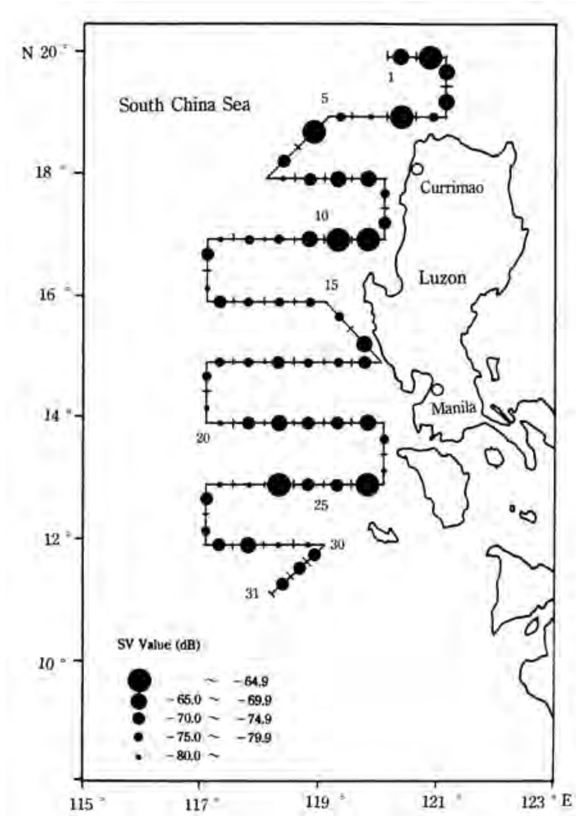

Fig. 3. Distribution pattern of SV along transect off western coast of Philippines in April/May, 1998. Numbers indicates the oceanographic survey stations.

Table 2. Depth layers and ranges for SV integration.

Depth Layer	Ranges (m)
1	10 - 20
2	20 - 40
3	40 - 60
4	60 - 80
5	80 - 100
6	100 - 130
7	130 - 160
8	160 - 200
9	10 – 5 (from Bottom)
10	5 – 1 (from Bottom)

Table 3. Average standard length (SL) and weight (w), and estimated TS (dB) for the representative species of pelagic fish off the western coast of Philippine waters, based on the catch by M/V Maya Maya.

Species	Standard length (cm)	TS (dB)	Weight (g)
Decapterus macrosoma	11.5	-44.8	19.1

Table 4. Estimated biomass for pelagic fish off the western coast of Philippines waters within Philippines EEZ , by using FQ-70.

	area (km^2)	Density (tonnes/km^2)	Biomass (tonnes)
Western Philippines	88,749	18.9	1,672,000

Table 5. Estimated MSY using Gulland's equation based on the biomass from the acoustic survey off the western Philippines waters in 1998.

Fish Group	Estimated Biomass (tonnes)	MSY (tonnes)	2/3MSY (tonnes)
Pelagic	1,672,000	1,356,000	904,000

Rosidi *et al* (1998) found the estimated fish density in Sabah/Sarawak is from 1.98 to 9.92 tonnes/km^2 during pre and post northeast monsoon season respectively.

Biomass and MSY estimation based on the limited area were 1.67 and 1.36 million tonnes respectively. The figures are quite high compared to the production records in the annual fishery statistics. Plankton and dynamics scattering layers (DSL) which are not 100% eliminated during analysis probably resulted in higher estimates. Better separation and reduction could be practiced if using Ei2nd software. However, the technology is not yet widely used due to limited experience and expertise. Perhaps it could be fully applied in the next survey excercises.

Figures 3 shows the distribution of SV values for pelagic fish with apparent differences by areas. However due to limited data, it is difficult to find a strong reason for the changes of SV distributions. These changes might be correlated to the oceanographic data available.

This report shows one of the approaches to estimate the fish biomass. Even though the report is also based on many assumptions, it is a step towards introducing the application of hydro-acoustic method in this region. Further efforts will be necessary to improve accuracy of multi-species biomass estimation. For example, the main target species need to be identified precisely for representative TS and weight applied for biomass. Further analyses could be done by Geostatistical Method (Pititgas, 1993) to infer the confidence interval of the fish biomass.

Acknowledgements

The authors would like to thank the Chief of MFRDMD for his support to conduct this study. We are also grateful for the cooperation shown by the crew of MV SEAFDEC while collecting SV data. Thanks are also due to Dr. T. Sasakura of SASA LABO. Co. Japan and Dr. T. Inagaki from the Ocean Research Institute, University of Tokyo, for their helpful advises.

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Visual Observation on Fishes Schooling and Fishing Activities in the South China Sea, Area III : Western Philippines

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ABSTRACT

Many schools of small bonito were observed at latitude 18°-19° N, longitude 118°-119° E, school of pompano dolphinfish *Corphaena equiselis* (Linnaeus, 1758) was also found and sampling during lured by light at night. Surface schooling of yellowfin tuna *Thunnus albacares* Bonnaterre, 1788) skipjack*, Katsuwonus pelamis* (Linnaeus, 1758) were found at latitude 14°-15° N and longitude 117° -118° E. Many fish schools were observed through acoustic equipment, Furuno FQ-70 at near shore of Zambales and off shore at latitude 13° - 14° N, longitude 117° - 118° E, in the deep layer of 100-250 meters depth. Oceanic squid has widely distribution over the area. Fishing activities are target on those resources. Tuna longline fishing operation was observed at latitude 16°-17° N and longitude 116°-117°E about 150 nautical miles away from shore. Payaws were set along the coastal line from northern Luzon until northern of Palawan and from near shore until 30-80 nautical miles away from coastline. Payaw in the central part were aimed for purse sein operation while the northern Payaw aimed to handline fishing. Handline fishing occupied all most near shore area from northern to the south. Squid fishing was observed many near Sanfernando.

Key word: Western Philippines, pelagic species, tuna-like fishes, oceanic squid, schooling, payaw, purse seine.

Introduction

Western Philippines is an Oceanic fishing ground of the Philippines. Main fisheries resources are pelagic species of the ocean such as tuna, tuna-like fishes, marlin, shark, squid and others. The SEAFDEC Interdepartmental Collaborative Research Program was emphasized on these resources, tuna is the most abundant resources in the ocean. The production of tuna and tuna-like fishes in the Philippines were 383,000 tons in 1995 (SEAFDEC, 1997), it was the biggest fishery industry of the country. Twenty-one species of tuna occur in Philippines waters but only four are caught in commercial quantity, namely, the skipjack *Katsuwonus pelamis* (Linnaeus, 1758), yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788),, eastern little tuna *Euthynnus affinis* (Cantor, 1849) and frigate tuna *Auxis thazard* (Lacepede, 1800). Important fishing gears used by commercial fishing boats were purse seine and ring nets operated in combination with fishes aggregating devices or called payaw and tuna longline. While the municipal tuna fishing which they had produced the most productive are small boat handliner. Northwestern Luzon is one of the most important tuna fishing ground of the Philippines. (Aprieto, 1980) Other group of fishery resources of this area is oceanic squid, few species of squid were observed in local market of Masinloc, Zambales on January 1998. One confirmed species was purpleback frying squid

Sthenoteuthis oualaniensis (Lesson, 1830). And other interesting species is diamondback squid *Thysanoteuthis rhombus* Troschel, 1857. Philippine fisherman caught this oceanic squid in the northeastern of Cebu, Camotes Sea by jigging and it has more abundance in Philippine waters (Jonathan 1996). These two oceanic squid have widely distribution in the tropical waters, they were found also in the Andaman Sea. (Nateewathana, 1995 and Nateewathana, Hylleberg 1989). Squid fishing in the Philippines mainly by jigging and scoop with luring light but diamondback squid is usually caught by jig in daytime.

Inorder to know situation of fisheries resources in the study area, the survey in various fields were designed such as resources survey by acoustic method, primary and secondary production were studied, oceanographic condition of fishing ground were investigated and fishing trials were designed to be carried out at the same time by research vessel, M.V. SEAFDEC. However, visual observation for fish school and fishing activity on the survey area was also very useful, it will provide others related information to those survey. And it could also provided some kind of information which they could not be covered by those survey and study, such as fish schooling on surface, fishing ground area, kind of fishing activities etc.

Method

Along the cruise of M.V. SEAFDEC no. 50-4/1998, the collaborative research survey in South China Sea, Area III : Western Philippines, fish school and fishing activities on the survey area were observed by sighting through binocular or through acoustic equipment, echo-sounder, scanning sonar. The observation by eye-sight and through binocular was conducted only in daytime, while the observation through echo-sounder (scientific echo-sounder, Furuno FQ-70) was conducted sometimes at day or night (Figue1). Scanning sonar was seldom used due to very few fish schools were found near the vessel (more than 1,000 meters). Three kind of binocular were used. 7x50 power 7.3°, 10 x 50 power 5.1° and 20 x 120 power with 3° visual angle. Generally 10 x 50 power with 5.1° binocular was used, it could be covered with the radius of 3-5 nautical miles, and the observation was carried out from compass deck (above navigation bridge). The observed school and fishing activity was record in the sighting data sheet. (Annex 1) And they were also recorded by photo and VDO camera, others marine animals were also observed and recorded such as dolphin, whale and seabird. Then all data, photos and VDO tape were checked and analyzed together with others survey data again at office in SEAFDEC/TD, Samut-Prakan

Results

The visual observation for 22 days on board M.V. SEAFDEC cruise No.50-4/1998 was carried out from April 17, 1998 at station No. 1 until May 8, 1998 at station No. 31. Fish school and fishing activities were observed continuously along the cruise track, they could be concluded in four kind of things, fishes school, marine mammal, fishing activities and fishing ground of the Western Philippines. These were observed during daytime by sighting through binocular and observed from acoustic equipment sometime, the summary is shown in Figure 2.

Fishes School

Not many surface schooling were observed. Schools of small bonito and small fish were observed at off shore of northwest of Luzon (about 120 miles away from shore). Surface schooling of yellowfin tuna, *Thunnus albacares* (Bonnaterre) and skipjack, *Katsuwonus pelamis* (Linnaeus)

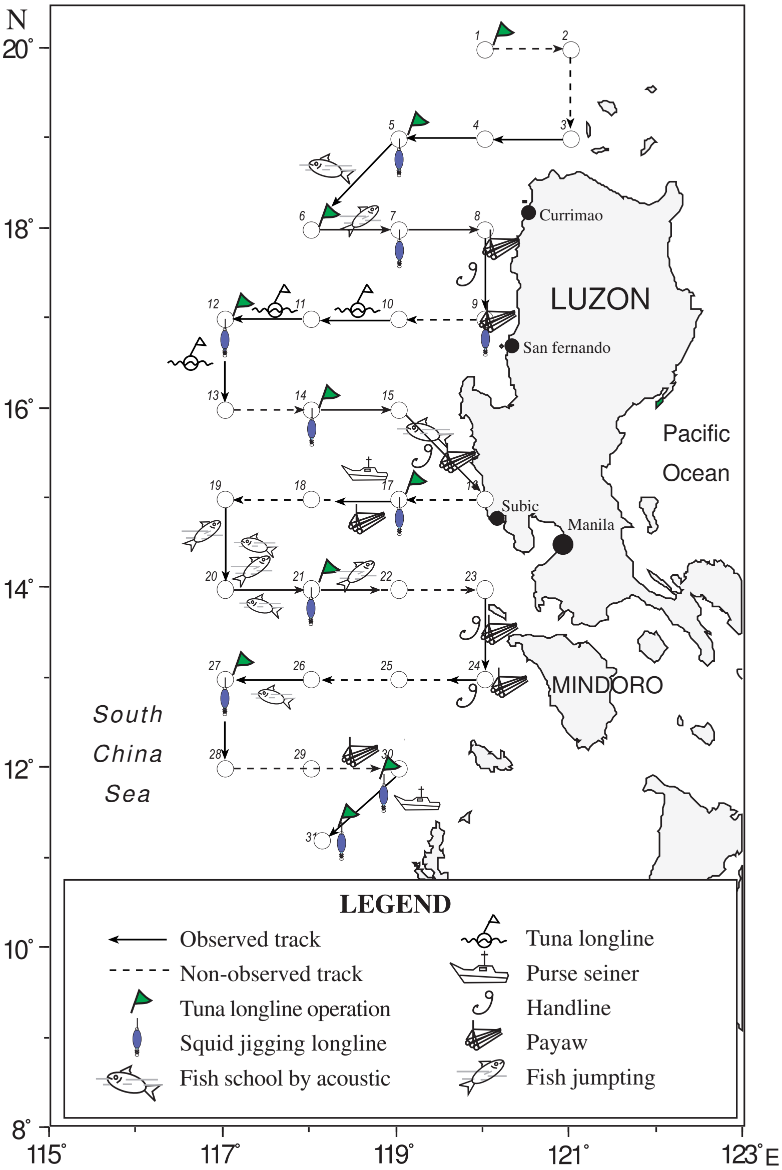

Fig. 1. Route of visual observation.

were found at latitude 14° N and longitude 117°-118° E, size of fish about 3-5 kilograms for skipjack and 10-30 kilograms for yellowfin tuna (estimated by sighting). Schooling with flock of bird was observed only one area at latitude 13° N and longitude 117°-30'.0 E, which fish cold not be observed on the surface. Big school of dolphinfish, *Coryphaena hippurus* (Linnaeus, 1758) was observed at the first station. Pompano dolphinfish, *Corypharena equiselis* (Linnaeus, 1758) schooling was observed in small school (10-100 fishes) at the surface during oceanographic survey and squid jigging operation in the night at all most of off shore stations. Most of its samplers taken by handline were full of eggs in their belly. There were a lot of fish schools in deeper layer observed through scientific echo-sounder, Furuno FQ-70 at 100 to 250 meters depth. Mostly they were found at near shore area of zambales coast and off shore at latitude 13° N, longitude 117°-118° E 150 nautical miles from coastline.

Marine mammal

Dolphin has wide distributed over the area, large school (over 100 dolphins) was observed near shore in the northern, off Zambales and at latitude 14° N., longitude 117°-118° - 30.'0 E

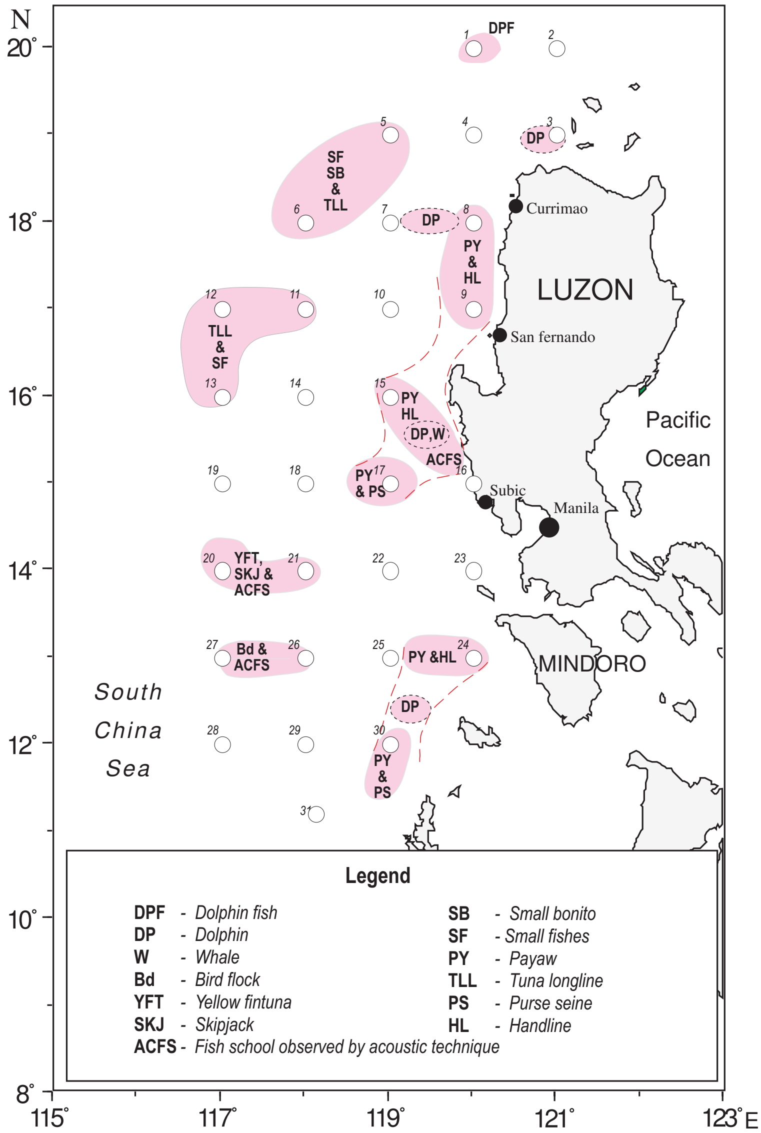

Fig. 2. Summary result of the visual observation.

150 nautical miles east of Manila bay. Few schools of small whale appeared near Zambales coast.

Fishing activities

Tuna longliners and their operating fishing gears were observed in off shore waters, 150-200 nautical miles east of Sanfernando. Almost of them were small size tuna longliners, 20-50 grosstonnage boats, direction of line setting was east-west. Ring neters and purse seiners were observed in the central part of the area, at 60-80 nautical miles east of subic bay. One large purse seiner was observed at 50 miles east of Mindoro Island (over 200 GT.). All of them operated in combination with fish aggregating devices (FAD) or payaw. Handline and trolling were the most fishing activities on the area, they fish in payaw area. Target species were tuna, tuna-like fishes and mackerel. Handlines occupied almost of payaw area close to the shore, 30-80 miles from coast line. Small out-rigger boat with inboard engine was their fishing vessel, size various from 5 to 10 meters long which they could sail at 10 to 15 knote. Squid fishing by jigging, scoop with luring light was observed at fishing ground near Sanfernando. Target catch were both oceanic and nerritic squid in the deep water near to the shore.

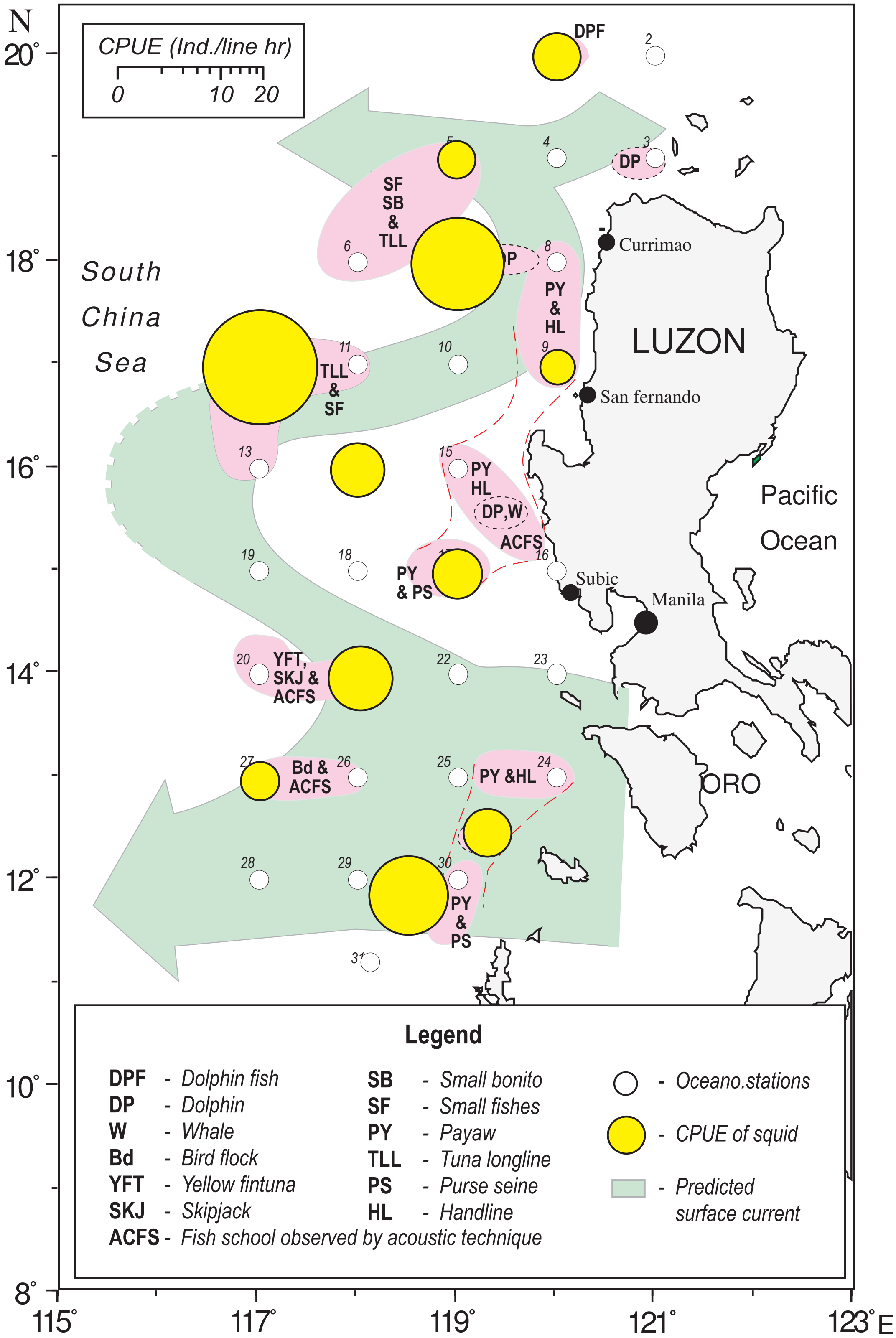

Fig. 3. Summary result in relation to surface current and catch efficiency of squid Jigging

Fishing Ground

There were a lot of payaw set along the coastline of Luzon from the north to the South (north of Palawan island), in the zone of 20-80 miles from coastline. Handlines occupied almost of payaw area while ring neters and purse seiners were observed many effort in the central and southern of the area. Tuna longline fishing ground was observed at off shore waters in the northeastern. Oceanic squid has distributed over the survey area, most abundance was observed in the northern part. Other interesting fish school in deeper water were observed at near shore of Zambales and off shore waters 150-200 miles east of Mindoro island. The species were not confirmed in this survey.

Discussion

In connection with this observation, the data and information of the visual observation was considered together with the preliminary result of squid jigging and geostrophic and residual current projects, summary result of this study is shown in Figure 3. The study shown some relation among the result of these three projects, it show some interesting area which should be good fishing ground of the Western Philippines, they were off-shore waters 120-150 miles east of Currimao (lat. 18°-19° N, log. 118°-119° E), near shore waters of Zambales (lat. 15°-16° N, long. 119°-120° E) and off-shore waters 180-200 miles east of Mindoro island (lat. 13°-14° N & long. 117°-118° E). Fish school in the deeper layer of those areas should be confirmed by using mid water trawl. Oceanic squid fishing could be promoted in off shore waters of the western Philippines.

Acknowledgement

The author would like to thank Dr. Somboon Siriraksophon and Mrs. Nathacha Sornvaree for helping manuscript preparation.

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Appendix 1/1

SIGHTING LOG SHEET

Ship name : M.V. SEAFDEC
Duration : 15/014-11/5/98

Cruise No. 50-4/1998
Survey Title: Collaborative Research Area III

Date	Time	Possition		Sea Condition	Observed objects description
		Latitude	Longitude		
4/17/98	20:00	20°-03.0' N	119°-55.0' E	Smooth	school of dolphinfish around the boat during squid jigging at station 1
4/18/98	15:00	20°-00.0' N	120°-03.0' E	Slight	acoustic survey from St. 1 to St. 2
4/19/98	7:00	19°-59.0' N	120°-53.0' E	Slight	acoustic survey from St. 3 to St. 4
4/19/98	8:35	19°-00.0' N	120°-43.0' E	moderate	big school of dolphin>100 pieces
4/19/98	9:00	19°-00.0' N	120°-39.0' E	moderate	small flock of bird (10-15 ps.)
4/19/98	13:50	19°-00.0' N	120°-00.0' E	Slight	acoustic survey from St. 4 to St. 5
4/19/98	20:30	18°-59.0' N	118°-59.0' E	Slight	small bonito gathering around boat
4/20/98	15:00	18°-55.0' N	118°-51.0' E	Swell	proceed to St. 6 and sighting
4/21/98	6:00	17°-58.0' N	117°-51.0' E	Smooth	one tuna longline in operation
4/21/98	14:20	17°-54.0' N	118°-04.0' E	Smooth	acoustic from. St. 6 to St. 7
4/21/98	16:35	18°-00.0' N	118°-20.0' E	Smooth	school of small bonito jumping
4/22/98	6:00	18°-00.0' N	119°-25.0' E	Slight	on the way acoustic to St. 8
4/22/98	6:40	18°-00.0' N	119°-35.0' E	Smooth	Dolphin school 20-30 pieces
4/22/98	8:10	18°-00.0' N	119°-49.0' E	Smooth	payaw, oil drum type and 5 buncus of handline operation
4/22/98	9:15	17°-59.0' N	119°-56.0' E	Smooth	at survey station 8
4/22/98	10:00	19°-58.0' N	120°-00.0' E	Smooth	proceed to station 9
4/22/98	12:00	19°-48.0' N	120°-00.0' E	Smooth	there are many payaw oil dum type
	14:00	17°-27.0' N	120°-00.0' E	Smooth	on the area about one mile interval
4/22/98	15:30	17°-05.0' N	120°-00.0' E	Smooth	area of payaw banboo type
4/25/98	7:00	17°-00.0' N	118°-14.0' E	Smooth	acoustic from. St. 10 to St. 11
4/25/98	11:00	17°-00.0' N	117°-59.0' E	Smooth	Tuna longline gear in the sea at St. 11
4/25/98	13:30	17°-00.0' N	117°-30.0' E	Smooth	TLL gear in the sea, proceed to St. 12
4/25/98	14:00	17°-00.0' N	117°-28.0' E	Smooth	TLL boat and dolphin school 5-10 ps.
4/25/98	15:00	17°-00.0' N	117°-18.0' E	Smooth	3 TLL boats (30-40 GT) on the fishing ground
4/26/98	14:00	17°-03.0' N	117°-03.0' E	Slight	proceed to St. 13
4/26/98	15:30	16°-50.0' N	117°-00.0' E	Slight	school of small fish on surface
4/26/98	17:00	16°-36.0' N	117°-00.0' E	Slight	TLL gear in the sea.
4/28/98	8:00	16°-01.0' N	118°-59.0' E	Slight	from St. 15 proceed to St. 16
4/28/98	9:00	15°-52.0' N	119°-07.0' E	Slight	fish school at 100-250 meters layer
	10:00	15°-45.0' N	119°-14.0' E	Slight	many fish school were observed by acoustic equipment, Furuno FQ-70
4/28/98	11:00	15°-37.0' N	119°-22.0' E	Smooth	payaw area, drumtype, small buncus hanline operation
4/28/98	12:30	15°-25.0' N	119°-37.0' E	-	dolphin and small whale observed
	14:00	15°-14.0' N	119°-45.0' E	-	small boat (buncus) handline and whale school about 10 pieces

Appendix 1/2

Date	Time	Possition		Sea Condition	Observed objects description
		Latitude	Longitude		
	15:00	15°-07.0' N	119°-52.0' E	-	many payaw at 25-30 miles from shore, big school of dolphin 20-30 ps
4/28/98	16:00	15°-00.0' N	120°-00.0' E	-	arived St. 16
4/29/98	14:20	15°-02.0' N	119°-02.0' E	Smooth	acoustic survey from. St. 17 to St. 18
4/29/98	15:00	15°-00.0' N	118°-53.0' E	Smooth	3-4 purse seiners and payaw in the area, large Purse seiner at St. 17
4/29/98	17:30	14°-59.0' N	118°-30.0' E	Smooth	purse seiner on fishing ground
4/30/98	6:00	15°-00.0' N	116°-59.0' E	-	proceed to St. 20
4/30/98	8:25	14°-47.0' N	117°-00.0' E	Slight	school of yellowfin guna medium size 20-30 kilogram jumping observed in far distance 1-1.5 mile
4/30/98	10:15	14°-11.0' N	117°-00.0' E	Slight	school at skipjack small size and many fish school in deeper layer observed by acoustic equipment 250-300 meter deep some school on surface
4/30/98	13:45	14°-00.0' N	117°-09.0' E	Slight	Leave St. 20 t St. 21. Many school were deteched by acoustic survey 50 meters deep., school of dolphin (50ps.)
4/30/98	20:00	14°-01.0' N	117°-59.0' E	Slight	jigging at St. 21 pompano dolphinfish was sampling
5/1/98	14:00	14°-01.0' N	118°-01.0' E	-	acoustic from St. 21 to St. 22
5/1/98	15:00	14°-00.0' N	118°-01.0' E	-	school of dolphin 10-20 pieces
5/1/98	16:35	14°-00.0' N	118°-15.0' E	-	few skipjack feeding on surface
5/4/98	9:50	14°-00.0' N	120°-00.0' E	Slight	scoustic from St. 23 to St. 24
5/4/98	14:35	13°-11.0' N	120°-00.0' E	Smooth	Payaw area, many handline boats. (5-10 buncus) payaw drum type
5/4/98	15:50	13°-00.0' N	119°-59.0' E	Smooth	Oceanographic survey at St. 24 many papaw and handline buncus
5/5/98	8:50	13°-00.0' N	117°-58.0' E	Slight	acoustic from St. 26 to St. 27
	13:30	13°-00.0' N	117°-10.0' E	Slight	flock of bird (20-50ps) fish below surface may fish were ddeteched by FQ-70 at 250-350 meters deep.
5/6/98	14:30	13°-00.0' N	117°-00.0' E	Slight	proceed to St. 28
5/7/98	6:30	12°-00.0' N	118°-00.0' E	Slight	acoustic from St. 29 to St. 30
5/8/98	10:30	11°-13.0' N	118°-20.0' E	Slight	one large purse seiner and payaw

Catch Rate of Oceanic Squid by Jigging Method in the South China Sea Area III: Western Philippines

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ABSTRACT

This paper presents the preliminary result of the exploratory fishing for oceanic squid by automatic jigging method in the South China Sea Area III: western Philippines. This was part of SEAFDEC's collaborative research survey on the fisheries resources of Area III with focus on tuna, oceanic squid and other migratory species. The research vessel M/V SEAFDEC covered 31 predetermined stations for oceanographic and fisheries survey, 10 of which were squid jigging stations. Jigging effort of four automatic jiggers at each station varied from 2-8 hours. The Indo-Pacific squid*, Sthenoteuthis (Symplectoteuthis) oualaniensis* (Lesson, 1830) was the only species caught throughout the fishing area. The total catch for 51.6 fishing hours consisted of 2538 individuals weighing 393.1 kg. The female-dominated catch had individuals with mantle length ranging from 9.8-24 cm and average weight of 155g. Catch-per-unit-effort (CPUE) of automatic jiggers averaged 6 ind/line/hour (968 g/l/h) or 0.4 ind/jig/h (45 g/j/h). High concentration of squid was observed at the northern portion of the survey area. Catch rates were high within 0-100 m jigging depth. *S. oualaniensis* in Area III occurred in two forms: the dwarf, early-maturing form without dorsal photophore (9.8-12 cm mantle length; 43 g average weight) and the middle-sized form with dorsal photophore (12-24 cm ML; 174 g average weight). The middle-sized form dominated the catch representing 86% of the total catch. The dwarf form was less abundant in all catches but occurred throughout the area. The middle-sized and dwarf forms had total weight of 377.5 kg (2175 individuals) and 15.6 kg (363 individuals), respectively. The females were dominant in both forms. The biomass of *S. oualaniensis* standing stock in the SCS Area III was estimated at 283 thousand metric tons.

Keywords: South China Sea*; Sthenoteuthis oualaniensis* (Lesson, 1830); jigging; catch-per-unit-effort (CPUE); biomass; stock density.

Introduction

The squid continuously occupies a leading place among the living resources of the sea that are the target of worldwide exploitation. The depletion of a number of fish stocks, the continued increase in the demand for squid products in domestic and foreign markets, and the valuable use of squids in biomedical research are some of the reasons many nations had focused their attention on the development of the fishery.

In the Philippines, the neritic squids form the basis of the country's cephalopod fishery. Since its advent, fishing for squids and other cephalopods is limited to coastal areas. There is now a felt need to extend fishing operation to new and deeper waters where the potential yield is believed to be large. The oceanic squids remain largely untapped.

The Philippines with its offshore area covering about 88% of its territorial waters offers vast potential for future harvesting of oceanic squid. At least two Ommastrephidae and one Onychoteuthidae species were reported to be present in Philippine waters. Test fishing study using giant squid jig in Calauag Bay (Pacific Ocean) yielded the diamondback flying squid, *Thysanoteuthis rhombus* [Dickson and Ramiscal (1992)].

This study on the oceanic squid resources was a part of SEAFDEC's collaborative research program in one of the most productive fishing areas – the South China Sea, specifically Area III which is the northern portion of the SCS off the west coast of the Philippines. Area III covers a total of 86,400 square miles from latitude 11°N to 20°N and longitude 11°E to 121°E, 95% of the area being deeper than 1,000 m. The research vessel M/V SEAFDEC covered 31 predetermined stations for the oceanographic survey and fishing activities from 15 April to 12 May 1998 to collect baseline information on the fisheries resources of SCS Area III with focus on tuna, oceanic squid and other migratory species (Fig.1). The objective of this particular study was to determine the species composition and estimate the abundance of oceanic squid in this area based on automatic jig catches.

Materials and Methods

Materials were collected from the 10 designated squid jigging stations, which represented the entire survey area. The jigging stations were located at latitude 11°59.8'N to 20°2.3'N (80 mi off the coast of Malampaya, NW Palawan to 95 mi off Batanes coast) longitude 117°4.77'E to 119°9'E (210 mi off the coast of La Union, Northern Luzon to 55 mi off the coast of Calamianes Islands, Northern Palawan). Water depths range from 1,260 to 4,657 m.

At each station, squids were fished using four automatic jigging machines. Each machine was equipped with two nylon monofilament lines, each line having a sinker and 18-30 jigs spaced at 1.0m interval (Fig. 2). The machines were set up at the portside of the research vessel illuminated by 40 (500W) light bulbs. Jigging was done at depths of 50 to 170 m. Jigging effort at each station varied from 2 to 8 hours.

The catch of *S. oulaniensis* at each jigging station was monitored and recorded to determine the average stock density expressed in kg/m^3 and come up with an estimate of the biomass of squid and potential yields in the survey area. The distribution of the species in terms of the catch-per-unit-effort (CPUE) is presented as follows: number of individuals and weight in gram per line per hour (i.e., ind/l/h and g/l/h) and number of individuals per jig per hour (i.e., ind/j/h and g/j/h). All squid catches were identified to species level [Roper et al. (1984)] and the following biological measurements were obtained: individual size (dorsal mantle length in cm), weight(g), sex and maturity stage (when evident).

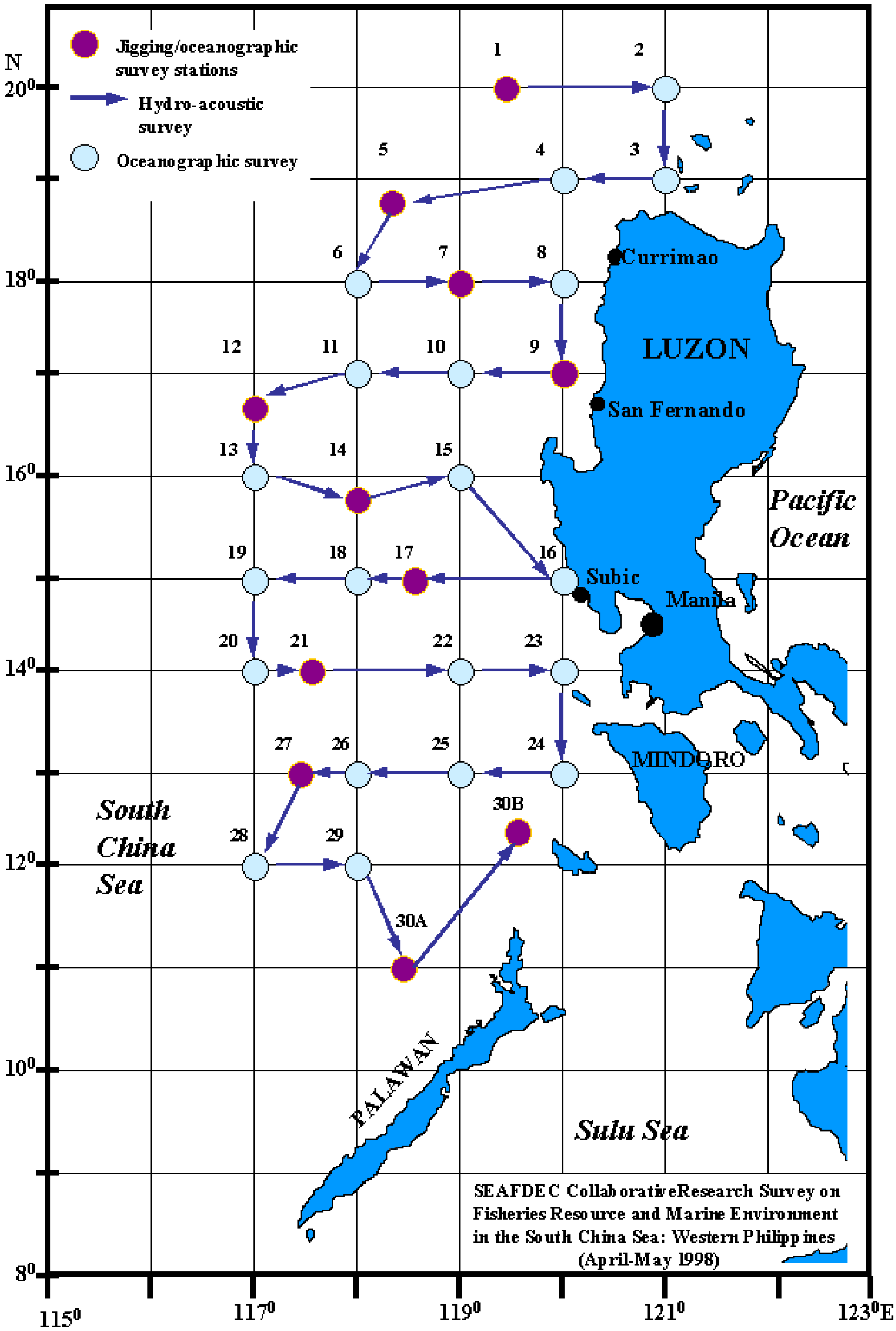


Fig. 1. Stations for oceanographic survey and fishing activities in the SCS Area III: Western Philippines.

Fig. 2. The automatic jigging machine used in squid fishing operations in the SCS Area III.

A **B**

Fig.3. Dwarf *Sthenoteuthis oualaniensis* collected by automatic jiggers in the SCS Area III. A) 9.8 cm ML B) 11.4 cm ML.

Fig. 4. Middle-sized *S. oualaniensis*, 18-24 cm ML.

Table 1. Catch rates of *S. oualaniensis* by automatic jiggers in the SCS Area III.

STATION NO.	1	5	7	12	14	17	21	27	30A	30B	T/AVE.
No. of lines	8	8	8	8	8	8	8	8	8	6	**78**
No. of jigs	240	128	154	178	176	176	176	182	153	132	**1695**
Total fishing hours	4.9	2.5	4.5	5.4	3.8	5	5.2	6.6	5.7	8	**51.6**
ALL SIZES:											
Total catch (no. of ind.)	116	26	422	739	141	130	267	138	159	400	**2538**
Total catch (g)	25900	4900	71500	100300	2300	23500	39600	16500	25700	62200	**393100**
ind/fishing hour	24	10	94	137	37	26	51	21	28	50	**48**
g/fishing hour	5286	1960	15888	18574	6052	4700	7616	2500	4508	7775	**7486**
ind/l/h	3	1	12	17	5	3	6	3	3	8	**6**
g/l/h	661	245	1986	2322	757	587	952	313	564	1296	**968.3**
ind/j/h	0.1	0.1	1	1	0.2	0.2	0.3	0.1	0.2	0.4	**0.4**
g/j/h	22	15	103	104	34	27	43	14	30	59	**45.1**
DWARF FORM: (9-12 cm ML)											
Total catch (ind.)	3	2	30	111	35	20	54	43	21	44	**363**
Total catch (g)	126	85	1291	4774	1503	860	2321	1848	899	1888	**15595**
ind/fishing hour	0.6	0.8	7	21	9	4	10	7	4	6	**7**
g/fishing hour	26	34	287	884	396	172	446	280	158	236	**291.9**
ind/l/h	0.05	0.1	1	3	1	0.5	1	1	0.5	1	**1**
g/l/h	3	4	36	111	49	21	56	35	20	39	**37.4**
ind/j/h	0.002	0.01	0.04	0.1	0.05	0.02	0.1	0.04	0.02	0.04	**0.04**
g/j/h	0.1	0.3	2	5	2	1	3	1	1	2	**1.7**
MIDDLE-SIZED FORM (12-24 cm ML)											
Total catch (ind.)	113	24	392	628	106	110	213	95	138	356	**2175**
Total catch (g)	25774	4815	70209	95526	21497	22640	37279	14652	24801	60312	**377505**
ind/fishing hour	23	10	87	116	28	22	41	14	24	44	**41**
g/fishing hour	5260	1926	15603	17690	5657	4528	7169	2220	4351	7539	**7194**
ind/l/h	3	1	11	14	3	3	5	2	3	7	**5**
g/l/h	657	241	1951	2211	707	566	896	277	544	1257	**930.7**
ind/j/h	0.1	0.1	1	1	0.2	0.1	0.2	0.1	0.2	0.3	**0.3**
g/j/h	22	15	101	99	32	26	41	12	29	57	**43.4**

Legend: ind – number of individuals; jm – jigging machine; h – hour; l – line; g – gram; j – jig

Results and Discussion

The ommastrephid *Sthenoteuthis oualaniensis* (Lesson, 1930) was the only species caught at the 10 designated squid jigging stations in the SCS Area III. This species is distributed throughout the equatorial, tropical and subtropical waters of the Indo-Pacific Region [Roper, et al. (1984); Piatkowski and Welsch (1991); Nesis (1993); Yatsu, et al. (1998)] which makes the target species for commercial fishery. Its biomass in the Region has been estimated at 8 to 11 million metric tons [Young and Hirota (1998)].

Nesis (1993) reviewed the worldwide population structure of *S. oualaniensis* indicating that this species has the most complicated population structure having three main forms: the dwarf (modal mantle length 9 to 12 cm) early-maturing individuals without the light organ (photophore) on the dorsal mantle; the middle-sized (modal ML 12 to 25 cm) most common and widespread form with dorsal photophore; and the giant (modal ML 30 to 40 cm) late-maturing form with dorsal photophore. In Area III, *S. oualaniensis* apparently occurs in two forms: the dwarf without dorsal photophore (Fig. 3) and the dominant middle-sized form with dorsal photophore (Fig. 4).

Abundance of *S. oualaniensis* based on catch-per-unit-effort.

Catch rates and catch-per-unit-effort (CPUE) of automatic jiggers are summarized in Table 1. Graphical presentations of these data are shown in Figures 5-7. The total catch obtained for 51.6 hours of fishing consisted of 2538 predominantly female *S. oualaniensis* weighing 393.1 kg (35 - 690 g) or an average weight of 155 g/ind. Mantle lengths were within the 9.8 to 24 cm limit. The catch rates ranged from 1 - 17 ind/l/h (245 g - 2.3 kg) and 0.1 - 1 ind/j/h (14 - 104 g) or an average CPUE of 6 ind/l/h (968 g) and 0.4 ind/j/h (45 g) (Fig. 5). The catch rates at the jigging stations indicated a proportion of 1 dwarf to 5 middle-sized form.

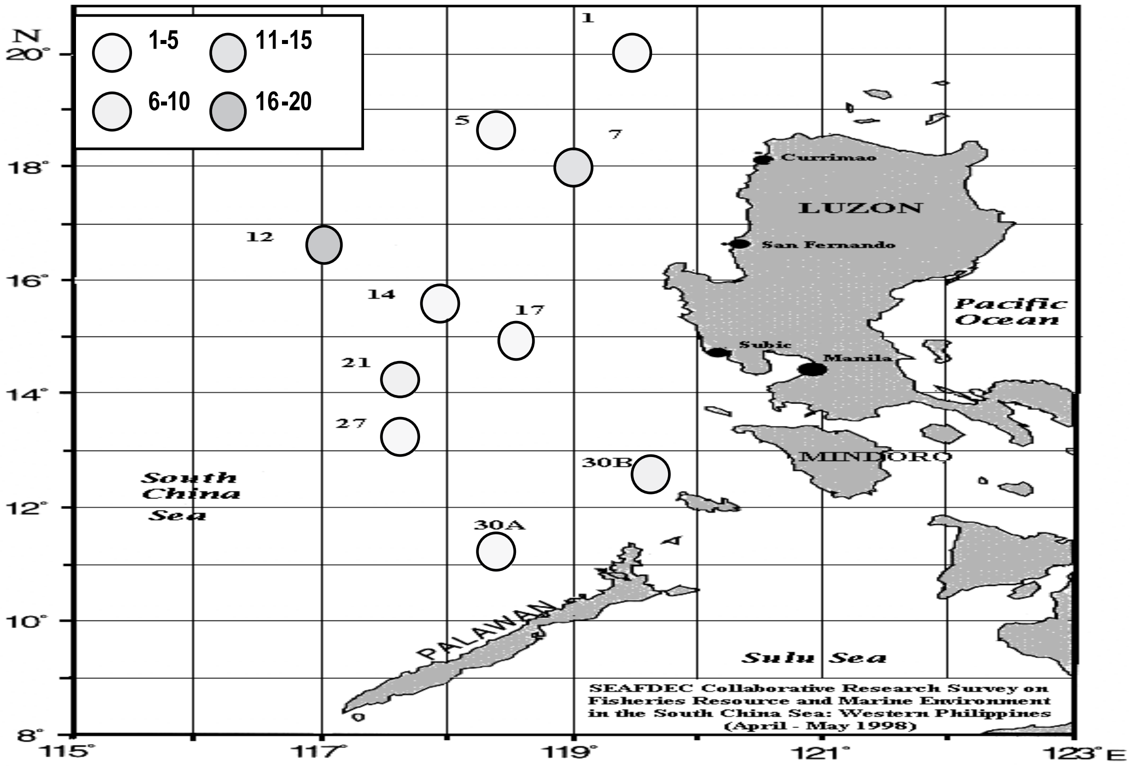
S. oualaniensis occurred throughout Area III but higher concentration was observed at the northern portion off the coasts of Northern Luzon Provinces from lat. 16°59.64'N to 20°2.3'N and long. 117°4.77'E to 119°56.7'E. The highest CPUE of 17 ind/l/h (2.3 kg) was obtained at 16°59.64'N 117°4.77'E (St. 12) off the coast of San Fernando, La Union. Another significant catch of 12 ind/l/h (1.99 kg) was obtained at 18°0.4'N 119°0.28'E (St. 7) off the coast of Currimao, Ilocos Norte.

At the central and southern portions of the survey area, CPUEs were high at 14°0.5'N 117°59.9'E (St. 21) about 155 mi off Batangas Coast and at 12°47.6'N 119°9'E (St. 30B) approximately 55 mi off the coast of Calamianes Islands, Northern Palawan with 6 ind/l/h (952 g) and 8 ind/l/h (1.3 kg), respectively.

The middle-sized form.

A total of 2175 middle-sized *S. oualaniensis* weighing 377.6 kg were caught at the jigging stations. Mantle length of individuals ranged from 12 - 24 cm and average weight of 174 g (50 - 690 g). The dominance of the middle-sized squid, representing 86% of the total catch is another proof that this form is the most common and widespread. The catch rates were 1 to 14 ind/l/h (241g – 2.2 kg) or 0.1 to 1 ind/j/h (12 – 100 g) and average CPUE of 5 ind/l/h (931 g) or 0.3 ind/j/h (43.4 g). It was notably high at St. 12 (14 ind/l/h) and St. 7 (11 ind/l/h) as shown in Fig. 6. The

A



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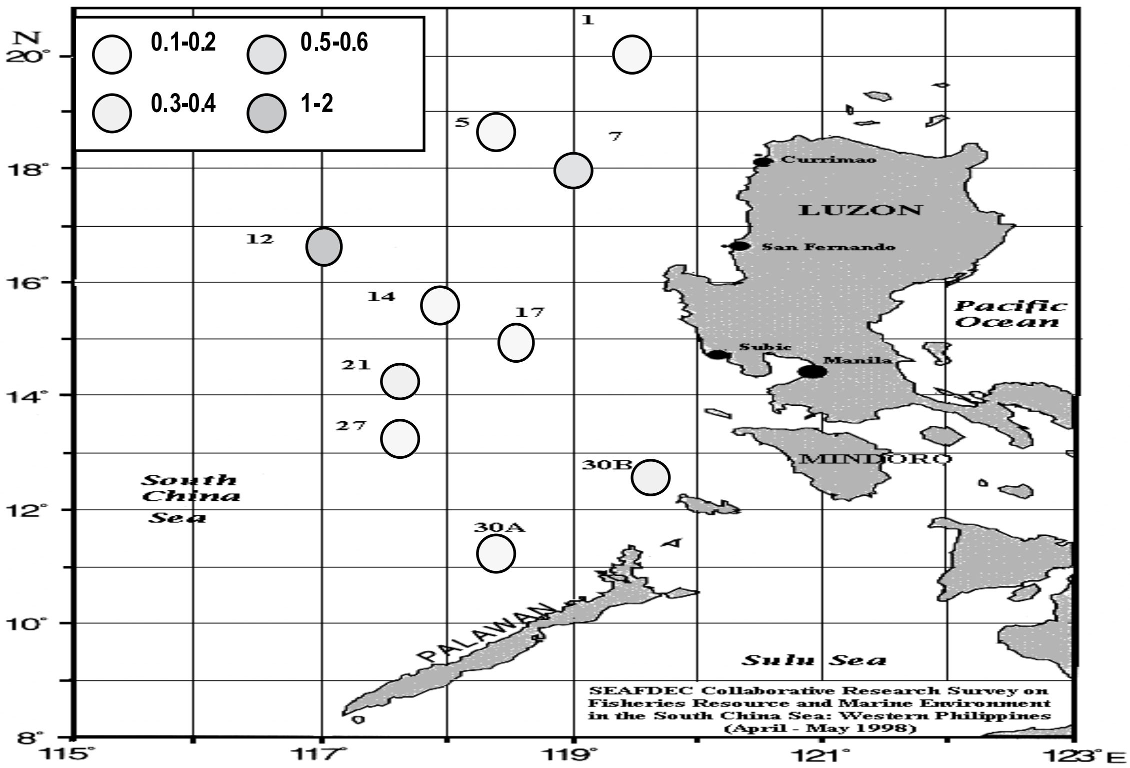

Fig.5. Catch-per-unit-effort (CPUE) of automatic jiggers for *S. oualaniensis*: A) ind/fishing hour, B) ind/jm/h.

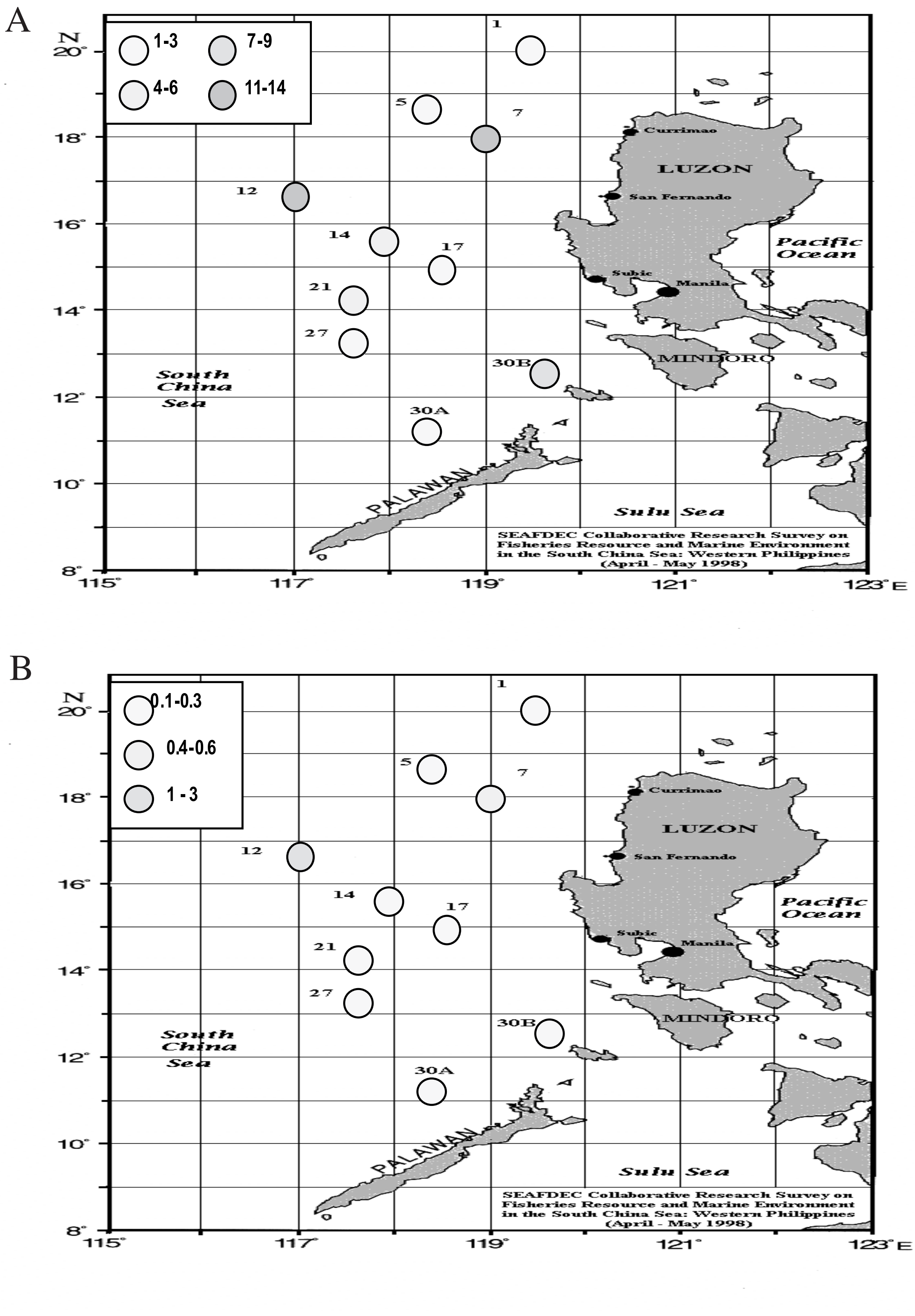

Fig. 6. CPUE of automatic jiggers for *S. oualaniensis*: A) ind/l/h , B) ind/j/h.

females dominated the males at about 1:5 ratio.

The dwarf form.

The dwarf *S. oualaniensis* (9.8-12 cm ML; 35-100 g), although less abundant, were caught throughout the survey area representing 14% of the total catch. The 363 dwarf individuals weighed 15.6 kg or an average of 43 g/ind. Like the middle-sized form, the females were abundant accounting for 70% of the total catch. Catch rates at the stations ranged from 0.05 to 3 ind/l/h (3 – 111 g) or 0.002 to 0.1 ind/j/h (0.1 – 5 g) and average CPUE of 1 ind/l/h (37.4 g) or 0.04 ind/j/h (1.7 g). St. 12 was also the jigging station with the highest CPUE for the dwarf form (Fig. 7).

The catches showed high concentration of *S. oualaniensis* within the 80 to 130 m jigging depths and highest at 100 m where 51% of the total catch was obtained. This observation supports the findings of earlier studies on the diurnal vertical movements of the species. Nesis (1993) indicated that *S. oualaniensis* ascends to the surface at night and some of them remain dispersed in the 0 to 100 m layer. During daytime, the dwarf form descends not deeper than 150 to 200 m while the middle-sized form would probably occupy the depths of 200 to 400 m, most of them at 350 to 400 m. Roper and Young (1975) reported that the species appeared to be some 120 to 200 m deep in the daytime but move up to the surface and near surface layers at night.

Stock density of *S. oualaniensis*.

During the entire squid fishing survey, M/V SEAFDEC covered a total drifting area of 601,678 m^2 and maximum jigging depth of 150 m (Table 2). Squid catches were obtained within water volume ranging from 2.713 x 10^6 to 1.934 x 10^7 cubic meter or an average of 8.96 x 10^6 cubic meter. Figure 8 shows the stock density at each jigging station, which averaged to 7.16 x 10^{-6} kg/m^3 or 7,160 kg/km^3. The highest densities were obtained at St. 7 with 2.64 kg x 10^{-5} (26,357 kg/km^3), St. 12 with 1.04 x 10^{-5} (10,390 kg/km^3) and St. 30B with 9.56 x 10^{-6} (9,564 kg/km^3).

If the SCS Area III covers a total area of 86,400 square nautical miles, approximately 44,000 km^3 can be assumed as fishing area for the purpleback flying squid *Sthenoteuthis oualaniensis*. By extrapolating the average stock density at the jigging stations and considering the mean weight of 0.155 kg, the biomass of squid in the SCS Area III is estimated at 319 thousand metric tons or 2.1 billion individuals within 0 to 150 m jigging depth. With this estimate, we can further assume a yield of 1.1 MT/km^2 or about 7,000 ind/km^2 from the survey area.

This study provides a glimpse into the population structure of the purpleback flying squid *Sthenoteuthis oualaniensis* (Lesson, 1830) in the South China Sea: west coast of the Philippines and its abundance based on the automatic jig catches. The findings, although preliminary, indicated the potential of *S. oualaniensis* for commercial fisheries. These data shall be correlated with the biological and ecological aspects of the species, which shall be discussed in detail in separate papers as part of the collaborative research survey. There is a need for more surveys to further understand the population dynamics and status of the species in this area for the sustainable utilization and management of this valuable resource.

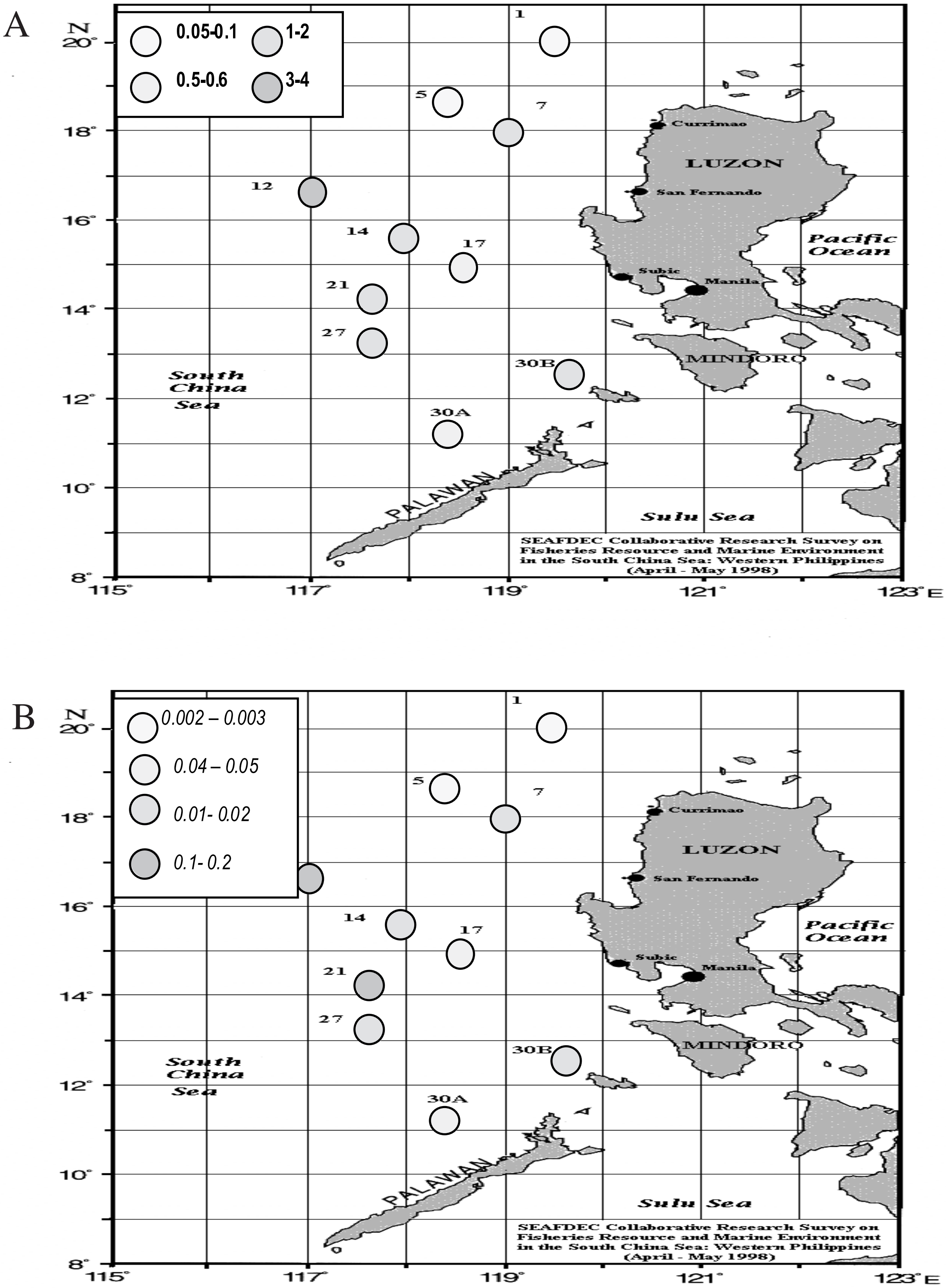

Fig. 7. CPUE for dwarf *S. oualaniensis*: A) ind/fishing hour B) ind/jm/h.

Table 2. Estimated density of *S. oualaniensis* at the jigging stations.

STATIONS	1	5	7	12	14	17	21	27	30B	Ave.
Distance drifted (m)	1343.1	7437	1043.4	4828.5	4861.8	3041.4	4084.4	1276.5	2890.4	
Length of jiggers (m)	20	20	20	20	20	20	20	20	15	
Max. jigging depth (m)	150	130	130	100	130	150	150	170	150	
Total weight (kg)	25.9	4.9	71.5	100.3	23	23.5	39.6	16.5	62.2	
Volume (V) = m^3	4.03×10^6	1.934×10^7	2.713×10^6	9.7×10^6	1.2641×10^7	9.124×10^6	1.225×10^7	4.3401×10^6	6.5034×10^6	
Density (J) = kg/m^3	6.43×10^{-6}	2.53×10^{-7}	2.64×10^{-5}	1.04×10^{-5}	1.82×10^{-6}	2.58×10^{-6}	3.23×10^{-6}	3.8×10^{-6}	9.56×10^{-6}	7.16×10^{-6}
= kg/km^3	6,433	253.4	26,357	10,390	1,819	2,576	3,232	3,802	9,564	7,160

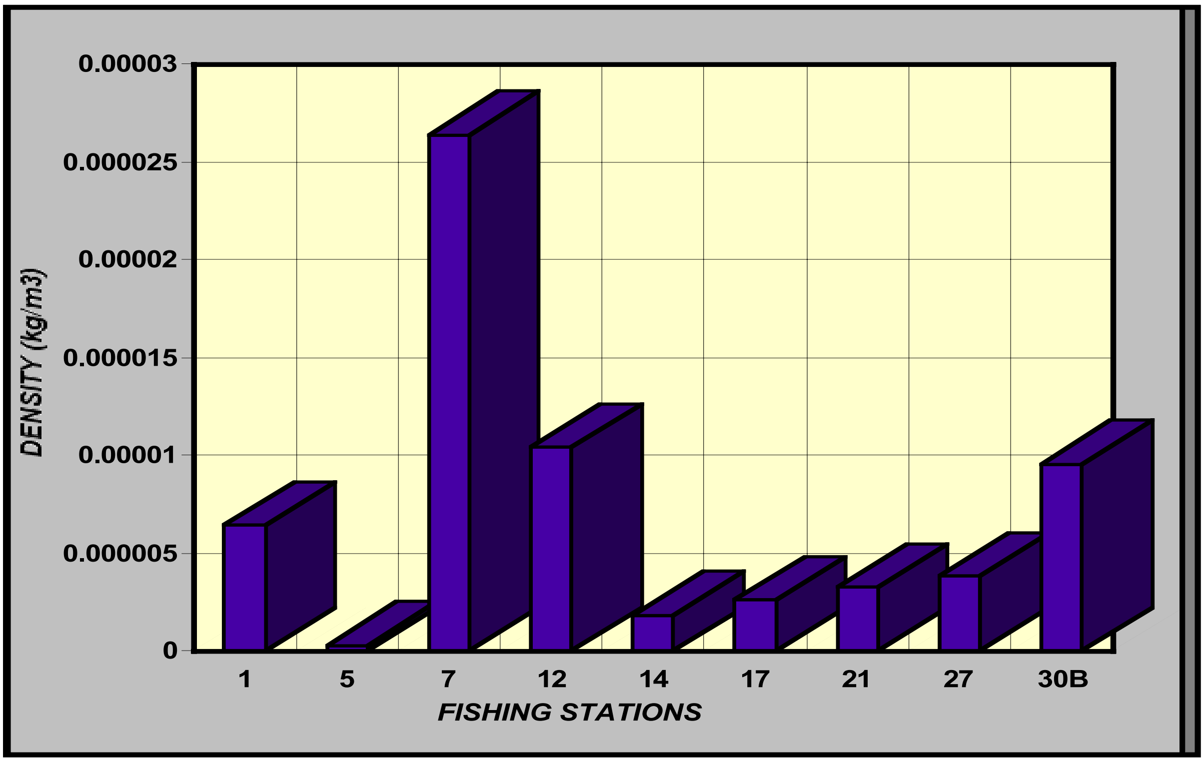

Fig. 8. Estimated stock density of *S. oualaniensis* at the jigging stations

Acknowledgement

I thank the officers and crew of M/V SEAFDEC, our Technical Coordinator – Mr. Cielito L. Gonzales and my fellow researchers for their cooperation to make this cruise a success. I am grateful to the following cephalopod scientists: R. Young (Univ. of Hawaii), K. Nesis (Russian

Academy of Sciences) and W. Piatkowski (Univ. of Kiel) for their support by providing me their valuable publications. My special thanks to my colleague – Ms. Rosarie G. Arreza for assisting in the organization of raw data, my peer reviewer – Mr. Gerry Silvestre for his valuable comments and suggestions, our Division Chief – Mr. Jose A. Ordonez for giving me the opportunity to participate in this endeavor, and to my Section Chief and mentor – Ms. Corazon M. del Mundo for cultivating my interest to work on cephalopods.

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Diamondback Squid (*Tysanoteuthis rhombus*) Exploration in the South China Sea, Area III: Western Philippines

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ABSTRACT

The diamondback squid (*Tysanoteuthis rhombus*) is a potential resource popularized mainly for the export market in the Central Philippines and the positive results from other experimental activities. Exploratory fishing for the species using the giant squid jig was conducted on board MV SEAFDEC and MV Maya-Maya in the South China Sea (Western Philippines) to determine its occurrence, abundance and distribution in these areas.

The gear employed is basically used in small boats hence, its operation on bigger vessels was very difficult. The result was discouraging with only one diamondback squid caught out of the 175 jigs set. The description and fishing operations of the gear are presented with comparison from other research and fishing results conducted in Camotes Sea, Calauag Bay, and Ormoc Bay which are considered potential areas.

Keywords: *Tysanoteuthis rhombus*, diamond-back squid, South China Sea, Exploratory survey.

Introduction

There are four (4) genera and seven (7) species of the squid species in the country with the *Loligo edulis, Loligo duvaucelli and Sepioteuthis lessoniana* considered the most common. Informations on effort, catch and biology of these species are cursory and often unavailable. Voss (1963) wrote the first extensive report on the taxonomy of Philippine cephalopods. Flores (1974) surveyed the traditional fishing grounds and identified some fishing gears. Hernando and Flores (1981) also described the different squid fishing gears used in the country and contributed information in terms of species identification, fishing seasons, and production.

Squid is considered as one of the few resources capable of increasing production (Chikuni, 1983). It is also suggested that other methods of squid fishing is not well developed. Dickson (1991) described the traditional giant squid jig gear and its construction being operated by fishermen in Camotes Sea in Central Visayas. Jigging is done during daytime from early morning to afternoon at depths from 364m to 455 m. Except for bad weather, fishing can be done the whole year round with peak months from May to August. The country produced 54,458 mt. of squid from the municipal and commercial fisheries sectors of which 24.6% were exported (BFAR, 1996).

Among the squid species, the diamond back squid (*Tysanotheuthis rhombus*) is the most uncommon and is a latent resource. Usually caught in pairs, this squid is caught for the export market in the Camotes Sea in the central Philippines. Fishing effort, production and other basic information are however, unavailable. With the exception of this existing fishery, this species and its harvest is virtually unknown in other parts of the country. Exploration of other fishing grounds was only given attention after the 1990 Most Outstanding Fishermen of the Year was awarded to a fisherman whose catch was mainly the diamondback squid. Records gathered from Escario (1990) from 1989 to 1990 showed that he was able to catch 384 pieces or 20 pcs, per month of the ***Tysanoteuthis rhombus*** in Camotes Sea.

Exploratory activities from 1991 to 1992 in a very limited area of Calauag Bay, Quezon Province yielded a total catch of 82 individuals (412 kgs) of this species or a mean catch-per-unit-effort (CPUE) of 4.84 individuals per 100 jigs or 0.018 kgs/jig/hour fishing. A total of 92 fishing days were completed using 1,650 jigs set. The occurrence of the species was obviously very seasonal from June to October with the highest CPUEs in August to September. The fishing area has an average depth of 145 m.

‘ Test fishing operation and monitoring of giant squid jig were conducted in Ormoc Bay, Leyte Province from March to December 1993 (Dickson, 1994). A total of 950 jigs were set at fishing depths of 182m, 209m and 237 m. The fishing operations yielded 159 kilograms (34 pieces) of *Tysanoteuthis rhombus*. The 237 m depth produced the highest number of catch (28 pieces). The weights ranged from 1.4 to 8.75 kg. each while the mantle length is from 362 to 669 mm. The catch per unit effort was 0.0051 kg/jig/hr or 3.41 pcs. per 100 jigs. Highest CPUEs was observed in August and September.

In Japan, the diamond back squid is caught by jigs and trapnet using 5 tonner boats. Known locally as “sode ika” its fishery only began in 1962 and became a new directed fishery with improvements on its commercial and fishing method. About 200 5-tonner boats are engaged in the operation and the average catch is 6-9 squid per boat during peak season. (Osako and Murata, 1983). The lack of information on its behaviour, migration and cause of quantitative variation are also recognized.

It is believed that diamondback squid is widely distributed and can be caught in the open seas. Exploratory fishing for the diamondback squid was undertaken during the recent SEAFDEC-BFAR Collaborative Research Survey on Fishery Resource and Marine Environment in the South China Sea: Western Philippines from April to May, 1998 to determine availability of the species in the area.

Materials and Methods

Fishing was carried out in sixteen (16) fishing stations (Fig. 1) using the giant squid jig. A unit of the gear is composed of a jig, monofilament line and a styropor bouy (Fig. 2). The line is fixed and coiled on the buoy and the jig is attached on the other end of the line. During setting, the jig is usually baited with milkfish. The weight of the baited jig automatically rolls the buoy and uncoils the line at a desired length. The gear is left to drift individually usually from early morning to mid-noon. Hauling requires manual coiling of the line into the buoy.

The operation of the gear was modified to suit for operation on board the 1,190 GT MV SEAFDEC and the 165 GT MV Maya-Maya.

MV SEAFDEC

Several setting techniques of the jigs were tried in Stations 1, 5, 7, 12, 14, 17, 21, 27, 30 and 31A. Using two (2) electric haulers located at the fore and aft port side of the vessel, the jigs were set at five (5) different depths from a line fixed at the haulers. A mainline of the tuna longline was also tried to set the jigs in a horizontal/longline manner necessitating positioning at the port side where haulers are located on the windward side. Setting on one end of the tuna longline was also tried. To coordinate with other activities of the research cruise, the shooting of the giant squid jig were done only after the tuna longline have been set and hauling was done before the hauling of the tuna longline. Fishing was done between 5 am to 12 nn with immersion time varying from 1.5 to 6.7 hours depending on the operation of the tuna longline.

MV MAYA-MAYA

A mainline was provided to form a long line of jigs and was connected at one end of the tuna longline during operation. The jigs were set at five (5) different depths. The duration of fishing ranged from 5 to 7.7 hours. The jigs operation was conducted in Stations 8, 9, 16, 17, 23 and 25.

In all of the operations, milkfish was used as bait following the baiting position as described in Figure 2.

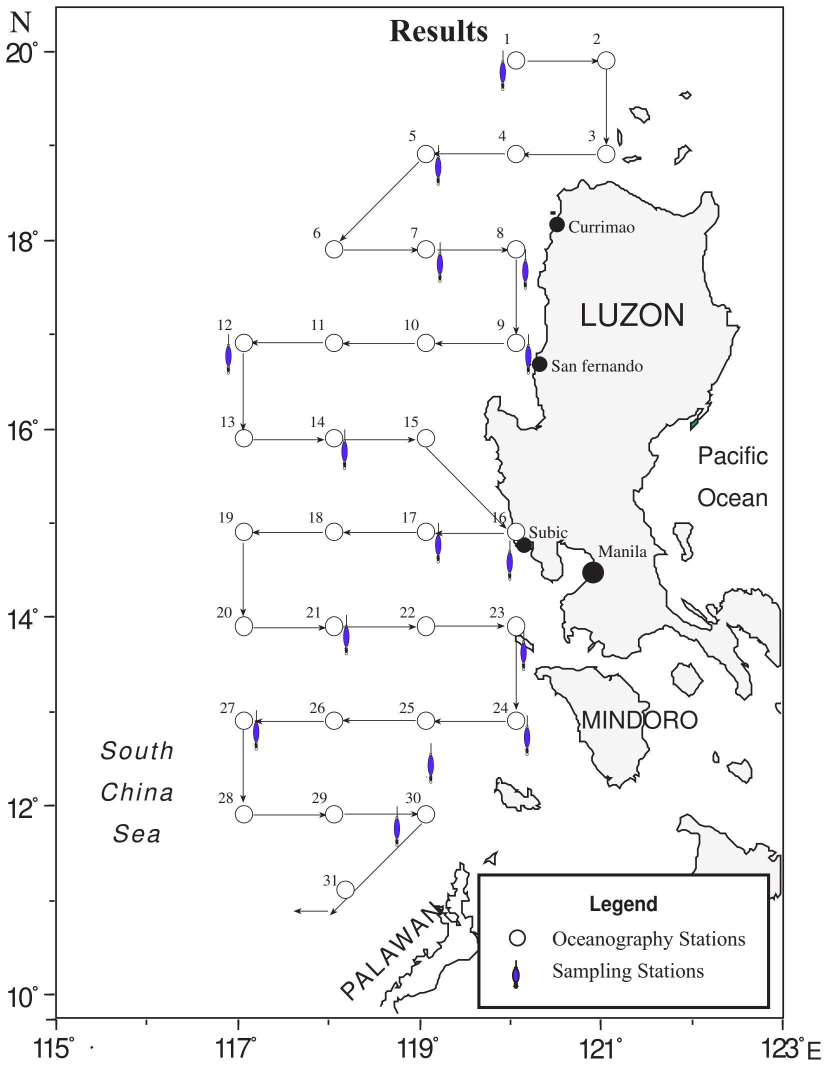

Fig. 1. Survey stations in the West Coast of Philippines

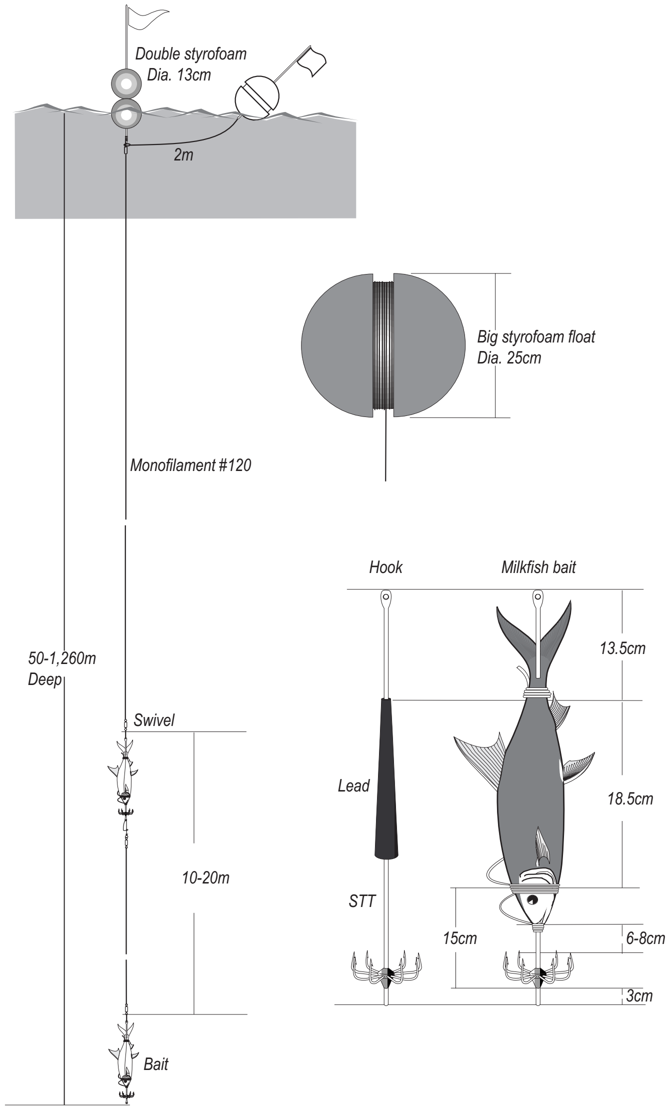

Fig. 2. Specification of the giant squid jig and its operation.

Results

The giant squid jig operations of both research vessels are summarized in Table 1. Fishing was tried using eight different lengths of line with emphasis on depths of 360m and 720 m. The deeper line was also recommended by Prof. Yoshihiko Nakamura, the Japanese consultant onboard MV SEAFDEC. Out of the 175 jigs set, 83 jigs or 47.4% were set at 360 m while 54 jigs or 30.8% were set at 720 m. The deepest set was at 1,260m.

The exploratory fishing indicated discouraging results with only one diamondback squid caught at a depth of 720m. The squid measures 54 cm mantle length and weighed 5.75 kgs. The other catch of MV MAYA-MAYA was 3 Pacific lancet fish. MV SEAFDEC operations yielded negative result. The temperature profile of the jigs stations is shown in Table 2. It appears that the range of the temperature was 30˚C to 6˚C from surface to a depth of 750 m.

The operation of the gear on board MV SEAFDEC was not easy with the single line attached to the haulers causing some troubles. Attempts to set the jigs in a longline position on the port side while the vessel was drifting and joining at one end of the tuna longline caused

Table 1: Giant Squid Jig Operations of M/V SEAFDEC and M/V Maya-Maya in South China Sea: Western Philippines,

Vessel	Stn.	Soaking Time (H)	Length of line (m)									Jig Hours	Catch
			150	180	360	540	720	900	1080	1260	Total		
SEAFDEC	*1*	*1.50*			*5*						*5*	*7.5*	*None*
	5	*2.27*			*6*						*6*	*13.6*	*None*
	7	*4.27*			*8*						*8*	*34.1*	*None*
	12	*4.55*	*1*		*2*	*2*	*2*	*2*			*9*	*41.0*	*None*
	14	*1.97*	*1*			*2*	*4*	*2*			*9*	*17.7*	*None*
	17	*1.97*	*2*			*2*	*4*	*2*			*10*	*19.7*	*None*
	21	*3.53*	*2*			*2*	*2*	*2*			*8*	*28.3*	*None*
	27	*5.10*	*2*		*2*	*2*	*2*	*2*			*10*	*51.0*	*None*
	31-A	*6.72*			*11*						*11*	*73.9*	*None*
	30-A	*4.67*			*9*						*9*	*42.0*	*None*
Subtotal		**36.53**	**8**	**0**	**43**	**10**	**14**	**10**	**0**	**0**	**85**	**328.7**	
MAYA-MAYA	*8*	*7.75*			*15*						*15*	*116.3*	*None*
	9	*6*			*15*						*15*	*90.0*	*2 lancetfish*
	16	*6.75*			*1*		*14*				*15*	*101.3*	*None*
	17	*6.92*		*1*	*5*		*2*		*3*	*4*	*15*	*103.8*	*1 lancetfish*
	23	*5.17*			*3*		*12*				*15*	*77.5*	*None*
	25	*6.67*		*2*	*1*		*12*				*15*	*100.0*	*1 gsquid (5.75 kg)*
Subtotal		*39.25*	*0*	*3*	*40*	*0*	*40*	*0*	*3*	*4*	*90*	*588.8*	
GRAND TOTAL		**75.78**	**8**	**3**	**83**	**10**	**54**	**10**	**3**	**4**	**175**	**917.5**	

entangled lines and trouble during operation. By using the skiff boat, the operation on MV Maya-Maya was easier joining the line at the end of the longline although manual coiling of very long lines was tedious.

Discussions

The effective capture of the diamondback squid is dependent on the determination of the appropriate jig line level, which corresponds, to an optimum condition where the species is likely to occur. It is usually distributed in the major currents like the Kuroshio and Tsushima Warm Current off Japan and good catches occurred in years when water temperature at 100m depth exceeds 17˚C and poor catches occurred during years when it was below 17˚C (Osako and Murata, 1983).

In the inland seas in the central Philippines, this species is caught by small bancas using similar jigs used in this survey at a depth of 150-300m deep. In a survey in Calauag Bay, a relatively shallow bay facing the Pacific Ocean, the squid was caught at about 70m-150m deep with temperatures ranging from 21˚C to 24˚C. The species was only caught in the months of June to October or just after summer. Good catches also coincided with the presence of lights being used by other gears in the bay (Dickson, *et. al*, 1993).

Table 2. Temperature profile on the Giant Squid Jig Stations.

Fishing Station	*Temperature (oC)*									
	Surface	*100m*	*150m*	*200m*	*300m*	*450m*	*600m*	*750m*	*900m*	*1200m*
1	*28*	*23*	*17*	*16*	*12*	*8*	*7*	*6*	*4*	*3*
5	*28*	*18*	*15*	*13*	*11*	*9*	*7*	*6*	*5*	*3*
7	*28*	*18*	*15*	*13*	*11*	*8*	*7*	*6*		
12	*30*	*19*	*17*	*14*	*12*	*9*	*7*	*6*	*4*	*3*
14	*30*	*23*	*17*	*15*	*12*	*8*	*7*	*6*	*5*	*3*
17	*30*	*22*	*17*	*15*	*12*	*8*	*7*	*6*	*5*	*3*
21	*31*	*21*	*16*	*14*	*12*	*9*	*7*	*6*	*5*	*3*
27	*31*	*21*	*166*	*14*	*12*	*8*	*7*	*6*	*4*	
30	*31*	*19*	*16*	*14*	*11*	*8*				
31	*30*	*24*	*17*	*15*	*12*	*9*				
No. of jigs set			*8*	*3*	*83*	*10*	*54*	*10*	*3*	*4*

Basing on ICTD data, the fishing depth temperature ranged from 4˚C to 24˚C. The temperature at 100m was about 18˚C to 24˚C. The only squid during this survey was caught using a 720 m line.

The previous surveys manifest its wide distribution over varying depths with migration and abundance largely due to changes in conditions like temperature, which may have caused the occurrence of the species in the deeper areas during this survey.

The stock size however appear to be scattered that fishing can only be practicable in nearshore areas and with the use of small boats. In addition, the operation of the squid jig was observed to be difficult in relatively large vessel like the MV SEAFDEC and MV MAYA-MAYA. This includes difficulties in maneuvering and in handling small but very long lines and may be only feasible in areas around the country with known squid concentration. The survey provided a very little information on the diamondback squid and further experiments should be recommended in other fishing areas to determine their occurrence and distribution as well as biological parameters in relation to oceanographic conditions.

Acknowledgment

The authors wish to thank Mr. Sakya Pradit, crew of the MV SEAFDEC for his assistance during the squid jig operations. We thank also Ms. Erlinda B. Clavo, Ms. Luthgarda V. Sebastian and Mr. Alberto Santiago III for the typing of the report and preparation of the illustrations. We are also grateful for the assistance of Director Dennis B. Araullo, Atty. Reuben A. Ganaden, Mr. Jose A. Ordonez and Ms. Alma C. Dickson for their encouragement and support on the inclusion of the project to the Joint SEAFDEC-BFAR Exploratory Survey in the South China Sea.

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Tuna Resource Exploration with Longline in the South China Sea, Area III: Western Phillipines

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ABSTRACT

An exploratory tuna longline fishing survey was conducted using the research and training vessels of the Southeast Asian Fisheries Development Center, the 1,178 GT MV SEAFDEC and the Bureau of Fisheries and Aquatic Resources, the 165 GT MV MAYA-MAYA in the South China Sea Waters, West of the Philippines from April to May, 1998. A total of 3,796 hooks was set in sixteen (16) fishing stations. There were no tuna caught during the entire survey but only minor and irrelevant species like the Pacific lancetfish, sharks and an opah species, *Lampris guttatus*. The important fishing and oceanographic factors during the survey and other research results on longline are described and analyzed. Additional longline studies within and near the Philippines territorial waters are also presented to substantiate the research results of the joint SEAFDEC/BFAR resource exploratory.

Keywords: tuna longline, tuna survey, South China Sea, Western Philippines.

Introduction

The waters around the Philippines is known to be migratory paths and rich fishing grounds for tunas, traditionally for longline fishing as observed in the reports of foreign vessels poaching in the South China Sea area. The Filipino fishermen, using simple and small scale gears like handline, troll line and gillnets have long been exploiting these species since time immemorial . However, it is only in the 70s that the country's fish production dramatically increased mainly due to the introduction and development of technology to catch tuna notably the introduction of commercial purse seine and ring nets. The payaw, found to be very effective in aggregating the tuna, was readily adopted in commercial fishing and enhanced the increased landings of tuna. Payaw has also been extensively used by small scale fishermen mainly to catch large yellowfin and bigeye tuna using handlines. It has significantly contributed, however, to the increased landings of small size tuna and poses a great impact on the tuna resource.

Long before the introduction of the purse seine and ring net for tuna, efforts have been made to develop tuna industry by using the tuna longline fishery (Martin, 1938; Tapiador, 1951; Fernandez, 1951) but it did not materialize to become a major contributor to the country's tuna production. Marquez (1976) studied the three types of baiting positions for tuna longline fishing and found out that horizontal baiting type showed a higher catch, significantly higher bait loss and lower bait recovery compared to vertical and upside down baiting.

The opening of the export market for the high-priced sashimi and the favorable policy in joint ventures in the late 70s to early 80s again enticed private companies to engage in tuna longline with about 25 tuna longliners in 1982. The joint ventures were not able to sustain operations because of the unstable export market and probably hardships in long operations (Tiongson, 1983).

As of 1997, there are 16 registered tuna longliners in the fishing grounds of Northeastern and Northwestern Luzon waters, the Celebes Sea area and eastern Mindanao. Production and other statistics are however, not being reported. It is admitted that the present sashimi grade market is largely being supplied by medium scale outriggered boats using handlines in the Celebes Sea.

Meanwhile, foreign fishing boats, notably longliners, are allegedly poaching inside the country's territory in the South China Sea and the Pacific Ocean. In fact, the main fishing grounds for the Taiwan fishery are close to both sides of the Philippine archipelago with most fishing done in the western side from January to April and in the eastern side from April to June (Sun and Yang, 1983 cited in Wang, 1991).

Thus, with this situation, longline fishing exploration was conducted during the collaborative oceanographic and resource survey with SEAFDEC and BFAR to determine the catch and composition of longline caught species in the South China Sea: Area III and describe the oceanographic and other factors affecting the fishery.

Materials and Methods

The Tuna longline (Figure 1)

The longline gear of MV SEAFDEC measures 350m long, 7mm dia mainline and the length used per basket depended on the number of branchlines. Polyester (PES) multifilament and nylon monofilament branchlines were used. The PES multifilament branchline, sekiyama and wire leader had a total length of 31m. The Monofilament branchline has no sekiyama and measure 23 m long. The buoy line was made of 7mm dia. Mansen line, 25m long. During the operation, PES branchlines were casted first.

The design and construction of the longline gear on MV MAYA-MAYA is a typical Japanese design. The mainline was made of PES 300 m long and 6 mm diameter. The branchline was also made of PES, 5mm. diameter. The total length of branchline was 27m including the sekiyama and the wire leader.

Fishing Operation

Shooting the gear on board MV SEAFDEC occurs at dawn and takes about an hour. The operations were conducted in station numbers 1, 5, 6, 12, 13a, 17, 21, 27, 30-A and 31-A (Figure 2). With an average of 319 hooks set, hauling starts at mid-noon and lasts for about 2 hours. Longer time were experienced when the line kinked and entangled with the lines of the giant squid jig. The number of hooks per basket was 4, 5 or 6 hooks depending on the desired fishing depth (Figure 3.) In general, fishing depth increase with the increase of hooks in a basket. Baits used were milkfish about 20-30 cm long and Indian mackerel about 15-20 cm long. The baits were hooked in the head assuming vertical position. Squids caught by the automatic jigging machine were also used as baits in some of the operations.

On MV MAYA-MAYA, the stations were 8, 9, 16, 17, 23 and 25 (Fig. 4). The number of hooks per basket was fixed at 5 pieces and set 20 baskets (total of 100 hooks) per operation during the entire period of the survey. Milkfish (20-30 cm) and big-eyed scad (15-20 cm) were

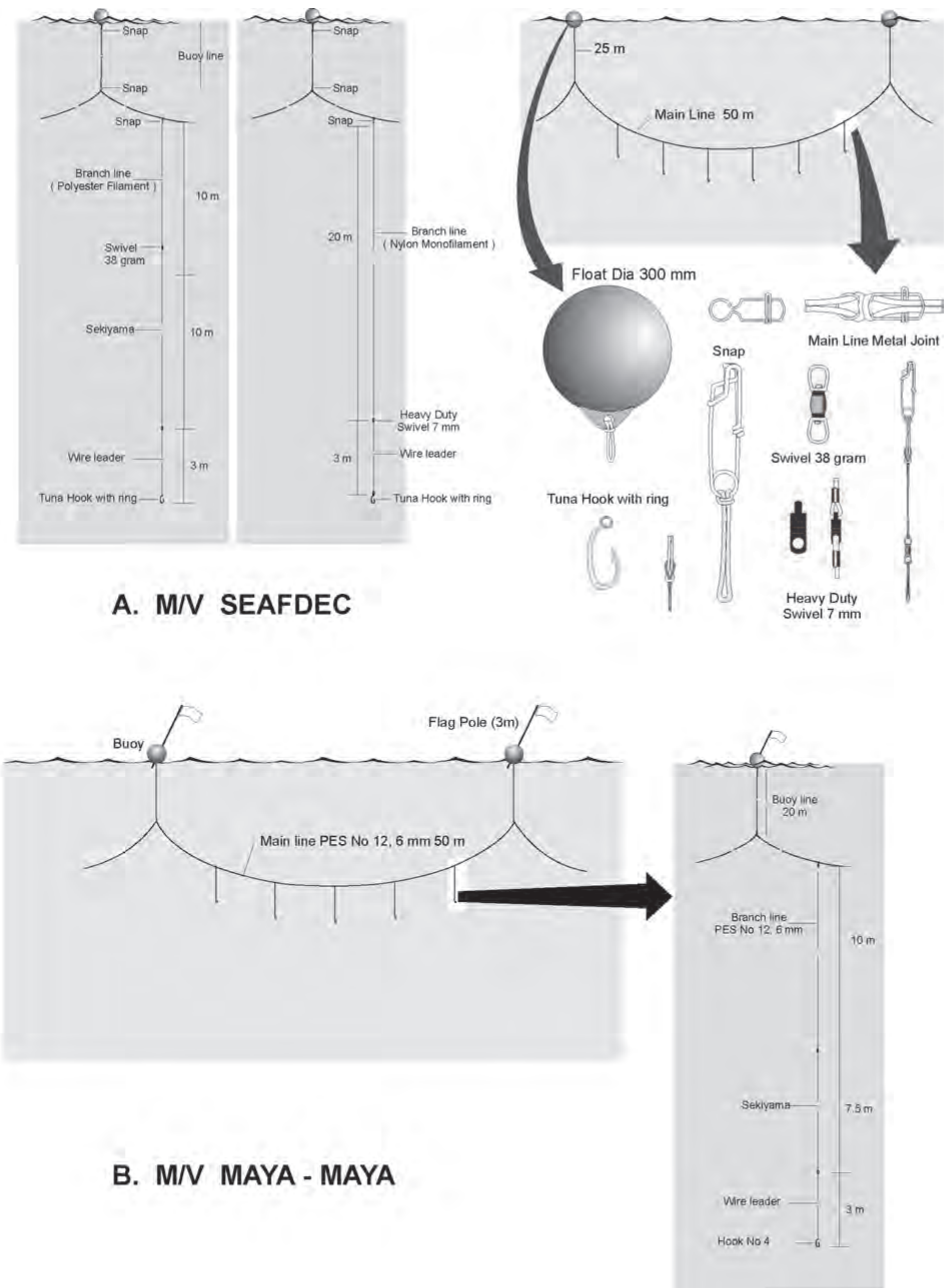
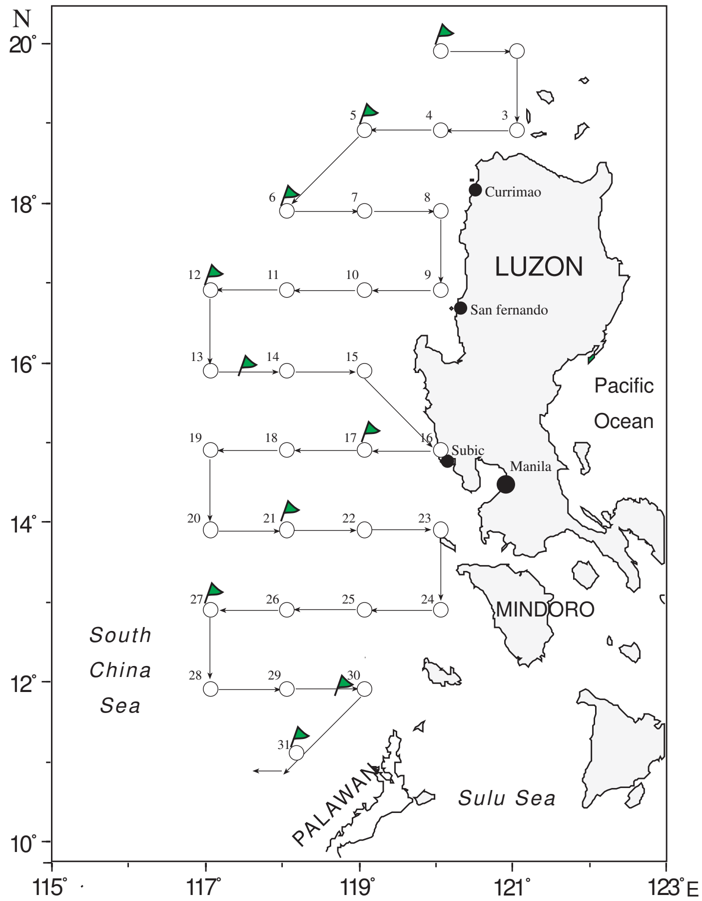


Fig. 1. Tuna Longline Gears of M/V SEAFDEC and M/V MAYA - MAYA.



Fig, 2 . Tuna Longline Stations of MV SEAFDEC.

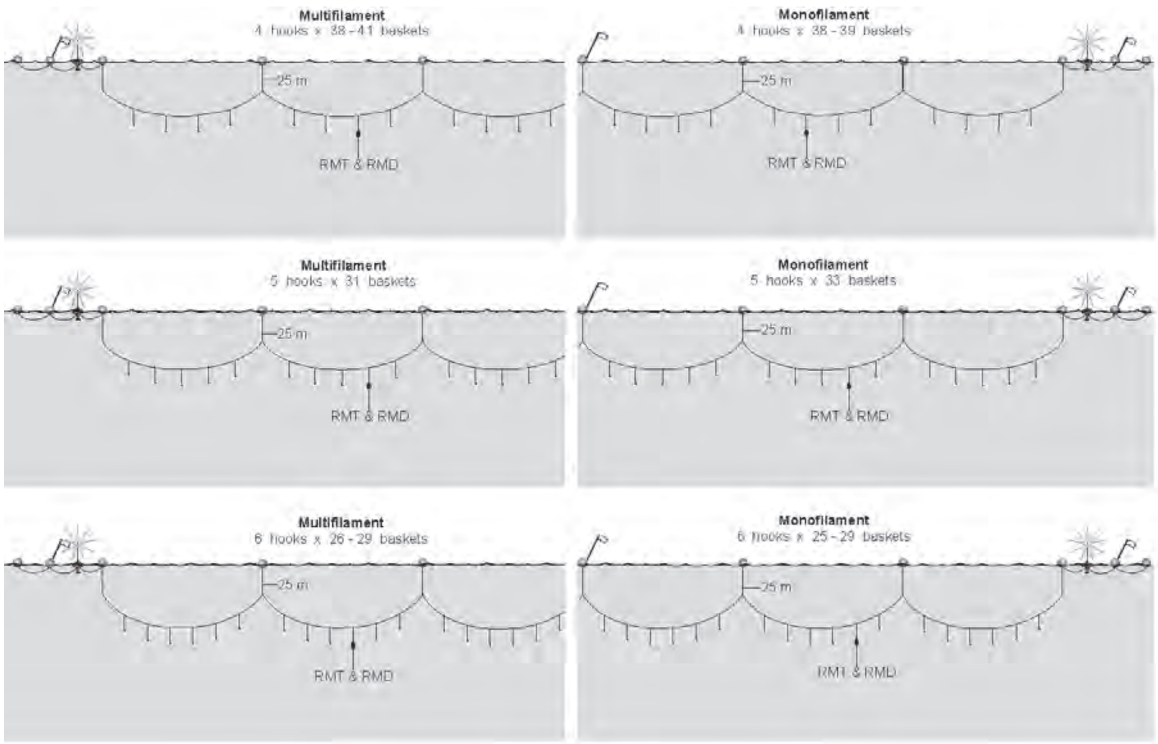
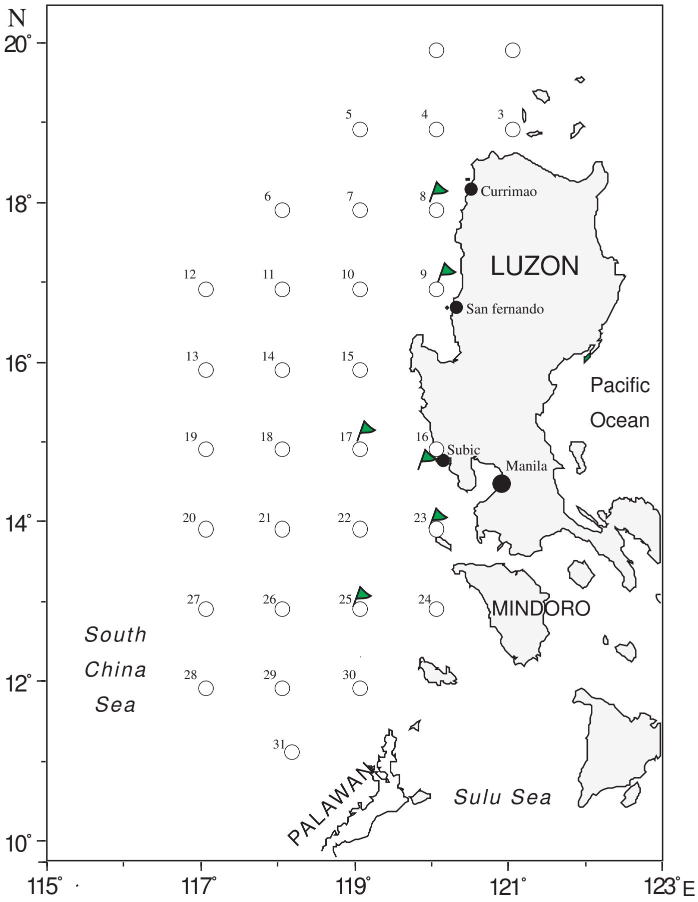


Fig. 3. Tuna longline arrangement with 4, 5 and 6 hooks per basket.



Fig, 4. Tuna Longline Stations of MV MAYAYA.

used as baits and hooked at the region of the first dorsal fin to assume the horizontal baiting position.

Oceanographic Conditions

The ICTD data from the fish sampling were used to infer important oceanographic conditions that may have affected the operations. In addition, the RMT/RMD device were attached to the deepest lines (i.e. center of a basket) in both multifilament and the monofilament branchlines to determine the respective depths and corresponding temperatures. Before any set was made, researchers discussed the results of the previous oceanographic conditions, line depth and catches which affected the operations.

Results

The longline fishing survey was conducted by the two vessels in sixteen (16) fish sampling stations having a combined of 3,796 hooks set. The survey yielded negative results for tuna. Only 34 Pacific lancet fish (*Alopius superciliosus*) 7 sharks and one opah fish *Lampris guttatus* were caught. Bait recovery was very high ranging from 67.9% to 98.08% while bait loss ranged from 1.92% to 32.1%. The average immersion time (i.e. period between setting began and hauling ended) was 9.1 hours for M/V SEAFDEC and 5 hours for M/V Maya-Maya (Table 1). Deeper hooks (i.e. 6 branchlines per basket) caught more fish with hook depth ranging from 80 to 170 meters. Out of 42 pieces, 28 or 66.6% consisted of 22 Pacific lancetfish, 5 sharks (*Alopias* *spp*.) and one (1) opah fish (*Lampris guttatus*). Shallower hooks (i.e. 4-5 branchlines per basket) caught 16 pieces of 12 Pacific lancetfish and 2 sharks. The hook depths ranged from 60m to 150m.

Based on the RMD/RMT, the hook depth of the deepest branchline was 170 m with a corresponding temperature of 17 ^{o}C. The shallowest hook depth is 60m with an average temperature of 20°C. This is located well within the thermocline layer which was determined to be unpronounced in the area. Basing on the research results of this survey, Tiongson (1983) and Tapiador (1952), it appears that the specification of the longline gear as well as temperature and baits were similar (Table 2).

The vertical profile of the fishing stations show a mixed layer of about 20m to 60 m deep after which the temperature starts to decrease gradually. This thermocline layer is evidently not prominent with temperatures of around 15-17 ^{o}C and 12-13^{o}C at 150 m and 250m, respectively. The levels of dissolved oxygen in these layers are about 2.7 –3.3 ml/l and 2.3-2.8 ml/l respectively. Salinity levels are at 33.8 to 34.7 ppt and 34.5 to 34.8 ppt at 40m and 200m respectively. (Table 3).

Discussions

The most important factor in the longline fishery is determining the suitable depths the target species concentrate since the catches are different by hook depth for each species caught (Hanamoto, 1974; Nishi, 1990; Boggs, 1992). Nakano et. al (1997) compared the shallow (< 180m branchlines) and deep longlines (> 180m) and indicated that the albacore, big-eye and lancetfish having catch rates increased with depths while yellowfin, swordfish, mako shark and blue shark had no clear catch rate trend with depth. The catch rate of striped marlin, Pacific blue marlin, sailfish, dolphin fish and snake fish decreased with depths.

Compared to the deep longline, the shallow longline has also been observed to have higher yellowfin tuna (Suzuki et. al., 1977 cited in Nakano et. al, 1997). Other observation showed that yellowfin has high catch rates at 90-100m, 120-150m and even at a range of 40-200m (Hishi, 1990 and Boggs, 1992 cited in Nakano, *et. al*., 1997).

Among the oceanographic parameters, temperature is probably the most important factor being considered in locating fishing grounds. Figure 5 shows sea surface temperature distribution and fishing for tuna species (Uda, 1952 cited in Laevastu and Hayes, 1981). Some studies indicates that albacore spends considerable time in thermocline layers of 10-12^{o}C although the lowest temperature distribution in Figure 3 is 14° C (Laevastu and Hayes, 1981).

Hanamoto (1987 cited in Nakano, et. al., 1997) suggested that water temperature and level of dissolved oxygen could be the limiting factors for the vertical distribution of bigeye tuna which could not live in waters where dissolved oxygen was lower than 1 ml/l and temperature must be between 11°C to 16°C at 250 m depth range.

Table 4 shows comparative temperatures between this survey and other tuna longline areas in the Pacific. Below the temperature turning point is considered as a good capture area (Kurita, 1990 cited in Munprasit et. al., 1991). In this survey, this point occurred at 20-60 m where hook depths of about 60-170m was well below that level.

The longlines used in this survey are also basically of the shallow Japanese design and fishing depths within the distribution of most of the target species like yellowfin, marlin and sailfish. Deeper areas which are still within the fishing range of most of the longline target species and where echos indicated presence of fish were however not tried during the exploration. In fact, more catch (regardless of species) were observed when the hook depth was made deeper.

Table 1 : Particulars of longline operations onboard M.V. SEAFDEC and M.V. MAYA-MAYA

1. M.V SEAFDEC

Station	Basket set			Total hooks	Immersion	Bait Recovery		Bait Loss		Catch
	Mono	Multi	Hools/basket	set	Time(hrs)	Number	Percentage	Number	Percentage	
1	25	28	6	318	9	216	67.9	67.9	32.1	4 Lancet fish
5	37	38	4	300	9	248	82.7	52	17.3	5 Lancet fish
										1 shark
7	38	40	4	312	9	306	98.08	6	1.92	1 Lancet fish
										1 shark
12	39	40	4	316	9	276	87.4	40	12.6	3 Lancet fish
14	38	41	4	316	9	285	90.2	31	9.8	1 Lancet fish
17	25	28	6	318	9	274	66.2	44	13.8	5 Lancet fish
										1 shark
21	28	29	6	342	9.3	281	82.2	61	17.8	5 Lancet fish
27	33	31	5	320	9.3	239	74.7	81	25.3	5 Lancet fish
31-A	27	26	6	318	9.3	223	70.1	95	29.9	2 Lancet fish
30-A	29	27	6	336	9.3	261	77.7	76	22.3	6 Lancet fish
										3 sharks
										6 L. guttatus

2. MV MAYA-MAYA

Station	Basket set		Hooks/basket	Total hooks	Immersion	Catch
	Mono	Multi		set	Time (hrs)	
8		20	5	100	6	2 Lancet fish
9		20	5	100	6	1 Lancet fish
16		20	5	100	5	
17		20	5	100	4.75	
23		20	5	100	3.42	
25		20	5	100	5	

Table 2 Fishing Indicators of Other Research Results on Tuna Longline Operations

Factor	This survey, 1998	Tiongson, 1983	Tapiador, 1952
Float line (m)	*25*	*25*	*13*
Mainline (m)	*50*	*24*	*36-72*
Branchline (m)	*23-31*	*22*	*31*
Total	*98-106*	*71*	*80-116*
Branchlines/basket	*4-Jun*	*9*	*6*
Total hooks covered	*3796*	*11, 174*	*27,900*
Bait	*milkfish, Indian mackerel, squid*	*horse mackerel (saury)*	*milkfish*
Fishing ground	*South China Sea*	*Sulu Sea*	*South China Sea, Sulu/Celebes Seas*
Approx. surface temp.(°C)	*28-31*		*27-30*
Approx. temp. at 50m(°C)	*22-28*		*25-29*
CPUE, all species(per 100 hooks)	*1.1**	*0.44***	*3.4***
CPUE for tuna (per 100 hooks)	*0*	*0.2*	*2.5*

** 80% lancet fish*
*** Only valuable species, shark included*

Table 3 Fishing Station Profile from M.V. SEAFDEC South China Sea : Weatern Philippines April-May 1998

Station No.	Hook Depth Range		Thermocline		Temperature (°C)					D.O (ml/l)		Salinity	(%)
	m	°C	start (m)	°C	Surface	50m	150m	250m	300m	150m	250m	40m	200m
1	141-170	18-17	60	25.7	28	27	17	13	12	3.3	2.8	33.8	34.8
5	60-120	22-17	25	25.5	28	23	15	12	11	3	2.3	34.1	34.6
7	60-95	21-18	25	26.5	28	-	15	12	11	3	2.3	33.7	34.5
12	70-120	24-18	40	27.3	30	27	17	13	12	3	2.3	33.7	34.6
14	70-100	26-22	60	27	30	28	17	14	12	2.7	2.5	33.9	34.6
17	80-150	25-17	25	32	30	28	17	13	12	2.7	2.4	34.7	34.7
21	60-140	17-16	20	30.3	31	27	16	13	12	3	2.5	33.9	34.6
27	90-150	21-16	30	30.4	31	28	16	13	12	3	2.5	33.8	34.6
31	100-150	18-16	20	30	30	24	17	13	12	2.9	2.5	34.2	34.6
30	95-165	20-17	20	30.6	31	26	16	13	11	3	2.5	33.9	34.6

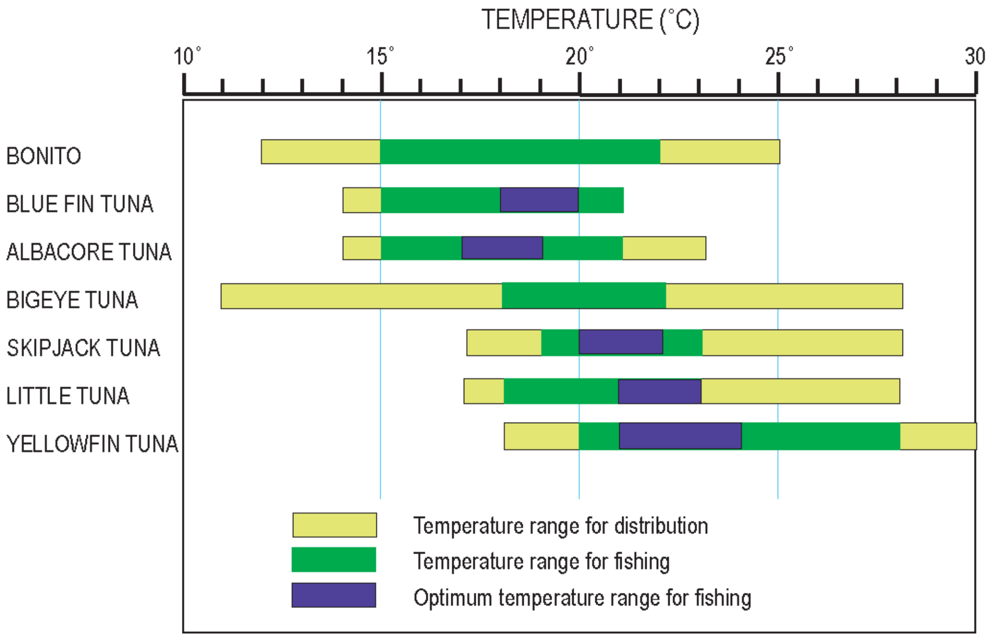


Fig. 5. Sea surface temperature distribution and fishing for tuna species.

Table 4. Oceanographic indicators of other studies on tuna longline operations.

Area	*Temperature (°C)*		*D.O (ml/l)*	
	150m	*250m*	*150m*	*250m*
SCS (This survey)	*15-17*	*12-14*	*2.5-3.5*	*2.3-2.5*
*Equator**	*18-23*	*11-14*	*3.0-4.5*	*1.5-3.5*
*East of Hawaii**	*16-20*	*11-13*	*4.5-5.5*	*3.5-4.5*
*Tropical Eastern Pacific**	*13-21*	*12-16*	*0.5-4.0*	*0.5-3.0*

** After Nakano, 1997*

Depth and temperature are however, not only the factors that affect fishing. It has been a fact that Taiwanese longline vessels prefer the use of live baits than frozen fish to increase catches.

It is important to note that longline catches may have significantly declined in the area. In the 1950s, it was indicated that the catch rate was around 3.4 fish/100 hooks (Tapiador, 1952) and may already have significantly declined in the 1980s (Tiongson, 1983). In a survey in 1981-82, the main fishing grounds for the Taiwan fishery were close to both sides of the Philippine archipelago but in 1985 the inshore longliners began to use Singapore, Palau and Indonesia as base ports. Although the reason for the shift is not clear, it may reflect exhaustion of the traditional fishing grounds or may be a result of rapid growth in power and capacity of the fishing vessels (Wang, 1994).

Nonetheless, longliners apparently Taiwanese types, were spotted several times within the Philippines EEZ during the survey. Since the last observation on board a Taiwanese tuna longline was done in the early 1980s, it is important to determine the present techniques employed in these fishing vessels to ascertain the potential/status of the fishery in the western part of the Philippines. Likewise, the survey was only done in 2 months time, hence, longer operations maybe needed to further validate the results. Continuous monitoring by long term effort is recommended. An Observers Program will be implemented to collect the fisheries data necessary for assessing the viability of various fishery and their effective management.

Acknowledgment

The authors wish to thank Mr. Pratakphol Prajakjitt of SEAFDEC for collecting and summarizing the results of the longline operation during the cruise and the participation of all the SEAFDEC/MAYA-MAYA officers and crew. Thanks also to Ms. Luth Sebastian, Marites Chiuco, Myrna Ramos, Erlinda Clavo and Alberto Santiago III for their assistance in revising the paper and preparation of the illustrations.

Above all, to Director Dennis B. Araullo, Messrs. Jose A. Ordonez, Atty. Reuben A. Ganaden and Ms. Alma C. Dickson for their support to the project for its inclusion in the Joint BFAR-SEAFDEC Collaborative Research Project.

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Round Scad Exploration by Purse Seine in the South China Sea, Area III: Western Philippines

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ABSTRACT

Round scad exploration by purse seine in the waters of western Philippines was conducted from April 22 to May 7, 1998 for a period of five (5) fishing days with a total catch of 7.3 tons and an average of 1.5 tons per setting. Dominant species caught were *Decapterus spp.* having 70.09% of the total catch, followed by *Selar spp.* at 12.66% and *Rastrelliger spp.* 10.70%. Among the *Decapterus spp.* caught*, D. macrosoma* attained the highest total catch composition by species having 68.81% followed by *D. kurroides* and *D.russelli* with 0.31% and 1.14% respectively. The round scad fishery stock was composed mainly of juvenile fish (less than 13 cm) and Age group II (13 cm to 14 cm). Few large round scad at Age group IV and V (20 cm to 28 cm) stayed at the fishery.

Other fishes caught were: *Auxis rochei* (0.85%), *A. thazard* (0.12%), *Caranx spp.* (0.45%), *Emmilichthys nitidus* (0.58%), *Euthynnus affinis* (0.42%), *Leiognathus ruconius* (0.58%), *Loligo sp.* (0.31%), *Megalaspis cordyla* (0.09%), *Rastrelliger spp.* (10.70%), *Sardinella longiceps* (0.03%), *Scomberoides lysan* (0.24%), *Selar spp.* (12.66%), *Sphyraena spp.* (0.90%), *Thunnus albacares* (0.96%) and others (1.02%).

Tuna and tuna like fishes such as yellowfin tuna, eastern little tuna, bullet tuna, frigate tuna and oceanic squid are distributed in the upper latitudes of the survey area. On the other hand, round scads, big-eyed scads and Indian mackerels are dominantly present in the lower latitudes of the survey area.

Keywords : round scad, tuna and tuna like fishes, purse seine, Waters of Western Philippines, South China Sea

Introduction

Round scad fishing has been developed in the Philippines before World War II with the use of bagnet or "basnigan". Bouki-ami was also introduced however, its use did not gain success. Until in 1962, a US West Coast type purse seiner was introduced (Ronquillo, 1970). Aside from these two fishing gears, several fishing nets and gears have been developed and used such as ringnet, gillnet, baby trawl as well as multiple handlines for catching round scads. *Decapterus spp.* (Round scad) locally known as "galunggong" of the family Carangidae is one of the most important small pelagic fishes caught in huge quantities in the Philippine waters most of the year. It ranked second among the major species of fish produced for over the span of twelve years from 1979 up to 1990 sharing an average of about 10.67 percent to total fish supply

(Fisheries Statistics, 1991). However, this species obtained the highest commercial landings with an average of about 132,224 MT from 1975 to 1985 (Calvello 1987) and 202,163 MT from 1986 to 1993 (Fish. Statistics 1986-1993). Most of the round scad catches are contributed mainly by the commercial sector. The price of the said fish is cheaper compared to other fishes due to the large volume of landings in the market.

There were six species of round scad caught in the Philippine waters namely *Decapterus macrosoma* (Long bodied scad); often been misapplied *to D. Layang*; *D. russelli* (Russel's mackerel scad); *D. kurroides* (Red-tailed scad), *D. maruadsi* (Yellow-tailed round scad); and *D. macarellus* (Mackerel scad).

Traditional fishing grounds of round scad in the Philippines both commercial and municipal sectors are: Sulu Sea, Visayan Sea, Moro Gulf, Lamon Bay, Cuyo Pass, Rangay Gulf, Batangas Coast, Tayabas Bay, Samar Sea, Camotes Sea, Sibuyan Sea, Bohol Sea, Davao Gulf and Babuyan Channel. Further, municipal fishing grounds includes areas of Northern and Southern Mindanao and Casiguran Sound. On the other hand, base on the findings of Tiews et. al. (1975), *Decapterus spp.* avoids salinities below 30%^{0} as well as the phytoplankton concentrations found in the bays of Philippine archepelago such as Manila Bay and San Miguel Bay area located on the Pacific side of Southern Luzon.

According to Ronquillo (1970) *D. macrosoma and D. russelli* dominated the fishery consisting mainly of one year class, Age Group II (13cm to 14 cm length). It matures while it is available in the fishery and leaves at stage of Age Group III (21 cm length) and breed after 10 to 12 months to which breeding period of both species extend from November to March in Palawan waters and 1 to 2 months delayed in Manila Bay. He also stated those large fishes of about 23 cm to 27cm (Age Group IV and V) representing returning fishes may be found at times in coral reefs. On the otherhand, according to Bhatiyasevi (1997), in waters of Thailand round scad breeding period has to peak, which are from February to March and June to August. Furthermore, asides from these two species of round scad *D. layang* similar to *D. macrosoma, D. kurroides* (Tiews et. al. 1975) and *D. maruadsi* (Cavello, 1987) are caught in the Philippine Waters.

Base from the Fishery Statistics of 1991 covering the round scad concentration of unloading in the Philippines from 1979 to 1990 indicated the following data: the National Capital Region (NCR) contributed 50 percent of the total fish catch through commercial fishing operations with an annual average of 70,862 metric tons and a growth rate of about 5.85 percent; Western Visayas with 16 percent share equivalent to about 22,827 metric tons having a yearly increase of 7.88 percent; western Mindanao of 10 percent share ith an increase at a marginal rate of 0.79 percnt. While Southern Tagalog and Northern Central Mindnao both have declining rates of unloadings. Municipal landings was concentrated at Southern tagalog with 23 percent share to the total fish catch and a yearly increase of 5.68 percent; Bicol and Western Mindanao with 19 percent each both having negative growth rates; Ilocos and Cagayan Valley contributed the lowest catch with 0.11 and 0.06 percent share respectively. Negative growth rate in the areas of Bicol and Western Mondanao indicates overexploitation of fishery resources. Same is true according to Calvello (1987), the annual catches of roundscad from 1978 and 1985 of commercial purse seiners, basnigs and ring netters indicates some evidence that catch per vessel declines with increasing number of boat. Further, decline in catch per vessel was also recorded in 1986 with a total catch of 89,826 metric ton of round scad to 1987 with a total catch of 77,844 metric tons having 296 and 280 numbers of commercial fishing vessel respectively (Fish. Statistics 1986-1987).

On the fishery Statistics of 1993 the data presented here refers to Purse seine fishing in 1992 of *Decapterus spp.* increased with a total of 209,311 metric tons while it decreased in 1993 by 15.51 percent having only a total of 176,843 compared to 1993 catch. Further, the volume of round scad exportations continue to decline by 39.37 and 38.13 percent from 1992-

1993 wherein the major export markets are Japan, USA and HongKong. Due to this continuous decline in catch it is recommended that management intervention of fishery stocks is timely to determine the feasibility of recovering and restoring natural productivity of the Philippine round scad resources.

This paper represents survey and sampling activities of Round scad exploration by Purse Seine to determine the occurrences, distributions and abundance of the said fish within South China Sea, Area III of Western Philippine Waters.

Materials and Methods

Fishing Vessels

The study was conducted onboard M/V MAYA-MAYA the training and research vessel of the Bureau of Fisheries and Aquatic Resources (BFAR). The steel marine vessel has a 56.74 net tonnage and 165 gross tonnage. It was built in 1967 at Niigata Shipyard Japan. It is rigged and equipped for purse seine and longline operations having an overall length of 29.35 meters breadth of 7.10 meters and depth of 3.20 meters. The vessel was equipped with nautical instruments such as Radar, GPS navigational system, Fish Finder, General Observation System, Color Scanning Sonar, Facsimile Receiver, Gyro Compass and Auto Pilot. Its radio equipments consist of Marine SSB Radio telephone, Marine VHF Radiotelephone, and Transceiver. The deck machineries of the said vessel was equipped with Windlass Hydraulic Driven, Steering Gear Electrohydraulic Type with Magnetic Compass Pilot and Engine Telegraph. It has a standard speed of 9.5 knots. Other fishing accessories and equipment were: one (1) unit Steel Skiff Boat (6.04 m x 3.02 m x 31.8 m), a rubber and a fiber glass boat.

Purse Seine

A typical sardine and mackerel purse seine was used measuring 672 meters long and 139 meters deep made of nylon knotless nettings. The main webbing were 210/18 twine size x 11 knot or 30 mm mesh size. Its floatline was made up of 26 mm diameter nylon rope with 2,909 pieces of SHE 30 floats having a buoyancy of 3,000 grams each. The sinkerline was made of Galvanized steel short link chain having 95 mm diameter with a total number of 77 pieces 19 mm snap rings thick by 110 mm long. (Figure 1). A Marco Type Hydraulic power block hauls the net.

Fishing Stations

The purse seine exploration lasted for 16 days covering the areas of Candon, Ilocos Sur; off Dasol, Pangasinan; off Subic Bay Zambales and off Paluan, Mindoro. Four out of eleven (11) stations were surveyed (See Figure 2). Stations 7,8 and 10 were aborted due to rough sea and heavy rains. Further the direction of wind and water currents in the said areas were opposite creating huge waves and causing the vessel to almost tilt. The sea anchor was damaged while maneuvering from station 8 to 7 limiting the fishing depth to less than 180 meters. The following day, the fishing operation was pursued in the shallower area located off Candon Ilocos Sur set near coral areas (within station 9). It was not possible for the vessel to continue surveying the perimeter within the stations 10 and 15 for the shallowest depth of the said area was more than 200 meters which is more than the anchorage capability of the vessel.

A seamount found in station 15 located off Dasol, Pangasinan enabled the vessel to anchor in a depth of 152.5 meters and set the purse seine net in deeper water. During the operation the sea was calm and the weather remained fair. On the other hand, slight rain showers were

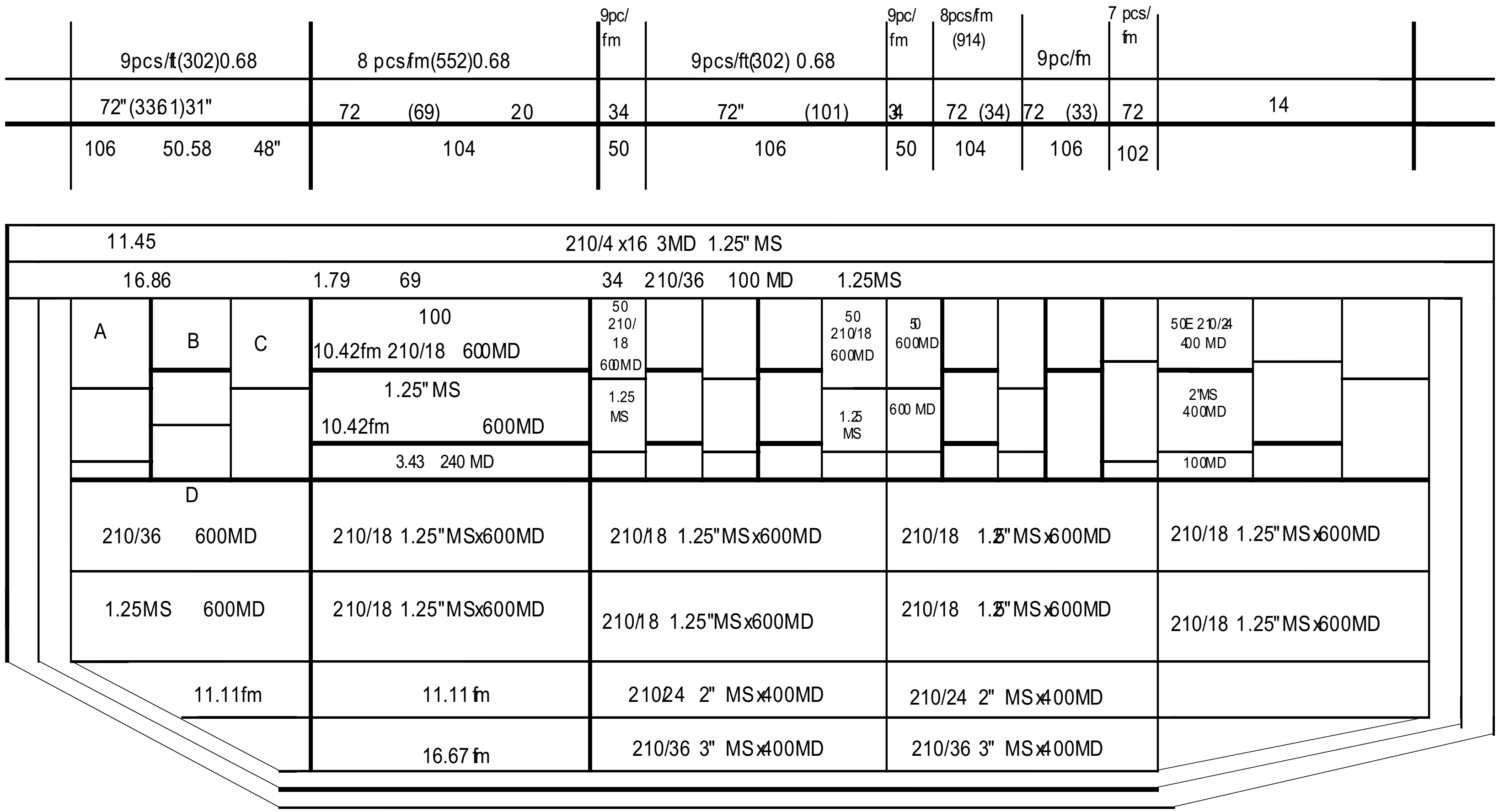

Fig. 1. Pruse seine net measuring 675m long by 135m deep.

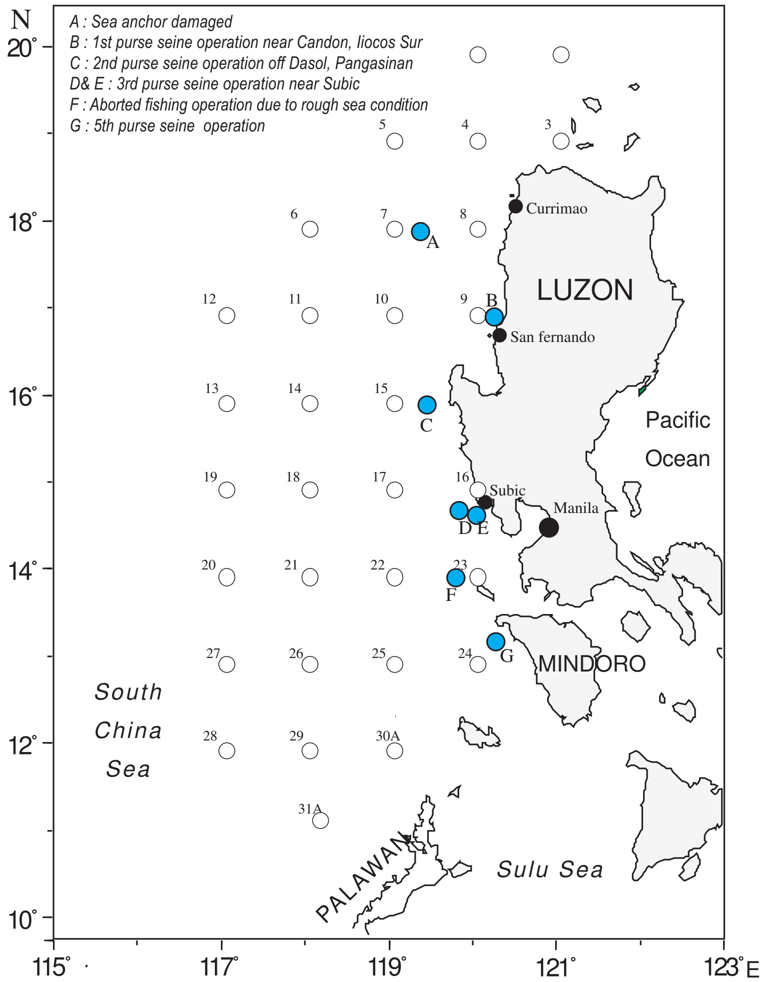

Fig. 2. Sardine purse seine sampling stations.

experienced at station 16 located near off Subic Bay, Zambales. The depth of the area was shallower compared to other stations enabling the vessel to operate twice off Subic Bay. Areas within the perimeter of stations 17 and 22 were no longer surveyed due to big waves encountered while cruising to the said stations.

There was an attempt to operate in station 23. However, strong water currents flowing in two directions unable the vessel to continue the operation within the perimeter of stations 22, 23, 24 and 25. For this reason, setting was moved outside the perimeter of the assigned areas to off Paluan, Mindoro waters, which was assumed as station 24. The area has shallower water depth but the presence of turbulent currents still affected the fishing operation.

According to the geographical data stated by Gonzales et. al. (1991) the western side of the Philippine Island has a cyclonic pattern surface water movement. This water movement is developed in the interior of South China Sea with the southerly flow along the western coast of Palawan and Luzon during the northeast monsoon. He also stated that during the southwest monsoon, water movement in the South China Sea is generally northeasternly flowing out through the Strait of Taiwan and the Luzon Strait.

Fishing Operation

Purse seine fishing operation was all done by one mother vessel (M/V MAYA-MAYA), a skiff and one light boat. Usually the mother boat arrives in the evening. With the use of fish finder and color search light sonar, fish school were located and the bottom of the sea was checked. The vessel was anchored in the place where fishes were expected to be in abundance. Luring of fishes commence during the late evening. The process of luring fishes involved the use of four halogen bulbs (3 kilowatts each) located on top of the mothership. All lights were turned-on at the mother ship and were-turned off after the light boat gained its position and had put on its light concentrating the fish in one area. Shooting of purse seine net took place at dawn and usually lasted for 4 to 5 minutes. Pursing the cable usually took 15 minutes and hauling the net by puretic power block usually took 1 to 2 hours. Entangling was prevented by keeping the purse seine net away from the mother boat with the use of skiff. Approximately three (3) tubs of fish at 105 kgs per tubs were taken from the bunt at random and were sorted according to species whenever possible. Sample of each species were measured to the nearest centimeter using a measuring board to determine the size composition. Weight and sex determination of fish samples was difficult due to rough sea condition.

Results

Round scad purse seine fishing in the waters of western Philippines resulted to a total catch of 7.3 tons with an average of 1.5 tons per setting. The catch composition was dominated by *Decapterus spp.* at 70.09% followed by *Selar spp.* at 12.66% and *Rastrelliger spp.* at 10.70%. Among the species of round scad, *Decapterus macrosoma* obtained the highest catch by species contributing a total percentage of 68.81% followed by *D. russelli* and *D. kurroides* at 1.142% and 0.31% respectively. It was observed that *D. macrosoma* was present throughout the station at all times and it has outnumbered other species. On otherhand, *D. kurroides* and *D. russelli* were in lesser quantity within the surveyed area. (Table 1)

Most of the *Decapterus spp.* caught were juvenile to which size ranges from 8.0 cm to 12.5 cm having a peak catch in 12 cm length followed by Age group II from 9.5 cm to 13 cm. Few were found at mature stage from 22 cm to 28 cm. Size of the caught round scad by species ranges as follows: *D. kurroides* 9 cm to 15 cm; *D. macrosoma* 10 cm to 28 cm; and *D. russelli* 10 cm to 17 cm. (Figure 3). It was said that *D. maruadsi* and *D macarellus* do occur in the Philippine waters (Calvello 1987).

Tuna and tuna like fishes which includes *Auxis rochei* (Bullet tuna), *Thunnus albacares* (Yellowfin tuna) and *Euthynnus affinis* (Eastern little tuna) were caught in the upper latitude such as in latitude 16° and 18° having the depths of 144 and 152.5 meters respectively. With the presence of the said fishes in the area, occurrence of *Loligo sp*. was observed extending to latitude 15° (off Subic Bay). Further at latitude 15°, tuna and tuna like fishes were not found since the depth of the ocean floor was only 74.34 meters. At lower latitude 13° of the surveyed area, occurrences of shortfin roundscad *(Decapterus macrosoma)*, big-eyed scads *(Selar crumenopthalmus)* and Indian mackerels *(Rastrelliger kanagurta)* were dominantly present. The depth of the area was 81 meters. (Table 1)

As per station the following results were taken based on the samples gathered during the purse seine fishing operation:

Station 9

Out of the 137kgs samples in station 9, *D. macrosoma* contributed 41kgs at 30% having a two year class from 7 cm to 12 cm (Age Group I) and 19 cm to 24 cm (Age group III and IV). The peak catch at Age Group I was at 8 cm length contributing 19.27% of the species samples

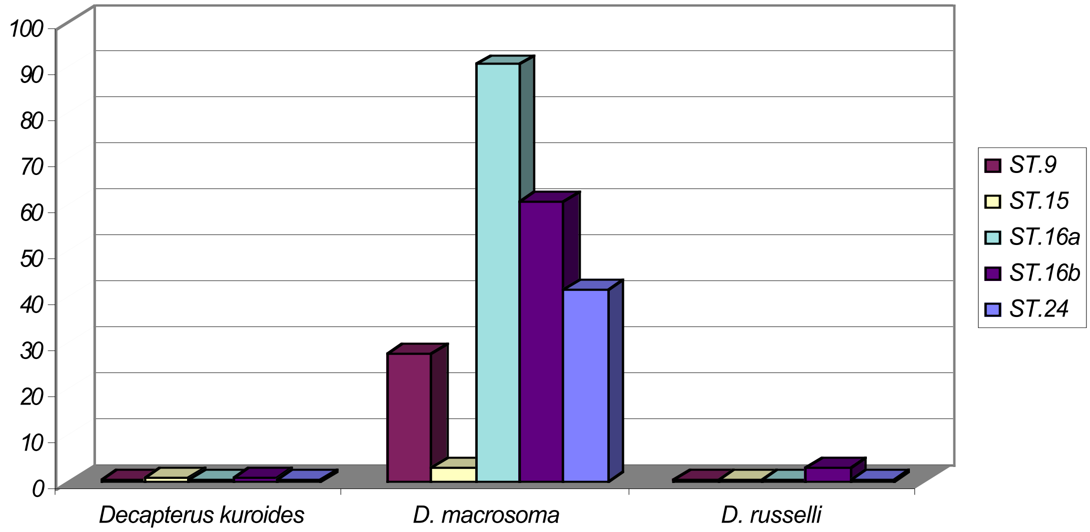

Fig. 3. Catch composition of *Decapterus* sp. in Stations 9, 15, 16a, 16b, and 24.

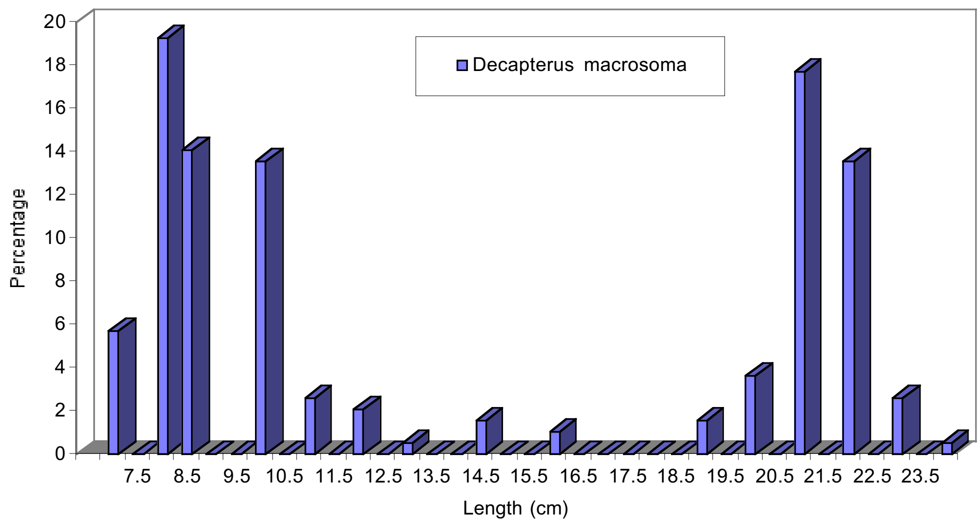

Fig. 4. Length composition of *Decapterus macrosoma* in Stations 9.

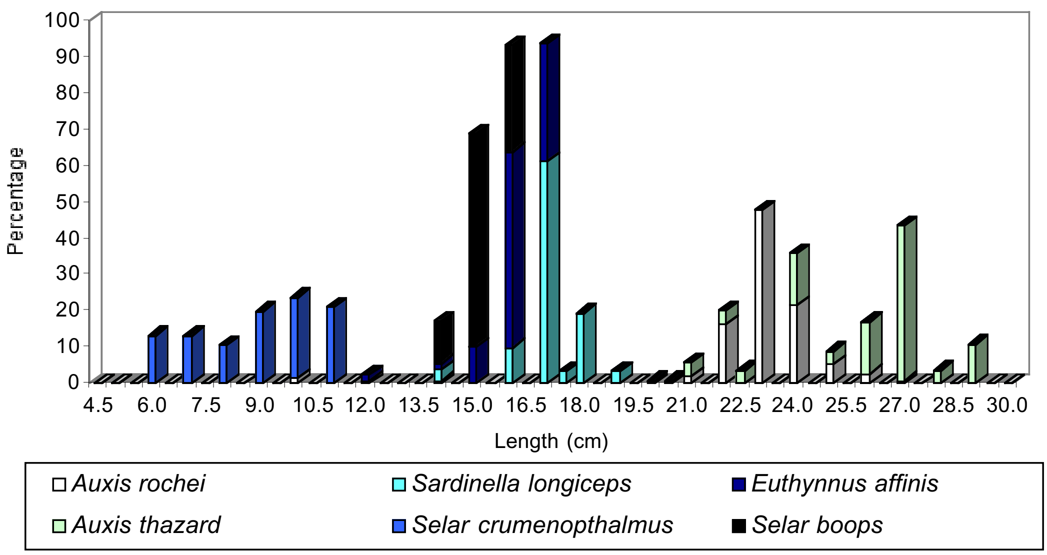

Fig. 5. Length composition of other species in Stations 9.

while the highest catch of Age Group III and IV was at 21 cm and 22 cm length with 17.71% and 13.54%. A total of 181 pieces *D. macrosoma* were sampled to which the sizes ranges from 7 cm to 24 cm length. (Figure 4)

The presence of Tuna and tuna like species during the brailing was observed with the following species *Auxis thazard* at 6.6%, *Auxis rochei* at 36.5% and *Euthynnus affinis* at 17.3% of the stations total catch. Samples of *Auxis thazard* ranges from 11cm to 29 cm with 28 pieces (9 kls) samples. Peak catch was at 27 cm length contributing of about 42.86%. *Auxis rochei* on the other hand, has a peak catch at 23 cm equivalent to 47.71% of the sample. Its size ranges from 10 cm to 27 cm length with a total of 153 (50 kls) pieces samples fish. Further, based on the length samples of *Euthynnus affinis*, its size ranges from 12 cm to 17 cm and a peak at 16 cm length equal to 54.27% with a total of 129 pieces samples. Length of *Selar crumenopthalmus* ranges from 5 cm to 11 cm with a dominant catch at 22.37%. *Selar boops* on the other hand, has 17 pieces samples with size ranges from 14 cm to 16 cm length with the highest at 15 cm equivalent to 58.82%.

Three (3) kilograms of *Loligo spp.* which represents 2.1 %; *Selar crumenopthalmus* at 14.6%; *Sardinella longiceps* at 1.46% of the total samples by station 9. Length of sampled *Selar crumenopthalmus* ranges from 5 cm to 11 cm having a peak at 10 cm equivalent to 22.37%. While samples of *S. longiceps* ranges from 4 to 9 cm with a peak at 7 cm length equivalent to 61.29%. Presence of snappers, surgeonfish, mackerel, *Caesio sp*. and squirel fish were recorded. (Figure 5)

Station 15

Samples of *Decapterus macrosoma* in station 15 showed that out of 281.45 kgs sample it obtain a 4.3 kgs equivalent to 1.76%. Sizes of the said species ranges from 7 cm to 25 cm length with a peak at 10.5 cm having 18.39% of the sampled species. The samples were composed primarily of Age Group I. A total of 223 pieces were measured. On the other hand, *D. kurroides* obtained 0.29% of the total samples with a 361 pieces at 700 gram. Size of the said fish ranges from 8 cm to 13 cm with a peak catch at 11 cm length equivalent to 22.22% of the samples. (Figure 6)

Auxis rochei of the tuna like species obtained 4.80% of the station's sample. A total of 223 pieces samples were measured with a dominant size at 13.5 cm which is 15.92% of the sample. Size of the said fish ranges from 11.5 cm to 22.5 cm length. Other species caught were *Euthynnus affinis, Selar spp.* and *Rastrelliger spp.* (Figure 7).

Station 16a

A total of 1,080 kgs of *Decapterus macrosoma* was caught in the first operation with a percentage of 94.69% of total catch. The length of *D. macrosoma* samples ranges from 8.5 cm to 16.5 cm with the highest catch recorded at 13 cm equivalent to 23.83% of the 256 pieces of sampled species. Samples were composed of Age Group I and II. (Figure 8)

Other important species such as *R. faughni* with size ranges from 11 cm to 19.5 cm and a peak at 13 cm equivalent to 13.70%; *R. kanagurta* at 1.23 cm with a peak of 16 cm equivalent to 15.49%; and *S. crumenopthalmus* at 15.3 cm to 22 cm with a peak at 17.5 cm at 16%. (Figure 9)

Station 16b

Three species of Decapterus were caught at the second operation namely; *D. macrosoma*, *D. kurroides* and *D. russelli*. *D. macrosoma* obtained the highest catch with 234 samples belonging to Age Group I. Size ranges from 8.5 cm to 17 cm and a peak catch at 17 cm equal to 19.65%. While *D. russelli* has 832 kgs total catch with 167 sampled fishes having a size that ranges from

Table 1: Percentage Distribution of Catch Per Station by Depth

Species	STATION NUMBER											
	9	%	15	%	16a*	%	16b*	%	24	%	kg	%
Auxis rochei	50.00	36.49635	11.70	4.800985	0.00	0	0.00	0	0.00	0	61.70	0.847232
Auxis thazard	9.00	6.569343	0.00	0	0.00	0	0.00	0	0.00	0	9.00	0.123583
Caranx spp.	0.00	0	33.00	13.54124	0.00	0	0.00	0	0.00	0	33.00	0.453139
Decapterus kurroides	0.00	0	0.70	0.287238	0.00	0	9.20	0.210346	0.00	0	9.90	0.135942
Decapterus macrosoma	41.00	29.92701	4.30	1.764465	2080.00	94.68533	2730.00	62.41798	156.00	46.98795	5011.30	68.81253
Decapterus russelli	0.00	0	0.00	0	0.00	0	83.20	1.902262	0.00	0	83.20	1.142.459
Emmilichthys nitidus	0.00	0	0.00	0	0.00	0	42.12	0.96302	0.00	0	42.12	0.57837
Euthynnus affinis	10.00	7.29927	3.50	1.436192	0.00	0	6.70	0.153187	10.00	3.012048	30.20	0.41469
Leignathus ruconius	0.00	0	0.00	0	0.00	0	42.12	0.96302	0.00	0	42.12	0.57837
Loligo spp.	3.00	2.189781	15.00	6.155109	4.50	0.204848	0.00	0	0.00	0	22.50	0.308958
Megalaspis cordyla	0.00	0	0.00	0	0.00	0	6.70	0.153187	0.00	0	6.70	0.092001
Rastrelliger faughni	0.00	0	0.00	0	28.83	1.312393	676.00	15.45588	0.00	0	28.23	0.387639
Rastrelliger kanagurta	0.00	0	0.00	0	23.17	1.05474	0.00	0	52.00	15.66265	751.17	10.31467
Sardinella longiceps	2.00	1.459854	0.00	0	0.00	0	0.00	0	0.00	0	2.00	0.027463
Scomberoides lysan	0.00	0	17.50	7.18096	0.00	0	0.00	0	0.00	0	17.50	0.240301
Selar crumenopthalmus	20.00	14.59854	8.30	3.405827	52.00	2.367133	676.00	15.45588	104.00	31.3253	860.30	11.81319
Selar boops	0.00	0	61.70	25.31801	0.00	0	0.00	0	0.00	0	61.70	0.847232
Sphyraena sp.	0.00	0	0.00	0	8.25	0.375555	57.20	1.307805	0.00	0	65.45	0.898725
Thunnus albacares	0.00	0	70.00	28.72384	0.00	0	0.00	0	0.00	0	70.00	0.961203
Others	2.00	1.459854	18.00	7.38613	0.00	0	44.50	1.017436	10.00	3.012048	74.45	1.022308
Total	137.00	100	243.70	100	2196.75	100	4373.74	100	332.00	100	7282.54	100
Fishing Depth (meters)	**144**		**152.5**		**74.34**		**74.7**		**81**			
Mean catch (kg/set)											1456.51	

** Two Setting at Station 16*

8.5 cm to 14.5 cm. The peak of the sample is at 9.5 cm contributing of about 30.54%. Samples were mainly juvenile having Age Group I and II. Among the two *D. kurroides* has the lowest catch with a total of 9.2 kgs and a 15 pieces sampled fish. Size of the said species ranges from 8 cm to 11 cm with a peak at 8.5 cm equal to 46.6% of its sample. (Figure10)

Other important species were *R. kanagurta* at 11.5 cm to 19.5 cm with a highest number sampled size at 12.5 cm equal to 39.05%: *S. crumenopthalmus* at 11.5 cm to 22 cm with peak 17.5 equal to 18.22%: and *E. affinis* at 20.6 cm to 25 cm peak equal to 36% of its samples. (Figure 11)

Station 24

Size of *D. macrosoma* ranges from 9.5 cm to 12.5 cm with a dominant sampled species at 10.5 cm equal to 29.78%. Most of the sampled fish composed mainly of Age Group I having 46.99% from the total catch composition of 156 kgs. (Figure 12)

Other important species include *R. kanagurta* and *S. crumenopthalnus* with size ranges from 10.5 cm to 19.5 cm and 15 cm to 21 cm respectively. (Figure 13)

Base on ICTD data, Physical oceanographic properties such as temperature, salinity, dissolved oxygen and pH of purse seine exploration covered by M/V Maya-Maya is shown in Table 2. It indicates that the temperature profile of the surveyed areas varies from 23°C to 28°C while the salinity and dissolved oxygen slightly varies from 34.1 ppt to 34.5 ppt and 4.1 ml/ to 4.5 ml/l respectively. Sea water pH remains constant to 8.25 throughout the four areas. The fishing operation's shallowest depth was 41.3 meters and deepest at 84.7 meters. Inspite of the variation in depth the temperature, salinity, dissolved oxygen and pH remains relatively similar. Gonzales et. al. (1987) stated that there is no great variation on the horizontal distribution of temperature of the surface water which ranges from 26 to 29°C. He also stated that salinity distribution is highly variable owing to the effect of river run-off, variation in precipitation rate, and mixing processes in coastal waters. (Table 2).

Table 2. Physical Oceanographic Data.

Physical Oceanographic Data
Purse Seine Operations
Fishing Station Profile from M/V SEAFDEC
South China Sea: Western Philippines
April-May 1998

Stations	Temperature	Salinity	Dissolve Oxygen	pH
9	23.5 °C	34.5 ppt	4.3 ml/l	8.25
15	26.0 °C	34.1 ppt	4.2ml/l	8.25
16	27.0 °C	34.5 ppt	4.2ml/l	8.25
24	28.0°C	34.5 ppt	4.5ml/l	8.25

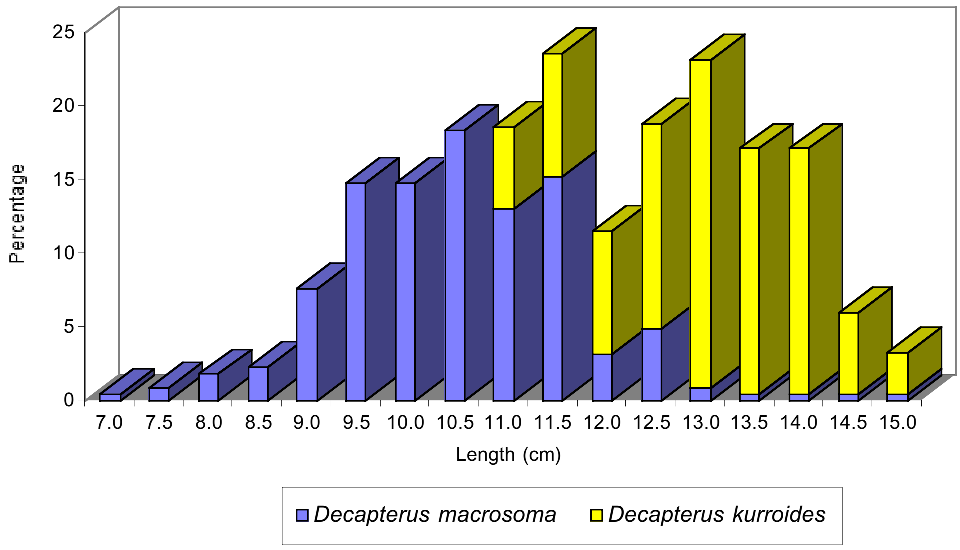

Fig. 6. Length composition of *Decapterus macrosoma and D. kurroides* in Stations 15.

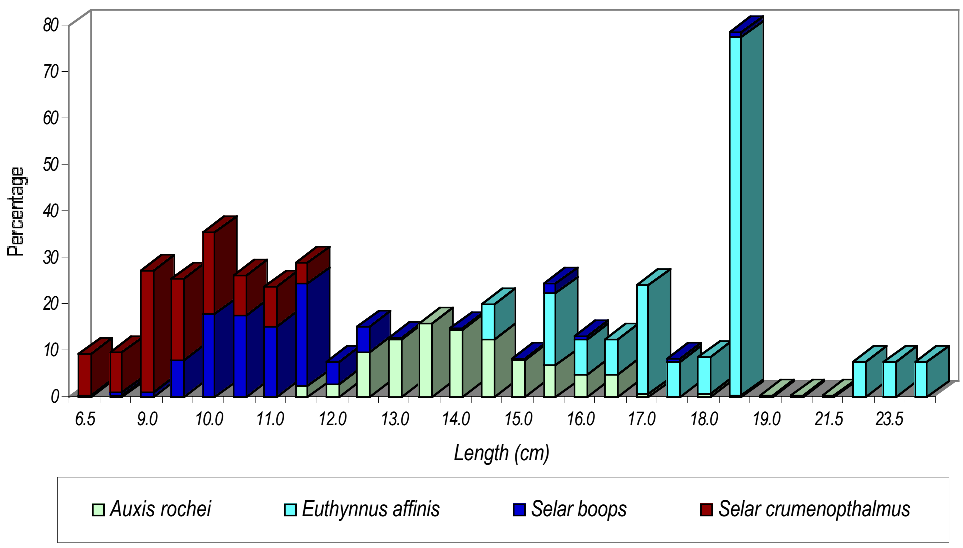

Fig. 7. Length composition of other species in Stations 15.

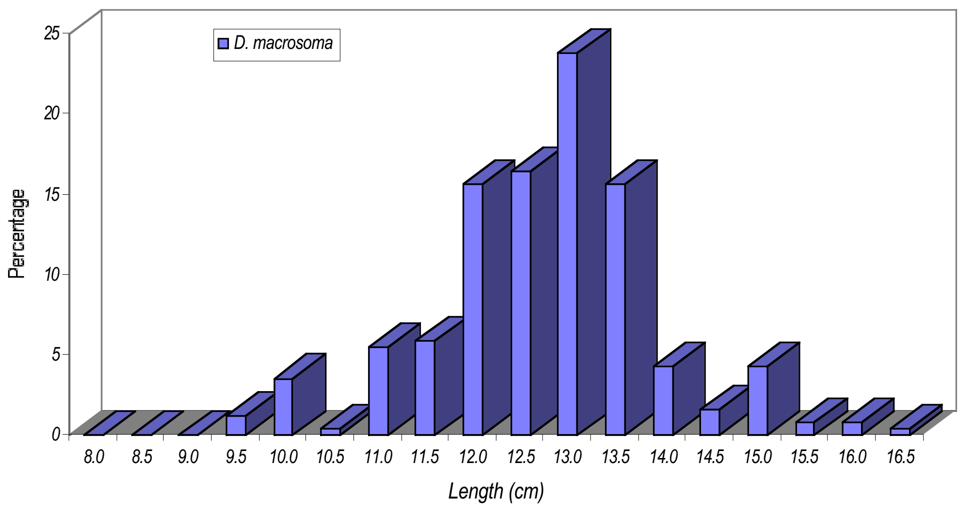

Fig. 8. Length composition of *Decapterus macrosoma* in Stations 16a.

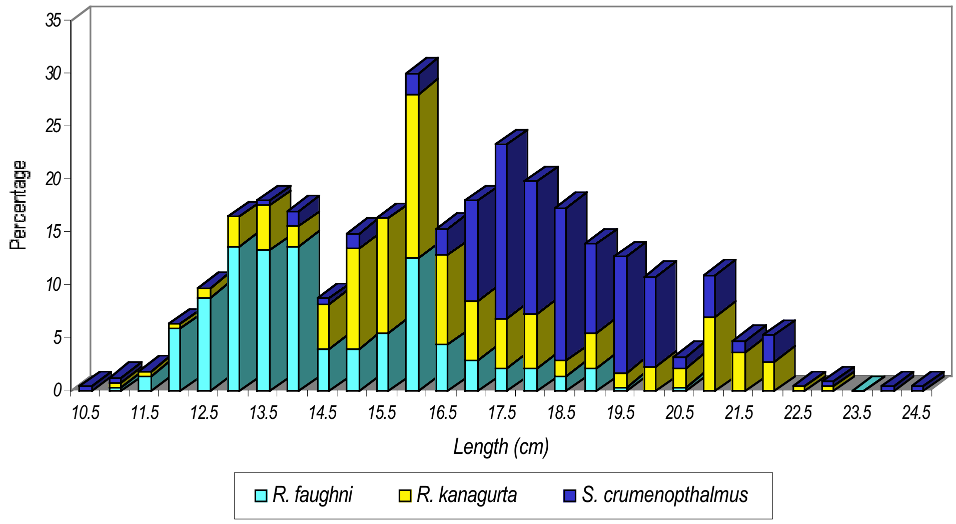

Fig. 9. Length composition of other species in Stations 16a.

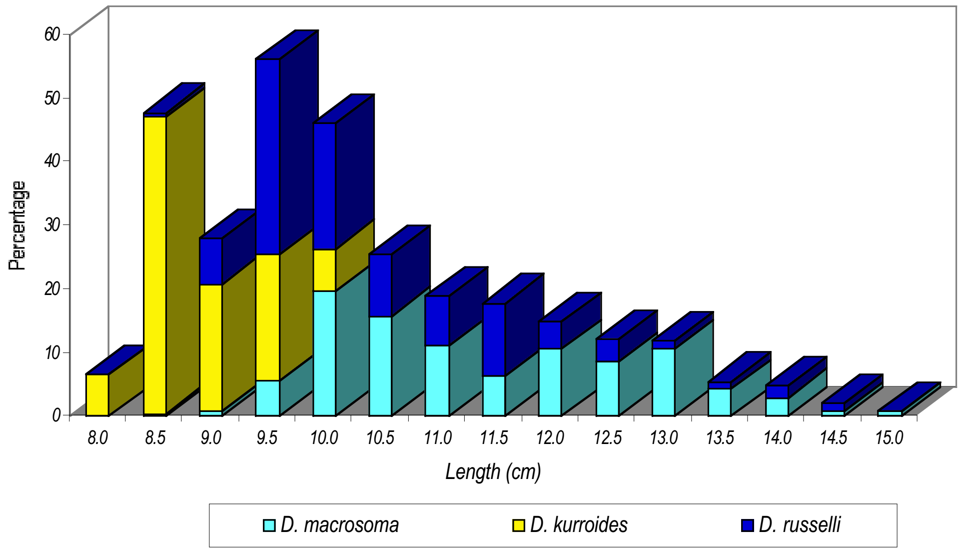

Fig. 10. Length composition of *Decapterus spp.* in Stations 16b.

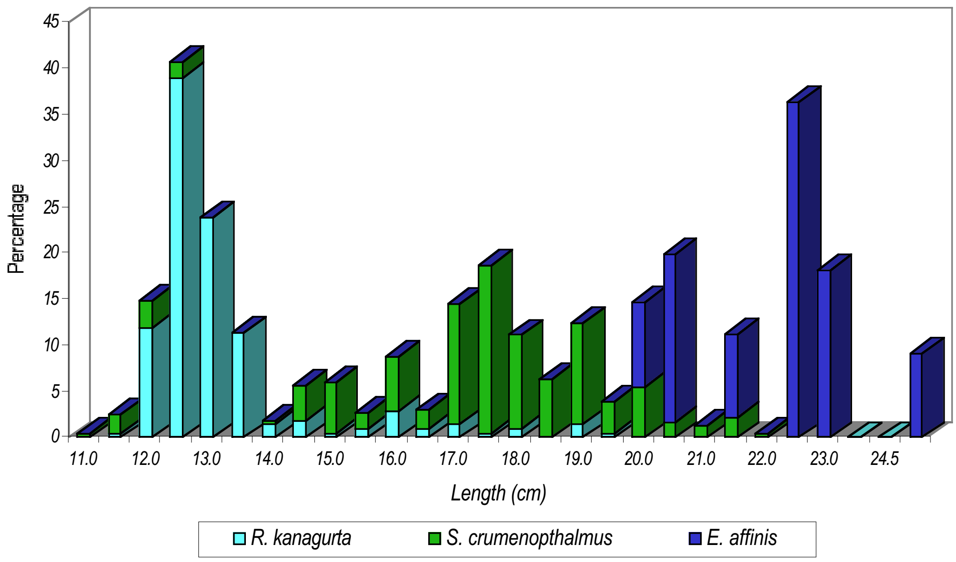

Fig. 11. Length composition of other species in Stations 16b.

Discussions

Success in purse seine fishing operation largely depends on the characteristics of the fishing ground. In the Philippines, the peak fishing season was during the Southwest Monsoon in Palawan water and Northeast Monsoon in the Visayan water (Masthawee 1986). A study made by Dickson and Pastoral (1997) on the seasonal distribution of catch for one year indicates that lowest catch rate was noted during the onset of the Northeast Monsoon in November and December while peak month occurred in the warmer month of April to June. Peak season of round scad composed mainly of *D. ruselli* and *D. macrosoma* period (August 1978 and July 1979) where 50% were small sizes having immature gonads. She also stated that only during tradewinds (April 1979 and April 1980), bigger sizes of all samples were found having 14.5 cm to 20.5 cm and 16.0 cm to 22.5 cm., respectively.

It was observed in Table 1 that *D. macrosoma* was present throughout the station and dominates the population at all times while *D. kurroides* and *D. russelli* was in lesser quantity within the surveyed area. Further, other species of Decapterus were rarely found such *as D. macarellus* and *D. maruadsi*. In the Gulf of Thailand, round scad was generally found at the depth of 20 to 70 meters of which two kinds of round scad can be found namely *D. maruadsi* and *D. macrosoma* but there are times that *D. macarellus* occurred (Bhatiyasevi, 1997).

D. macrosoma was the only species of round scad caught in station 9 (off Candon, Ilocos Sur) having 30% of the station's total catch. It was out weighed by *Auxis rochei* at 36.5%. *Auxis thazard, Euthynnus affinis, Loligo spp. Sadinella longiceps and Selar crumenopthalmus* were among the other species caught. At station 15 (off Dasol, Pangasinan) *Thunnus albacares* has the highest catch contribution of about 24.87% followed by *Selar boobs* 21.92% and 0.25% respectively. The occurrences of *Selar sp.* and *Thunnus sp.* that eat the round scads probably had cause the decrease in the population of the said fish. Other species and fish caught were *E. affinis*, *A. rochei*, *Selar spp.*, *R. faughni*, *Caranx malabaricus*, *Caranx armatus*, *Scomberoides lysan* and *Priancanthus spp*. (Table 1)

Highest catch of *D. macrosoma* was observed both in the two purse seine operations at station 16 (off Subic Bay Zambales) and contributed of about 94.78% for the first hauling and 62.42% for the second hauling. The said fish remained dominant in station 24 (off Palauan, Mindoro) having 46.99%. Other species caught within the two stations were *Euthynnnus affinis, Selar spp., Rastrelliger kanagurta, Sphyraena jello, Scomberoides lysan*, *Leiognathus ruconius, Emilithcthyes nilidus, Megalaspis cordyla* and *Priacanthus sp.* (Table 1)

Tuna and tuna like fishes which includes *Auxis rochei* (bullet tuna), *A. thazard* (frigate tuna), *Thunnus albacares* (yellowfin tuna) and *Euthynnus affinis* (eastern little tuna) were caught in the upper latitude such as in latitude 16°C (Candon, Ilocos Sur) and 18°C (off Dasol, Pangsinan) having the depths of 144 and 152.5 meters respectively. Ordoñez' (1988) in his presentation of the overview of the marine fishery resources of the Philippines tuna and tuna like fishes are mostly caught in the two earlier areas mentioned. With the presence of the said fishes in the area, occurrence of *Loligo spp.* (squid) was observed extending to latitude 15°C (off Subic Bay). Other species caught at latitude 16°C were *Decapterus spp., Caranx malabaracus, Caranx armatus, Scomberoides lysan,* and *Priancanthus sp*. However, at latitude 15°C occurrences of *Sphyreana jelo*, (banded baracuda), *Rastrelliger spp., R. ruconuis, Emilichthyes nilidus, Megalaspis cordyla* and *Priancanthus sp.* were observed. Further at latitude 15°C tuna and tuna like fishes were not found since the depth of the ocean floor is only 74.34 meters (Table 1). Temperature within the area varies from 23.5 to 26°C (Table 2).

At the lower latitude of the surveyed area, occurrences of shortfin scads *(Decapterus macrosoma)*, big-eyed scads *(S. Crumenopthalmus)* and indian mackerels *(Rastrelliger kanagurta)*

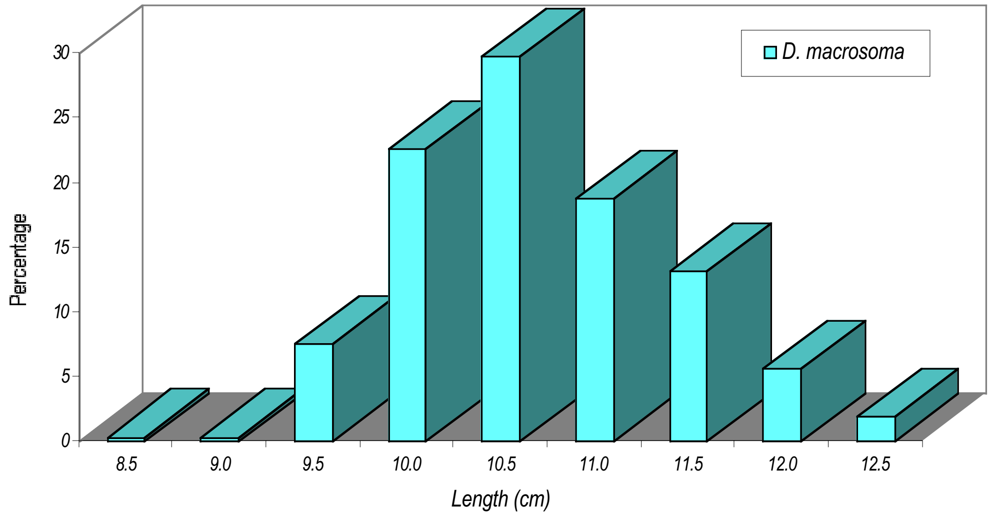

Fig. 12. Length composition of *Decapterus macrosoma.* in Stations 24.

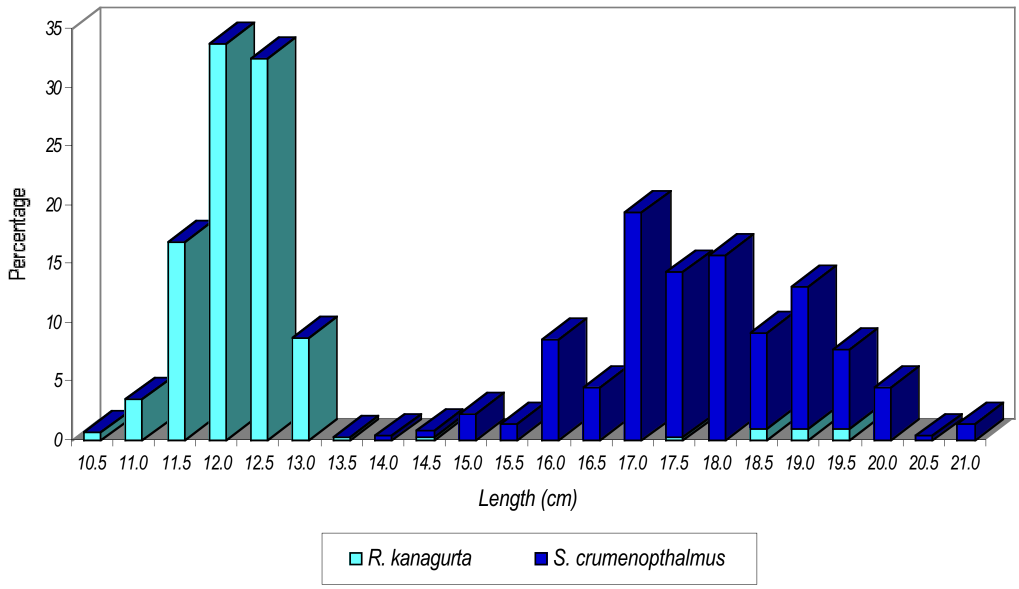

Fig. 13. Length composition of other species in Stations 24.

were observed and caught at the depth of 81 meters. Temperature within the areas was slightly higher compared to the upper latitude which ranges from 27 to 28°C. *Euthynnus affinis* and *Priacanthus sp.* were also caught at the same area.

Although there is no clear evidence on the heavy exploitation of pelagic stocks due to increasing numbers of fishing boats and fisherman, destructive fishing, capture of juvenile and man-induced stress such as pollution had apparently resulted in a decline of catch rates in the Philippines pelagic species (Malig et.al. 1987). Most of the areas in the coastal waters of Southeast Asia Regions in the Western Pacific according to Chikuni (1987) may have nearly fully exploited which includes roundscad. Excessive fishing efforts has caused a decrease in fish production, size of individual fish caught and changed in composition of fish in the Java Sea that further resulted to the extension of fishing ground to the South Sulawesi area (Naamin 1987).

Conclusions

1. Roundscad were present at all times during the surveys with the dominant species of *D. macrosoma, D. russeli* and *D. kurroides.*
2. Most of the *Decapterus spp.* found in Area III, Western Philippines were juvenile less than 13 cm, several were at Age Group I (13 cm. to 19.5 cm) and a few at matured stage of Age Group Age Group IV and V (22 cm to 28 cm).
3. Roundscads, big-eyedscads and Indian mackerels were dominantly present in the lower latitudes of the waters of Western Philippines while tuna and tuna like fishes such as yellowfin tuna, eastern little tuna, bullet tuna, frigate tuna and oceanic squid are distributed in the upper latitudes.

Acknowledgment

The authors wish to thank Director Dennis B. Araullo, Atty. Reuben A. Ganaden Assistant Director, Mr. Jose Ordoñes and Mrs. Alma C. Dickson for their encourangement and support on the inclusion of the project in the Joint SEAFDEC-BFAR Exploratory Survey in the South China Sea.

We are also grateful for the assistance of the Officers and crew of M/V MAYA-MAYA under the leadership of Captain Fortunato Cabezas during actual Sardine Fishing Operation, Mr. Jonathan Dickson for technical advisory support, Ms. Marylene Mandreza for encoding and analysing the data; Mr. Zaldy Perez for finalizing this report.

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Catch of Experimental Longline, Purse Seine and Handline in the South China Sea, Area III: Western Philippines

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ABSTRACT

This paper presents the tuna longline fishing operation conducted in western Philippine waters as well as the port sampling conducted in Zambales.

The longline fishing operation was not successful in catching tuna but caught the deep swimming species such as sharks, lancet fish and opah. The undefined and shallow thermocline might have contributed to the unsuccessful fishing operations. Another reason might be the spatial distribution of tunas brought about by the El Niño event, which causes the spreading of the warm water mass from the western Pacific Ocean to the eastern Pacific Ocean allowing the yellowfin tunas to have a wider space to move.

Yellowfin tuna stock in the western Philippine waters belongs to the juvenile and sub-adult population while the skipjack tunas belong to the adult population as most of the catch observed during port sampling were mature. The juvenile and sub-adult stages of yellowfin tunas were not the proper size for the longline fishery, which may explain in part why no tuna was caught during the research cruise. These sizes are available principally to the purse seine fishery as observed in the port sampling survey.

Keywords: tuna resources, western Philippine waters

Introduction

The South China Sea is one of the major fishing grounds for tunas in the Philippines. However, major fishing activities are limited to the first half of each year because of the change of weather during the rest of the year. A fishing fleet is composed of one mother boat or the purse seine boat, one light boat, one skiff boat and two carrier boats that alternately transport the catch from the mother boat to the landing center. Normally the large fishing companies deploy their mother boat in the South China Sea from the first five to six months and have to move their payaos or Fish Aggregating Device (FAD) to other fishing grounds of the country when the sea becomes rough. Fishing boat operators who are based in the provinces facing South China Sea can do limited fishing during the second half of the year on a daily basis. Their payaos are located close to shore and the mother boat can fish during calm weather at least once a day. Handline fishing boat also fish when the weather permits them to operate in the South China Sea, also on a daily fishing operation.

The tunas are caught the whole year round in western Philippine waters. However, the magnitude of catches depend on the competence of the fishermen to fish during the second half of the year brought about by the rough sea condition. Tunas particularly yellowfin, bigeye and skipjack are the main catch and the targeted species of the fishing companies operating in South China Sea. Roundscad is the major by-catch, while rainbow runner, dolphinfish, trigger fish are also caught by purse seine in deeper waters while other small pelagics are caught in shallower waters, like, big-eyed scads and mackerels. Large companies normally catch tunas for the canning factories while the catch of the smaller fishing boat operators go to the local market and are sold fresh or chilled.

The major fishing gears used in South China Sea are purse seine and handline. Almost all fishing operations by the purse seines are done using payaos. Handline fishing are also done within the vicinity of payaos. Payaos are an important accessory in tuna fishing in the country. It is widely used not only for tuna fishing but also for fishing small pelagics. Fish schools are first aggregated around payao by using a light boat that starts lighting a payao after sunset until fishing operation starts which is normally done early in the morning at around four o'clock.

This report cover fishing operations using a longline gear conducted on board MV SEAFDEC along the western Philippine waters as well as activities conducted during port sampling in Masinloc, Zambales. Port sampling data was used in this report due to the absence of data from the SEAFDEC Cooperative Research Cruise III for the proposed study on the biology of tuna in South China Sea.

Materials and Methods

Experimental longline fishing

A total of ten (10) longline fishing operations were conducted by the MV SEAFDEC (Figure 1). The ten fishing operations were conducted in pre-selected oceanographic stations. Data on fishing operations were recorded using a prepared fishing log form (appendix 1). The longline fishing operations is discussed in a separate paper included in the report of the SEAFDEC Collaborative Research Cruise III (Dickson et. al., this vol.).

Port Sampling

Data on port sampling conducted in Masinloc, Zambales during the months of April and May 1998 was used in this report. The data were collected in two landing sites in Masinloc, Zambales (Fig. 1). These data were utilized to supplement the results of the longline fishing made during the SEAFDEC Collaborative Research Cruise III.

A total of ten sampling days per month were made for the two-month period for both purse seine and handline fishing vessels. Data collected included the following: total landed catch by fishing boat/gear, number of fishing boat unloading that day, length and weight measurements of fish.

Results and Discussion

The ten longline experimental fishing operations did not yield any catch of tuna. However, other fish species were caught such as lancet fish which dominated the catch, sharks and opah. A total of 36 pieces of lancet fish were caught. In addition two unidentified sharks, one tiger shark, one short fin mako shark, two small tooth thresher shark and one opah were caught (Table 1). Only one of the ten fishing operations did not yield any catch.

Large adult tunas are known to swim just above the thermocline. However, during the research cruise, the thermocline depths were not clearly defined and observed to be shallow ranging from about 25 m to 60 m. In the Philippines the thermocline is at depths between the surface and 100 m with a mean temperature decrease of only 0.03ºC/m (Selga, 1931b, CSK 1974, 1980). Wyrtki (1961) showed that there was evidence of a thermocline between 100 and

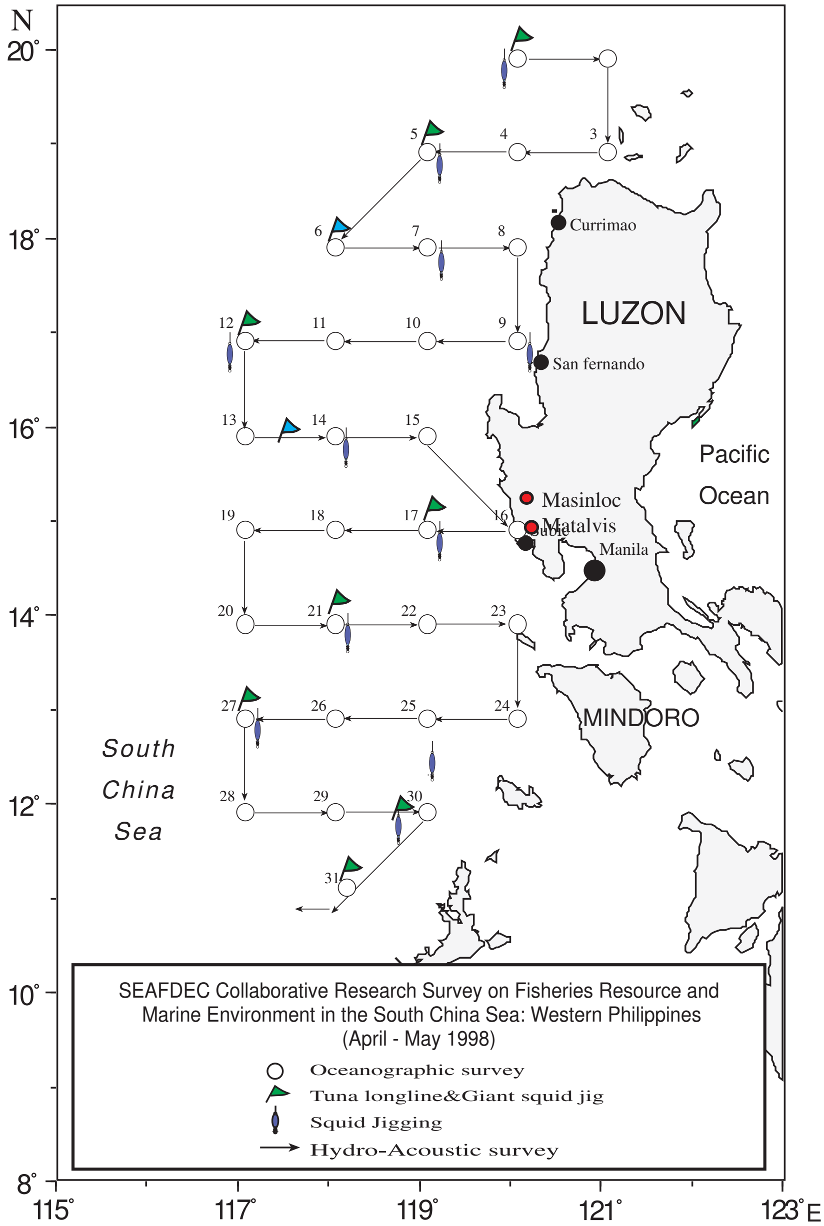

Fig. 1. The ten tuna longline fishing stations off Western Philippines.

300 m where the temperature declines swiftly to 12-15ºC. Magnusson (1970) also reported the thermocline in Sulu Sea and Northern Palawan to be between 100 and 150 m. The report also showed that the thermocline can change in depth and thickness rapidly over a short period of time and that this would have an important effect for pelagic fishes. The effect of El Niño might have contributed to the shallow thermocline level as in the western Pacific where the thermocline become shallower during El Niño events (TOGA).

Relative to the longline fishing done, setting might not have been properly payed out at the sustained level of thermocline, which may be one of the reasons why there was no tuna caught. Due to the spreading of the warm water mass from the western Pacific to the eastern Pacific waters during El Niño events, the tunas may have moved out of the South China Sea and are spatially dispersed. Instead deep swimming marine species were caught as shown in table 1.

The result of the port sampling is presented in tables 2 to 10. Skipjack was the dominant catch of purse seine contributing 39% of the total catch in April followed by yellowfin tuna

(37%) and frigate tuna (15%). The rest of the catch was contributed by the other fish species. In May, roundscad pre-dominated the catch of purse seine contributing 30% followed by yellowfin tuna (25%), skipjack tuna (19%) and frigate tuna (13%). Other species included in the total catch are shown in table 2.

Yellowfin tuna was the major catch of handline in April and May contributing 91% and 93% respectively. Bigeye tuna was recorded second in April with a total landed catch of 344 kg while skipjack tuna was the second dominant catch of handline in May recorded at 140 kg (Table 3).

Handline catch of yellowfin was mostly between the 22 to 46 cm size class with a few large yellowfin between 114-140 cm recorded during the 2-month survey. In the case of purse seine, the smallest and biggest yellowfin tuna caught was 10 cm and 65 cm both observed in May. Majority of the purse seine catch were from 24 to 28 cm and relatively larger size observed were between 40 to 50 cm. The number and size of yellowfin observed in April and May during the port sampling may also indicate that large yellowfin tuna which is the target of longline fishing operation might not be in the vicinity of South China Sea and may be in other bodies of water. Simpson, *et. al*. (1976) reported that the tunas from the Moro Gulf moved to Sulu Sea as

Table 1. Species and number of catch during the tuna longline fishing operation in western Philippine waters. See also Fig. 1.

Date	Fishing Station No.	Species	Number	Remarks
April 18, 1998	*1*	*Lancet Fish (Alepisaurus ferox)*	*4*	
April 20, 1998	*2*	*Lancet Fish (Alepisaurus ferox)* *Shark (unidentified)*	*5* *1*	
April 21, 1998	*3*	*Lancet Fish (Alepisaurus ferox)* *Shark (unidentified)*	*1* *1*	
April 26, 1998	*4*	*Lancet Fish (Alepisaurus ferox)*	*3*	
April 27, 1998	*5*	*Lancet Fish (Alepisaurus ferox)*	*1*	
April 29, 1998	*6*	*Lancet Fish (Alepisaurus ferox)* *Tiger shark (Galeocerdo cuvier)*	*5* *1*	
May 1, 1998	*7*	*Lancet Fish (Alepisaurus ferox)*	*5*	
May 6, 1998	*8*	-	-	*No catch*
May 8, 1998	*9*	*Lancet Fish (Alepisaurus ferox)*	*6*	
May 9, 1998	*10*	*Lancet Fish (Alepisaurus ferox)* *Short fin mako shark (Isurus oxyrinchus)* *Small tooth thresher shark (Alopias pelagicus)* *Opah (Lampris gutatus)*	*6* *1* *2* *1*	

Table 2. Species composition of purse seine catch (in kg) landed in April and May 1998 at Masinloc and Matalvis, Zambales.

Species	April (kg)	May (kg)
Yellowfin tuna (*Thunnus albacares*)	41,837	54,896
Bigeye tuna (*Thunnus obesus*)	2,597	6,135
Skipjack tuna (*Katsuwonus pelamis*)	44,185	41,605
Frigate tuna (*Auxis thazard*)	16,878	27,972
Bullet tuna (*Auxis rochei*)	2,516	-
Roundscad (*Decapterus* spp.)	3,288	66,893
Rainbowrunner (*Elagatis bipinnulatus*)	-	17,824
Trigger fish (Balistidae)	1,830	2,863
Dolphinfish (*Coryphaena hippurus*)	-	3,374

Table 3. Species composition of handline catch (in kg) landed in April and May 1998 at Masinloc and Matalvis, Zambales.

Species	April (kg)	May (kg)
Yellowfin tuna (*Thunnus albacares*)	6,156	5,014
Bigeye tuna (*Thunnus obesus*)	344	94
Skipjack tuna (*Katsuwonus pelamis*)	34	140
Eastern little tuna (*Euthynnus affinis*)	4	-
Rainbow runner (*Elagatis bipinnulatus*)	48	-
Blue marlin (*Makaira mazara*)	75	104
Dolphinfish (*Coryphaena hippurus*)	76	53
Big-eyed scad (*Selar crumenophthalmus*)	10	-

tunas in Sulu Sea are a year older than the tunas in Moro Gulf. They also reported that Moro Gulf and Sulu Sea are probably nursery areas for both skipjack and yellowfin tunas as most of the these tunas are 1, 2 and 3 years old. Some tunas from Sulu Sea probably move further to South China Sea and eventually move out of South China Sea to Northern Philippine Waters then to the Pacific Ocean. This port sampling observation will also tell us that probably the yellowfin tuna stock during April and May in the western Philippine waters belongs to the juvenile and sub-adult population. This may be the main reason why no large tunas were caught during the longline fishing operation during SEAFDEC cruise III.

Table 4. Length frequency data of yellowfin tuna caught by handline off western Philippines waters.

Length Class (cm)	Number April	Number May
20	3	-
21	-	-
22	-	-
23	1	1
24	2	6
25	15	12
26	-	-
27	-	-
28	13	12
29	-	-
30	13	10
31	-	-
32	-	-
33	-	-
34	3	-
35	10	5
36	1	-
37	2	-
38	11	1
39	-	-
40	2	20
41	-	-
42	5	-
43	4	5
44	-	-
45	25	8
46	2	2
47	15	3
48	21	3
49	-	-
50	-	-
=	=	=
95	-	-
96	-	-
97	1	-
98	-	-
99	-	-
100	-	-
101	-	-
102	-	-
103	-	-
104	-	-
105	-	1
106	-	-
107	-	-

Length Class (cm)	Number April	Number May
108	-	1
109	-	-
110	-	-
111	-	-
112	-	-
113	2	-
114	-	-
115	1	1
116	3	1
117	-	4
118	1	3
119	-	1
120	-	-
121	-	-
122	2	-
123	-	-
124	-	-
125	3	1
126	2	-
127	-	-
128	1	2
129	-	-
130	1	3
131	-	-
132	-	-
133	-	1
134	3	-
135	2	-
136	1	1
137	3	-
138	2	1
139	-	-
140	-	1
141	-	-
142	1	-
143	-	-
144	1	-
145	-	-
146	-	-
147	-	-
148	-	-
149	-	-
150	1	-
Total	**179**	**110**

Table 5. Length frequency data of yellowfin tuna caught by purse seine off western Philippines waters

Length Class	Number	
(cm)	April	May
10	2	3
11	-	-
12	-	-
13	-	-
14	-	-
15	-	12
16	-	1
17	-	-
18	-	1
19	-	-
20	-	15
21	-	-
22	-	2
23	-	-
24	30	2
25	80	13
26	5	3
27	5	3
28	96	-
29	1	-
30	11	12
31	-	-
32	-	1
33	-	-
34	-	3
35	6	13
36	-	13
37	-	4
38	1	3
39	-	9
40	5	22
41	-	1
42	3	22
43	13	20
44	1	15
45	33	35
46	11	20
47	33	19
48	23	19
49	1	22
50	-	27
51	-	-
52	-	8
53	-	2
54	-	7
55	-	4
56	-	5
57	-	-
58	-	-
59	-	-
60	-	10
61	-	-
62	-	6
63	-	2
64	-	3
65	-	1
Total	**360**	**383**

Table 6. Length frequency data of bigeye tuna caught by handline off western Philippines waters.

Length Class	Number	
(cm)	April	May
25	April	-
26	3	-
27	-	-
28	-	-
29	2	-
30	-	-
31	1	-
32	-	-
33	-	-
34	-	-
35	1	-
36	1	-
37	-	-
38	-	-
39	2	-
40	-	5
41	-	-
42	-	-
43	-	2
44	-	-
45	-	3
46	4	2
47	-	-
48	-	1
=	2	-
90	-	-
91	1	-
92	-	-
93	-	-
94	1	1
95	-	-
96	3	1
97	-	-
98	1	-
99	-	-
100	-	-
101	-	-
102	-	-
103	-	-
104	-	-
105	-	-
106	-	-
107	-	-
108	-	1
109	-	-
110	-	-
111	-	-
112	-	-
113	-	1
114	-	-
115	-	-
=	1	
137	1	-
Total	**24**	**16**

Table 7. Length frequency data of bigeye tuna caught by purse seine off western Philippines waters.

Length Class (cm)	Number April	Number May
15	1	-
16	-	-
17	-	-
18	-	-
19	-	-
20	-	-
21	-	-
22	-	-
23	-	-
24	3	-
25	9	-
26	2	-
27	3	-
28	15	-
29	-	-
30	2	-
31	-	-
32	-	-
33	1	-
34	-	-
35	-	-
36	-	-
37	-	-
38	-	-
39	-	1
40	1	3
41	-	-
42	1	3
43	-	1
44	4	-
45	-	12
46	-	2
47	2	-
48	1	3
49	-	-
50	-	2
51	-	-
52	-	1
53	-	-
54	-	-
55	-	-
56	-	1
57	-	-
58	-	-
59	-	-
60	-	1
Total	45	30

Table 8. Length frequency data of skipjack tuna caught by handline off western Philippines waters.

Length Class (cm)	Number April	Number May
20	1	-
21	-	-
22	-	-
23	-	1
24	-	1
25	-	2
26	-	-
27	-	-
28	1	10
29	-	-
30	4	2
31	-	-
32	-	-
33	-	-
34	-	-
35	1	-
36	-	-
37	-	-
38	-	-
39	-	-
40	1	1
41	-	-
42	1	-
43	-	4
44	-	-
45	6	-
46	2	1
47	3	-
48	4	2
Total	24	24

Table 9. Length frequency data of skipajck tuna caught by purse seine off western Philippines waters.

Length Class	Number	
(cm)	April	May
15	2	-
16	-	-
17	-	-
18	1	-
19	-	-
20	6	-
21	-	6
22	-	-
23	2	-
24	7	-
25	53	-
26	1	3
27	2	2
28	43	1
29	-	2
30	18	-
31	-	4
32	-	1
33	1	-
34	1	-
35	10	2
36	1	12
37	-	9
38	2	1
39	-	4
40	11	5
41	-	17
42	8	-
43	5	13
44	-	12
45	18	9
46	3	18
47	-	15
48	7	19
49	-	11
50	-	24
51	-	16
52	-	-
53	-	8
54	-	1
55	-	3
56	-	4
57	-	2
58	-	2
59	-	1
60	-	5
61	-	14
62	-	-
63	-	1
64	-	1
65	-	1
66	-	2
Total	202	251

Table 10. Length frequency data of frigate tuna caught by purse seine off western Philippines waters.

Length Class	Number	
(cm)	April	May
20	2	-
21	-	-
22	-	-
23	1	-
24	4	-
25	23	-
26	4	-
27	-	-
28	7	-
29	-	-
30	18	-
31	-	-
32	-	-
33	1	-
34	5	-
35	19	-
36	3	-
37	-	-
38	19	-
39	2	7
40	6	12
41	-	-
42	3	7
43	1	1
44	-	-
45	1	-
46	1	-
Total	120	27

Table 11. Length frequency data of bullet tuna caught by purse seine off western Philippines waters.

Length Class	Number	
(cm)	April	May
20	1	-
21	-	-
22	-	-
23	-	-
24	2	-
25	11	-
26	-	-
27	-	-
28	3	-
29	-	-
30	2	-
31	-	-
32	-	-
33	-	-
34	-	-
35	1	-
36	-	-
37	1	-
38	1	-
39	-	-
40	1	-
41	4	-
42	-	-
43	-	-
44	-	-
45	-	-
46	-	-
47	-	-
48	-	-
49	-	-
50	-	-
Total	27	-

Handline caught two-size groups of bigeye tunas, one between 22 cm to 48 cm and the larger group between 90 cm to 115 cm. The same was true for bigeye tuna catches observed landed by purse seine during the port sampling activities which also showed two modes with the first mode between 24 to 30-cm size class and another mode between 40 to 50-cm.

The size range of skipjack caught by handline was from 20 cm to 48 cm with most of the catch in the 40 to 48 cm size range. Purse seine catch of skipjack has a wide range of class interval ranging from 15 cm to 66 cm. In both gears, most of the catch observed was between 40 cm to 50-cm size class. Compared to the southern area of the country, the sizes of the skipjack caught by purse seine in the northern area were relatively larger than the catch of the purse seine operating in Moro Gulf. These sizes also showed that the bulk of the skipjack resources in South China Sea belong to the matured or adult stock as skipjack in Philippine waters are observed to start spawning at length between 40 cm to 44 cm (Ronquillo, 1962; White, 1982).

The frigate tunas caught by purse seine were also bigger in size compared with that of the frigate tunas caught in Moro Gulf. The smallest frigate tuna caught by purse seine in South China Sea was 20 cm and the largest was 46 cm observed in April. In May, most of the catch were larger than that of the catch in April. The smallest frigate tuna observed in the landed catch was 39 cm and the largest was 43 cm .

Bullet tuna was observed only in April with size ranging from 12 cm to 33 cm. Only one size class was recorded for eastern little tuna, which was observed only in April at length 30 cm.

Acknowledgement

The author would like to acknowledge the generous assistance of the crew of M/V SEAFDEC during the entire survey cruise. The support cooperation of all the scientists and researchers on board the research vessel is likewise acknowledge and appreciated.

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Appendix 1. Fishing log form for tuna longline

recorded by...

Cruise no. **Station no.** **Date**	**Name of Vessel**		**Air temp.** **Air press.** **Humidity**
Moon age	**Start shooting**	**Finish shooting**	**Water**
Weather condition	Time	Time	Surface temp.
Sea condition	*Lat.*	*Lat.*	Bottom temp.
Wind dir. **Wind speed**	*Long.*	*Long.*	Thermocline
Current Condition	**Start hauling**	**Finish hauling**	**Transparency**
	Time	Time	**Total basket number**
Depth *Speed* *Direction*	*Lat.*	*Lat.*	**No. of hook/basket**
	Long.	*Long.*	**Total catch in number**
	Shooting course/speed		**Total catch in weight**
	Setting distance		**Immersion time**
Memorandum	**Drifting information**		**Type of bait**

No.	Species	Length cm	Weight kg	Remark

Systematics and Distribution of Oceanic Cephalopods in the South China Sea, Area III: Western Philippines

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ABSTRACT

Four species of cephalopods were collected in the South China Sea, area III (Western Philippines) during April–May 1998. An oceanic species, *Sthenoteuthis oualaniensis* (Lesson, 1830) was caught by automatic squid jigging on board M.V SEAFDEC and three additional cephalopod species, *Sepioteuthis lessoniana* Lesson, 1830, *Thysanoteuthis rhombus* Troschel, 1857 and *Nototodarus hawaiiensis* (Berry, 1912) were caught by squid jigging and purse seine of M.V. Maya Maya. *S. oualaniensis* was the dominant oceanic species in the study area. Descriptions, measurements and distributions of these squids were included.

Introduction

The SEAFDEC Interdepartmental collaborative research program in the South China Sea, area III (West coasts of the Philippines) has been carry out by the research vessel SEAFDEC during 7 April –19 May 1998. 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 survey was focused on tuna, oceanic squid and other highly migratory species in the area. A number of the oceanic squid materials were collected during the investigation. Aim of the present study is to describe all these species of the oceanic squids. This research will be provided better foothold for the fishery scientists interested in the exploitation of the oceanic cephalopods in the area.

Materials and Methods

Study area

The study area is in the northern part of South China Sea (Area III, off the West Coast of the Philippines). The area covers from latitude 11°N to 20°N and longitude 117°E to 121°E, a total of 86,400 square miles (Fig.1). Most of the area is rather deep (95% being deeper than 1,000 m). It is characterized as having oceanic conditions.

Collected material

A total of 11 stations for fishing surveys on the oceanic cephalopods were carried out using a squid jigging method by M.V. SEAFDEC during 17 April to 10 May 1998 in the study area. Descriptions of fishing method are described in Siriraksophon *et al.* (1999). Collected materials were preserved in 10% neutralized formalin. All oceanic squids were not relaxed or

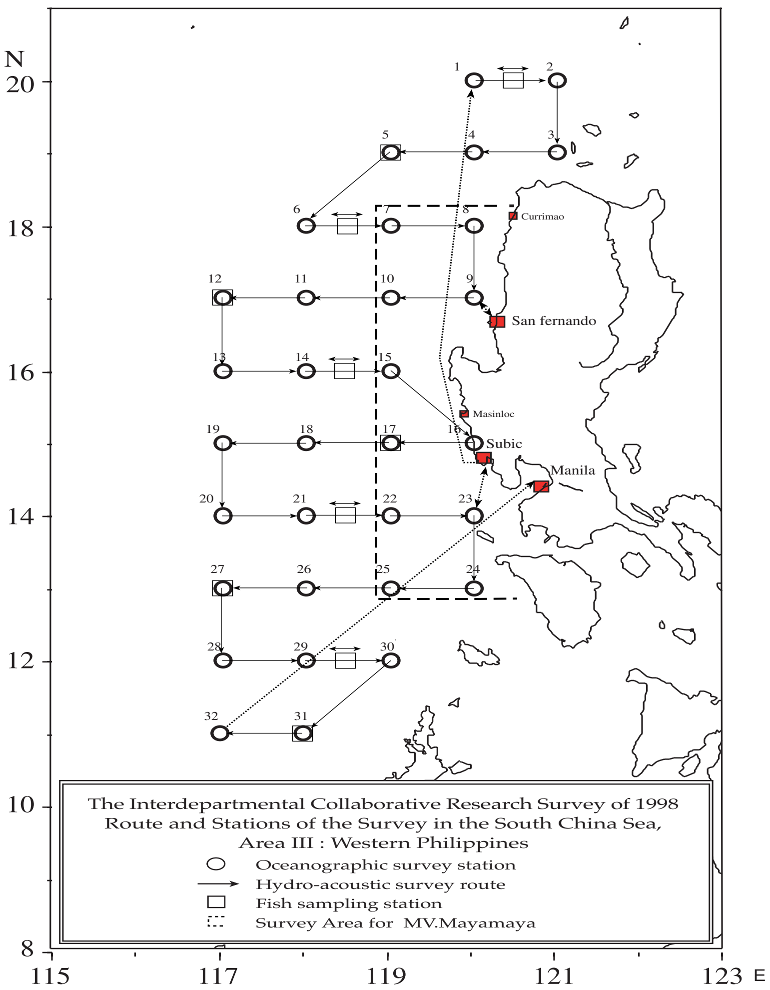

Fig. 1. Map of study area.

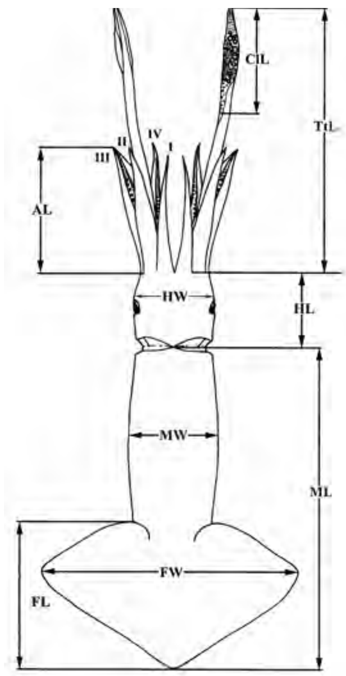

Fig. 2. Diagrammatic illustrations of the measurements in squids. Dorsal view, AL= Arm Length, ClL=Club Length, FL=Fin Length, FW=Fin Width, HL=Head Length, HW=Head Width, ML=Mantle Length, MW=Mantle Width, I=dorsal arm, II=dorso-lateral arm, III=ventro-lateral arm, IV=ventral arm, TtL=Tentacular Length.

killed prior to preservation since they were dead after capture. The fixed-specimens were later transferred to 75% ethyl alcohol for permanent storage. In order to accomplish systematics of the cephalopods in the study area, some additional material were also collected from the purse seine operated by M.V. Maya Maya.

Descriptions and measurements

All 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. The buccal mass was removed from some specimens and the beaks and radulae extracted, cleaned, and illustrated. The beaks, radulae and spermatophores were drawn with the aid of a camera lucida. The enlargement section of the spermatophores and most of the radulae were stained in methylene blue in order to get higher contrast during examination and illustration in the compound microscope.

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

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 Loliginidae Lesueur, 1821
Genus *Sepioteuthis* Blainville, 1824
sensu Vecchione *et al.* 1998

Diagnosis:

Fins occupying almost entire lateral margin of mantle, except in paralarvae. Posterior mantle not elongated into tail-like structure. Egg large, length>5 mm. Arm-sucker rings with pointed teeth around entire margin. Proximal suckers on hectocotylus unmodified. Hectocotylus without crest, hectocotylization consists of reduction in sucker size and elongation of sucker stalks along modified portion of arm to form papillae on both dorsal and ventral rows. Photophores absent. Spermatophore with short cement body.

Sepioteuthis lessoniana Lesson, 1830
Fig. 3, Table 2

Sepioteuthis lessoniana –Sasaki, 1929:127, pl. xiv, figs. 15-17, pl.29, figs.8-9, textfigs. 74-77; -Adam, 1939:21, fig.1-2, pl.I; -Voss, 1963:77-81, fig.13; -Voss & Williamson, 1971:66-67, figs. 19,20,26, pl.20; -Lu & Tait, 1983:183-190, figs. 1-4, 8a; -Roper*, et al*., 1984:109-110.

MATERIAL EXAMINED:

7 specimens, 3 males, 4 females, Purse seine operation by M.V. Maya Maya, west coast of the Philippines, 1998.

DESCRIPTION:

Mantle (Fig.3a,b) long, robust, tapering and rounded at posterior end; median antero-dorsal lobe rounded, slightly pronounced; ventro-lateral lobes pointed, conspicuous; ventral mantle margin concave. Fins large, thick, length from 83-94% of ML; anterior lobes narrow and widest at about 1/3 from the posterior end, broadly oval shape, their width from 54-71% of ML. Fins united posteriorly around the end of the mantle by a fleshy ridge. Head large, narrower than the width of anterior mantle; the neck and mantle dorsally connected by a prominent nuchal locking apparatus. Eyes large, entirely covered by a transparent secondary cornea, a distinct pore (lacrimal) present in front of anterior eye, olfactory crest behind eyes prominent (Fig.3c). Funnel (Fig.3d) strong, conical, extends deeply to the ventral surface of the head; funnel valve subterminal and well developed; dorsal funnel organ inverted V shaped, two oblong pads (Fig.3e). Nuchal cartilage fiddle-shaped, slightly wider in anterior than posterior part; funnel cartilage simple, straight and slightly curved outward at the posterior end, a deep groove present in the middle; mantle cartilage straight.

Arms stout with pointed tips, unequal in order of III.IV.II.I. Arm I short, triangular with an aboral keel along its length. Arm II flattened with a low aboral swimming keel, broadest at the middle of arm. Arm III broad, with a thick, low aboral keel. Arm IV lacks aboral keel, broad and flats web present along the edge of dorsal arm. Protective membranes strong trabeculated on arm I-III, weaker on arm IV. Biserial suckers present in all arms; diameter less than 2 mm, the size decreases distally to the tips. Ring of suckers with 17-28 sharp, acute teeth (Fig.3f). Left arm IV of male hectocotylised (Fig.3g), modification of distal 20-30%. Size and general shape of left arm similar to that of right arm. The unmodified proximal portion of arm with 25-30 pairs of suckers arranged in two rows, each sucker bears 25-30 sharp acute teeth, large on proximal part and decreasing in size towards the distal end, trabeculae protective membrane weak, similar to the right ventral arm. Modified distal portion bears biserial, long, fleshy papillae decreasing in size towards the arm tip, each papilla has a small sucker at its apex but lacks sucker rings.

Tentacles long, stout; stalk naked and laterally compressed. Club slightly expanded (Fig.3h), bordered on either side by a strong and well-developed membrane with prominent supports, aboral surface bears a strong keel. Four rows of tentacular suckers on manus and dactylus; 1-2 rows on indistinct carpus. Median manal suckers large and bear 17-18 widely spaced acute teeth (Fig.3i). Dactylus suckers small, decrease in size to distal end.

Gladius with rachis stout, broad anteriorly, then evenly narrowing to the posterior end (Fig.3j); median groove rounded, thickened laterally. Vane broad, greatest width on posterior third; thickened in a broad band on the three-fourth of posterior portion but the edge not thickened.

Buccal membrane with seven buccal lappets, supported by strong buccal membrane connectives; each lappet bears 0-7 buccal suckers, sucker ring comprises of 18-25 small, sharp teeth, which are largest on distal margin. Upper beak (Fig.3k) with long, curved rostrum and hood; hood less than half of crest, rostral tip curved and strong, wing with a large tooth at jaw angle; black to dark brown from rostral tip to anterior half of hood and wing; crest curved and unpigmented, lateral wall large. Lower beak (Fig.3l) short, strong curved rostral tip, hood short, wing large, black on rostral tip and cutting edge of anterior portion of wing, crest curved, unpigmented. Radula (Fig.3m) with seven transverse rows of teeth in both sexes; rachidian tooth short, stout with low lateral cusps, first and second lateral teeth similar to rachidian tooth but somewhat bigger; third lateral row with slender hook-like teeth; oval marginal plate.

Spermatophores (Fig.3n-o) measure about 4.5 mm in length and 0.15 mm in width, sperm mass comprises three-fourth of total length of the spermatophore. Cement body with constriction in the middle, almost separated into two parts, aboral part somewhat bigger than the oral part. Ejaculatory apparatus consists of several tightly large coils in the oral end of the spermatophore. Ink sac pyriform, lacking photophore, silvery and blue-green outer layer, with lines on the ventral side of the visceral mass on the dorsal side of the intestine.

Colour in alcohol cream; dorsal surface of mantle, fins, head and arms covered with large and dense chromatophores; less concentrated on ventral surface of mantle and absent on ventral fin surfaces; dark patch present dorsal to each eye.

Table 2. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sepioteuthis lessoniana* from the western Philippines.

	MALES				FEMALES			
Index	n	mean	S.D.(n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	3	132.3	5.7	126.0-137.0	4	130.5	11.8	122.0-148.0
MWI	3	36.8	1.9	34.7-38.3	4	37.0	2.8	35.2-41.1
HLI	3	22.4	2.6	20.7-25.4	4	21.8	5.8	17.8-30.3
HWI	3	26.3	1.4	25.4-27.9	4	25.5	1.9	23.5-27.4
FLI	3	94.0	2.0	94.0-96.0	4	91.6	2.5	88.5-93.6
FWI	3	65.9	5.3	61.1-71.6	4	64.4	5.8	57.1-71.3
$AL_{I}I$	3	31.0	3.1	28.4-34.4	4	36.1	7.2	27.8-45.4
$AL_{II}I$	3	44.6	2.1	42.9-47.0	4	41.8	4.6	35.9-45.7
$AL_{III}I$	3	52.2	3.5	48.3-55.0	4	51.8	5.7	45.8-59.4
$AL_{IV}I$	3	51.0	3.6	47.7-54.8	4	53.9	4.1	50.6-60.0
TtLI	3	116.2	20.3	93.6-132.8	4	118.7	19.3	92.5-135.2
ClLI	3	44.7	6.4	37.4-49.6	4	43.6	3.4	40.1-48.3

GEOGRAPHICAL DISTRIBUTION:

Tropical Indo-West Pacific. From the Red Sea, Arabian Sea, northern Australia to Japan and Hawaiian Islands.

REMARKS:

Adam (1939) and Lu & Tait (1983) have reviewed *Sepioteuthis lessoniana in detail*. The species is one of the most widely distributed loliginids in the Indo-Pacific; it is likely to include a number of cryptic species, as proposed by recent findings in Okinawa (Segawa *et al*., 1993). The examined material is in accordance with the description of Voss (1963).

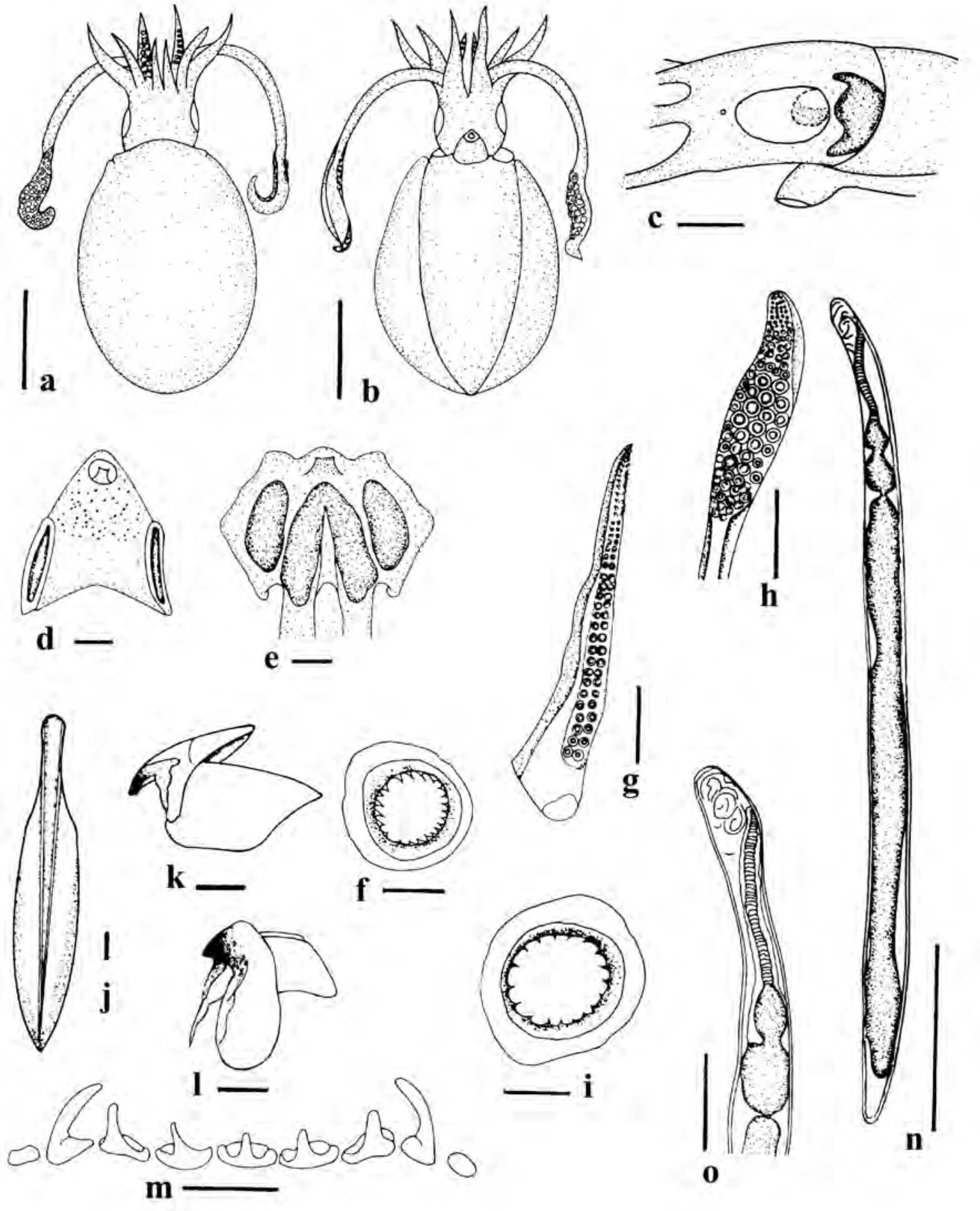

Fig.3. *Sepioteuthis lessoniana*. a, dorsal view. b, ventral view. c, head, side view. d, funnel, ventral view. e, dissected ventral view. f, 3rd arm sucker. g, hectocotylised arm. H, tentacular club. I, club sucker. j, gladius. k, upper beak. l, lower beak. m, radula. n, spermatophore. o, oral end of spermatophore. Scales: a,b,j = 50 mm; c,d,e,g,h = 10 mm; k,l = 5 mm; f,I,n = 1 mm; m, o = 0.2 mm

Family Ommastrephidae Steenstrup, 1857
Subfamily Todarodinae Adam, 1960

Nototodarus Pfeffer, 1912

Diagnosis:

Funnel groove with foveola but without side pockets, dactylus of tentacular club with quadriserial suckers, photophores absent in all life stages, right and left arms IV hectocotylized.

Nototodarus hawaiiensis (Berry, 1912)
Fig.4, Table 3

Ommastrephes hawaiiensis –Berry, 1912:434
Nototodarus sloani philippinensis –Voss, 1962:175; -Voss, 1963:128-133, fig.28
Nototodarus sloani hawaiiensis –Voss, 1962:175
Nototodarus hawaiiensis –Wormuth, 1976:2, 17-21, fig.3; -Dunning, 1988:159-168

MATERIAL EXAMINED:

5 females specimens, Purse seine operation by M.V. Maya Maya, west coast of the Philippines, 1998.

DESCRIPTION:

Mantle (Fig.4a-b) moderately long, cylindrical anteriorly about 2/3 and tapering at about the level of fins to a conical tip; median antero-dorsal lobe low, round; ventral mantle margin excavated. Fins small wider than long; anterior margins convex; lateral lobes pointed; posterior margins slightly concave to a narrow posterior point. Head stout, as broad as mantle; dorsoventrally flattened; three large olfactory crests present on posterior margin. Eyelid large, with a deep distinct sinus on the anteroventral border. Funnel stout, tapering anteriorly; funnel valve subterminal, rectangular and well developed; dorsal funnel organ sharply inverted v-shaped with oval ventral pads. Funnel groove with foveola (Fig.4d), no longitudinal ridges. Locking apparatus inverted T-shaped (Fig.4c), with a deep median pit and longitudinal groove.

Arms moderately long, unequal, in order of III.II.I.IV or II.III.I.IV. Arm I long and slender, low keel presents on basal. Arm II slightly dorsoventrally flattened, with low keel. Arm III stout, with keel and with a deep triangular swimming membrane. Arm IV trapezoidal in section, keel present. Biserial suckers in all arms. Arm sucker rings toothed with about 20 teeth all around; proximally, teeth are flattened broad platelets that grade distally into sharp, pointed teeth, the distal central tooth much enlarged, pointed and curved. No male in the present collection, therefore the hectocotylus could not be observed.Tentacles short and stout (Fig.4e). Tentacular club long, occupy about 60% of ML; carpal area indistinct; about 12 median manal suckers, with 14 to 18 large, sharp teeth, the central one enlarged.

Colour in alcohol yellow cream, dorsal surface of mantle, head, and arms covered with scattered dark gray chromatophores; skin rough.

GEOGRAPHICAL DISTRIBUTION:

Hawaiian Islands to Midway Island, South China Sea, Andaman Sea and northern Australia

REMARKS:

Unique characters of the genus *Nototodarus* are having the simple foveola in the funnel

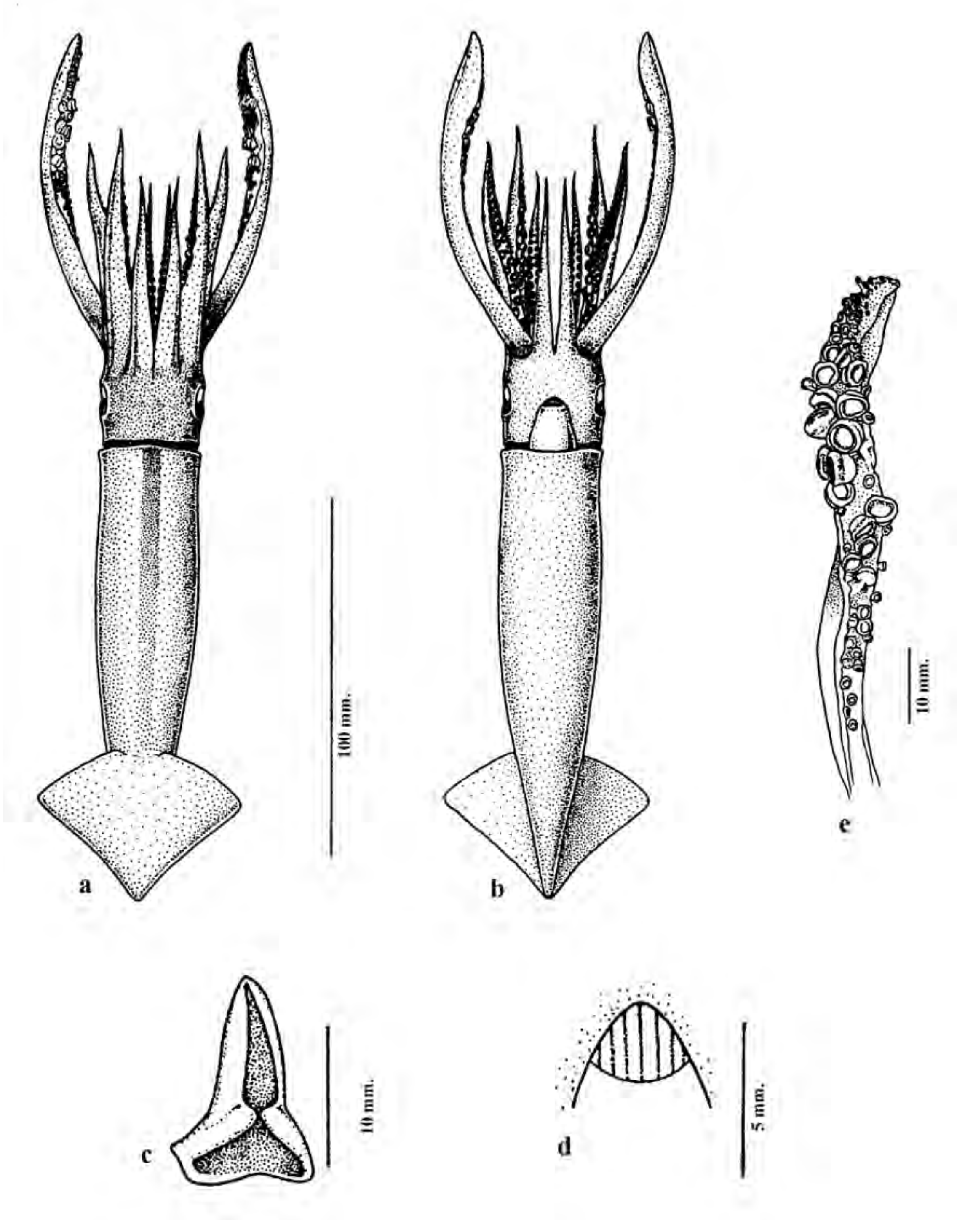

Fig.4.*Nototodarus hawaiiensis*. a, dorsal view. b, ventral view. c, funnel locking cartilage. d, foveola. e, tentacular club.

groove, absence of light organs and hectocotylization of both ventral arms in males. Six nominal forms of the genus *Nototodarus* have been described from continental shelf and slope waters of the Indo-Pacific region. According to Dunning & Forch (1998), of these six nominal species, three are considered valid: *N. sloanii* (Gray, 1849), occurring around southern New Zealand; *N. gouldi* (McCoy, 1888), occurring around northern New Zealand and southern Australia; and *N. hawaiiensis* (Berry, 1912), broadly distributed in slope waters in the Indo-Pacific region. The species differ in the structure of the hectocotylus and in the number, arrangement, and dentition of suckers on the sessile arms.

Table 3. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Nototodarus hawaiiensis* from the Western Philippines.

	MALES				FEMALES			
Index	n	mean	S.D.(n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	-	-	-	-	5	131.8	14.6	118.0-152.0
MWI	-	-	-	-	5	27.1	1.7	25.7-29.6
HLI	-	-	-	-	5	23.4	8.8	18.6-39.2
HWI	-	-	-	-	5	23.8	10.4	15.0-41.8
FLI	-	-	-	-	5	36.0	3.0	33.9-41.1
FWI	-	-	-	-	5	70.6	5.4	65.8-79.1
$AL_{I}I$	-	-	-	-	5	37.4	1.5	35.9-39.3
$AL_{II}I$	-	-	-	-	5	41.9	3.3	36.6-45.1
$AL_{III}I$	-	-	-	-	5	46.4	2.2	43.3-48.5
$AL_{IV}I$	-	-	-	-	5	42.2	5.4	33.6-48.0
TtLI	-	-	-	-	5	98.7	4.9	98.3-104.3
ClLI	-	-	-	-	5	29.7	2.8	25.8-33.6

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.5A-D, Table 4-13

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.

MATERIAL EXAMINED:

A total of 2,542 specimens were caught during the operations. Only 98 specimens were collected for identification. Data for each station is presented in Table 4-13.

DESCRIPTION:

Mantle (Fig.5A-a) long, slender, cylindrical, muscular, and tapering abruptly from the anterior margin of fins to a sharp pointed end (Fig.5A-b); median antero-dorsal lobe low rounded; ventral mantle margin slightly concave below funnel. Fins terminal, rather large, rhombic, occupying about 42-45% of the mantle length; anterior margins slightly convex; lateral margins pointed; posterior margins straight, continuous to the apex of mantle. Head large, as wide as mantle, sharply set off from the neck by a transverse ridge; each side of the head with three nuchal folds connected to the transverse ridge (Fig.5B-a). Eyes (encircled by a free eyelid, forming a rounded triangle, truncated posteriorly and with a sharp narrow anterior sinus (Fig.5B-a). Funnel large, compact and set in a deep pit on the ventral side of the head; funnel valve large and well-developed; dorsal funnel organ large and inverted v-shaped; ventral pads elongate, oval shape; foveola (Fig.5B-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.5B-c).

Arms moderately long, stout with pointed tip, unequal in order of III.II.IV.I. Arms compressed with sharp keel along the edges. Arm III triangular, broad, strongly keeled on the proximal half of arm. Protective membranes well developed with prominent trabeculae. Biserial suckers present in all arms; arm sucker rounded with about 12 sharp teeth laterally and distally, of which the median is largest (Fig.5B-d). Left Arm IV of males hectocotylized (Fig.5C-a), enlarged and thicker than other arms; proximal half of arm with 12 suckers arranged in two longitudinal rows bordered by heavy flap-like modification of the supports of the protective membrane; a series of pits in a single row present along the base of protective membrane on each side of the proximal part of arm (Fig.5C-b); distal arm devoid of suckers and papillae.

Tentacles moderately long, stout, laterally compressed, and with elongated club (Fig.5C-c). Protective membranes slightly expanded on manus, trabeculae well developed. Aboral keel present along the club. Club suckers quadriserial on dactylus and manus; two median rows of suckers 2-3 times larger than the lateral rows; carpal suckers small, arranged in two irregular rows. Enlarged club sucker dentition on dactylus and manus with about 20 sharp teeth and one in each quadrant enlarged (Fig.5C-d); carpal suckers with smooth honey rings; one to four distinct tubercles or knobs present on the carpus.

Gladius (Fig.5C-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. Buccal membrane with seven buccal lappets, and with strong ribs projecting beyond the margin in sharp points; two pores present under arm I and between arm III, continuous with each other below the overhanging dorsal connective membranes; no suckers; numerous small oval seminal receptacles surrounding the mouth of mature females. Upper beak (Fig.5D-a.) with long, sharply pointed, curved rostrum tip; jaw angle deep; hood length almost half of crest; lateral wall large. Lower beak (Fig.5D-b) with short, conical rostrum; hood short; wing large; lateral wall long. Radula (Fig.5B-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.5D-c) long and small, sperm mass comprises 50-60% of total length; cement body oval, slightly constricted at the posterior quarter of the body (Fig.5D-e); ejaculatory apparatus coiled at oral end (Fig.5D-d).

Colour in alcohol yellowish brown often with dark purple colouration in the mid-dorsal line of mantle.

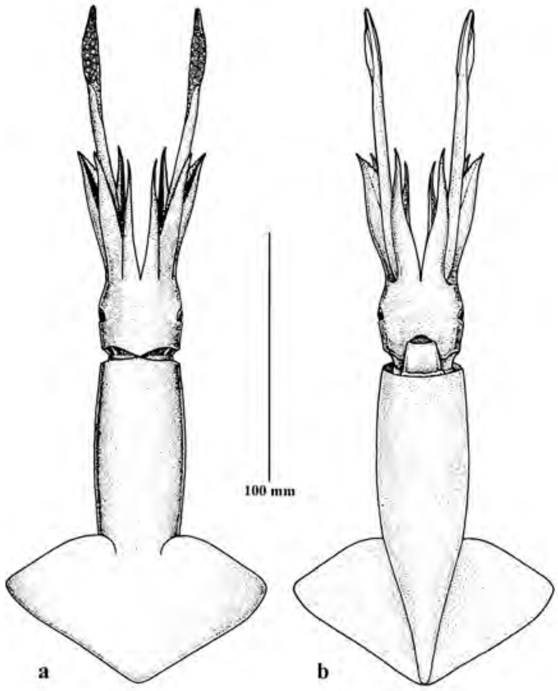

Fig. 5A. *Sthenoteuthis oualaniensis*. a, dorsal view and b, ventral view.

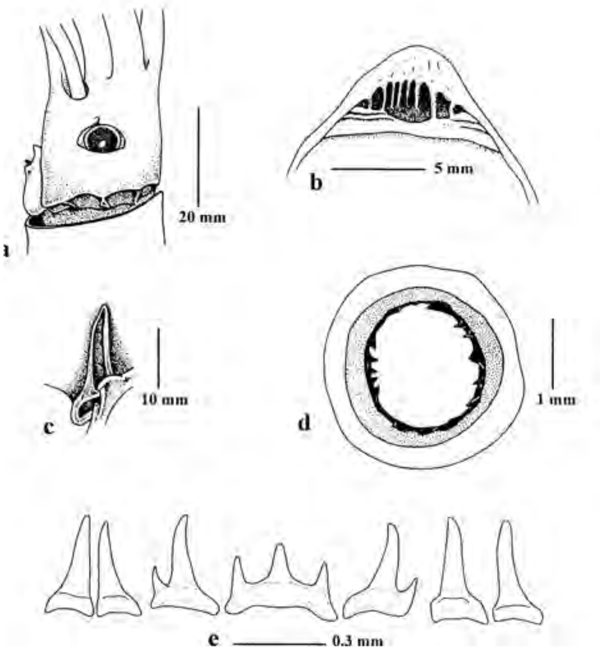

Fig. 5B. *Sthenoteuthis oualaniensis.* a, head. b, foveola and side pockets. c, funnel and mantle locking cartilages. d, arm sucker. e, radula.

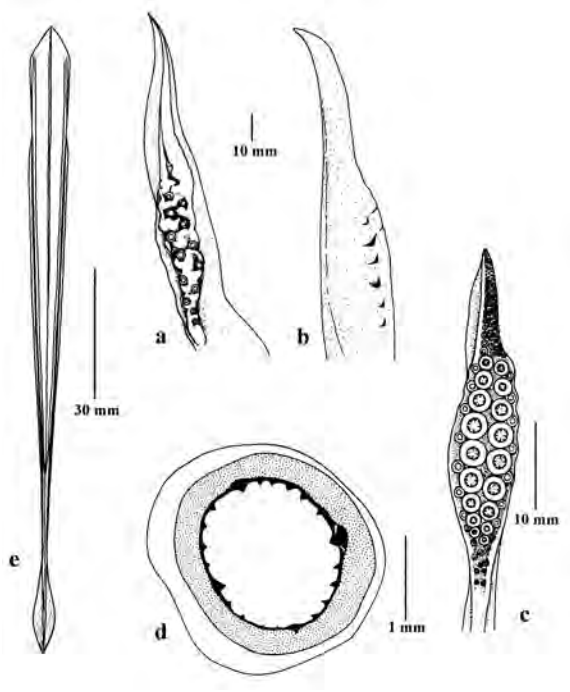

Fig. 5C. *Sthenoteuthis oualaniensis.* a, hectocotylised arm. b, lateral view of hectocotylised arm showing a series of pits. c, tentacular club. d, club sucker. e, gladius.

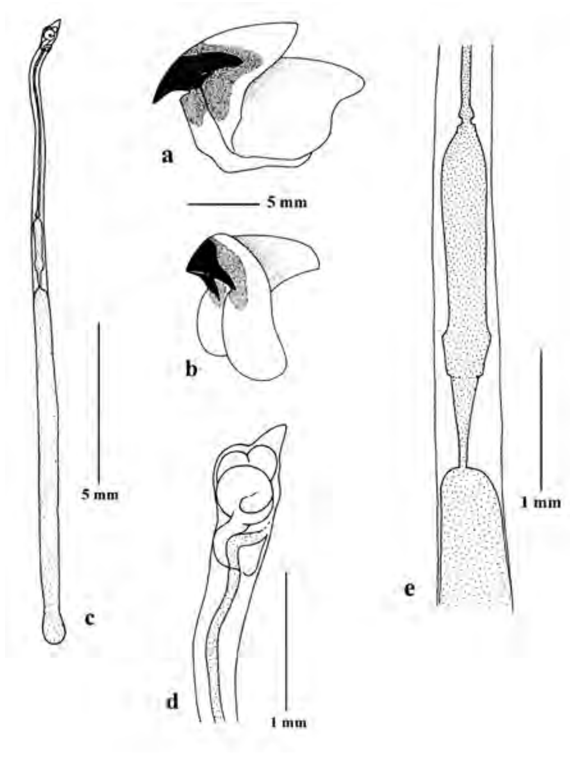

Fig. 5D. *Sthenoteuthis oualaniensis*. a, upper beak. B, lower beak. c, spermatophore. d, enlargement of oral cap. e, enlargement of cement body.

GEOGRAPHICAL DISTRIBUTION:

Tropical Indo-Pacific; from the Red Sea to Mozambique Channel and natal, from southern Japan to southern Queensland and from the south of Baja California to northern Chile.

REMARKS*:*

S. oualaniensis belongs to subfamily Ommastrephinae of family Ommastrephidae. It has unique character of the subfamily *i.e.* foveola and side pockets, another character, photophore, may be present or absent. Two forms of the species, both forms are represented by males and females, are known: one small, without dorsal photophore, another larger, with dorsal photophore (Clarke 1965; Roper *et al*. 1984). Besides the presence or absence of the dorsal photophore, they differ by the structure of the hectocotylus. Most investigators have suggested that the two forms might present two valid species, but they have not yet been described. Until Nesis (1993) has considered *S. oualaniensis* as a single species.

Table 4. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no. 1. 8G, 8E, Lat. 20º 02.6N, Long. 119º 56.8 E. Auto squid jigging, angling depth 80-120 m, time 1900-2400 hrs, surface temperature 25ºC, M.V. SEAFDEC 17 Apr. 1998, total catch in weight 25.920 kg and in number 116 pcs.

	MALES				FEMALES			
Index	n	mean	S.D. (n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	8	130.7	14.8	101.0-145.0	8	162.5	40.9	121.0-225.0
MWI	8	22.4	1.2	20.6-24.1	8	22.1	2.9	18.7-28.0
HLI	8	21.1	2.3	17.4-23.6	8	20.3	2.0	17.6-23.2
HWI	8	20.7	1.0	19.0-21.8	8	20.6	3.0	17.9-25.6
FLI	8	42.7	2.7	37.9-45.3	8	40.5	4.3	36.1-45.8
FWI	8	73.6	3.1	69.8-78.9	8	65.8	8.4	55.0-75.6
$AL_{I}I$	8	33.0	2.8	29.5-37.0	8	33.3	4.5	27.9-39.7
$AL_{II}I$	8	40.0	3.5	34.6-45.9	8	39.4	4.7	32.1-45.2
$AL_{III}I$	8	42.5	3.4	38.8-48.1	8	40.1	5.4	32.1-48.7
$AL_{IV}I$	8	40.5	3.1	37.3-45.9	8	38.6	3.5	32.8-43.7
TtLI	8	75.2	11.5	57.5-88.7	8	77.1	16.6	60.9-110.9
ClLI	7	32.9	6.3	22.6-39.2	8	33.0	10.6	19.3-47.3

S. oualaniensis was first described as *Loligo oualaniensis* by Lesson (1830). Later Pfeffer (1900) transferred to genus *Ommastrephes*, and subsequently to genus *Symplectoteuthis* the species. 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).

Table 5. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no. 5. 7E, Lat.18º 59.2 N, Long.118º 59.7 E. Auto squid jigging, angling depth 80-100 m, time 2055-0100 hrs, surface temperature 26.2ºC, M.V. SEAFDEC 19 Apr. 1998, total catch in weight 5.760 kg and in number 29 pcs.

	MALES				FEMALES			
Index	n	mean	S.D. (n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	-	-	-	-	7	217.3	45.6	120.0-257.0
MWI	-	-	-	-	7	23.2	1.5	20.5-25.2
HLI	-	-	-	-	7	17.3	2.5	13.8-20.8
HWI	-	-	-	-	7	21.5	2.3	18.7-25.0
FLI	-	-	-	-	7	44.4	1.3	42.2-46.1
FWI	-	-	-	-	7	69.2	3.0	66.1-72.6
$AL_{I}I$	-	-	-	-	7	33.9	1.7	30.9-36.7
$AL_{II}I$	-	-	-	-	7	40.0	1.1	38.9-41.7
$AL_{III}I$	-	-	-	-	7	40.4	2.9	36.7-44.4
$AL_{IV}I$	-	-	-	-	7	40.4	2.2	37.1-43.1
TtLI	-	-	-	-	6	72.8	16.0	47.6-96.7
ClLI	-	-	-	-	6	42.8	11.3	31.0-54.5

Table 6. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no. 7. 5G, 5E, Lat. 18º 00.4N, Long. 119º 00.3E. Auto squid jigging, angling depth 70-120 m, time 2224-0300 hrs, surface temperature 25.9ºC, M.V. SEAFDEC 21Apr. 1998, total catch in weight 71.505 kg and in number 422 pcs.

	MALES				FEMALES			
Index	n	mean	S.D. (n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	5	134.0	7.2	126.3-146.0	5	160.1	32.9	116.5-195.0
MWI	5	21.3	0.7	20.4-22.2	5	22.3	1.6	19.7-23.6
HLI	5	21.8	1.7	18.8-22.9	5	20.9	2.1	17.7-22.7
HWI	5	21.5	1.9	19.8-24.4	5	20.7	2.3	17.2-23.4
FLI	5	45.3	1.5	43.8-47.6	5	44.2	1.6	42.6-46.3
FWI	5	72.8	5.3	67.6-79.7	5	67.0	4.1	61.4-71.2
$AL_{I}I$	5	34.4	2.0	32.6-37.2	5	33.4	3.9	26.6-36.3
$AL_{II}I$	5	42.1	2.9	39.2-46.5	5	37.2	3.1	33.9-41.0
$AL_{III}I$	5	40.9	1.9	39.1-43.5	5	39.2	4.9	32.2-45.3
$AL_{IV}I$	5	41.2	3.4	36.9-44.8	5	38.8	3.7	32.9-42.9
TtLI	5	84.6	16.3	66.5-101.1	5	86.1	17.8	63.9-113.3
ClLI	5	39.0	6.8	32.5-49.8	5	39.7	9.3	24.2-49.1

Table 7. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no. 12. 6G, 6E, Lat. 16° 59.8N, Long. 117° 04.7E. Auto squid jigging, angling depth 100 m, time 1915-0130 hrs, surface temperature 27.8°C, M.V. SEAFDEC 25 Apr. 1998, total catch in weight 100.299 kg and in number 739 pcs.

	MALES				FEMALES			
Index	N	mean	S.D. (n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	6	131.4	3.8	124.0-135.0	6	192.5	15.1	179.0-216.0
MWI	6	20.2	0.7	19.1-21.2	6	23.3	1.6	21.8-25.7
HLI	6	20.4	1.8	17.8-22.4	6	20.1	2.6	16.1-24.0
HWI	6	20.1	1.6	17.5-22.3	6	20.5	1.7	18.0-23.2
FLI	6	39.0	1.6	37.2-41.7	6	36.6	7.7	21.0-40.2
FWI	6	73.0	4.2	66.9-78.2	6	70.5	2.1	67.1-73.3
$AL_{I}I$	6	33.1	3.6	28.5-37.5	6	34.8	2.1	32.2-37.0
$AL_{II}I$	6	36.7	2.1	34.6-40.7	6	38.9	3.5	33.6-43.7
$AL_{III}I$	6	37.5	3.3	32.1-41.5	6	41.1	2.2	37.0-43.3
$AL_{IV}I$	6	37.6	1.6	36.0-40.3	6	41.0	2.5	37.0-44.3
TtLI	6	70.8	11.3	61.6-90.3	6	89.5	17.6	74.1-122.1
ClLI	6	27.1	1.9	23.3-28.6	6	35.4	2.8	30.2-37.9

Table 8. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no 14. 4G, 6E, Lat. 15° 59.5N, Long. 118° 00.6E. Auto squid jigging, angling depth 130 m, time 1850-2310 hrs, surface temperature 27.6°C, M.V. SEAFDEC 27 Apr. 1998, total catch in weight 23.014 kg and in number 141 pcs.

	MALES				FEMALES			
Index	N	mean	S.D. (n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	4	135.2	7.9	127.0-145.0	6	196.2	15.3	176.0-213.0
MWI	4	20.2	0.1	20.1-20.3	6	22.7	4.3	19.1-25.3
HLI	4	21.2	3.1	17.2-24.5	6	20.4	1.7	19.2-23.3
HWI	4	19.1	2.5	16.1-22.1	6	19.6	1.0	18.1-21.1
FLI	4	39.6	0.7	38.6-40.2	6	39.7	0.4	39.2-40.3
FWI	4	73.8	3.9	70.3-79.5	6	70.6	3.8	64.1-72.3
$AL_{I}I$	4	34.3	2.1	32.2-36.8	6	37.5	2.8	34.2-40.0
$AL_{II}I$	4	37.5	4.9	32.3-43.7	6	41.1	3.6	36.4-45.2
$AL_{III}I$	4	40.7	3.6	37.2-45.8	6	41.9	1.9	40.2-45.0
$AL_{IV}I$	4	40.0	1.7	39.0-42.5	6	43.3	3.7	39.6-49.9
TtLI	4	68.1	9.9	58.0-81.2	6	88.7	24.2	64.8-127.8
ClLI	4	29.5	3.3	26.2-34.1	6	32.0	2.2	30.0-35.8

Table 9. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no 17. 5G, 5E, Lat. 15º 00.6N, Long. 118º 59.5E. Auto squid jigging, angling depth 100-130 m, time 2342-0448 hrs, surface temperature 32.5ºC, M.V. SEAFDEC 29 Apr. 1998, total catch in weight 23.485 kg and in number 131 pcs.

	MALES				FEMALES			
Index	n	mean	S.D.(n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	5	132.6	10.5	118.0-147.0	5	192.6	18.9	171.0-216.0
MWI	5	21.8	1.1	20.0-22.7	5	22.2	2.2	18.7-24.3
HLI	5	20.8	1.1	19.5-22.4	5	18.6	2.6	15.4-22.3
HWI	5	20.6	1.2	19.0-22.4	5	22.5	3.0	19.6-27.5
FLI	5	43.7	1.6	41.1-45.1	5	41.3	2.0	39.5-44.4
FWI	5	71.5	1.8	69.1-73.5	5	71.6	2.7	68.5-74.8
$AL_I I$	5	30.7	1.3	29.2-32.0	5	34.4	3.0	30.6-38.1
$AL_{II} I$	5	37.2	2.4	34.1-40.3	5	40.1	4.6	35.2-44.7
$AL_{III} I$	5	37.3	2.0	34.7-40.2	5	39.8	1.7	37.4-41.5
$AL_{IV} I$	5	38.7	2.5	36.2-42.7	5	40.1	4.9	33.8-46.8
TtLI	5	76.8	13.2	55.8-92.3	5	88.1	22.4	59.4-117.5
ClLI	5	28.1	3.5	25.0-33.6	5	31.3	4.2	25.9-36.7

Table 10. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no 21. 3G, 8E, Lat. 14º 00.5N, Long. 117º 59.9E. Auto squid jigging, angling depth 100mm, time 1910-0100 hrs, surface temperature 30.4ºC, M.V. SEAFDEC 30 Apr. 1998, total catch in weight 39.633 kg and in number 267 pcs.

	MALES				FEMALES			
Index	n	mean	S.D.(n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	3	126.3	6.3	119.0-130.0	8	171.2	25.6	135.0-207.0
MWI	3	19.5	1.1	18.2-20.3	8	22.1	1.6	20.1-25.4
HLI	3	20.9	3.2	17.5-23.8	8	20.1	1.5	16.8-21.8
HWI	3	17.8	2.8	17.0-20.9	8	21.0	1.0	20.3-23.0
FLI	3	37.4	1.0	36.3-38.3	8	39.4	1.4	36.5-40.6
FWI	3	76.2	10.1	64.7-83.8	8	71.8	3.7	64.0-76.1
$AL_I I$	3	34.1	2.5	31.9-36.8	8	36.0	2.1	33.2-38.5
$AL_{II} I$	3	37.7	2.1	36.1-40.1	8	39.8	4.7	31.5-45.3
$AL_{III} I$	3	40.0	3.9	37.7-44.6	8	41.6	3.0	37.9-46.3
$AL_{IV} I$	3	41.1	2.6	38.8-44.0	8	41.7	1.9	39.6-45.1
TtLI	3	87.8	19.9	68.9-108.5	8	84.5	20.4	55.6-105.9
ClLI	3	26.3	4.5	23.5-31.5	8	31.5	2.8	28.1-35.7

Table 11. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no 27. 1G, 3E, Lat. 13° 00.2N, Long. 117° 06.4E. Auto squid jigging, angling depth 100 m, time 1840-0300 hrs, surface temperature 31.3°C, M.V. SEAFDEC 5 May 1998, total catch in weight 16.506 kg and in number 138 pcs.

	MALES		FEMALES			
Index	n	Value	n	mean	S.D. (n-1)	Range
ML (mm)	1	125.0	3	137.3	10.3	126.0-146.0
MWI	1	20.2	3	19.9	1.9	18.2-22.0
HLI	1	22.5	3	19.5	2.1	17.5-21.7
HWI	1	18.4	3	20.3	0.2	20.1-20.5
FLI	1	40.4	3	38.4	1.5	36.8-39.9
FWI	1	72.8	3	69.4	1.0	68.2-70.0
$AL_{I}I$	1	30.0	3	32.1	1.6	30.3-33.1
$AL_{II}I$	1	40.0	3	37.4	2.9	34.3-39.9
$AL_{III}I$	1	44.2	3	40.6	4.1	36.3-44.4
$AL_{IV}I$	1	45.1	3	40.2	1.9	38.8-42.3
TtLI	1	72.8	3	71.4	21.4	52.0-94.4
ClLI	1	30.9	3	29.1	2.9	25.8-30.9

Table 12. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no 30A. 1G, 7E, Lat. 11° 59.8N, Long. 118° 45.3E. Auto squid jigging, angling depth 100 m, time 1950-0245 hrs, surface temperature 31.0°C, M.V. SEAFDEC 8 May 1998, total catch in weight 25.728 kg and in number 159 pcs.

	MALES		FEMALES			
Index	n	Value	n	mean	S.D.(n-1)	Range
ML (mm)	1	119.0	7	151.7	27.0	124.0-191.0
MWI	1	23.8	7	22.5	2.1	20.5-26.6
HLI	1	21.4	7	19.7	2.2	16.6-22.6
HWI	1	20.7	7	22.1	1.9	19.3-25.6
FLI	1	42.0	7	45.1	1.3	43.5-47.0
FWI	1	78.1	7	72.7	4.2	66.7-78.3
$AL_{I}I$	1	33.1	7	35.3	2.3	31.7-37.9
$AL_{II}I$	1	44.5	7	38.5	1.7	35.9-40.6
$AL_{III}I$	1	40.3	7	38.7	2.2	35.2-41.6
$AL_{IV}I$	1	39.5	7	39.2	4.7	31.7-44.2
TtLI	1	85.7	7	68.8	15.4	54.9-82.7
ClLI	1	32.3	7	33.0	3.7	27.6-38.8

Table 13. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Sthenoteuthis oualaniensis*. Station no 30B. 4G, 6E, Lat. 12º 47.6N, Long. 119º 09.0E. Auto squid jigging, angling depth 100 m, time 1845-0300 hrs, surface temperature 31.4ºC, M.V. SEAFDEC 9 May 1998, total catch in weight 62.19 kg and in number 400 pcs.

	MALES				FEMALES			
Index	n	mean	S.D. (n-1)	Range	n	mean	S.D.(n-1)	Range
ML (mm)	4	124.7	4.2	122.0-131.0	6	188.2	14.3	166.0-209.0
MWI	4	20.5	1.2	19.0-21.9	6	21.1	1.4	19.3-22.9
HLI	4	19.1	1.3	17.9-20.2	6	19.4	1.4	18.4-21.0
HWI	4	21.6	1.9	18.8-22.7	6	20.4	1.4	18.4-22.5
FLI	4	34.6	8.7	21.9-41.8	6	39.7	1.3	37.3-40.9
FWI	4	76.7	6.4	69.9-85.2	6	69.8	1.3	67.9-71.1
$AL_{I}I$	4	30.7	3.1	26.2-32.8	6	32.5	1.6	30.5-34.5
$AL_{II}I$	4	35.2	4.3	30.4-40.5	6	38.8	1.4	37.2-41.4
$AL_{III}I$	4	39.9	3.6	35.9-44.7	6	39.2	1.9	37.4-41.8
$AL_{IV}I$	4	38.1	3.3	33.8-41.6	6	38.9	1.9	35.7-41.2
TtLI	4	69.4	18.2	58.5-95.9	6	58.3	6.9	49.2-66.5
ClLI	4	26.6	4.1	21.1-31.1	6	27.5	1.3	26.2-29.7

Family Thysanoteuthidae

Thysanoteuthis rhombus Troschel, 1857
Fig.6A-B, Table 14

Thysanoteuthis rhombus –Sasaki, 1929: 301-304, pl. XXIV, figs. 6-8, text. 141; –Nateewathana & Hylleberg, 1989: 227-233, figs.1-3; -Nateewathana, 1997: 462-463, fig.6

MATERIAL EXAMINED:
1 G, Western Philippines, M.V. Maya Maya, 1998.

DESCRIPTION:
Mantle (Fig.6A-a,b) long, thick, muscular, truncate anteriorly and tapers to a blunt tip posteriorly. Anterior dorsal margin slightly projection on the middle part, ventral margins almost straight. Fins long, broad, rhombic, occupying almost the entire length of mantle. Head somewhat narrower than mantle, wider than long, separated from the mantle by a distinct neck region. Eyes large, prominent, not projecting and without cornea and in open contact with seawater. Funnel stout, slightly narrowed anteriorly, extends to about mid-eye level; funnel valve broad, semicircular and well developed; dorsal funnel organ inverted V-shaped, two oblong ventral pads. Funnel cartilage (Fig.6B-a,b) large with a long, narrow longitudinal groove and a short, broad transverse groove; a nuchal-mantle lock with two distinct knobs that fit into opposing pits.

Arms subequal, order III. II. IV. I. Arm I about half as long as arm III, dorsal surface with low triangular keel extending for the distal three-fourth of the arm. Arm II similar to arm I, but the keel extends the whole length of the arm, and widens proximal. Arm III largest, compressed

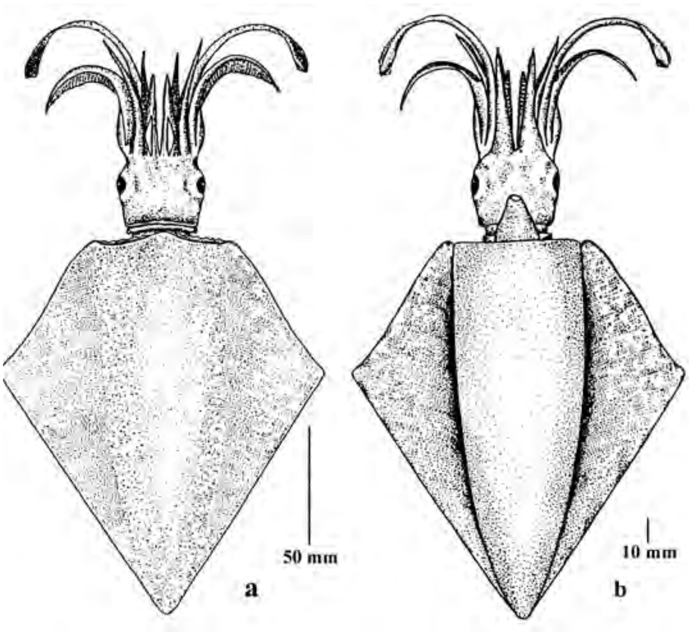

Fig. 6A. *Thysanoteuthis rhombus*. a, dorsal view. b, gladius.

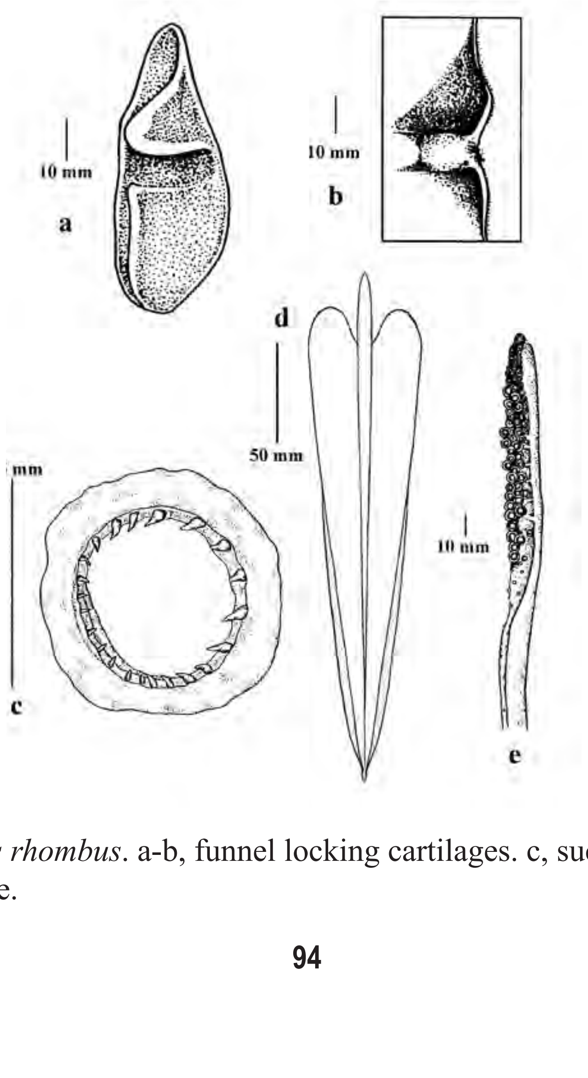

Fig. 6B. *Thysanoteuthis rhombus*. a-b, funnel locking cartilages. c, sucker of left arm III. d, gladius. e, tentacle.

with a conspicuous keel on the proximal half. Arm IV quadrangular, aboral surface marked off by sharp edges on sides, trabeculae well developed about twice as broad as thickness of arms. Buccal connectives attached to ventral borders of arm IV. Biserial suckers present on all arms, sucker rings with 22-25 pointed teeth (Fig.6B-c).

Tentacles (Fig.6B-e) long, about twice of arm lengths. Tentacular club long, narrow, bordered on each side by well developed protective membranes and bears one row of small carpal suckers on middle third of tentacular stalk, four transverse rows of larger suckers on manus and dactylus. Sucker ring with about 17 pointed teeth. Gladius (Fig.6B-d) with long rachis and broad vane. Buccal membrane with seven buccal lappets.

Colour in alcohol grayish brown, deeper above, no special markings discernible.

GEOGRAPHICAL DISTRIBUTION:
Temperate and tropical seas.

REMARKS:
This is a fully described species of unquestioned status.

Table 14. Means, standard deviations and ranges of selected measurements and indices (in percent) of *Thysanoteuthis rhombus* from the Western Philippines.

	MALE		FEMALES			
Index	n	Value	n	mean	S.D.(n-1)	Range
ML (mm)	1	460.0	-	-	-	-
MWI	1	38.0	-	-	-	-
HLI	1	40.2	-	-	-	-
HWI	1	23.9	-	-	-	-
FLI	1	98.9	-	-	-	-
FWI	1	83.7	-	-	-	-
$AL_{I}I$	1	30.0	-	-	-	-
$AL_{II}I$	1	38.0	-	-	-	-
$AL_{III}I$	1	60.2	-	-	-	-
$AL_{IV}I$	1	37.8	-	-	-	-
TtLI	1	101.7	-	-	-	-
ClLI	1	22.8	-	-	-	-

Discussions

Species Composition.

The oceanic squids are comprised of the Oegopsida, which are distinguished by the presence of an opening (slit) in the corneal membrane exposing the lens of the eye to the water. Almost all-oceanic squids spend their entire life span in the open ocean. There are about 200 species of oceanic squids belonging to about 28 families known to occur in the world oceans (Worms 1983). Although a number of species occur in oceanic waters, many owing to their small size and unfavorable consistency of their body, are not suitable for human consumption but are important as forage to tunas, billfishes and toothed whales. Only a few species of oceanic squids are commercially and potentially important and they belong to the families Ommastrephidae, Histioteuthidae, Lepidoteuthidae, Onychoteuthidae, Veranyidae, Gonatidae and Cranchiidae (Voss 1973). Of these, the members of the family Ommastrephidae are by far the most important because many species of this family, *i.e. Ommastrephes bartramii* (Lesueur, 1821), *Sthenoteuthis* spp. *Illex* spp., *Nototodarus* spp. and *Todarodes* spp., are already exploited in commercial fisheries by some countries particularly in the Pacific and Atlantic waters.

Although more than 50 species of cephalopod fauna have been reported from the Philippines waters, especially an intensive work of Dr Voss (1963), only four species of cephalopods were collected during the present investigation, *i.e. Sepioteuthis lessoniana* Lesson, 1830; *Nototodarus hawaiiensis* (Berry, 1912); *Sthenoteuthis oualaniensis* (Lesson, 1830); and *Thysanoteuthis rhombus* Troschel, 1857. In fact a species of paper nautilus, *Argonauta hians* Solander, 1786 was also collected from the stomach content of a fish during the survey, but the species is excluding from the present report. The species have been described and reported from the Philippine waters by Voss (1963). The first three described species in the present study were collected by squid jigging and purse seine of M.V. Maya Maya. The last species was collected by automatic squid jigging machine on board of M.V. SEAFDEC. *S. lessoniana* is a neritic species, while the last three species are the oceanic species.

Since during the fishing operations of 11 stations in the present study, the automatic squid jigging gear were operated in the upper layer of the ocean. Angling depth of jigging line was between 70-130 m. The dominant oceanic squid caught during the operation was *S. oualaniensis*. Catch and effort data collection of the species will be provided by Siriraksophon *et al.* (1999).

Distribution.

Brief information on distribution of the four species collected from the cruise will be compiled and given herein.

S. oualaniensis. The species occurs throughout tropical surface waters of the Indo-Pacific, with its northern boundary in the Pacific from southern Japan to southern California. It occurs in the Indian Ocean south to southeastern Africa and Cape Leeuwin off Western Australia. In the South Pacific its distribution extends from the Coral Sea eastward to the Line Islands (Dunning 1998). Adults of *S. oualaniensis* occur predominantly in tropical oceanic waters, whereas larvae and juveniles also have been caught on the continental slope and shelf. It exhibits positive phototaxis and is of aggressive nature. Hooks and lines commercially catch it with light at night in the waters around Okinawa to Taiwan. According to Chikuni (1983), in the eastern Arabian Sea, the fishing methods applied were drift gillnet at night by Indian research vessels, round dipnet and pelagic trawl at night with light attraction by the USSR research vessels and jigging both in daytime without light and at night with light attraction by Japanese research vessels. It is interesting to see that squid were caught even in the daytime (16.30-17.20 h) without light attraction, while the species generally appeared to inhabit the 120-200 m depth zone during the daytime judging from the acoustic data. However, once a few squid were jigged at the deep layer by a long-line hook and hauled on board, many specimens were attracted towards the surface and jigged at the near-surface layer. It is reported that *S. oualaniensis* usually forms small schools consisting of about thirty individuals of nearly the same size, most likely to avoid cannibalism (Wormuth 1976).

Some aspects of the fishery biology of this species in the South China Sea have been investigated on the populations around Taiwan. Reproductive development of *S. oualaniensis* from around Taiwan (19°N-26°N) was described by Tung (1976) for squid caught between March and October (spring to autumn). Males reached maturity at smaller sizes than did females. Spermatophores were evident in squid as small as 110 mm ML. Little development of the ovary was evident in females less than 155 mm ML. At 190 mm ML, the majority of females had ova present in their oviducts.

T. rhombus. This oceanic squid is a cosmopolitan pelagic species usually found in warm water area of the world oceans. This is the only known species of the genus *Thysanoteuthis* and normally occurs in small groups of two or more individuals swimming in the surface waters. Adult commonly grow to a large size of about 60 cm ML (Okutani 1977) and to maximum size is about 100 cm ML (Roper *et al*. 1984). This squid has been subjected to commercial exploitation in Japan. The fishery *for T. rhombus* according to Osako & Murata (1983) was initiated in 1962, in San-in district (the westernmost area of Honshu), Japan. This species is fished mainly by squid jigs and trapnets. It is generally caught in the upper 50 m of the water column. Commercial fisheries for this species from August through December with peak in October are peculiar to the Sea of Japan, while annual catches fluctuate remarkably from 0-500 tons (Kasahara 1991). Occurrences and biology of this squid in Japan were fully discussed by Nishimura (1966).

N. hawaiiensis. The species was recorded from slope waters around the Philippines and Hong Kong where it is a minor component of the bycatch of domestic trawl fisheries (Voss 1963; Voss & Williamson 1971). The species has been taken around Hawaii in shrimp trawls and occasionally on jigs over depths of 230-710 m (Young 1978), and specimens of up to up to 140 mm ML described by Dong (1963) were trawled at a depth of 290 m off Hainan, southern China. Around Hong Kong, the species has been caught on the bottom at depths of 275-650 m (Voss & Williamson 1971). *N. hawaiiensis* were also caught in demersal trawls on the upper continental slope of northern Australia in depths of 162-500 m (Dunning & Förch 1998).

Sepioteuthis lessoniana. The species is a widely distributed in the Indo-West Pacific. It is a neritic species occurring from the surface down to at least 100m depth. The species is of commercial value all over Southeast Asia where it is captured throughout the year, with lure-hooks, seines or purse seines in inshore waters and by trawlers on the continental shelf.

Acknowledgement

We would like to thank Mr Udom Bhatiyasevi, Secretary of SEAFDEC, for supporting the research. We are grateful to Dr Maitree Duangsawad, former Secretary of SEAFDEC, for reading and correcting the manuscript. We are also very grateful to the fishing master, captain and crews of M.V. SEAFDEC for their assistance during the survey. Supporting fund from the SEAFDEC is sincerely acknowledged.

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Ecological Aspects of Oceanic Squid, *Sthenoteuthis oualaniensis* (Lesson) in the South China Sea, Area III: Western Philippines

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ABSTRACT

In an attempt to come up with initial jigging fishery on oceanic squid in the Southeast Asian Region SEAFDEC conducted a comparative study on the squid in the Philippines Exclusive Economic Zone off the coast of Western Philippines from 17 April to 9 May 1998. The survey objectives are to determine the distribution and abundance of the oceanic squid in relation to oceanographic conditions and to examine the feasibility of harvesting squid with jig gear.

Results from 11 sampling stations show that only one species of the purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) were caught by autometic squid jigging gear. The distribution and abundance of the purpleback flying squid in term of the catch-per-unit-effort (CPUE, number of squid per line hour) are presented. Over the entire survey area, the CPUE of the squid averaged 5.7 squids/line hour. Drop-off rates for jigs fished on the jigging machines ranged from 0 to 0.33 squid/line hour. Angling depth where the squid were abundant ranged from 50 m to 100 m.

The squid had a mean overall mantle length of 147 mm and an averaged weight of 0.17 kg. A total of 2,592 squid were measured and mantle length ranged from 90 to 250 mm. Female dominated the catch, accounting for 1,380 squid or 81% of the 1,701 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 140 and 150 mm mantle length. A similar length-weight relationship coefficients between male and female was found.

The squid were found in a warm water mass where the sea temperature ranged from 14˚c to 31˚c at the depth from 150m up to sea surface at night. Good fishing grounds of the squid were at 18˚N latitue (18.5 squids/line hour) and at 19˚ N lattitude (11.6 squids/line hour) off the San Fernando and Currimao coasts, respectively where the upwelling occurred. Dissolved oxygen where squid abundant was ranged from 3.27 to 4.4 ml/l. Downwelling was found at 16˚N along the 118˚E where less potential of the squid, the water transparency depth in this area was deep of about 44 m. A period of 6 days before and after full moon day was good fishing day, while the percent illumination of the moon was less than 30%

Keywords: purpleback flying squid, *Sthenoteuthis oualaniensis,* fishing ground, south china sea

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 totaled 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).

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 Resources Survey Program. 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 first experimental fishing which was carried out in the Philippines Exclusive Economic Zone off the coast of Western Philippines by M.V. SEAFDEC from 17 April to 9 May 1998.

Materials and Methods

Survey Area

Experimental fishing and oceanographic conditions were conducted by M.V.SEAFDEC in the Philippines Exclusive Economic Zone off the coast of Western Philippines from 17 April to 9 May 1998. All 31 oceanographic survey stations and 11 experimental fishing stations were designed covered from 11˚ to 20˚ N Latitude and from 117˚ to 121˚ E longitude as shown in **Figure 1**.

Fishing Gear

Squid sampling were collected by four automatic squid jigging machines: **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 18 to 30 typical japanese squid jigs spaced approximately 1m apart by nylon mono-filament leaders (30 to 50 lb test) as shown in **Figure 2a-b**. 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

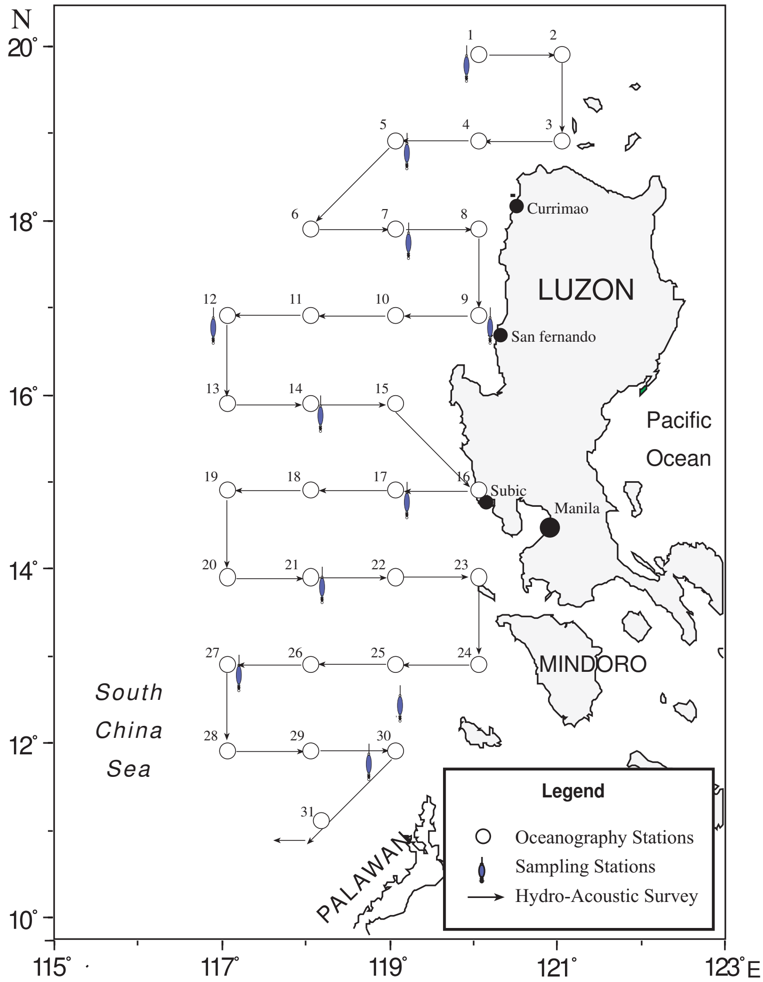


Fig. 1. Locations of fish sampling and oceanography stations in the survey area, off west coast of Luzon Islands

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

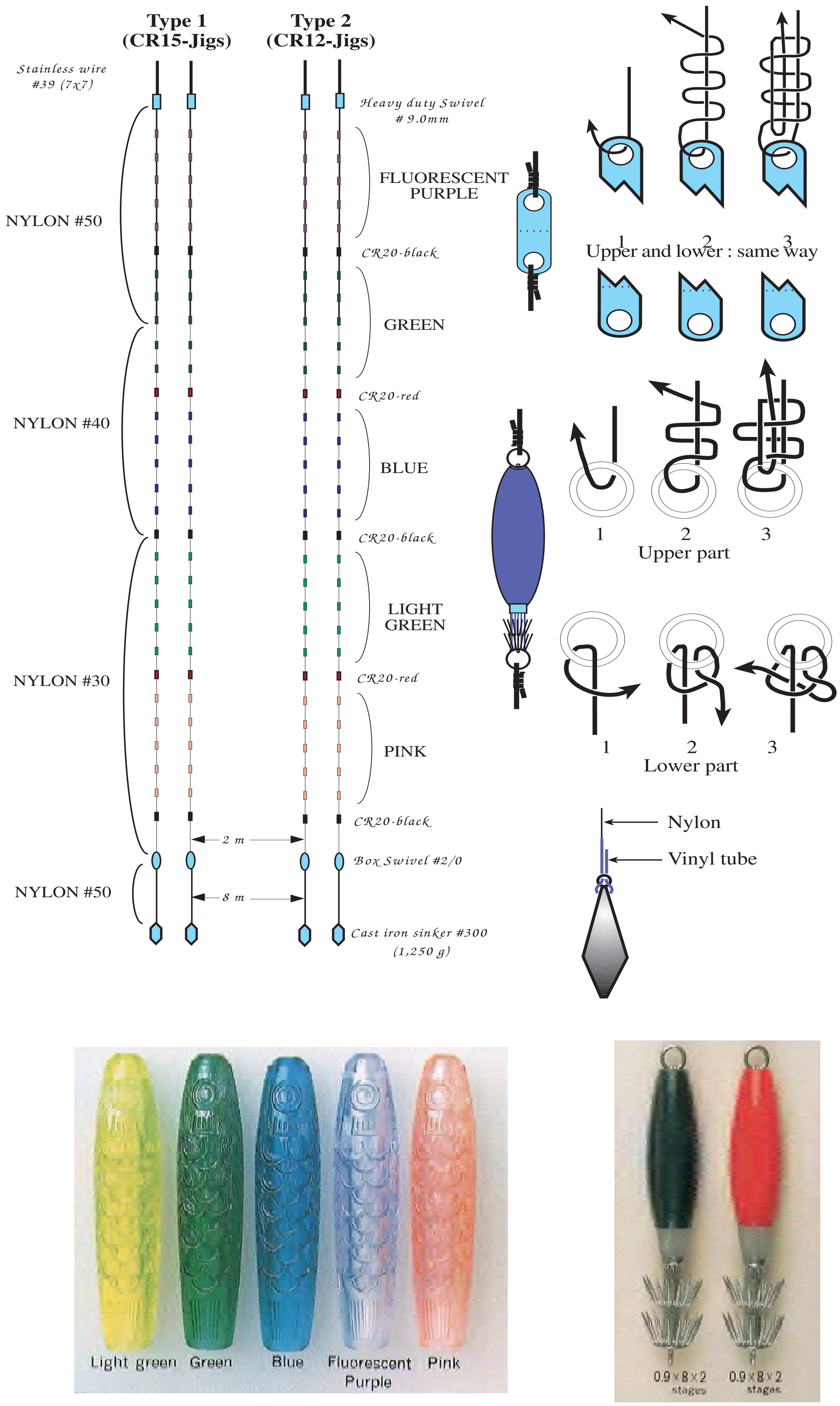
Catch and data effort data were collected at each fishing station. Target species caught were counted and if not all weighted, a sub-sample was weighted and counted to extrapolate the total catch weight at each station. Effort was recorded in line hours, which were calculated by multiplying the number 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.

Biological feature information was collected from target species. Length frequencies (mantle length) were recorded in millimeters 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 west coast of the Philippines. 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.

a)

b)



CR15 New Kaio Hook   CR20 Bakelite Cased Hook

Fig. 2. Arrangement of squid jig line(a) and types of squid jig (b) used in the experiment.

Dynamic depth relative to the surface was calculated by the EG & G CTD Post-acquisitive Analysis Software at every dbar pressure interval. Density figures were derived from temperature and salinity data using sigma-t computation tables. The dissolved carbonate system in seawater was calculated from total alkalinity and pH was measured using the in situ sensor attached to the ICTD [It was later measured on board using the Fisher Scientific model 1002 pH meter, when the pH sensor malfunctioned]. Total alkalinity was measured as the capacity of seawater to neutralize Hydrochloric acid and the saturation level of seawater was calculated from the ratio between actual carbonate concentration and its concentration at equilibrium. 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).

Light intensity in the water column was measured by Quantum Light Sensor for underwater

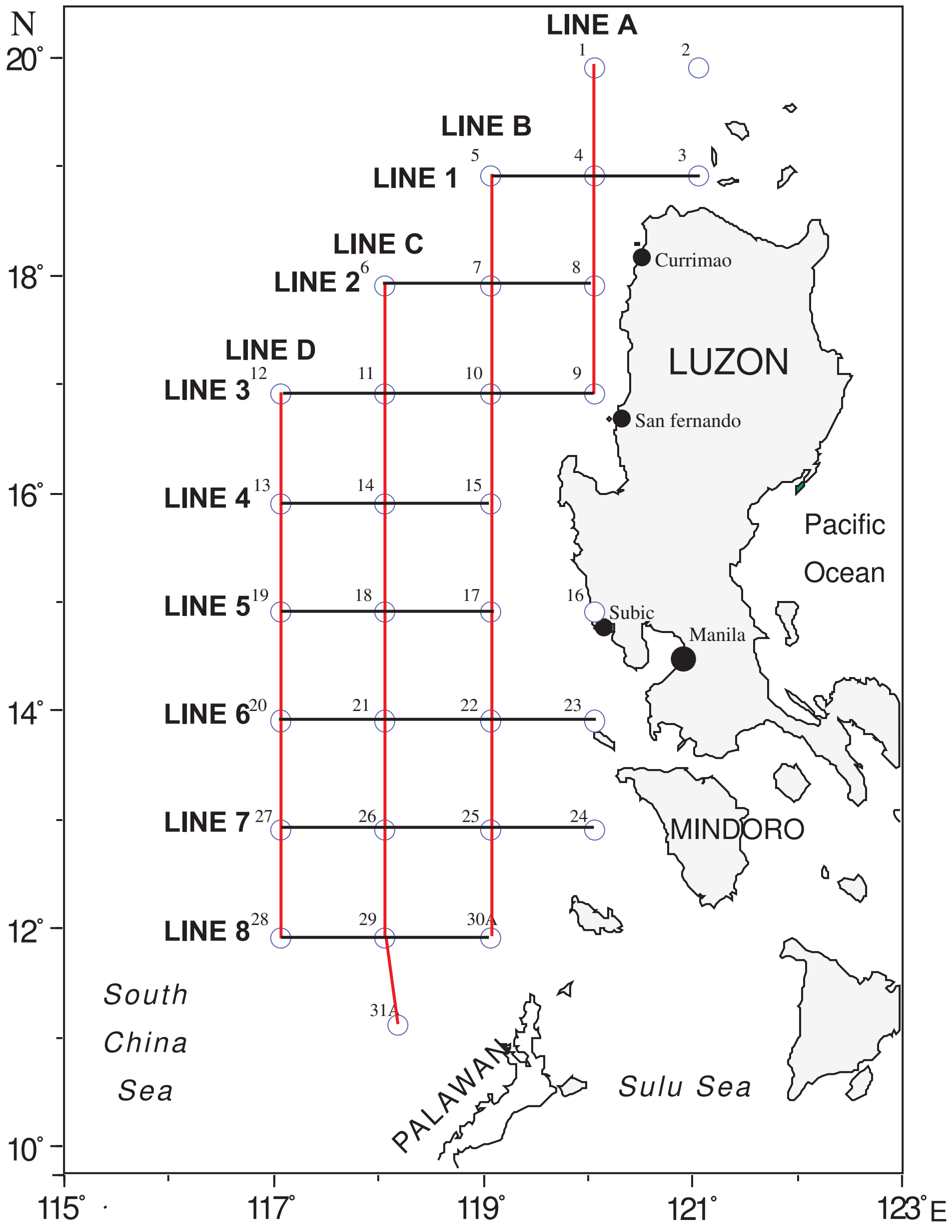


Fig. 3. Lines of cross section

and in air. These data were recorded on Data Logger IL1000 at the day-time stations. Water transparency was measured by Sechi disc in unit of meter at day-time stations. The average light intensity near sea surface (I_0) was used to estimate light intensity at a desired depth (I_z), from the following equation (Jerlov 1976):

$$I_z = I_0 \, exp\, (-kz)$$

where *k* is the attenuation coefficient (m^{-1})

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-A to D for the north-south direction and along latitude of each Line-1 to 8 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 version3.4" (Fortner software).

Results and Discussion

Catch

Results from 11 sampling stations of the survey area show that only one species of the purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1930) were caught by the automatic squid jigging gear. This was confirmed by Anuwat *et al*. 1999. **Table 1** shows the information of

Table 1. Information of sampling stations and catch results of the purpleback flying squid in the South China Sea, Area III: Western Philippines during April-May 1998.

No.	St.	Date	Position		Number	Number	Time	Total Catch Data		CPUE
	No.		Lat. (N)	Long.(E)	of lines	of Jig	(h:min)	Weight (kg)	Number (ind)	Ind./line hour
1	1	17-Apr	20° 02.30'	119° 56.70'	8	240	5	25.920	116	2.900
2	5	19-Apr	18° 59.18'	118° 59.68'	8	128	2	5.760	29	1.813
3	7	21-Apr	18° 00.40'	119° 00.28'	8	156	4.55	71.505	422	11.593
4	9	22-Apr	16° 59.90'	120° 01.70'	8	156	4	5.109	50	1.563
5	12	25-Apr	16° 59.64'	117° 04.77'	8	178	5	100.299	739	18.475
6	14	27-Apr	15° 59.50'	118° 00.60'	8	176	4.5	23.014	141	3.917
7	17	29-Apr	15° 00.64'	118° 59.52'	8	176	5	23.485	131	3.275
8	21	30-Apr	14° 00.50'	117° 59.90'	8	176	6	39.635	267	5.563
9	27	5-May	13° 00.40'	117° 06.41'	8	176	8	16.506	138	2.156
10	30a	8-May	11° 59.80'	118° 45.30'	8	153	6.5	25.728	159	3.058
11	31a	9-May	12° 47.60'	119° 09.00'	6	176	8	62.190	400	8.333

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 5.7 squids/line hour. The minimum and maximum of CPUE of the squid were 1.6 and 18.5 squids/line hour, respectively. The CPUE more than 11 squids per line hour were found at St.#7 and St.#12. Drop-off rates for jigs fished on the jigging machines ranged from 0 to 0.33 squid/line hour.

Biological features

A total of 2,592 purpleback flying squid were measured and their mantle length ranged from 90 to 250 mm. The squid had a mean overall mantle length of 147 mm and an averaged weight of 170 g. **Figure 4** shows the sex composition and the CPUE distribution of the squid

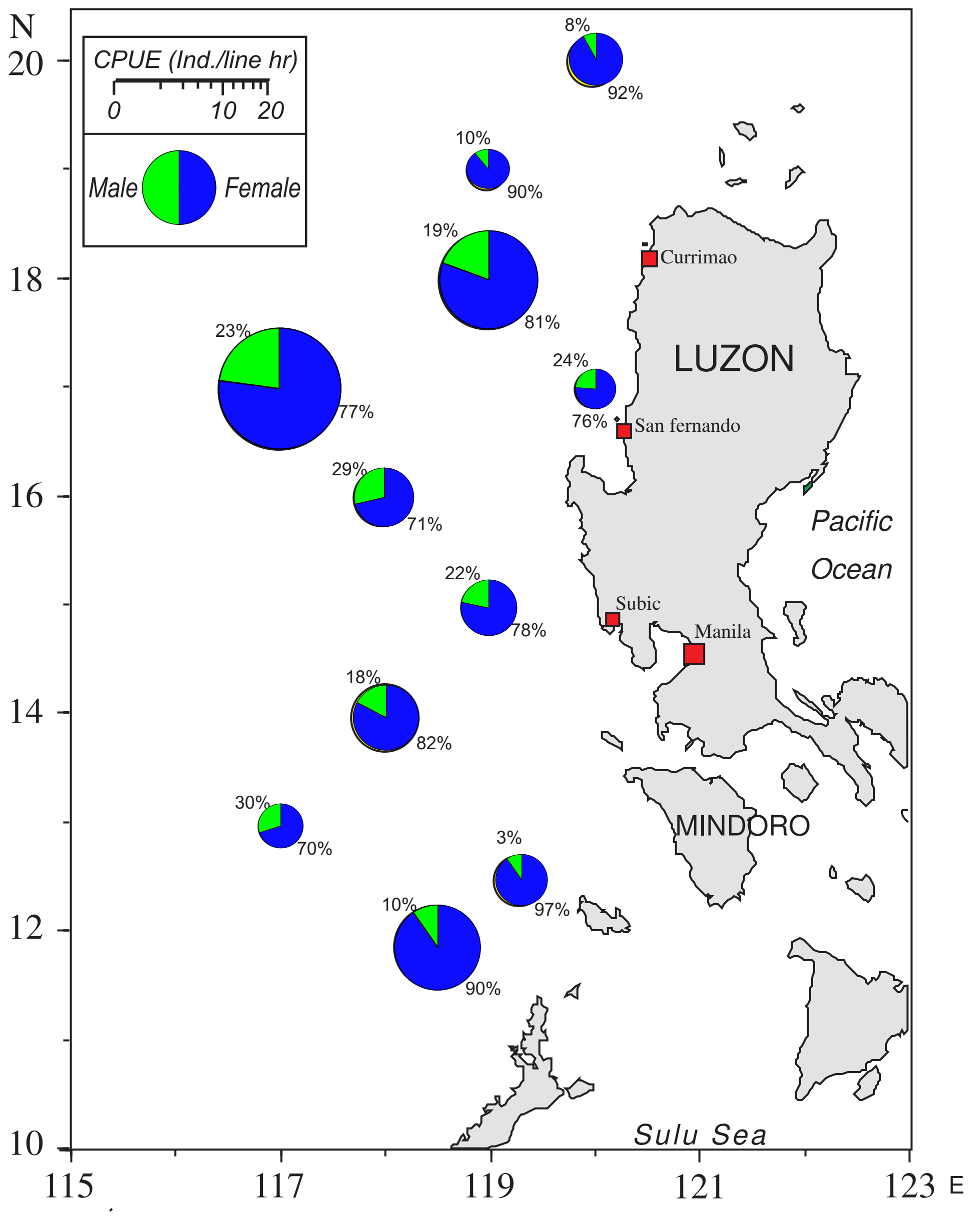


Fig. 4. Sex composition and CPUE distribution of purpleback flying squid caught in the South China Sea: Western Philippines during April-May 1998.

Fig. 5. Purpleback flying squid (male) caught in the South China Sea: Western Philippines during April-May 1998.

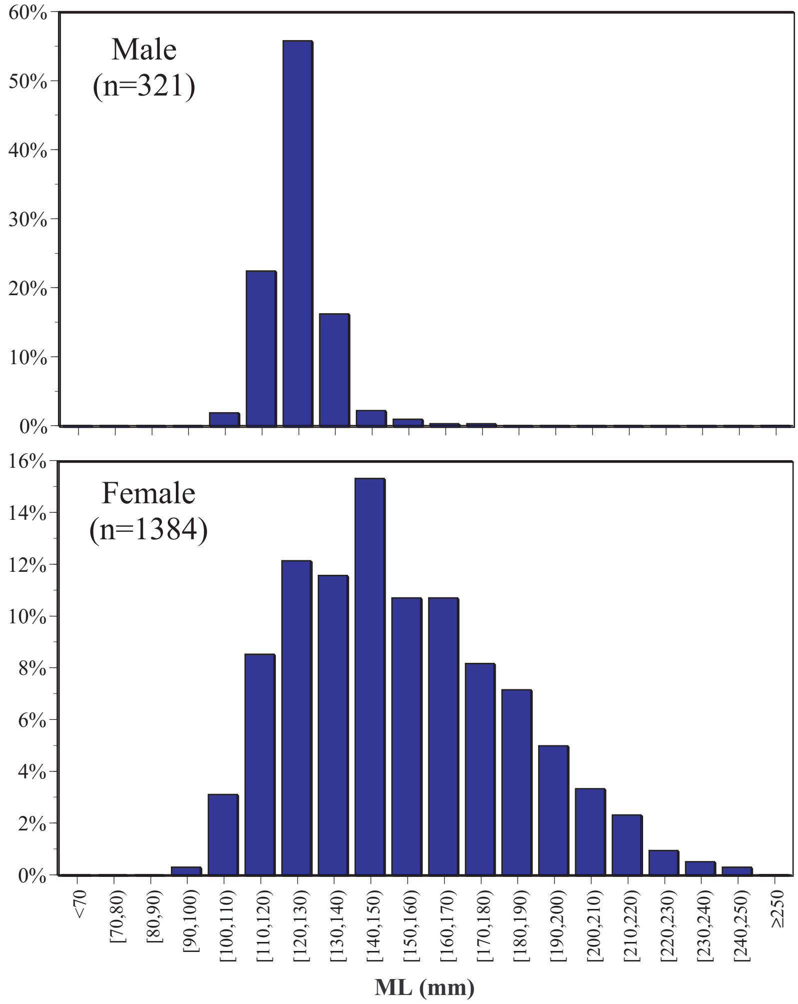


Fig. 6. Mantle length composition of purpleback flying squid caught in the South China Sea: Western Philippines during April-May 1998.

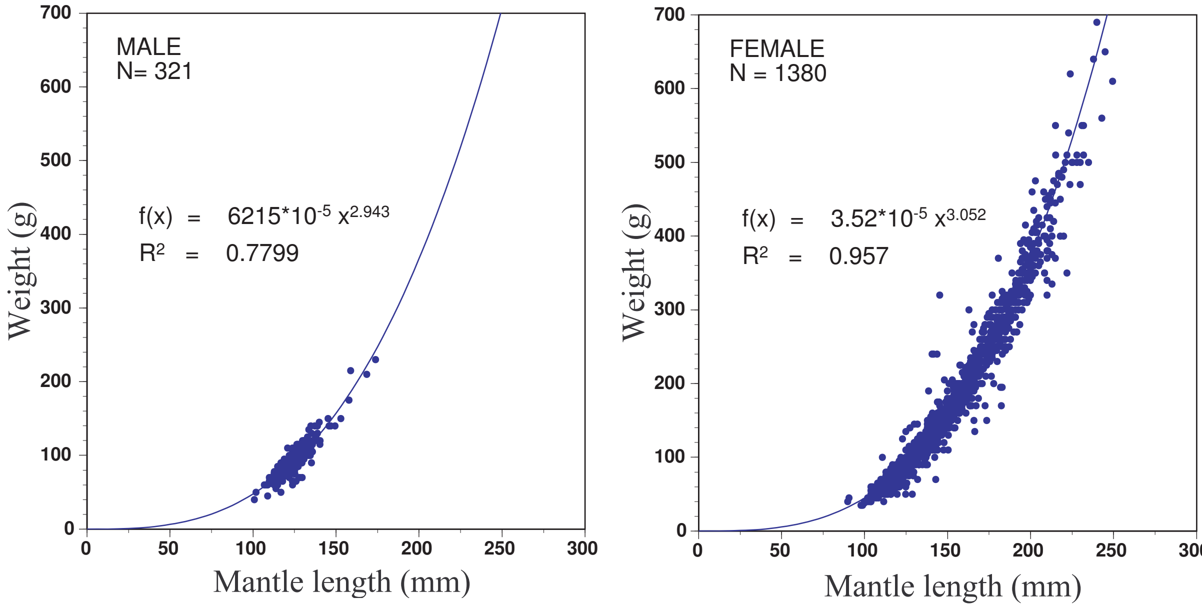


Fig. 7. Length-weight relationship of purpleback flying squid caught in the South China Sea: Western Philippines during April-May 1998.

caught in each sampling station. It is clearly shows that female dominated the catch, accounting for 1,380 squid or 81% of the 1,701 squid sexed. Males were generally smaller than females as shown in **Figure 5**. **Figure 6** show the mantle length composition of the squid caught in the survey area. Both of male and female, their mantle length composition have a single peak mode at between 120 and 130 mm (a) and at between 140 and 150 mm mantle length, respectively. Length-weight relationship coefficients for male, female of the purpleback flying squid are presented in **Figure 7**. It can be concluded that there are no difference in length-weight relation between male and female.

Fishing Ground Environment

Figure 8 shows the vertical profile of CTD and dissolved oxygen parameters varied by depth at all sampling stations. In the survey area, the mixed layer depth was clearly showed at all stations at the depth observed from 12 m to 71 m. Permanent thermocline generally appeared at about 50m deep from the surface where sea temperature was about 28˚c down to 1500 m deep where sea temperature was about 2.7˚c. Salinity from depth between sea surface to 150 m deep irregularly changed from 33.7 to 34.6 PSS, the salinity at deeper than 150m was almost constant about 34. 5 PSS. For dissolved oxygen at nearby sea surface down to 150m deep performed irregular change within between 4.4 ml/l and 3.1 ml/l, respectively and guadully decreased to a constant value of about 2.0 ml/l at deeper than 400m.

Figure 9 shows the horizontal profile of temperature at sea surface layer (a) and 100m (b) in the survey area. Most of the temperature ranged from 28˚ to 30.7˚c at sea surface and from 18˚ to 23.5˚c at 100m deep. The figure clearly shows a cold water flowed from the Pacific Ocean into the South China Sea in the northern Luzon. At 18˚N the sea temperature at 100m deep was low about 18˚c compared with the surrounded area where temperature was about 23˚c, this cold water appeared up to the surface where the sea temperature was found to be about 28˚c. Anond (1999) reported a cyclonic eddy was found in this area and its occurrence was due to wind turbulence in the South China Sea Area.

Figure 10 shows a horizontal profile of water transparency (m) of the survey area. The sea water was very clear which the transparency depth was about 44m, this location was between north latitude of 17 and 18˚ along 118˚ east longitude. Anond 1999 indicate this area as downwelling so that the catch results were very poor. However it is indicated that the good fishing at st.#7 and st.#12 located at the boundaries area where water transparency was in a range from 27 m to 33 m.

Figure 11 shows the vertical profile of temperature at LINE A, LINE B, LINE C and LINE D. The vertical profiles along the LINE A and LINE C indicate that the mixing layer was not much change, it was about 40-50 m for LINE A and 50-60 m for LINE C. Along LINE B, the thermocline represented by 27˚c is located at a depth of about 22 m in the north at st.#5 and 7,

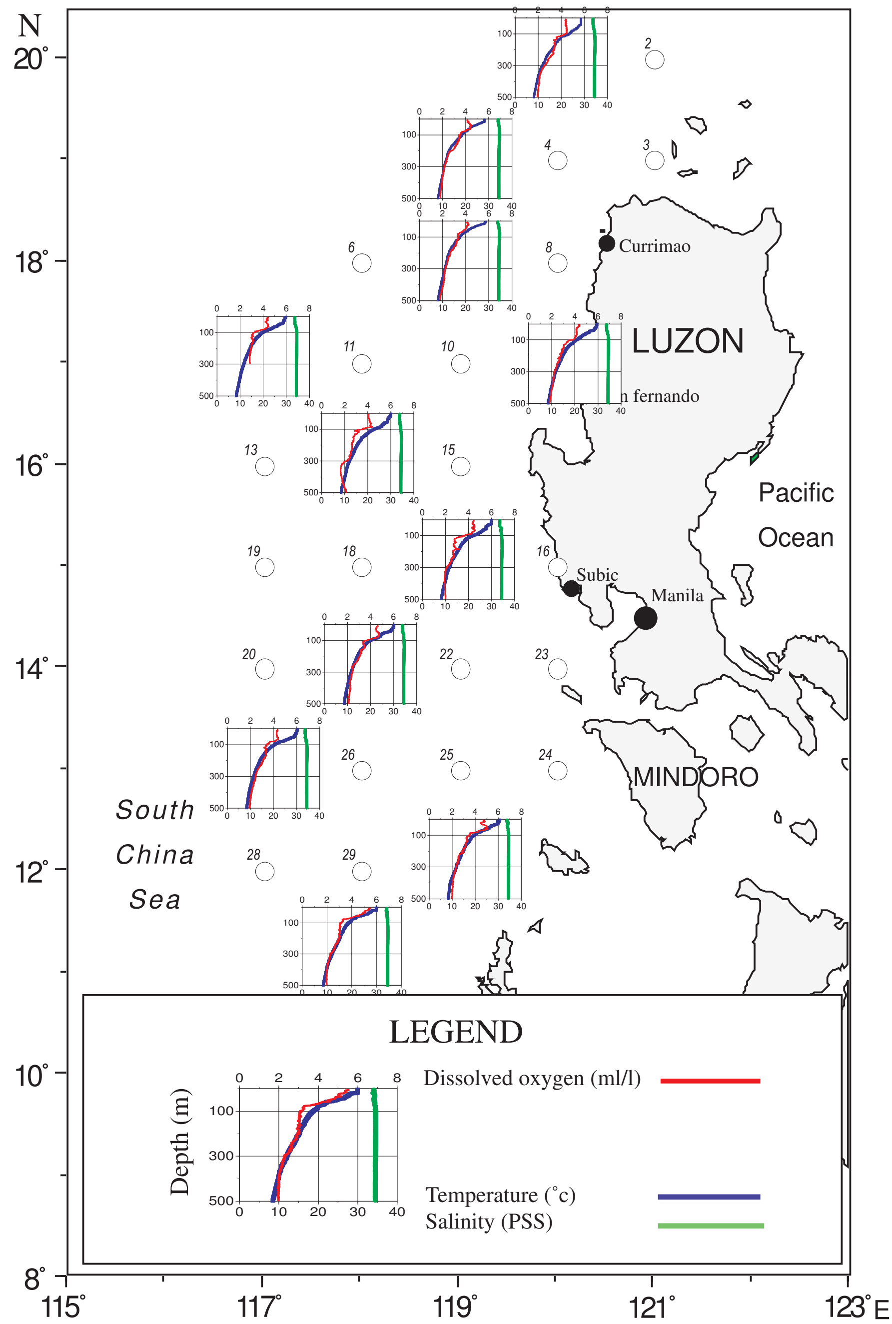


Fig. 8. CTD and dissolved profiles at squid sampling stations during April-May 1998.

while at depth of about 70 m, deeper by 48 m, in south. The upwelling was found at the st.# 7. A similar north-south change of thermocline was found along LINE D between st.#12 and st.#19.

Figure 12 shows the vertical profile of temperature at LINE 1 to LINE 8. West-east variation of thermocline was found not to be remarkable in the waters south of LINE 2, but significant along the LINE 1. Along LINE 1, the position of thermocline represented by 28˚c and the thickness of mixing layer showed significant west-east variation. It is noted that the vertical profile of temperature along west-east section showed no thermal gradient.

Angling Depth

By sight observation found that the squid behave aggregative nature and positive phototaxis, they swim on the surface of the sea at night. From the experimental results found that purpleback flying squid scattered covering the entire area and generally caught at the depth ranged from sea surface down to 200 m deep at night. The abundant depth was ranged from 50 m to 100 m as shown in **Figure 13** because some of the squid were caught and identified as purpleback flying squid. During fishing the quantum light intensity at 50 m deep was measured to be about 0.048µE$m^{-2}s^{-1}$. From the equation 1) the light intensity at sea surface (I_0) was observed more than 200µE$m^{-2}s^{-1}$ in day time, in which I_z was 0.048µE$m^{-2}s^{-1}$ as the optimum light intensity of

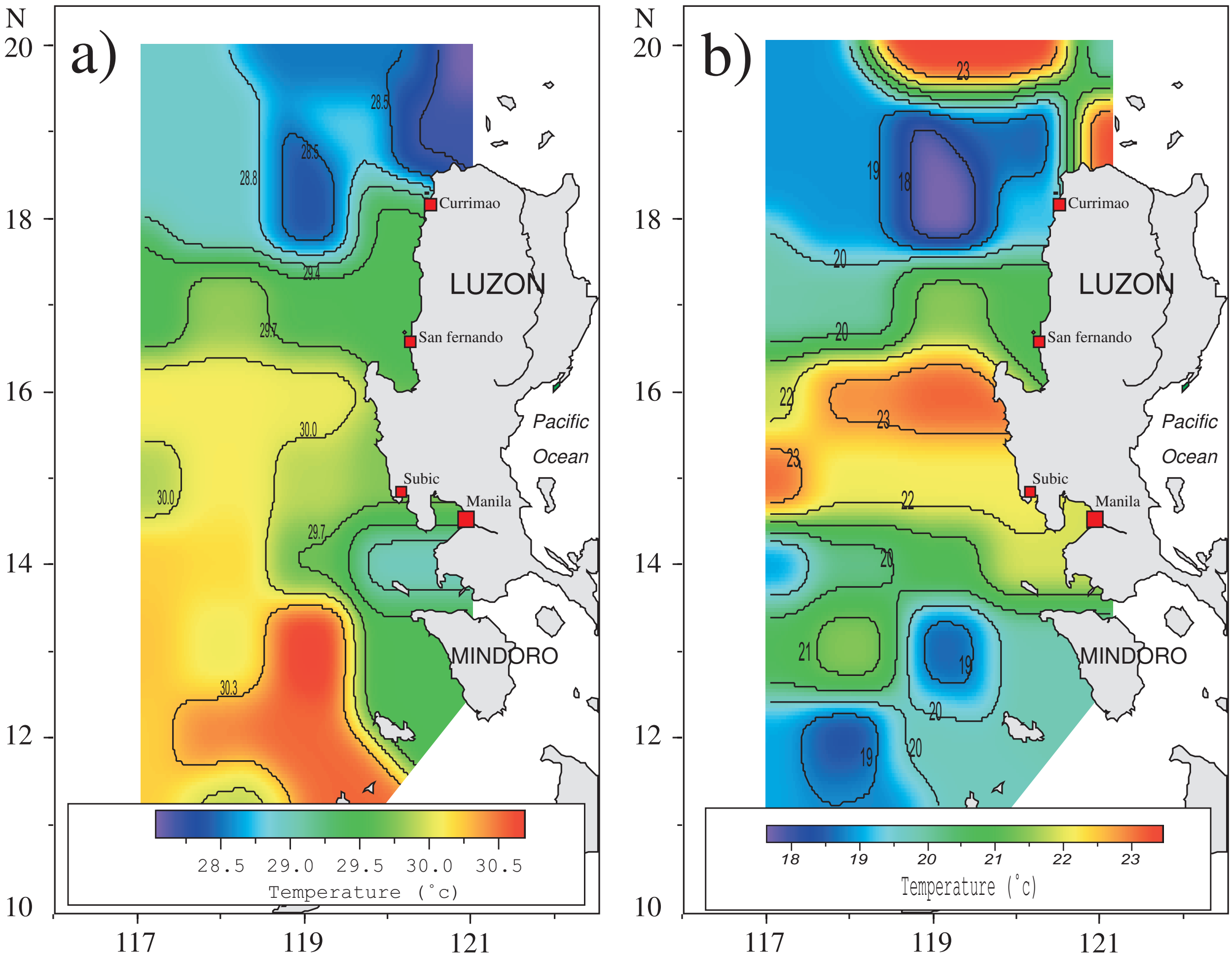


Fig. 9. 23 day synoptic chart of the sea surface temperature (a) and 100m deep (b) in the South China Sea: Western Philippines during 17 April- 9 May 1998.

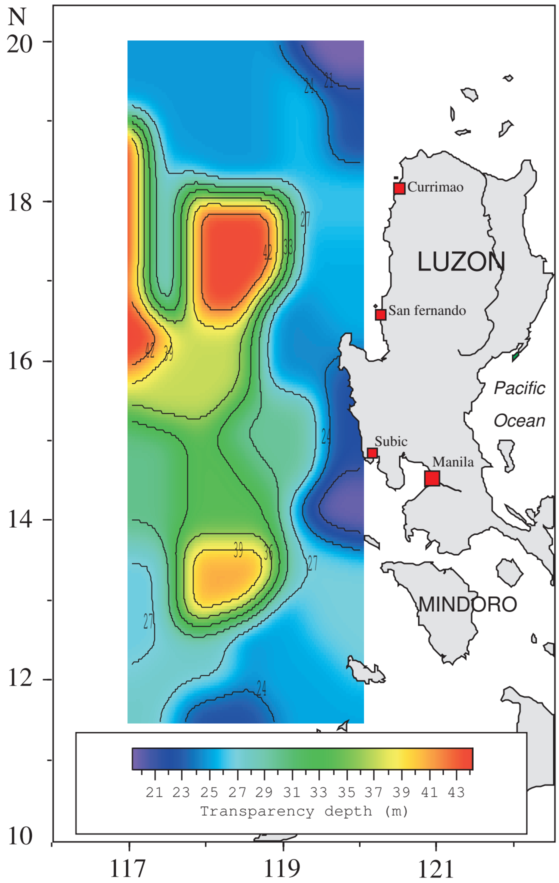


Fig. 10. 23 day synoptic chart of the water transparency depth (m) in the South China Sea: Western Philippines during 17 April- 9 May 1998.

the squid and ***k*** was 0.01m^{-1} obtained from the experiment, therefore the squid shall be living at deeper than 350m in the day. This is may be useful information for daytime operation.

Lunar Effects

Figure 14 shows the result of catch in CPUE related to percent of moon illumination. It was found that within the period before and after dark moon occurrence which the moon illumination is less than 30%, the catch of squid by jigging is high. A similar result was reported by Nakamura *et al.* showed that the oceanic squid species are generally active on feeding behaviour under dim light or less illumination from moon. How ever it will also depend upon the fishing ground conditions.

Acknowledgement

We wish to express our appreciation to the Captain and Crew of MV SEAFDEC for their kind cooperation during the survey.

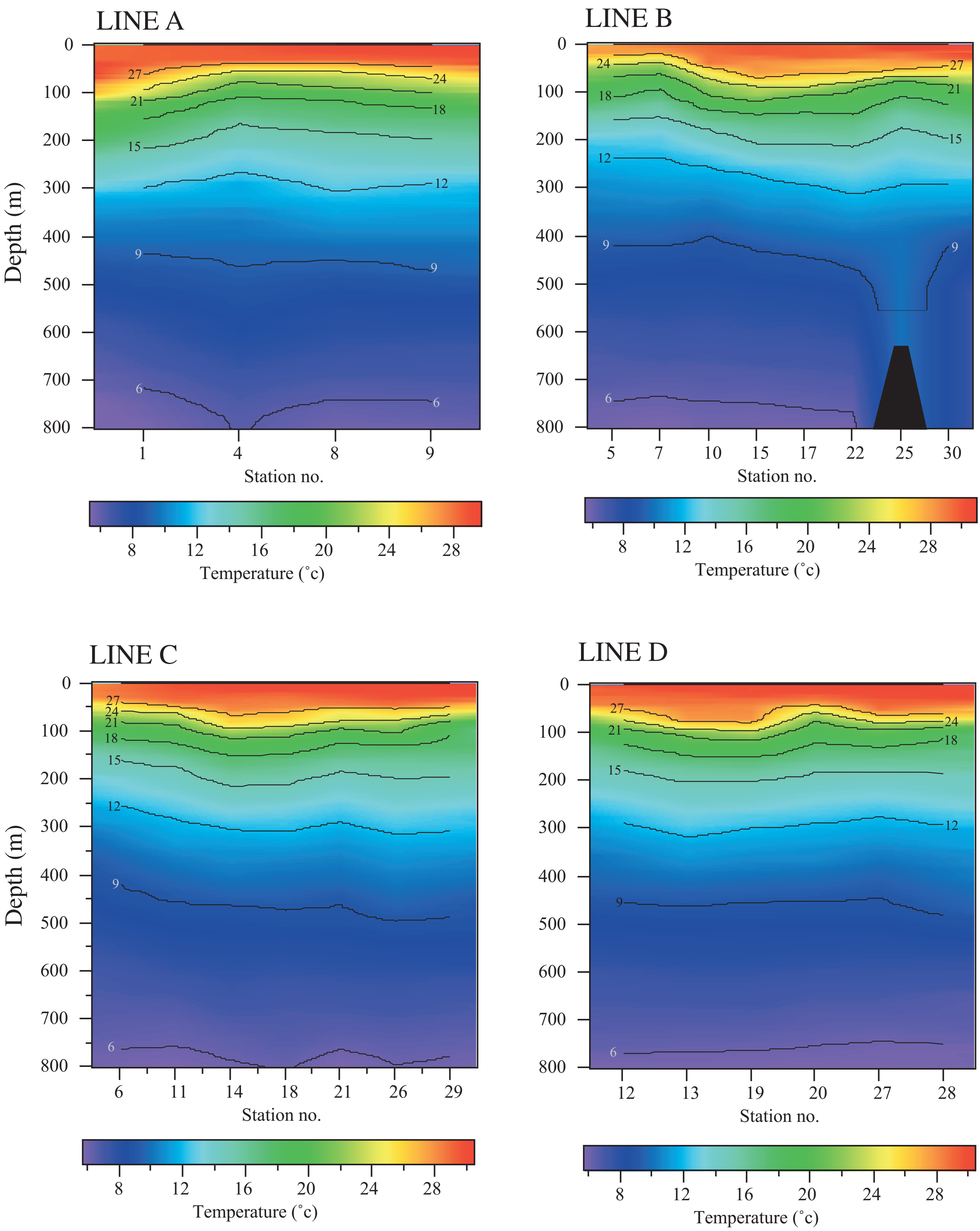


Fig. 11. Vertical profile of temperature (3˚c interval) at the cross section of LINE A , LINE B, LINE C and LINE D in the South China Sea: Western Philippines during April-May 1998.

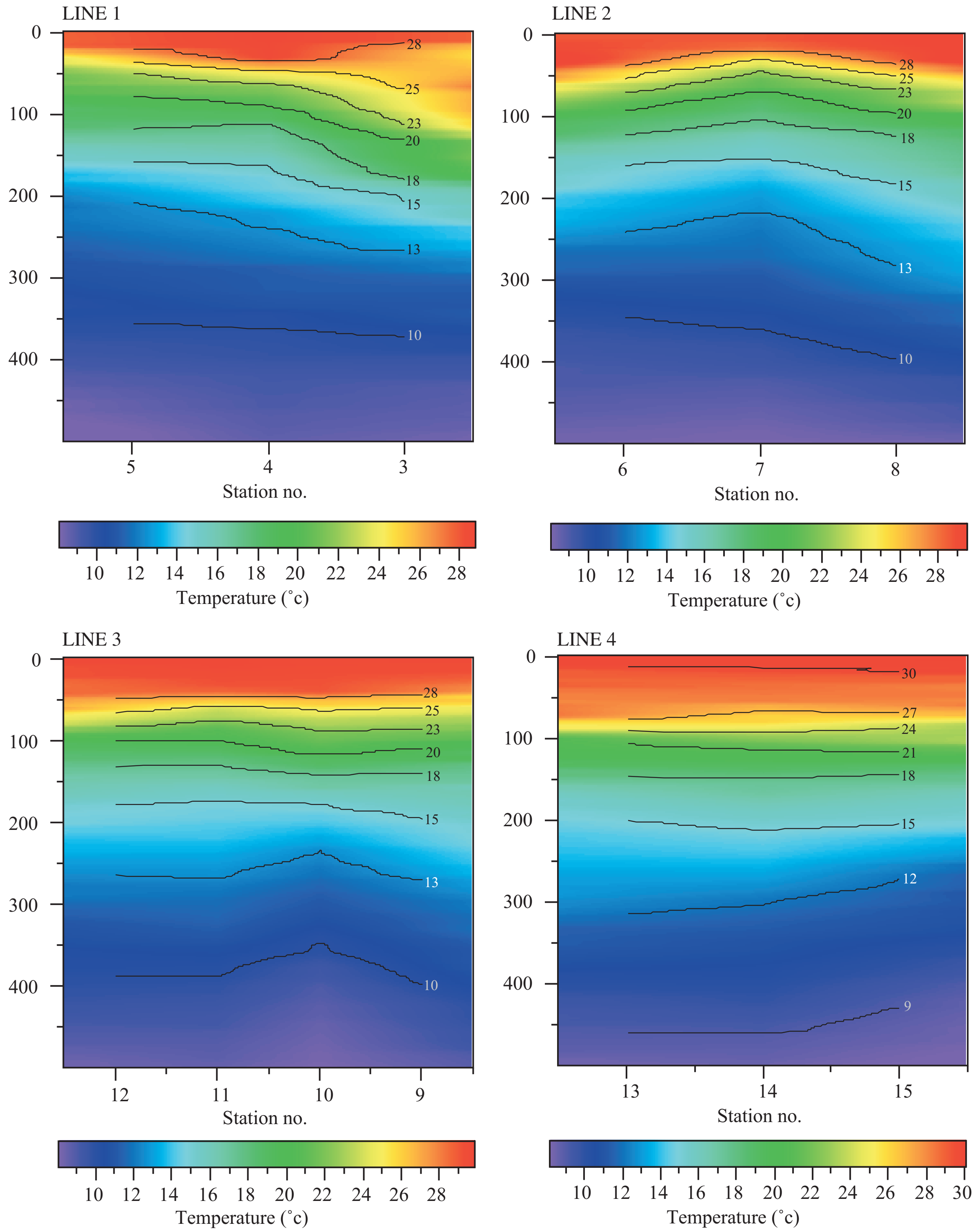


Fig. 12-1. Vertical profile of temperature (3˚c interval) at the cross section of LINE 1 , LINE 2, LINE 3 and LINE 4 in the South China Sea: Western Philippines during April-May 1998.

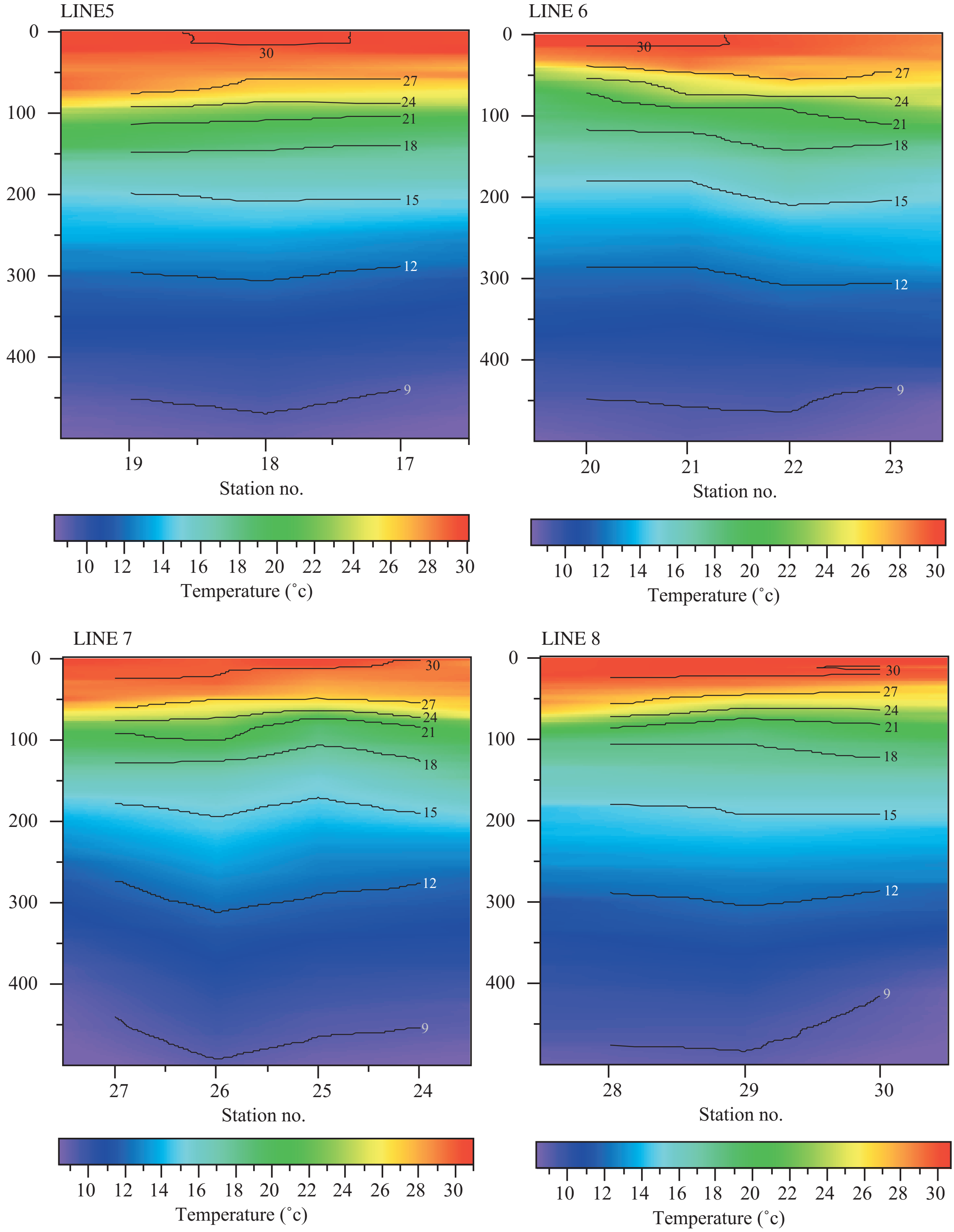


Fig. 12-2. Vertical profile of temperature (3˚c interval) at the cross section of LINE 5 , LINE 6, LINE 7 and LINE 8 in the South China Sea: Western Philippines during April-May 1998.

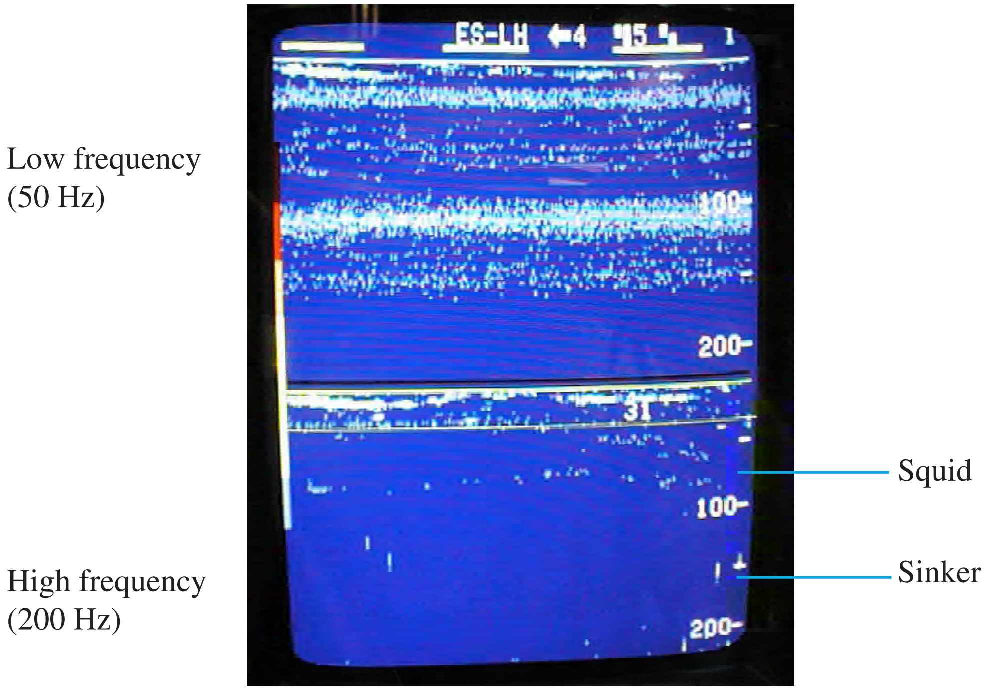


Fig. 13. Echo trace of the purpleback flying squid observed from colour echo sounder at 50 Hz and 200 Hz.

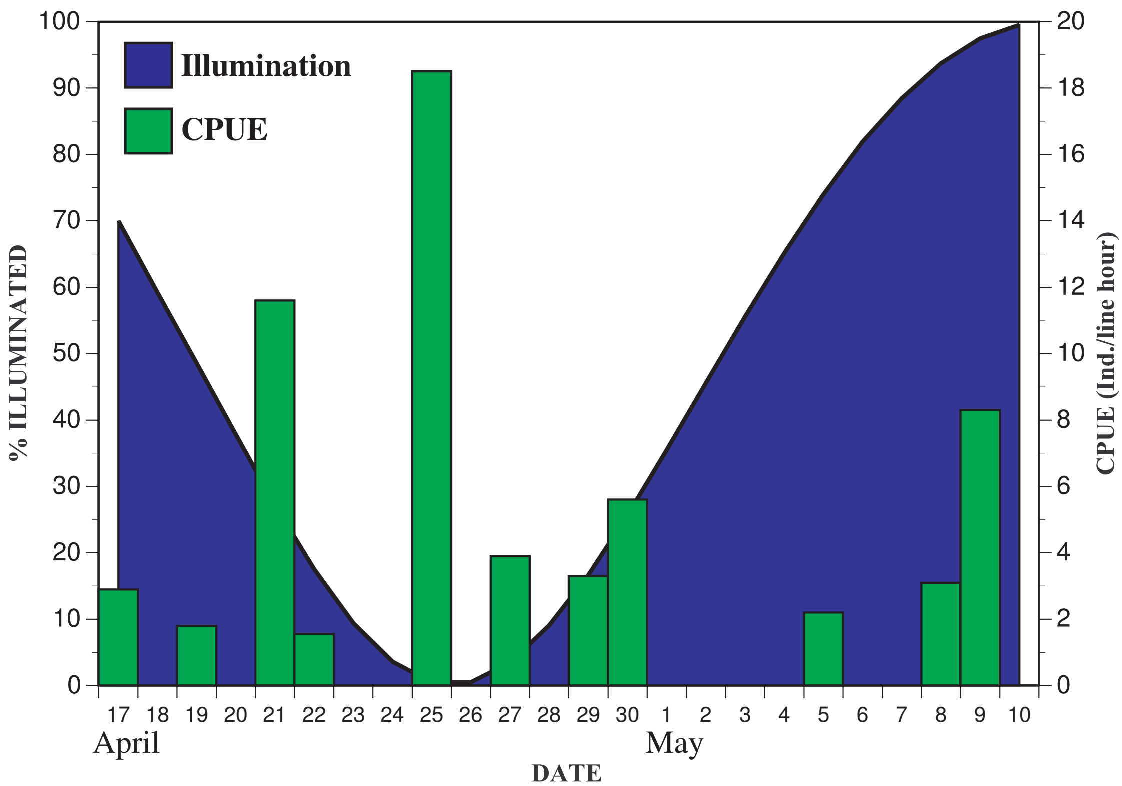


Fig. 14. Relationship between percent of illumination from the moon and result of catch in CPUE of the purpleback flying squid in the South China Sea: Western Philippines during April-May 1998.

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Age and Growth Studies of Oceanic Squid, *Sthenoteuthis oualaniensis* using Statoliths in the South China Sea, Area III, Western Philippines

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ABSTRACT

Studies on age and growth using statolith of oceanic squids, *Sthenoteuthis oualaniensis* collected from Western Philippines, South China Sea, Area III have been conducted from 7 April – 19 May, 1998 by MV SEAFDEC Cruise No. 50-4/1998. A total of 1,707 squids were sampled and measured onboard. 74 statoliths which consist of 53 statoliths from female specimens and 21 from male specimens were extracted and processed using statolith ageing techniques with the body mantle length range from 107 – 217 mm and 115 – 167 mm, respectively. The male is smalled than the female where the male does not exceed 180 mm and the the female can grow upto 260 mm.There is slighly a different dimension of growth at the statolith microstructure between the male and female specimens. In the ground statolith, growth increments were examined and grouped into four growth zones distinguished mainly by the width of the increments. It was found that the male exhibit slower growth and maturation occur at the same time with the female but at smaller size. The age of the male and female ranged from 135 – 259 days and 95 – 275 days, respectively. The life span of the species was considered within one year. It was also observed that the putative microcohort of the female could be explained from the length frequency distribution of the immature and mature female and a pool data of length frequency distribution from all stations.

Keywords: squids; statoliths; age and growth; Philippines waters; South China Sea

Introduction

There has been increasing worldwide interest in cephalopod resources, especially in squid species(Caddy,1989). Loligonid species is one of the most numerous and economically valuable squid species compared to other species as they are a neritic species occurring in coastal waters.

The application of daily growth increments to age determination has been used primarily to age larval and juvenile fish (Methot and Kramer, 1979; Steffensen, 1980; Barkman *et al.*,1981; Powell, 1982). Growth of young-of-the-year fish and timing of behavioural changes have been documented(Brothers and McFarland, 1981; Methot,1981; Victor, 1982; Lough *et al.*, 1982) and the technique has also been used to age young tuna(Wild and Foreman, 1980; Uchiyama and Struhsaker, 1981; Radtke, 1983). The ability to locate the position of the first annulus has been a major contribution to routine age determination.

Daily growth increments have been of little use in ageing older fish or in solving interpretation problems in adults. The studies on squids shows that most of the squids are short life species with a life span of 1 – 2 years and and can be age by using the method of daily growth increments(Hixon and Villoch, 1984; Dawe *et al.*, 1985; Natsukari *et al.*, 1988; Jackson, 1990; Nakamura and Sakurai, 1990; Arkhipkin, 1993; Arkhipkin and Nekludova, 1993; Arkhipin *et al.*1996) by assuming that the growth increments were deposited daily.

Oceanic squids of the genus *Sthenoteuthis* were common in the upper region of the South China Sea which inhibit deeper water. However, information on the population biology parameters of these species is still scarce, and has justified recent efforts to improve data quality and quantity. Several countries have collaborated in a research project to improve knowledge on these squid and provide a solid basis for their exploitation or conservation. So therefore, the aim of this paper is to provide basic information on their age and growth of *Sthenoteuthis oualaniensis* using microstructure of the statoliths.

Materials and Methods

Data were collected on *Sthenoteuthis oualaniensis* during a preliminary survey of oceanic squid in the South China Sea, Area III, Western Philippines(Fig.1) by MV SEAFDEC Cruise No. 50-4/1998 between 7 April – 19 May 1998. Four squid jigging machines were used in the survey with a depth operation ranged between 0 – 150 m from the surface. The number of jigs on each machines ranged from 32 – 46 jigs and two jigs size has been used during the operations.

Sampling stations

A total of 11 selected stations have been choosen at a depth more than 1,000 m. that is, station No. 1, 5, 7, 9, 12, 14, 17, 21, 27, 30A and 30B. Their basic physical data of the sampling stations is as shown in Table 1. Station 9 was selected as an extra station near a coastal shallow water while sample for station 12 include the specimens from the searching method using echo traces of the echo sounder(50 specimens). The position for station 30A and 30B were slightly different from the original sampling station 30 and 31.

Length frequency sampling

A total of 1,707 specimens of *Sthenoteuthis oualaniensis* were measured during the expeditions, including both male and female specimens(number of female = 1,383 and number of male = 324). A systematic random sampling were done at each stations where an alternate number of five specimens of squids landed were taken as a subsamples, i.e. the squids number 1-5, 11-15, 21 – 15, 21 – 25 etc. Dorsal mantle length (ML) was measured to the nearest 1 mm and total body weight (BW) to the nearest 5 g using kitchen spring balance onboard MV SEAFDEC. The sex were determined through their external morphology and their sex ratio calculated. The length-frequency curve for each sex were then constructed at each sampling stations.

A total of 279 specimens from 11 sampling stations were brought to the Laboratory, Faculty of Applied Science and Technology for further analysis. The measurement of the preserved sample, i.e., length and weight were again measured to the nearest 1 mm and 0.1 g, respectively and sex recorded. These data were used to construct the curve of length-weight relationship.

Age sampling

A total of 74 statolith reading were taken under the scheme of representative sampling to ensure that all lengths and maturity stages were equally well sampled(Dawe and Natsukari,1991) from the subsamples taken for length frequency analysis which include 53 female specimens and 21 male specimens. A total of five specimen were taken at each interval class of 1-cm and at each maturity stages. However, the dissection were made only on the mature male and female

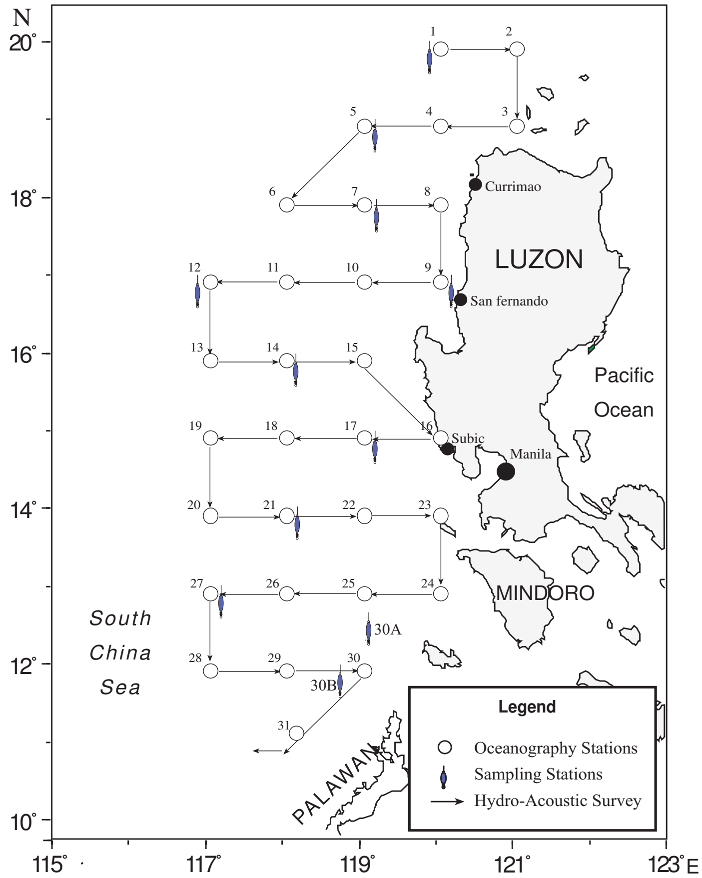

Fig. 1. The maps shows the sampling stations during the MV SEAFDEC cruise at South China Sea, Area III, Western Philippines from 7 April – 19 May 1998. The dark shows the position of the squids sampling stations.

specimens at various maturity stages. However, we could not found in our subsamples the large-size male and female specimens which have already spent. The statolith taken were first washed in distilled water, and labeled and stored in oil-paper envelopes in 96% ethanol.

Statolith ageing analysis

The statolith terminology used in this paper followed Clarke(1978) and Lipinski *et al.*(1991). Preparation of statoliths for age analysis has been made by the method described in Dawe and Natsukari(1991). The statolith weight, length of the rostrum, length of the wing, length of statolith body and statolith length were recorded before grinding process(Fig. 5). The statoliths were ground (on 800 grit) and polished (on 1,200 grit) wet waterproof sandpaper. Because the direction of the maximum growth within statoliths changed during ontogenesis, it was necessary to grind the convex side of the same statolith in two planes; one plane running through the lateral and dorsal domes and spur, and the other plane running through the spur and along the central axis of the rostrum. This method of grinding exposes the growth increments lying immediately below the wing. The ground statolith was not flat and thin as in Natsukari *et al.*(1993) but thickened in the region of the lower part of the lateral dome and the proximal part of the rostrum. This feature allowed all increments from the nucleus to the most distal part of the rostrum to be ambiguously resolved.

Ground statoliths were embedded in glycerin and covered with glass for immediate reading. Statoliths were read under a light microscope with 200 – 500X magnification. Growth increments were counted from the nucleus to the distal part of the rostrum and from farther within the rostrum as described by Natsukari *et al.* (1993) by using the eyepiece. To avoid possible counting errors, each statolith was counted at least twice by two observers, and if the difference between readings was less than 5%, squid age was taken as the mean of these counts. Readings were made only after achievement of the maximum resolution of growth increments with fine-adjustment focusing.

Results and Discussions

Length frequency distribution

The length-frequency distribution of oceanic squids, *Sthenoteuthis oualaniensis* at each sampling station is as shown in Fig. 2 and Fig. 3. While complex, the length frequency histograms are quite similar in all the stations sampled. And are consistent with the assumption of an underlying annual cycle and a lifespan of approximately one year especially the male which have only one size mode. However, putative microcohorts are more readily identified in data for female at each station, but when the data are pooled together from all stations it tends to show one normal distribution skewed towards the right side of the curve. Sexual dimorphism in size clearly occur in this species and similarly to other species such as *Loligo forbesi* (Pierce *et al.*,1994; Guerra and Rocha,1994), *Berryteuthis magister*(Arkhipkin *et al.*,1996), *Illex coindefii* and *Todaropsis* (Gonzalez et al, 1994) and therefore, by implication, effect the growth rates. The males are significantly smaller than the female at all post-recruitment sizes and, consequently, in all population studies the male and female components must be treated separately. It was found that the male does not exceed 18 cm while the female can grow up to 26 cm .

The fishery by automatic squid jigging operated during night time may cause an error in samplings. This might be caused by either the selectivity of the gear and technique used which in turn are related to ecological factors such as feeding behaviour and vertical distribution (Porteiro and Martins, 1994). Since net are not employed, small squid were not collected at all stations and as a results the population sample might not represent the true population.

Length-weight relationship

Since, the length frequency distribution shows that there is a significant different between the male and female specimens, therefore, we will separate all our analysis according to their sex. The length-weight relationships of male and female *S. oualaniensis* is as shown in Fig. 4. Only data from the preserved samples were used since the data for weight during the onboard MV SEAFDEC would not be appropriate for the analysis. The relationship for;

a) Female

$\ln(BW) = 2.9209 \ln(ML) - 9.6818$; $r^2 = 0.8094$ $n = 223$

b) Male

$\ln(BW) = 3.2331 \ln(ML) - 11.28$; $r^2 = 0.7981$ $n = 56$

where the length for female and male specimens range from 107 – 234 mm and 114 – 181 mm, respectively. This gave a sex ratio between female and male of 4:1 and this ratio is also equivalent to the whole sampling (1,707 where the female is 1,383 and male is 324).

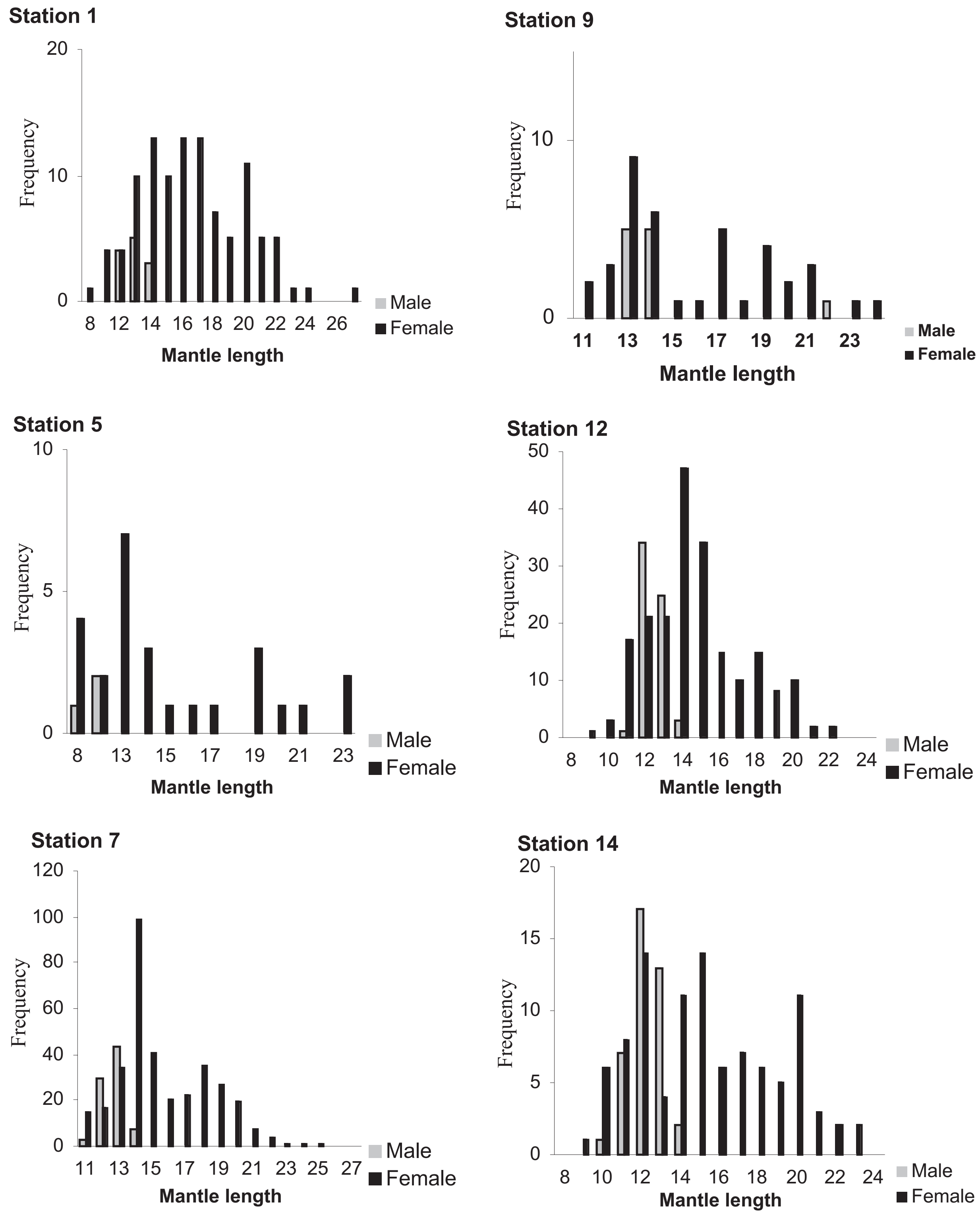

Fig.2. The length frequency distribution of male and female oceanic squid, *Stenoteuthis oualaniensis* at station 1,5,7,9,12 and 14.

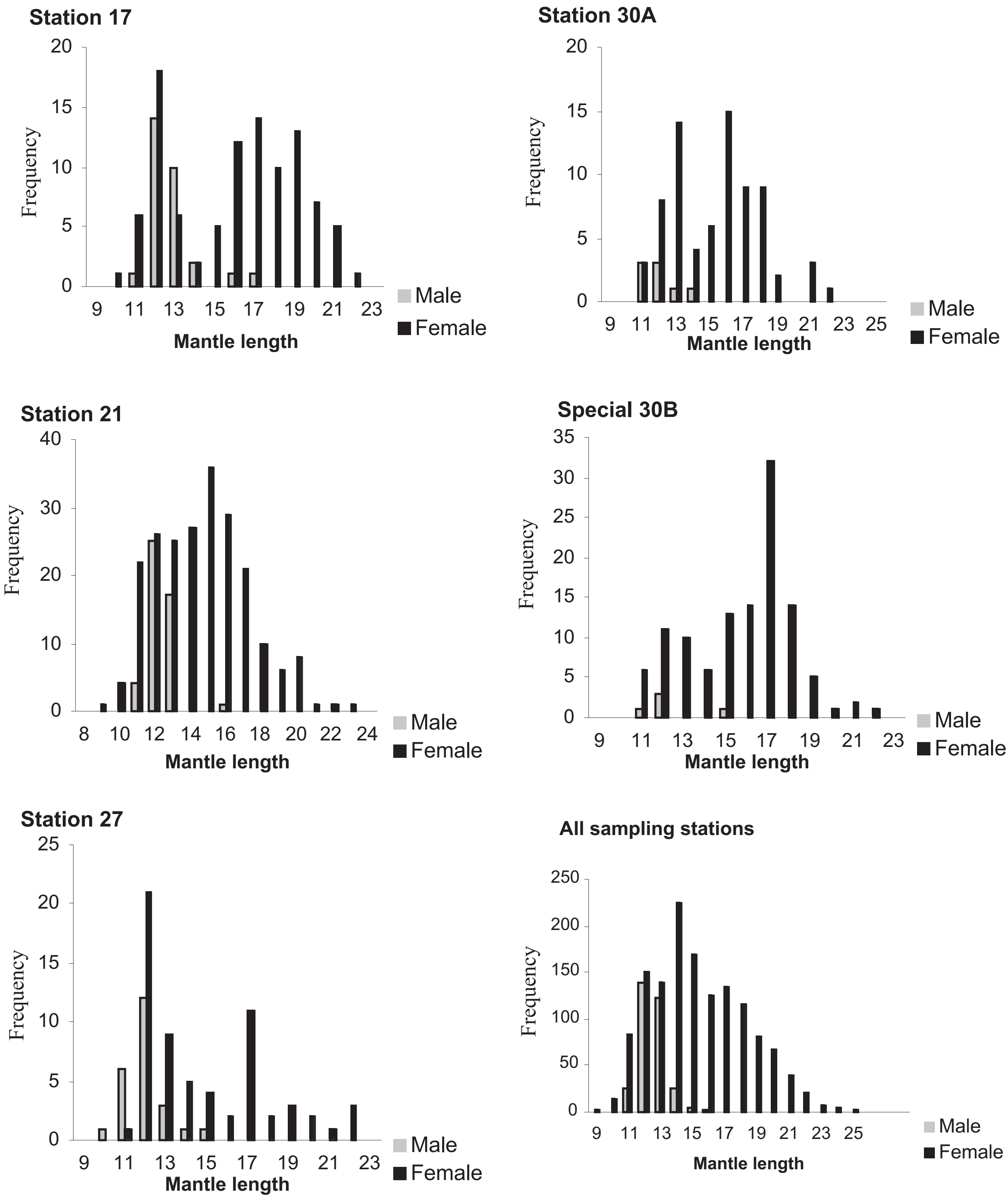

Fig.3. The length frequency distribution of male and female oceanic squid, *Stenoteuthis oualaniensis* at station 17,21,27,30A, 30B and pool data from all sampling station

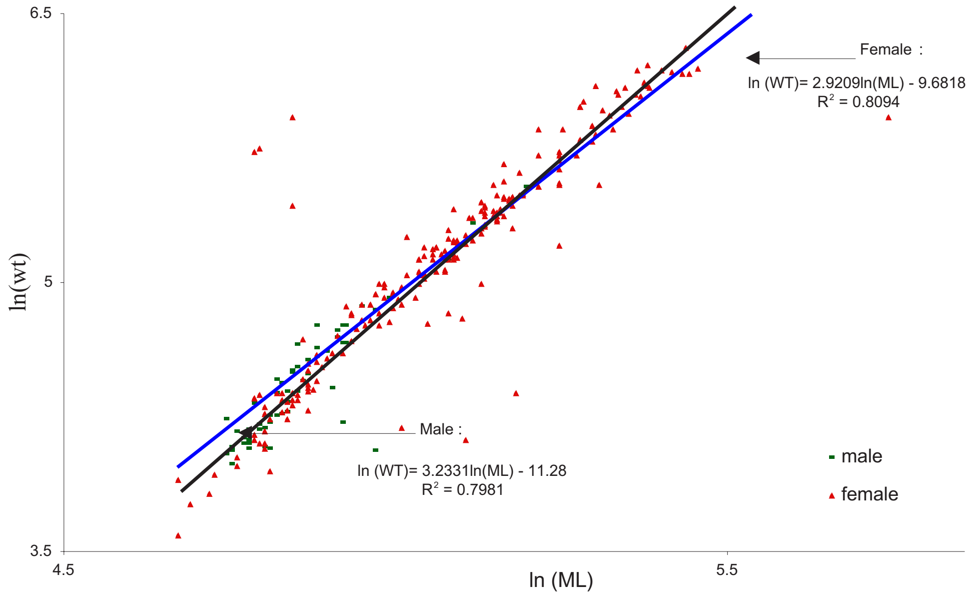

Fig.4. The length-weight relationship of male and female oceanic squid, *S. oualaniensis.*

Statolith morphology and microstructure

Statolith growth increments were faint but clearly visible in all statolith preparations. They are smooth and tiangular(Fig.5) with the dorsal dome relatively small and rounded. A lateral dome is present and is smooth. The rostral angle is obtuse and the rostrum long.

In the ground statolith of *Sthenoteuthis oualaniensis* four growth zones were observed (Fig. 6). The nucleus is oval in shape and is situated under the spur and is surrounded by the first faint growth increment. The post-nuclear zone is dark-coloured, located between the nucleus and the opaque zone. The number of narrow growth increments (0.9 – 1.2 µm) in the post-nuclear zone ranged from 12 to 29. According to Morris(1991), the post-nuclear zone is developed during embryogenesis. The well-pronounced check('natal ring') lies on the boundary between the post-nuclear and opaque zones. It was observed that the growth ring of the male specimens are much clear and easier to processed as compared to the female specimens.

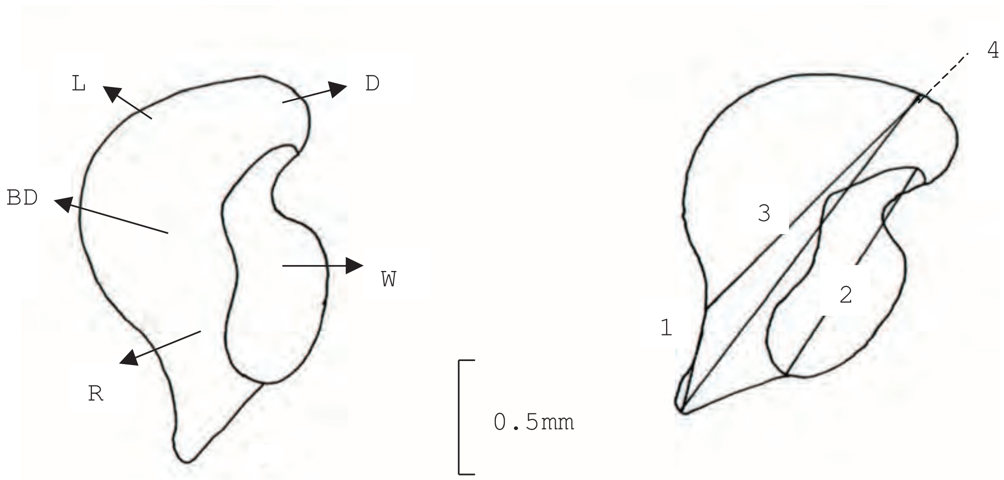

Fig. 5. Statolith of *Stenoteuthis oualaniensis*(mature female, ML 165 mm, (A) the anterior view of the statolith; D, dorsal dome; L, lateral dome; R, rostrum; W wing: BD statolith body, and (B) their measurements; 1, length of the rostrum; 2, wing; 3, statolith body; and 4, statolith length.

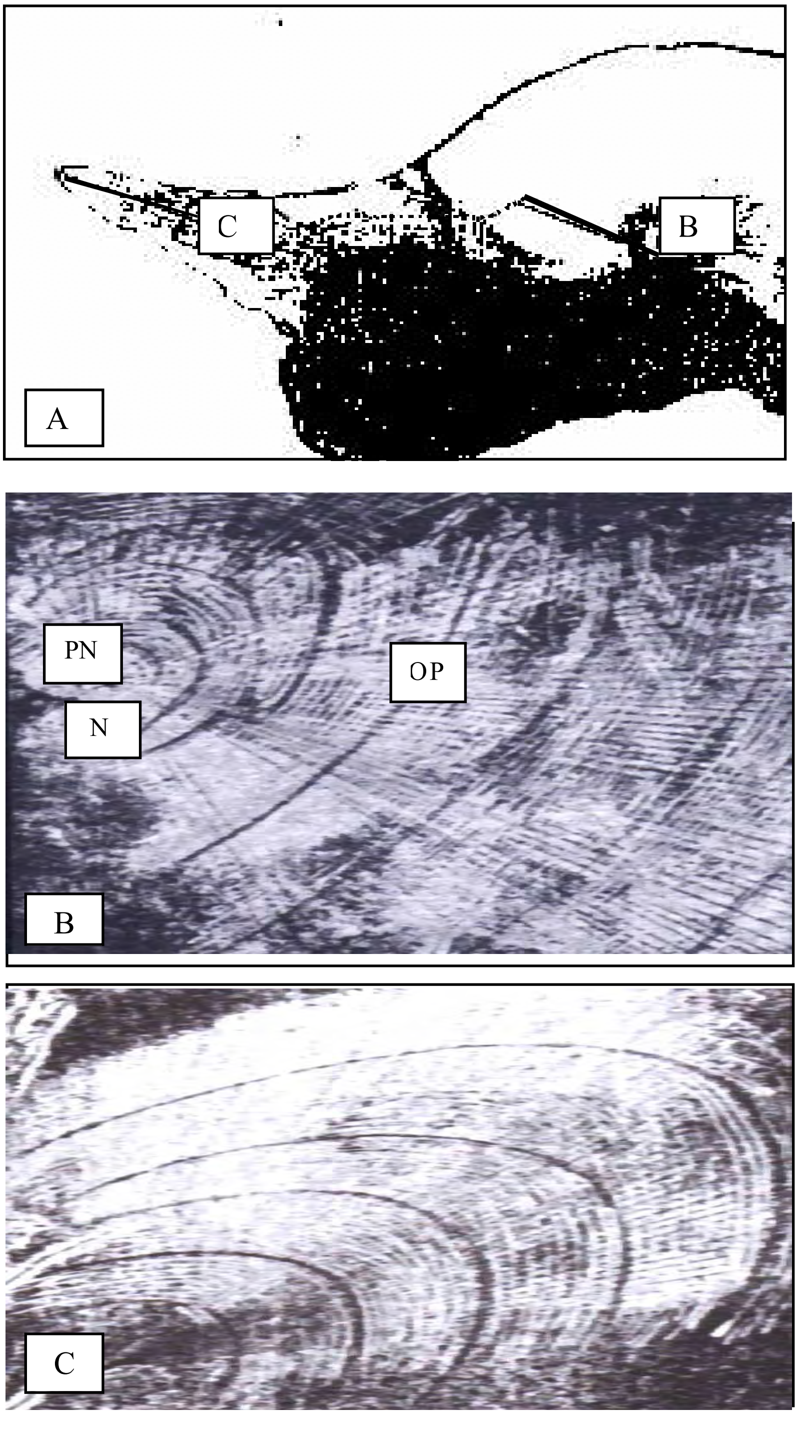

Fig. 6. Light micrograph of statolith *Stenoteuthis oualaniensis* from South China Sea, Western Philippines, Area III. (A) General view, (B) Growth zones; N, nucleus, PN, post-nucleur, OP, opaque, (C) Peripheral zone (PF) in the rostrum.

The opaque zone is light and almost translucent in transmitted light, but slightly opaque in reflected light. Growth increment are wide. A transition between the opaque and the peripheral zones is not clearly recognized and can be distinguished by a decreased in the width of the growth increments ranging from 2.2 to 3.7 µm in the peripheral zone of the rostrum. The peripheral zone is translucent. The number of growth increments in both opaque and peripheral zones ranges from 95 to 275.

Statolith growth

The correlation between the body size [dorsal mantle length(ML) and body weight(BW)] *vs* the statolith weight (sw) were depicted in Fig. 7 and Fig. 8. It was found that the male developed heavier weight of statolith compared to female. This might be due to the wider increments of the width of the male statoliths compared to the female at the same size (see Fig. 9).

At the same size of the dorsal mantle length the total statolith length of the females grow longer than the males population as shown in Fig. 10. It was also observed that there are three growth stages of female, i.e., first, the transitions periods from the immature to mature where the growth rates are slow, secondly, the growth rate increases dastically during various maturity stages and finally the growth reach their asymptode. The same phenomena also observed for male populations but at lower size class.

Allometric growth of the different parts of the statolith was studied. An index was calculated by dividing the statolith body, rostrum and wing lengths by the statolith length and multiplying the result by 100 for a percentage. Allometric growth was negative with the index of the body length and rostrum length(Fig. 11A and 11B) and positive for wing length/total statolith length.

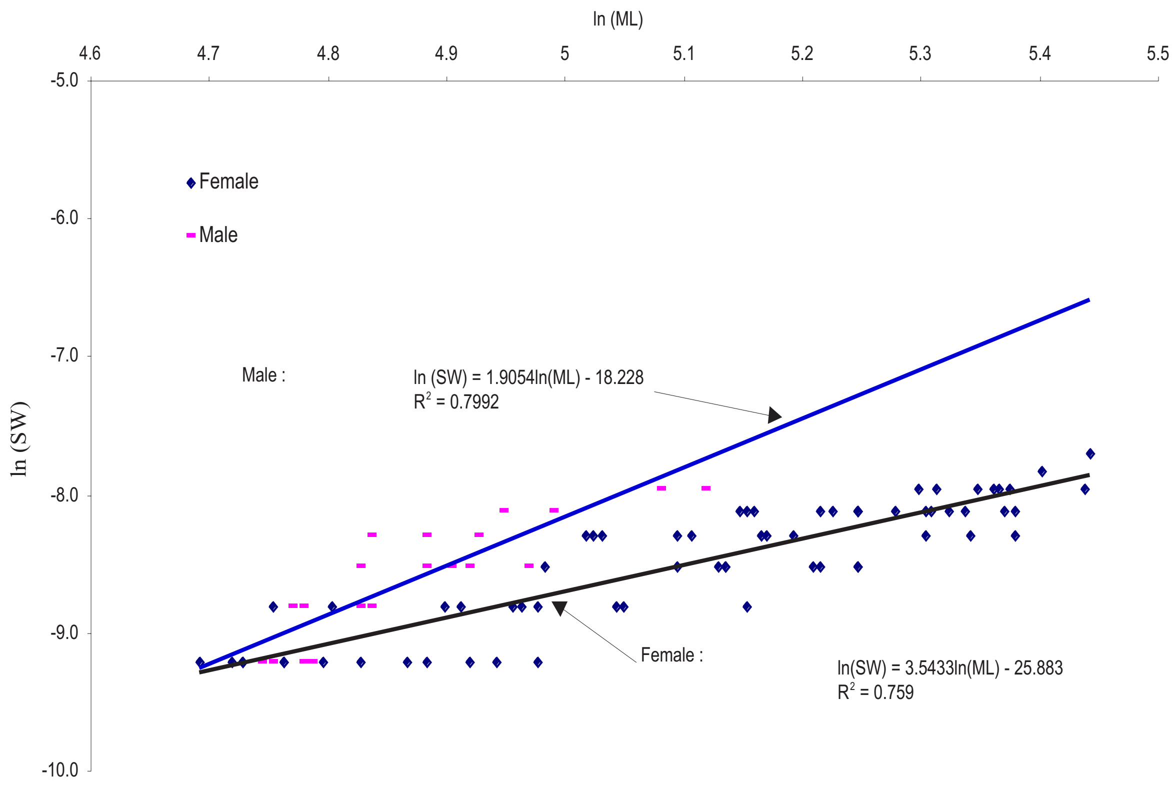

Fig. 7. Relationship between mantle length vs statolith weight of male and female oceanic squid, *Stenoteuthis oualaniensis.*

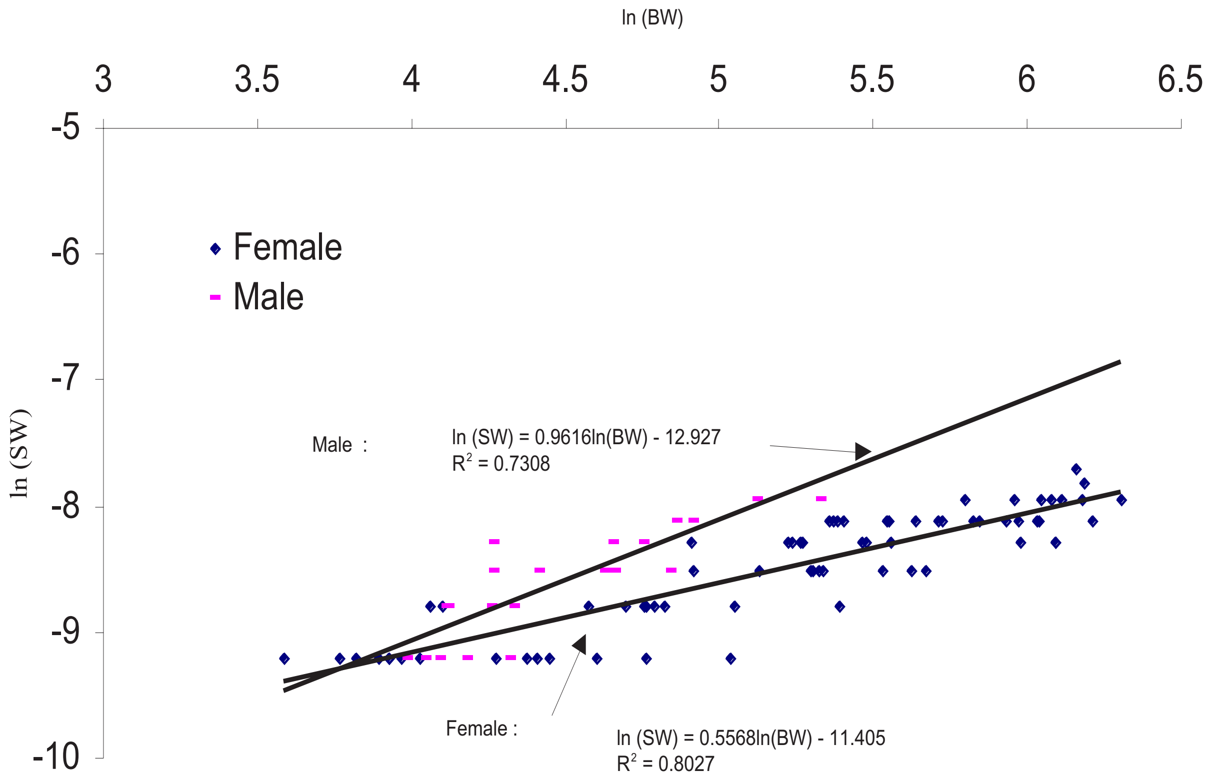

Fig.8. Relationship between body weight vs statolith weight of male and female oceanic squid, *Stenoteuthis oualaniensis.*

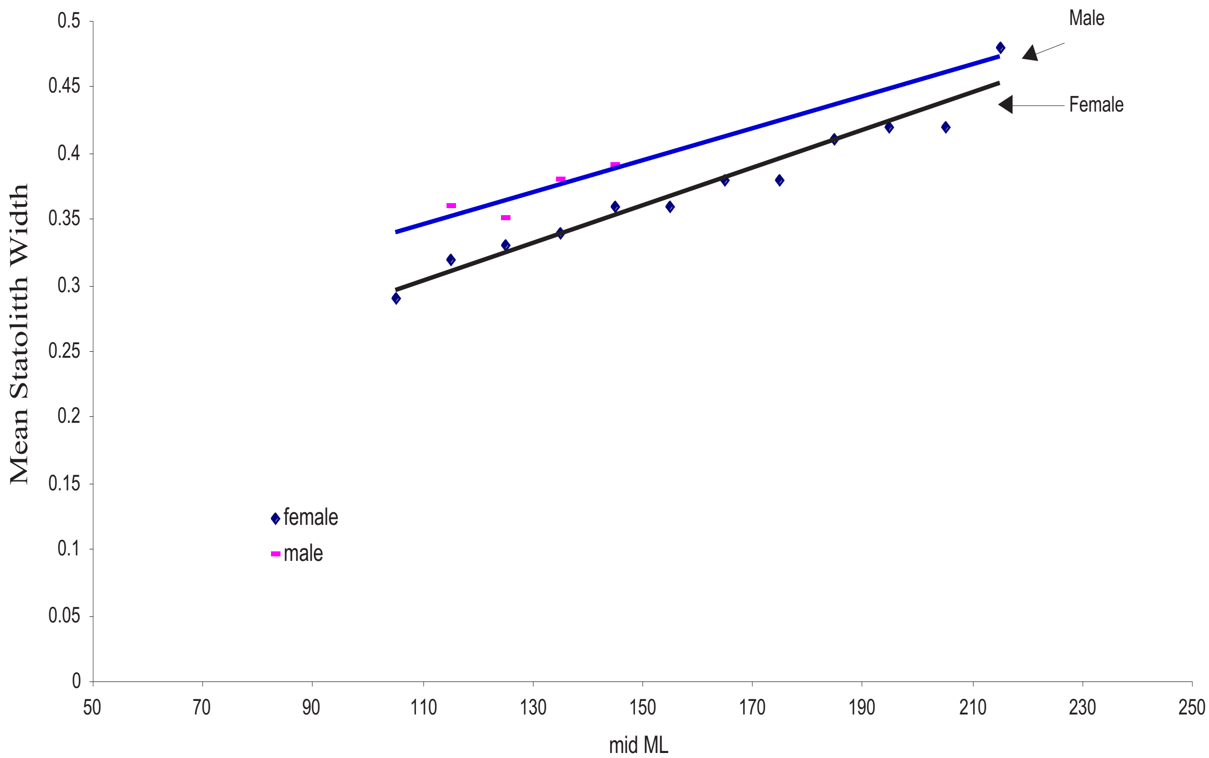

Fig.9. Comparison of the width length of the statolith for male and female oceanic squid, *Stenoteuthis oualaniensis.*

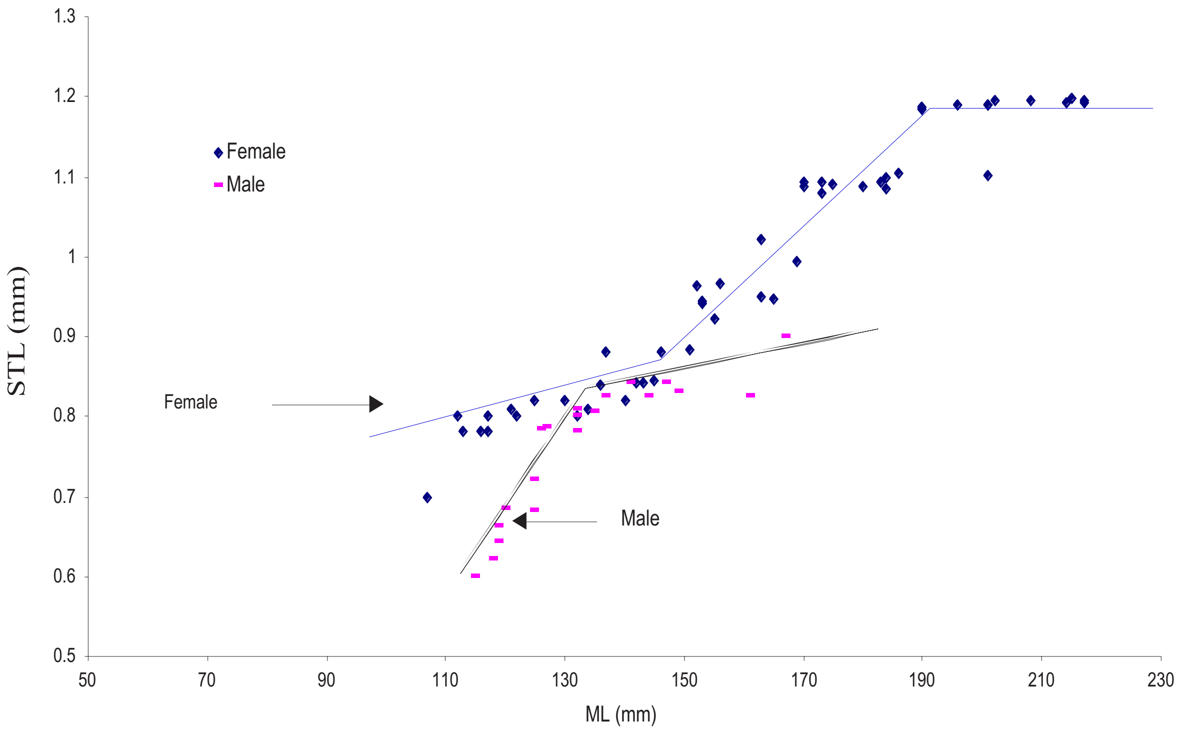

Fig. 10. Allometric growth of the total statolith length (TSL) vs mantle length (ML) for male and female oceanic squids, *Stenoteuthis oualaniensis*.

Age and growth of squids

In our samples, the smallest oceanic squids, *S. oualaniensis* of 107 mm ML was 102 d old. In female, *S. oualaniensis* the maximum age obtained was 275 d (217 mm ML) and for male 259 d (161 mm ML). These data shows that the females live longer than males. The females grew faster than males after they reach 100 mm (see Fig. 12).

It was observed that there is a weak correlation between the total body weight and the number of growth increments for male specimens. It would suggest that it is better that the correlation between the number of growth increments and the body mantle length be used rather than body weight especially for male (see Fig. 13) for these species.

Conclusions

Statolith of *S. oualaniensis* have a similar shape with loligonid statoliths, which are characterized by a well developed lateral and dorsal dome and a long finger-shape rostrum (eg. *Loligo forbesi*, Clarke,1978; *Photololigo edulis*, Natsukari *et al.*, 1988). However, there are slightly different in the dimension of growth between the males and females where males towards a wider statolith width length and female towards longer statolith length.

Since the length frequency distribution shows that there are two different cohorts of female sample population, i.e., the immature and mature population it might suggest that there might exist a prolong spawning seasons (see Fig. 14). The difficulty is that our population samples does not include the small squids size. This might be due to the selectivity of the fishing gears used during the sampling procedures.

We have dissected a sample of *S. oualaniensis* onboard of MV SEAFDEC which were chosen at

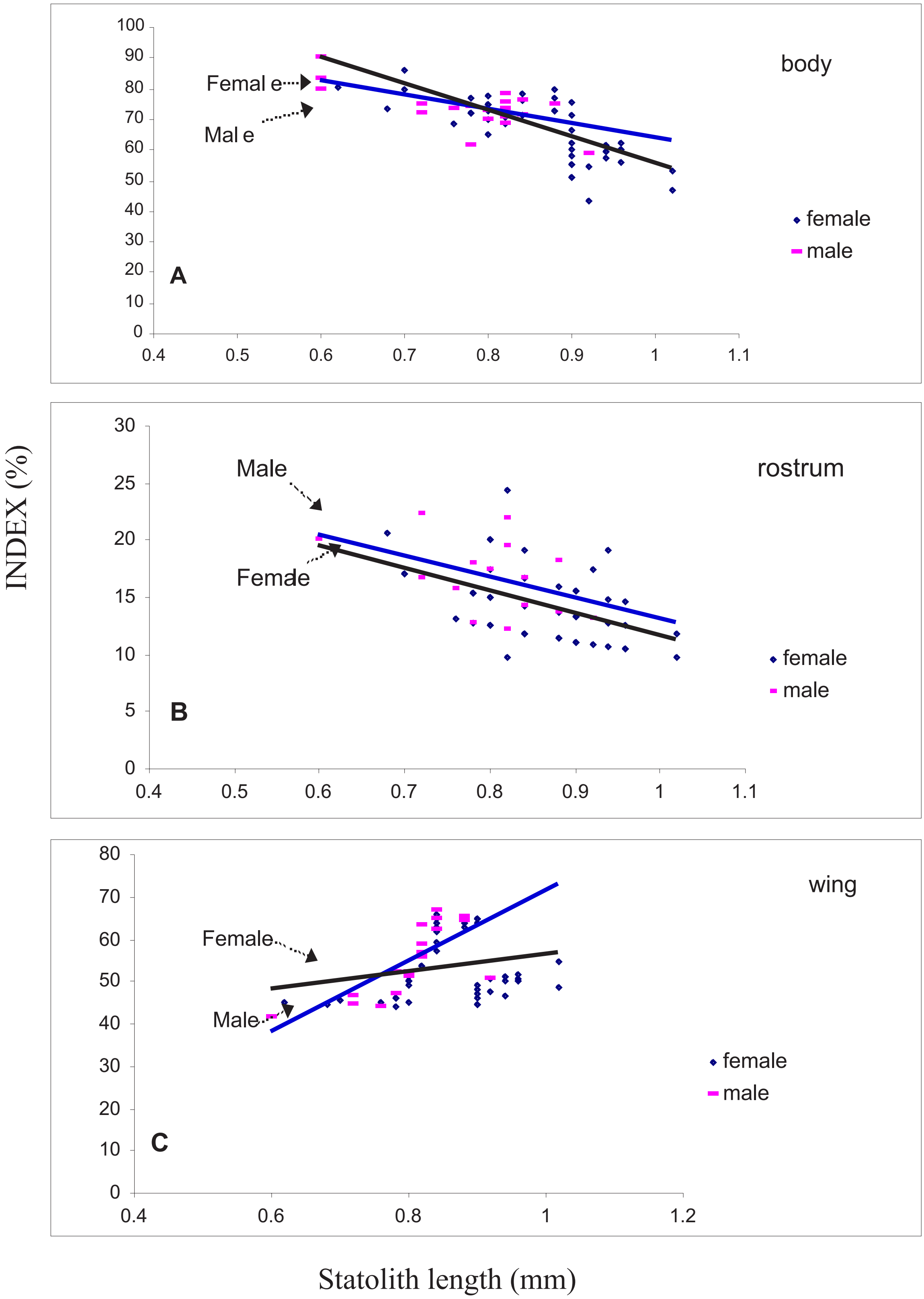

Fig. 11. Allometric growth of the length of (A) statolith body, (B) the rostrum and (C) the wing vs statolith length of oceanic squids, *Stenoteuthis oualaniensis*.

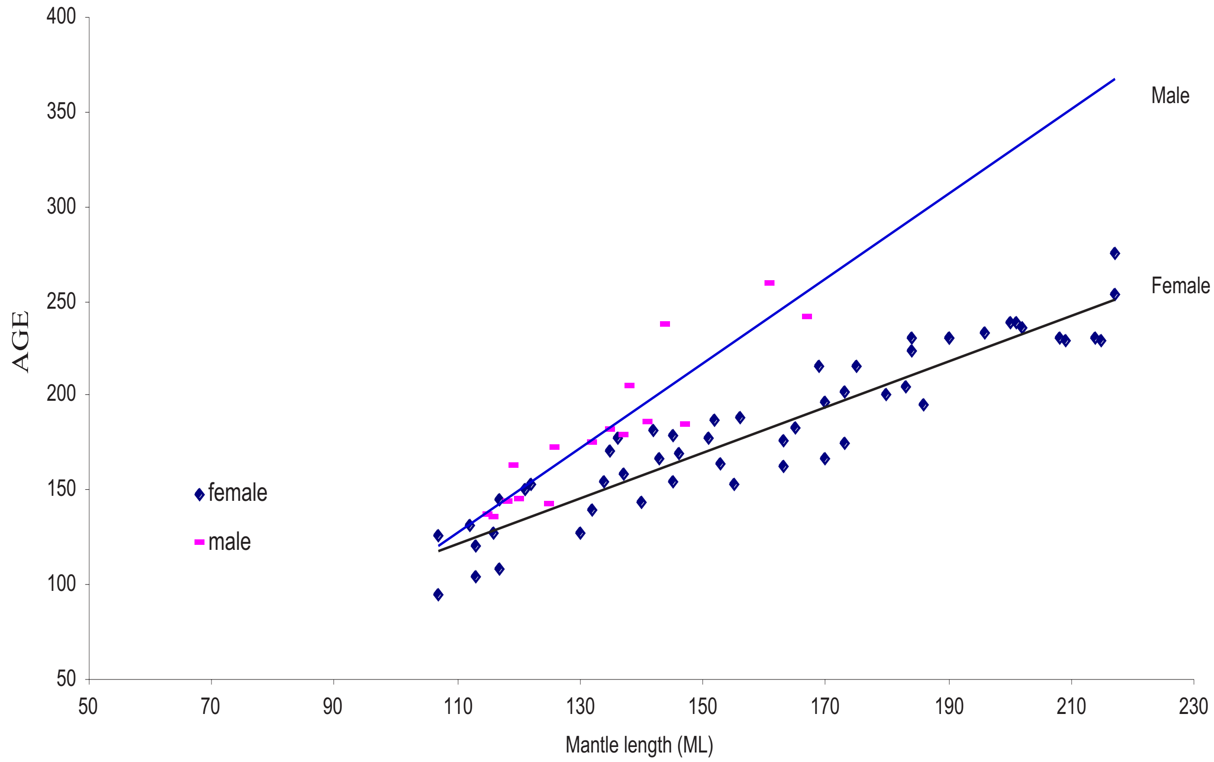

Fig. 12. Relationship between age (number of daily growth increments) and mantle length of male and female oceanic squids, *Stenoteuthis oualaniensis.*

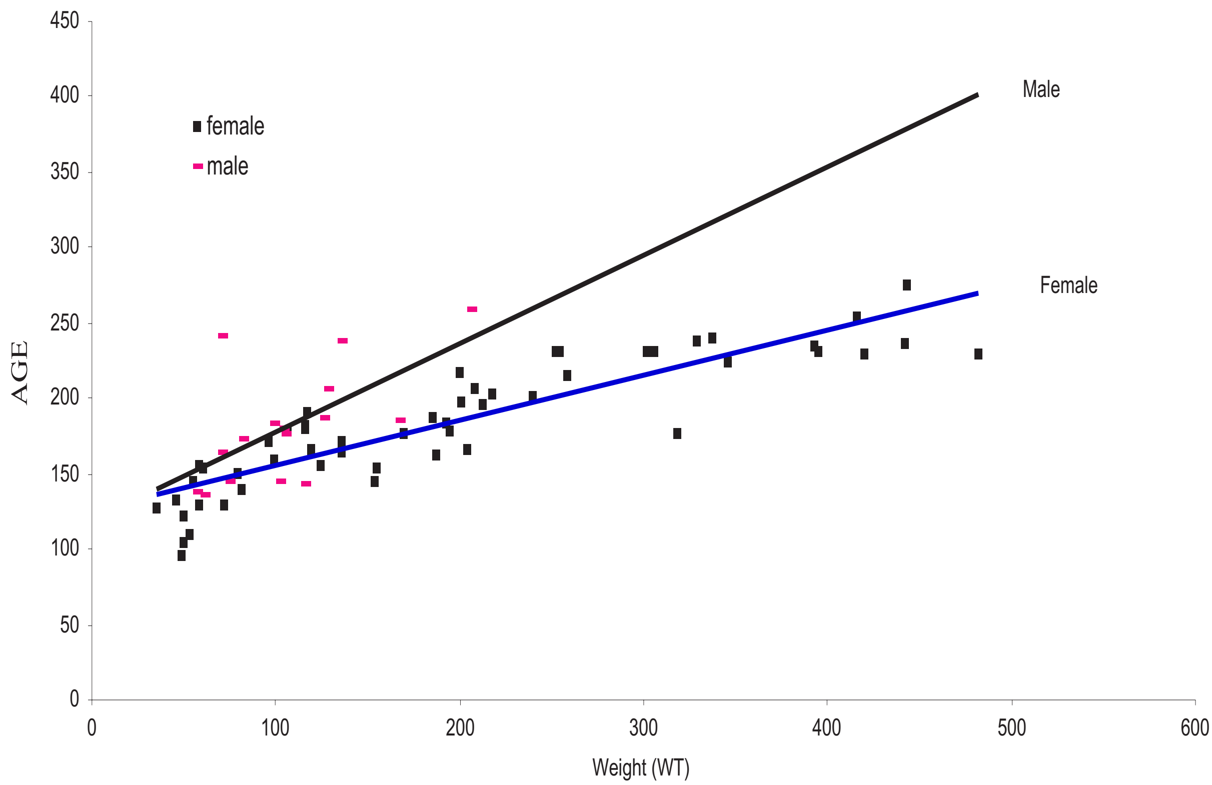

Fig. 13. Relationship between age(number of growth increments) and total body weight of male and female oceanic squids, *Stenoteuthis oualaniensis*

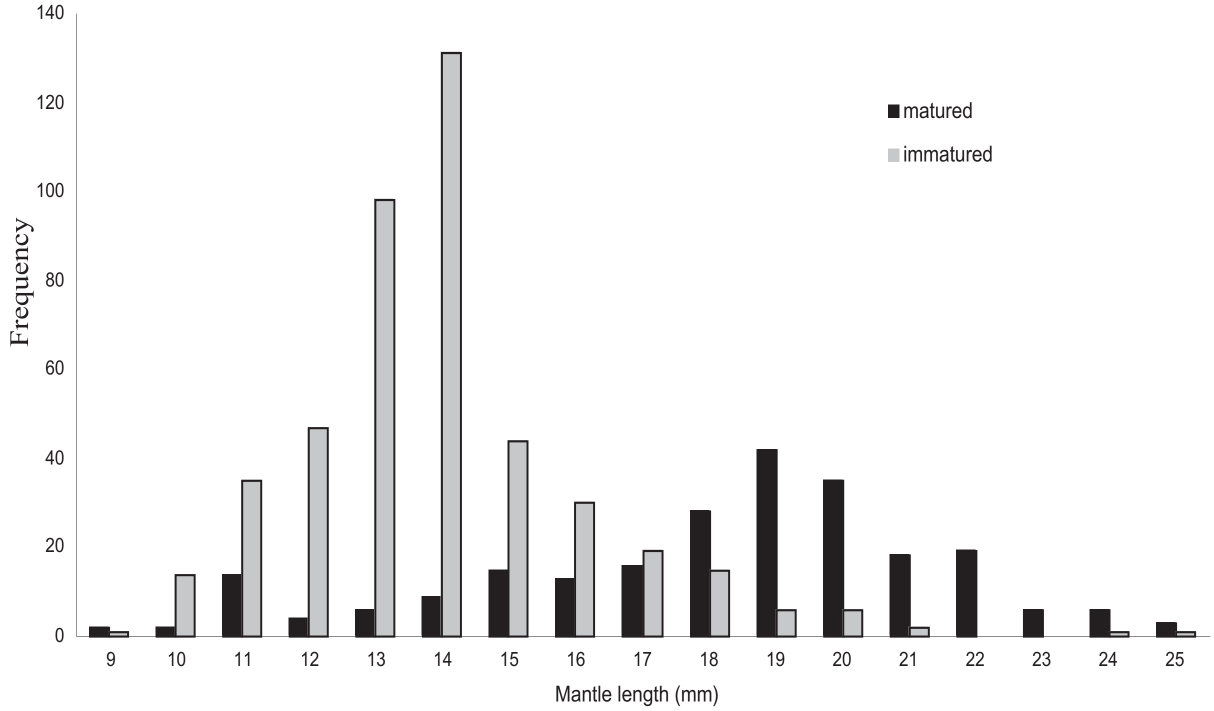

Fig. 14.Length frequency distribution of matured and immatured female of oceanic squid, *Stenoteuthis oualaniensis.*

a random sampel to quantified their maturity stages according to length. The result shows that there is roughly a correlation between the length of the female samples and the maturity stages (see Fig. 15). It can be assumed that the growth rate are very fast and these confirmed with the age reading through daily growth increment according to size. Therefore, the life span of the *Sthenoteuthis oualaniensis* are considered within 1 years. The presence of one peak for male and female would confirm these hypothesis. While the two or more peak for female representing the immature and mature female and the growth rate are very fast during these size.

Fig.15. The figure shows the maturity stages of oceanic squid, *Stenoteuthis oualaniensis* according to their length

Table 1. The table show the date and position of the sampling stations and their basic physical parameters and jigging operations

Stations	Date	Position Start	Position End	Luring (time)	Jigging Start (time)	Jigging End (time)	No of jigs (number) M1	M2	M3	M4	Water depth (m)	Angling depth (m)	Trans-parency (m)	SST °C
1	17.04.1998	Lat. 20° 2.600' N Long. 119°56.800'E	20° 2.70' N 119°55.90'E	1825	1850	0000	60	60	60	60	3644	0 -120	23	25.9
5	19.04.1998	Lat. 18° 59.182'N Long. 118°59.675'E	18°59.70'N 118°55.51'E	2000	2150	0100	32	32	32	32	2782	0 - 100		26.2
7	21.04.1998	Lat. 18° 0.400'N Long. 119° 0.280'E	17°59.40'N 119° 1.00'E	2105	2225	0300	32	46	44	32	1075	0- 120		25.9
9	22.04.1998	Lat. 16°59.900'N Long. 120° 1.700'E	17° 1.00'N 120° 4.30'E	1830	1835	2235	32	46	44	32		0 – 120		
12*	25.04.1998	Lat. 16°59.700'N Long. 117° 7.700'E Lat. 16°59.640'N Long. 117° 4.770'E	 17° 0.48'N 117° 2.01'E	1910	1930 1938	1938 0130	44 44	44 44	46 46	44 44	 4042	0 – 120 0 - 120		
14	27.04.1998	Lat. 15°59.500'N Long. 118° 6.000'E	15°56.60'N 118° 3.64'E	1830	1830	2300	44	44	44	44		0 – 120		
17	29.04.1998	Lat. 15° 0.640'N Long. 118° 59.520'E	15° 5.10'N 118° 57.30'E	2320	2345	0445	44	44	44	44		0 – 120		30.16
21	30.04.1998	Lat. 14° 0.500'N Long. 117°59.900'E	14° 5.30'N 117° 57.10'E	1900	1910	0110	44	44	44	44		0 – 120		30.4
27	05.05.1998	Lat. 13° 0.400'N Long. 117° 6.410'E	13° 3.60'N 117° 5.40'E	1826	1830	0300	44	44	44	44	1260	0 – 120		30.26
30A	08.05.1998	Lat. 11°59.800'N Long. 118°45.300'E		1905	1950	0230	40	40	43	30	1622	0 – 120		30.69
30B	09.05.1998	Lat. 12°47.600'N Long. 119° 9.000'E	12°49.70'N 119° 7.20'E	1830	1845	0300	40	40	43	-	2109	0 -120		31.35

*jigging operation at first location by searching using echo sounder.

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Biological Feature of an Oceanic Squid, *Sthenoteuthis oualaniensis* in the South China Sea, Area III: Western Philippines.

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ABSTRACT

Several species of oceanic squids are believed to occur in the South China Sea, especially off the west coast of the Philippines. *Sthenoteuthis oualaniensis* was one of the species that dominated the catch during the research survey off western Philippines in April to May 1998. Preliminary study was carried out on some biological features of *Sthenoteuthis oualaniensis*, particularly on maturity pattern, sex ratio and stomach content. There was a similarity in maturity pattern throughout the study areas with the same proportion of mature and immature squids. In all stations, the female squids out numbered the male and the size of the female was general bigger then the male squids. ML50% of female was estimated to be at 175 mm while range of mature female was between 110 - 240 mm. Fish and cephalopods were the most frequently occurring prey taxa found in the diet of *Sthenoteuthis oualaniensis*, contributing between 37% - 46% and 30% - 43% respectively. Identification of prey taxa especially to species level was strictly limited, due to lack of proper references and understanding of the nature of fish species composition within the study areas. Results discussed in this paper may serve as early information for future biological study on *S. oualaniensis*.

Key words: *Sthenoteuthis oualaniensis,* maturity pattern, diet, stomach content, Philippines.

Introduction

Sthenoteuthis oualaniensis known as purpleback flying squid of Family Ommastrephidae is an oceanic squid widely distributed in the western Pacific and Indian Ocean. It covers throughout tropical and temperate waters of both the northern and southern hemispheres (Roper et al., 1984). It is known to carry out diurnal vertical migration between the surface at night to the deeper layers during the day. *Sthenoteuthis oualaniensis* in one of the oceanic squids occurring in the Philippine waters beside other common oceanic squid species such as *Nototodarus philippinensis and Todarodes pacificus*. Information on its biological features and ecological aspect such as stock structure, age span, spawning season and spawning grounds are still lacking compared to *Todarodes pacificus* which has been studied since late 1910s (Tioda, 1915). The fishery status of this species is also not known and not well documented, especially on monthly and annual landings and effort data. In the Philippines, oceanic squid fishery is practiced on a small scale and most of these squids are of relatively low market values.

The use of research cruise data to study the biology and the distribution of the squids have widely been used in other areas especially on *Loligo forbesi* (Holme, 1974; Collins et al., 1995). However, since most of the squids are mobile and migratory species, their abundance and distribution in certain areas will need survey data from several cruises. From survey data, analysis on stock assessment on squid fisheries can be used e.g. to provide recruitment indices, real time indices of adult abundance, or direct estimates of adult stock size (Lange and Sissenwide, 1983; Okutani and Watanabe, 1983). To date, no information on biology and abundance of the S. oulaniensis off the Western Philippines based on the survey data analysis is available.

The objective of this study was to preliminarily determine some basic biology of *Sthenoteuthis oualaniensis* based on the data collected from the research survey by the M.V. SEAFDEC. It included studies on sex ratio, length weight relationship, cohort and maturity patterns of the squids and the stomach contents, major prey composition by areas. Knowledge on the change in distributions of the oceanic squids with respect to time during the research survey was also very important in the study of their biology but this aspect was covered by another paper.

Materials and Methods

Samples of the squid were collected using the MV SEAFDEC along the west coast off Philippine waters, beginning at the first station in 120^0 00' E 20^0 00' N and finished at the last station in 119^0 09' E ,12^0 47.6' N. (Fig.1). The cruise took place from the beginning of April until the end of May 1998. The samples were caught using 4 automatic jigging, operating at difference depths ranging from 80 m to 120 m onboard the MV SEAFDEC.

The squids obtained from the sampling were sexed and measured their dorsal mantle length to the nearest millimeter. An initial body weight of individual squids were taken using spring balance to get an estimated body weight. For the maturity samples, after measuring the DML and body weight, the samples were kept in the ice room at -20^{o}C for further analysis in the laboratory. Samples for stomach content study were taken onboard. The squids were immediately dissected after measurement of ML and body weight. The stomach contents were removed, their fullness (0-4) estimated, using subjective scale (O, empty; 1, one-quarter full, 2, half full; 3, three-quarter full, 4, full). The stomachs were then stored (-20^{o}C) for further laboratory analysis.

In the laboratory, stomachs were thawed and washed in tap water over 0.35 mm sieve. Prey remains were then examined under a binocular microscope and presence and absence of major prey taxa were, noted. The remains for fish included bones, otoliths, scales, eye-lenses, skin and flesh while for cephalopods, the remains were beaks, arm suckers, gladius, flesh, skin and eye-lenses. For crustaceans, the remains usually consisted of fragments of exoskeleton, and pinkish eyes. Fish otoliths, selective fish bones, pieces of crustacean exoskeleton and sucker rings of cephalopods were removed and kept in dry bottle for further identification. Fish species identification through otoliths was limited as source of reference for fish species from the otoliths was unavailable unlike in cases such as those from the North Sea fish species (Harkonen, 1986), fish jaws and vertebrae (Watt et al., 1994) and for cephalopod beaks (Clarke, 1986).

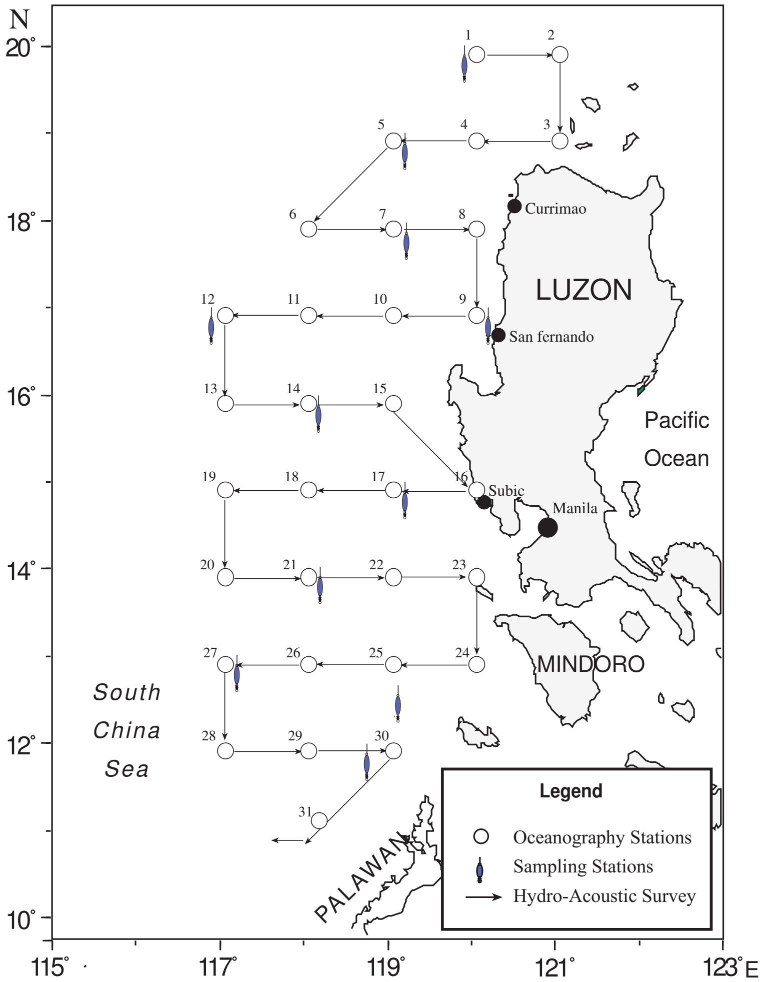


Fig. 1. Sampling stations on the South China Sea : off Western Philippines.

The maturity stages of male and females were assessed using a maturity scale of five stages (Boyle and Ngoile, 1993a) and maturity indices calculated as follows; for female maturity index, ML = NGL / ML where NGL is nidamental gland length (Durwad et al., 1979). The NGL/ML ratio was recommended as the best index of maturation for population studied because it is easily determined, continuously variable (and can therefore be easily and meaningfully averaged) and well correlated with other development events. For male, MI = HL / ML where HL is the proportion of arm length hectocotylized (Schuldt, 1979) is recommended instead of spermatophore length which tends to increase with squid length. Gonadosomatic index GSI was also calculated as GSI = GW / BW x 100 where GW is gonad weight (Guerra et. Al., 1992).

Results

Sex ratio

Fig. 2 shows the sex composition of *Sthenoteuthis oualaniensis* caught in the waters off western Philippines. The number of females outnumbers the males in most of the stations. The variation in number caught between both sexes were so significant that in certain stations less than 10 males out of the total number were caught. The whole population seemed to be dominated by females, which have has much longer mantle length than male showing a natural sexual dimorphism of this species.

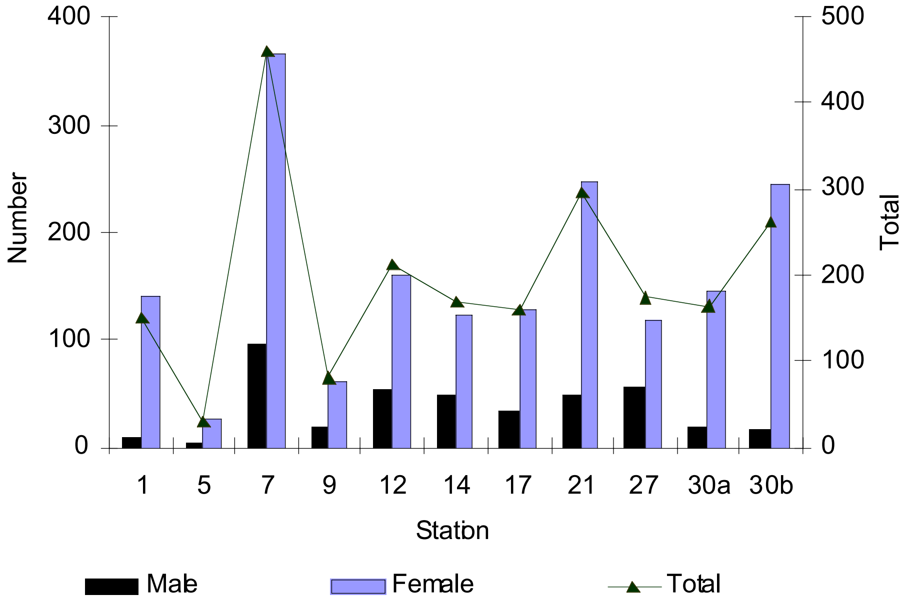


Fig. 2. Difference in sex compositoion of S. oualaniensis caught during the survey in the waters off Western Philippines.

Length-weight relationship

Regression analyses were carried out on *Sthenoteuthis oualaniensis* on 1239 and 298 female and male samples respectively (Fig. 3). Regression on both male and female were significant (P < 0.001) and the coefficient of determination of female was higher that male (r^2 = 0.971, female; r^2 = 0.849, male). The slope of female (3.1029) was slightly higher than male (3.04225) but did not show significant difference between sexes, indicating a similar increase in weight with increasing length.

Length frequency distribution

The smallest size of the squids caught by automatic jigging was 90 mm for female and 101 mm for male respective. These are the sizes being recruited and entering the fishery along the West Coast of Philippines waters. Fig. 4 shows length frequency distribution of male and female *S. oualaniensis* during the survey period. At all the stations, the female quite obviously showed the presence of more than one cohorts. However, in male it seemed to show only one cohort present in every station. The number of male samples was too small to show any obvious mode. The biggest male and female squid caught during the research survey in were 197 mm and 249.5 mm respectively. Overall mantle length average of the male and female *S. oualaniensis* were 126.17 mm and 154.17 mm respectively. It seemed that the length of the largest female was almost twice the size of male squid.

Maturation

Table 1 shows the maturation process in females which can easily be observed through morphological features, the nidamental gland to mantle length ratio (NGL/ML) and the ovary to body weight ratio (OW/BW). The NGL/ML ratio seemed to be more distinct to categorize the

Table 1: Characteristic of the maturation stages in female *Symplectoteuthis oualaniensis*

Maturation stages	Range of NGL/ML	Ranges of NGL (mm)	Ranges of OW/BW	Ranges of OW (g)
I	m<=0.1	9 - 12	m <=0.003	0.12 - 0.6
II	0.1 < m <=0.15	14 - 23	0.0015 < m <= 0.015	0.4 - 1.3
III	0.15 < m <= 0.25	22 - 40	0.006 < m= 0.04	0.8 - 7
IV	0.25 < m <= 0.4	30 - 80	0.01 < m <= 0.12	3 - 50
V	0.4 <= m	65 - 120	0.13 < m	20 - 66

maturity stages of the female squid. The mature squids were counted as those above stage 3 and evaluation was a combination between Maturity Indices and visual observation. Fig. 5 shows the maturity percentage of male and female squids along the West Coast of Philippine waters. In all the stations, except station 9, the mature and immature females were equal. However, in male the mature and immature seemed to vary significantly in many stations except for station 14. Since the number of male samples was small, it was unable to note any distinction between different maturity stages.

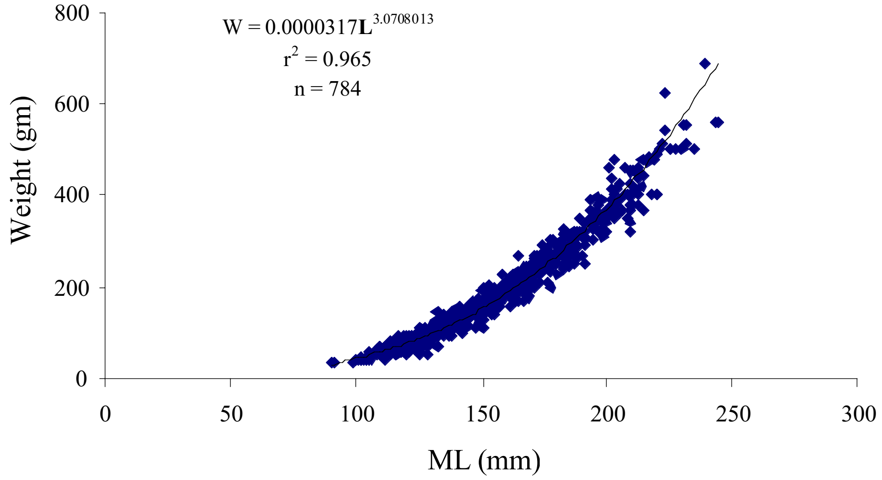
ML of mature females was range from 110 - 240 mm and the female reached the mean size of maturity (50% ML) at 180 mm (Fig. 6). A single mode in the length frequency distribution of the mature female suggests that the spawning of the female only occurred from single cohort and single rate. Although there were small mature females, the mode was not obvious.

Stomach contents

Table 2 shows the percentage of stomach fullness in *Sthenoteuthis oualaniensis* from three different stations. It seemed that the percentage of squids having empty stomach were relatively higher in station 27 and 30B and only single squid in station 30A. The percentage of full stomach

Table 2. Percentage of squids at different stomach fullness and relation to mantle length range.

	Station					
Stomach	27		30A		30B	
fullness	%	ML range (mm)	%	ML range (mm)	%	ML range (mm)
0	14.81	117 - 212	1.96	175	17.39	120 - 186
1	5.56	117 - 173	37.25	110 - 210	28.26	116 - 188
2	16.67	113 - 179	31.37	116 - 192	32.61	124 - 182
3	31.48	113 - 185	19.6	120 - 210	15.22	120 - 200
4	31.48	115 - 224	9.8	158 - 220	6.5	164 - 178
n	54		51		46	



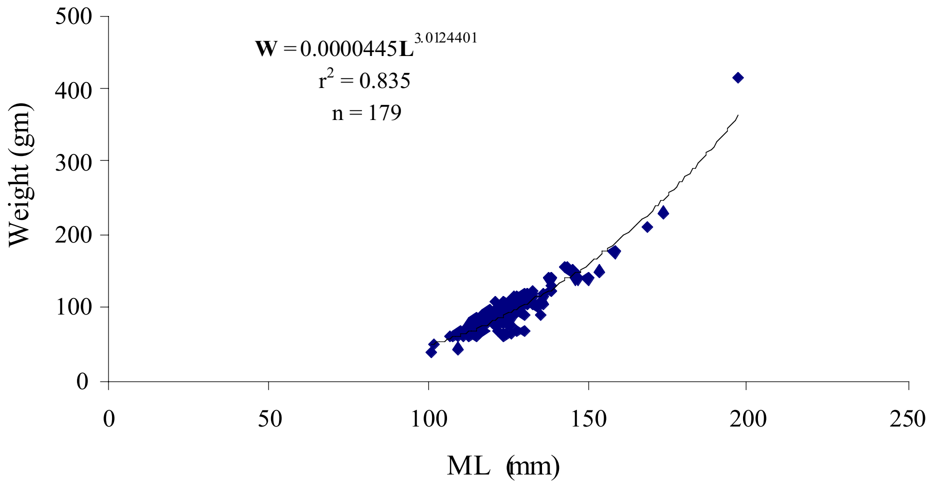


Fig. 3. Length-weight relationship for male and female *S. oualaniensis.*

were very low in stations 30A and 30B but higher in station 27. Size ranges and stomach fullness relationship seemed not to show any pattern. This shows that feeding intensity is not influenced by the size of the squids, an indications that size is not an important factor.

The major prey groups found in the *Sthenoteuthis oualaniensis* diet were fish, cephalopods, crustacea and others. Fig 7 shows the occurrence percentage of these major preys in the diet of *Sthenoteuthis oualaniensis*. Generally, in all the stations, fish and cephalopods were the major components of the preys. Many of the stomach contents consisted of mixture of fish and cephalopod, thus giving high percentage of their occurrence in the diet. Otoliths, eye-lenses, vertebrae and bones of fish, fragments of exoskeleton and appendages of crustaceans, cephalopod beaks, lenses, gladii were found.

Identification of preys to the lowest taxa using otoliths for fish and beaks for cephalopod was quite limited. Many of the references are related to the North Sea and temperate species such as otoliths guide (Harkonen, 1986), identification of cephalopods through beaks and statoliths (Clark, 1986) and crustacean through main exoskeleton fragments such as telson, rostrum and spination (Lagardere, 1971: Smaldon, 1979). Therefore understanding the nature of species composition of fish, cephalopods and crustacean found in the study areas will help to identify preys to the lowest taxa.

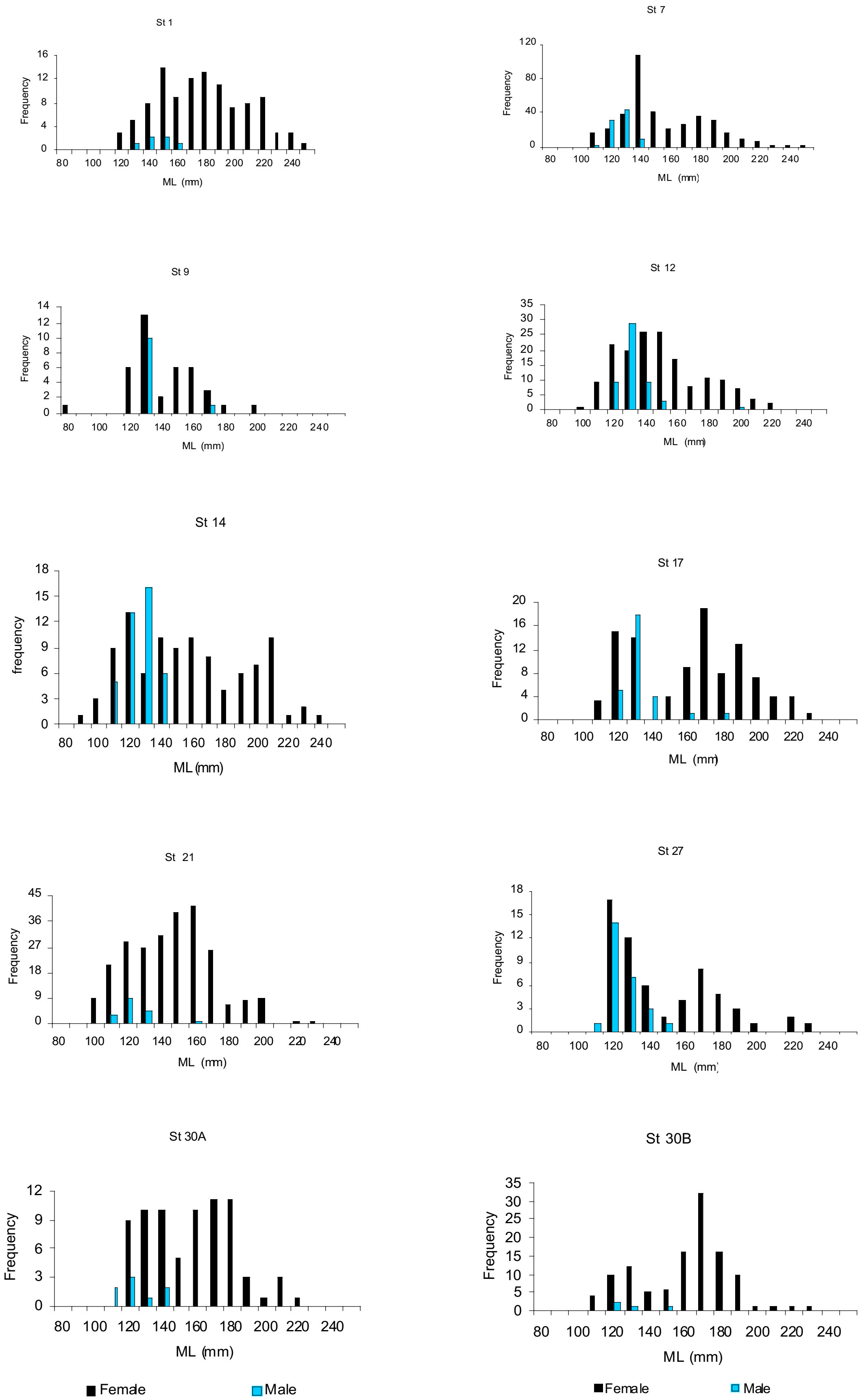


Fig. 4. Length frequency distribution of male and female S. oualaniensis caught in the South China Sea off Western Philippines.

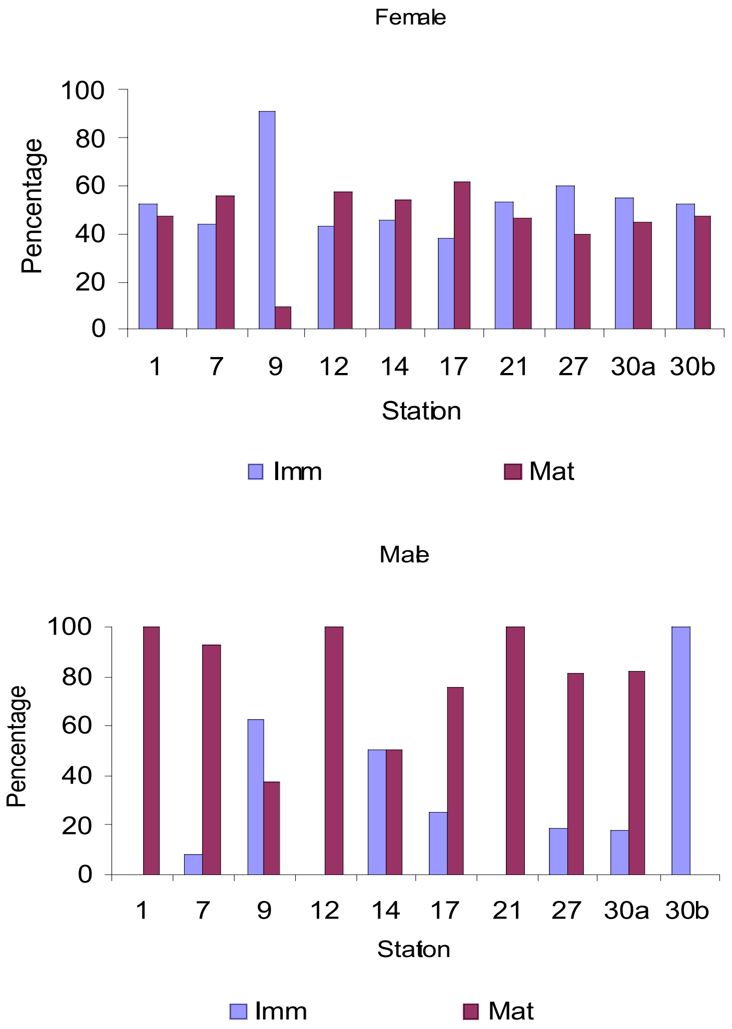


Fig. 5. Percentage of mature and immature squids by stations

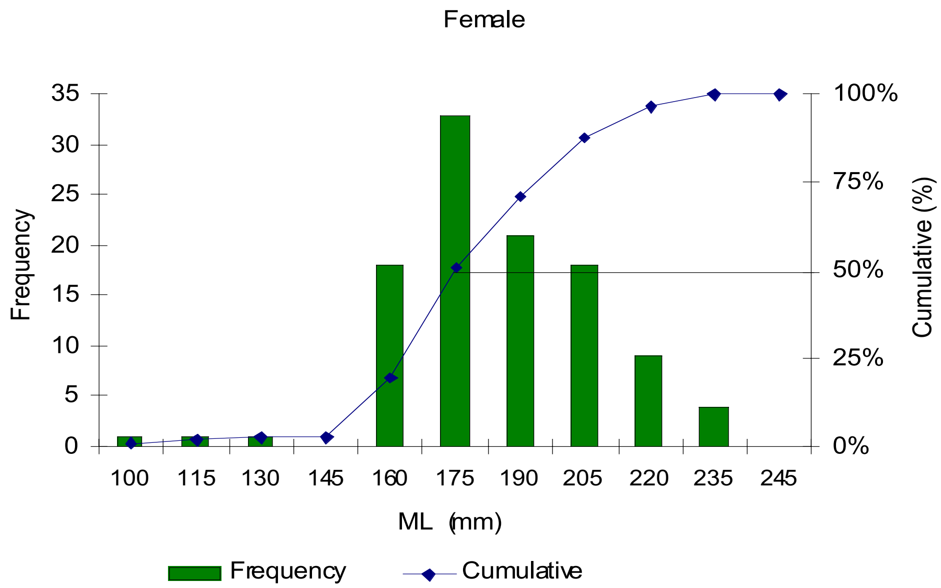


Fig. 6. Frequency distribution of ML of female squid.

Table 3 shows the frequency occurrence of the preys found in *Sthenoteuthis oualaniensis stomach contents*. Certain fish species such as *Trichiurus sp* could be identified through its silvery content of the stomach. Number of otoliths in the stomachs helped in the estimation of the number of fish preys. The highest number of otoliths found with different sizes was 18. Eye-lenses of fish and beaks were also commonly found. Fish lenses are normally round compared to squid lenses which are hemispherical semi-circular. Identification of cephalopods species was mostly through sucker rings. If the stomach contents only consisted of gladii or beaks they would therefor be referred to as other possible cephalopod species, especially ommastrepids (*Nototodarus philippinensis and Todarodes pacificus*) that were found in those areas. The presence of copepods in some specimens was high. And the common species were *Calanus and Labidocera* spp. A number of gastropods and bivalves were also found in the stomachs.

Table 3. Frequency occurrence of the preys found in the stomach contents

Taxon		Frequency accurrence Station	
	27	30A	30B
Fish (Total)	27	37	33
Trichiurus sp		1	2
Gobidae	3		
Clupeidae	6	3	5
Carangids		2	3
Unidentified	18	31	23
Cephalopoda (Total)	31	27	25
Sepia sp	3	4	1
S. oualaniensis	15	10	11
Ommastrephids	3	4	5
Unidentified	10	9	8
Crustacean (Total)	9	13	15
Decapoda	3	3	4
Isopoda	1	2	1
Euphausiidae	2	4	2
Calanus sp	1		2
Labiddocera sp		2	2
Oncaea venusta	1		
Unidentified	1	2	4
Other Mollusc (Total)	5	2	9
Gastopod	3	1	6
Bivalves	2	1	3

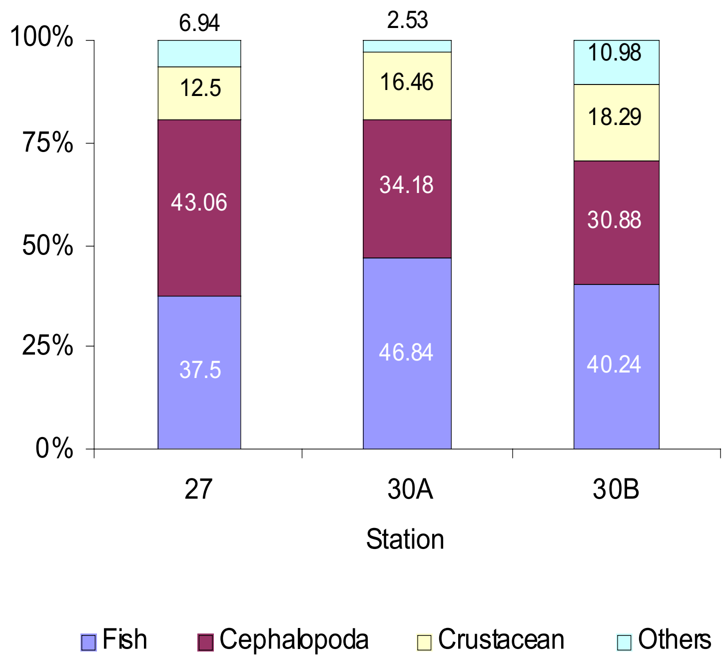


Fig. 7. Occurance percentage of the different prey groups in the diet of S. oualaniensis caught in the South China Sea : Off Western Philippines.

Discussion

Equal percentage of mature and immature squids that were caught from all sampling areas may indicate that the month of April to May was not peak spawning period. There may be an indication of constant recruitment of mature squids. It also explains the extended reproductive season where the presence of mature-maturing squids occur over a long period. It could be similar to myosip species such as *Loligo forbesi* which has a prolonged spawning season and with less clear peaks (Lum-Kong et. al., 1992; Collin et. al., 1993a). But small number of samples used in the maturation study may not end in sound conclusion. However, time series sampling on land based study may assist in precise determination of the spawning period and pattern of the species. Similar maturity pattern that had been shown throughout the study areas suggested that possible population migration to search for particular areas for spawning purpose is not happening in this species. Since the species is known as diurnal vertical migration species, it may be possible that spawning activity occurred within their population areas.

Small number of males does not effect the spawning process. A fully matured male will mate with several females (O'Dor, R.K., 1978). Thus, it is tentatively concluded that males both recruit to the fished population and disappear from the fished population earlier than females. Cannibalism could serve as another factor as to the low number for male squids. Smaller mantle sized males than female squids tent to make smaller males as the likely victims. Amaratunga (1980b) found out that in *Illex illecebrosus,* cannibalism appears to be an important element in the life cycle of the species. In nature it increases as total feeding decreases, and the largest squids are the most cannibalistic. Starvation about three days are needed to induce cannibalism and single victim may be divided between several cannibals (O'Dor et. al., 1980a).

Evaluating and identifying the diet composition of the stomach contents always face various difficulties (Hyslop, 1980; Pierce and Boyle, 1991). In cephalopods, the difficulty includes partial ingestion, fragmentation and rapid digestion of preys. Identification of fish preys in always associated with otoliths, vertebrae, bones and scales and this has enabled for more precise and quick detection of the main groups of fish eater. Identification of otoliths and bones from very small fish is particularly difficult due to different morphological appearance of small fish compared to a fully formed fish.

Fish and cephalopods were the two most frequently occurring prey taxa in the *Sthenoteuthis oualaniensis* diet. This happened at all the sampling stations and had further verified possible higher cannibalism happening among the *S. oualaniensis* population. In term of species composition of the diets apparently, there were no distinct variation between these three sampling areas except at station 27 where the occurrence percentage of cephalopods exceeded the fish species.

Acknowledgements

This work was mostly funded by the SEAFDEC under the Interdepartmental Collaboration Research Program in the South China Sea. I wish to convey my gratitude to the Director General of Fisheries Malaysia. Dato' Mazlan Jusoh, the Director of MFRDMD Mr. Ismail Taufid and Director of FRI Penang Mr. Ismail Awang Kechik for their permission and encouragement to conduct this study. My thank also to Mr. Mohammed Shaari bin Sam Abdul latiff as a technical editor to this manuscript for his advice and critical comments.

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Composition, Abundance and Distribution of Ichthyoplankton in the South China Sea, Area III: Western Philippines

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ABSTRACT

Composition, abundance and distribution of ichthyoplankton were investigated in the South China Sea, western Philippines. Larval fish samples were collected at 31 stations by surface and double oblique tows in April/May 1998. A total of 7371.67 fish larvae, representing 85 families, were collected in the samples. Abundance of fish larvae were dominated by the Myctophidae followed by the Gonostomatidae. The ten most abundant families of fish larvae found in this study were separated into three broad categories: (1) inshore fishes, represented mainly by the Bregmacerotidae, Gobiidae, Apogonidae, and Carangidae; (2) mid zone fishes represented mainly by the Hemiramphidae, Labridae and Engraulidae; (3) offshore fishes represented mainly by the Myctophidae and Gonostomatidae. Depth and time of day appeared to affect the abundance of fish larvae and fish eggs. Fish larvae were found mainly in double oblique tows while fish eggs were found mostly in surface tows. The larvae caught at night were more abundant than larvae caught during the day. Abundance and distribution of tuna larvae are also discussed.

Keywords: Composition; abundance; distribution; ichthyoplankton; fish larvae; fish eggs; South China Sea; western Philippines.

Introduction

The SEAFDEC Interdepartmental Collaborative Research Program has aimed to collect and analyse the data and information necessary for the management of fishery resources and the protection of the environment through collaborative research among member countries and organisations concerned. The first two areas in the Southern part of South China Sea and the Gulf of Thailand (Area I&Area II) characterised as a coastal water condition were surveyed from 1995 to 1997. In 1998, the collaborative research program continued the next survey (Area III) in the northern part of South China Seas (off the west coast of Philippines) with the aim of assessing the fisheries resources in relation to oceanographic conditions.

Research on ichthyoplankton which has been very limited in this area was one of the major surveys, with even basic information on distribution and abundance sparse. The presence of fish larvae is an indicator of the fertility of the waters. Field investigation of the eggs and larvae of marine fin fish is, therefore, a practical check of the fisheries status as well as the survey on adult fishes. The survey on ichthyoplankton could also clarify the spawning grounds and spawning seasons of fishes.

In this paper, a 23-day study of ichthyoplankton in South China Sea is reported. Plankton samples were collected with the aim of obtaining information on composition, abundance, and distribution of ichthyoplankton. Tuna stock assessment was another major objective on this cruise and data on the distribution, abundance and length-frequency of tuna larvae are also presented in this paper.

Materials and Methods

Study site

Area in the South China Sea off the west coast of the Philippines (Area III), covers approximately 579,578 km^2 (latitude 11^{0}N to 20^{0}N and longitude 117^{0}E to 121^{0}E). The study site is oceanic with 95% of the area exceeding depths of 1000 metres. 31 survey sites, each separated by a 155.40 km interval, were set out in this area (Fig. 1).

Field work.

Ichthyoplankton was sampled on M.V. SEAFDEC from 17 April to 9 May 1998. Stations were trawled on arrival, regardless of the time of the day. Surface and double oblique plankton tows were simultaneously taken at each station with a 500 µm mesh net attached to 1 m ring and a pair of bongo nets (60 cm dia, 500 µm and 330 µm mesh respectively). Double oblique tows

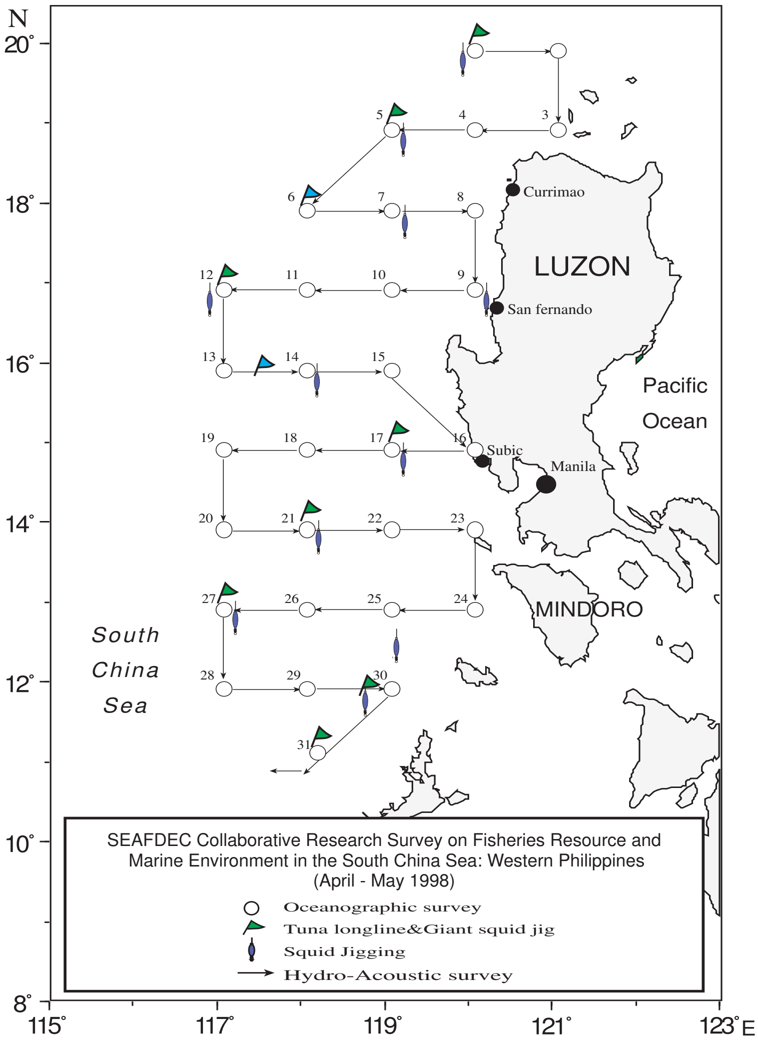

Fig. 1. Sampling stations in the South China Sea, Area III, Western Philippines

Table 1. Zone (inshore, middle, offshore) by region [northern (N), central (C) and southern (S)] in South China Sea (west coast of Philippines).

Region	Zone		
	inshore	middle	offshore
N	St. 3, 8	St. 2, 4, 7	St. 1, 5, 6
C	St. 9, 15, 16	St. 10, 14, 17	St. 11, 12, 13, 18, 19
S	St. 23, 24, 30A, 31A	St. 22, 25, 29	St 20, 21, 26, 27, 28

were taken to a depth of approximately 60 m. Depth and tow profiles were monitored using a depth sensing unit. Each tow was of about 30 min duration at a speed of approximately 2-3 knots. Volume filtered was calculated for each net using a calibrated flow meter. All ichthyoplankton samples were then immediately preserved with 95% ethanol and were brought to a laboratory at Bangkok Marine Fisheries Development Center for processing.

Laboratory work

Fish larvae and fish eggs were sorted from the samples using a rotatable sorting ring under a dissecting microscope and, when necessary, eggs were subsampled. Ichthyoplankton were counted and identified to the lowest possible taxon with information currently available. The term larva used in this paper included the preflexion, flexion and postflexion stages as described by Leis and Rennis (1983). Larvae that could not be identified at either the species, genus or family level (including damaged specimens) were placed in the unidentified category. Tuna larvae were separated from the ichthyoplankton and the standard length (SL: tip of the snout to tip of the notochord or the hypural crease in postflexion larvae) was measured to the nearest 0.1 mm under a dissecting microscope with an ocular micrometer.

Statistical analysis

Individual stations were assigned to one of 3 regions (northern, central, and southern) and each region was subdivided into 3 zones: inshore (innermost station), mid zone (station between outermost and innermost station), offshore (outside station). Each region and zone combination is presented in Table 1.

The total number of larvae and the numbers of each species caught at each station were summed and converted to a concentration, i.e., numbers per 1000 m^3 volume filtered.

Two-factor analysis of variance (ANOVA) was used to determine differences in the mean numbers of larvae among regions, zones, tow types (surface and oblique), and towing time of the day (day and night). Homogeneity of variance was tested using Bartlett's Test. The numeric data were ln (x+0.001) or third root (x+0.0001) transformed prior to ensure normality and to remove heterogeneity of variance. Data distribution was then tested for normality using Shapiro-Wilk W Tests. The results were considered to be statistically significant if $P < 0.05$. Kruskal-Wallis's Test was used to test the difference between two or more factors if data were not normally distributed and were considered to be statistically significant if $P < 0.001$. Statistical packages JMP 3.1 and Statview 4.02 were used for analysis.

Table 2. Rank by abundance (number per 1000 m^3) of families of fishes collected as larvae at 31 stations located in the South China Sea (Area III, west coast of Philippines), based on collections made during 17 April to 9 May 1998. Uncertain identification is denoted by a question mark. Percentage for contributions of each family and species to total larval fish fauna are given when they exceed 0.1%.

Rank	Family/Species	Total contribution	
		Family (%)	Species (%)
1	Myctophidae	2285.2 (31.0)	
	Undetermined spp.		2285.2 (31.0)
2	Gonostomatidae	779.3 (10.6)	
	Cyclothone spp.		306.4 (4.2)
	Vinciguerria spp.		237.1 (3.2)
	Undetermined spp.		193.8 (2.6)
	Diplophos spp.		41.9 (0.6)
3	Bregmacerotidae	543.8 (7.4)	
	Bregmaceros spp.		543.8 (7.4)
4	Gobiidae	376.4 (5.1)	
	Undetermined spp.		376.4 (5.1)
5	Hemiramphidae	271.8 (3.7)	
	Undetermined spp.		271.8 (3.7)
6	Scombridae	216.6 (2.9)	
	Thunnus spp.		99.7 (1.4)
	Undetermined tuna		67.4 (0.9)
	Katsuwonus pelamis		13.2 (0.2)
	Euthynnus spp.		15.9 (0.2)
	Auxis spp.		5.6 (0.1)
	Acanthocybium spp.		12.6 (0.1)
	Scomberomorus sp.		2.2 (< 0.1)
7	Labridae	181.7 (2.5)	
	Undetermined spp.		181.7 (2.5)
8	Carangidae	162 (2.2)	
	Undetermined spp.		162 (2.2)
9	Apogonidae	149.3 (2.0)	
	Undetermined spp.		149.3 (2.0)
10	Engraulidae	116.9 (1.6)	
	Undetermined spp.		116.9 (1.6)
11	Lutjanidae	115.2 (1.6)	
	Undetermined spp.		115.2 (1.6)
12	Bothidae	90.2 (1.2)	
	Undetermined spp.		90.2 (1.2)
13	Paralepididae	79.8 (1.1)	
	Lestidiini		51.2 (0.7)
	Undetermined spp.		17.9 (0.2)
	Sudinae		9 (0.1)
	Stemonosudis sp.		1.8 (< 0.1)
14	Serranidae	65.8 (0.9)	
	Anthiinae		32.3 (0.4)
	Epinephilinae		12.4 (0.2)
	Grammistine		10.9 (0.1)
	Undetermined spp.		7 (0.1)
	Serraninae		3.2 (< 0.1)
15	Mullidae	62.6 (0.8)	
	Undetermined spp.		62.6 (0.8)
16	Gempylidae	58.0 (0.8)	
	Undetermined spp.		58.0 (0.8)
17	Caesionidae	55.9 (0.8)	
	Undetermined spp.		55.9 (0.8)
18	Scaridae	51.8 (0.7)	
	Undetermined spp.		51.8 (0.7)
19	Nemipteridae	45.5 (0.6)	
	Nemipterus spp.		45.5 (0.6)
20	Priacanthidae	38.2 (0.5)	
	Undetermined spp.		38.2 (0.5)
21	Synodontidae	36.9 (0.5)	
	Undetermined spp.		29.6 (0.4)
	Synodus spp.		7.3 (0.1)

Table 2 (continued)

Rank	Family/Species	Total contribution Family (%)	Species (%)
22	Scorpaenidae	36.3 (0.5)	
	Undetermined spp.		33.8 (0.5)
	Helicolenus sp.		2.5 (< 0.1)
23	Teraponidae	35.4 (0.5)	
	Undetermined spp.		29.2 (0.4)
	Terapon spp.		6.2 (0.1)
24	Exocoetidae	34.8 (0.5)	
	Undetermined spp.		34.8 (0.5)
25	Pomacentridae	32.6 (0.4)	
	Undetermined spp.		16.0 (0.2)
	Abudefduf spp.		16.6 (0.2)
26	Astronesthidae	24.2 (0.3)	
	Undetermined spp.		24.2 (0.3)
27	Balistidae	20.1 (0.3)	
	Undetermined spp.		20.1 (0.3)
28	Lutjanidae/Caesionidae	18.9 (0.3)	
	Undetermined spp.		18.9 (0.3)
29	Callionymidae	18.4 (0.2)	
	Undetermined spp.		18.4 (0.2)
30	Melanostomiidae	15.9 (0.2)	
	Undetermined spp.		9.6 (0.1)
	Eustomias spp.		4.6 (< 0.1)
	Photonedes sp.		1.7 (< 0.1)
31	Acanthuridae	15.6 (0.2)	
	Undetermined spp.		15.6 (0.2)
32	Congridae	15.4 (0.2)	
	Undetermined spp.		15.4 (0.2)
32	Leiognathidae	15.4 (0.2)	
	Undetermined spp.		15.4 (0.2)
34	Holocentridae	15.0 (0.2)	
	Undetermined spp.		15.0 (0.2)
35	Champsodontidae	14 (0.2)	
	Undetermined spp.		14 (0.2)
36	Leptobramidae?	13.8 (0.2)	
	Undetermined spp.		13.8 (0.2)
37	Gempylidae?	13.3 (0.2)	
	Undetermined spp.		13.3 (0.2)
38	Siganidae	13.1 (0.2)	
	Undetermined spp.		13.1 (0.2)
38	Schindleriidae	13.1 (0.2)	
	Undetermined spp.		13.1 (0.2)
40	Clupeidae	12.1 (0.2)	
	Undetermined spp.		7.4 (0.1)
	Dussumieriinae		2.4 (< 0.1)
	Dussumieria		2.4 (< 0.1)
41	Creediidae	9.9 (0.1)	
	Undetermined spp.		9.9 (0.1)
41	Cynoglossidae	9.9 (0.1)	
	Undetermined spp.		9.9 (0.1)
43	Pomacanthidae	8.9 (0.1)	
	Undetermined spp.		8.9 (0.1)
44	Ophidiidae	8.8 (0.1)	
	Undetermined spp.		8.8 (0.1)
45	Gerreidae	8.5 (0.1)	
	Undetermined spp.		8.5 (0.1)
46	Coryphaenidae	8.2 (0.1)	
	Undetermined spp.		8.2 (0.1)
47	Monacanthidae	8.1 (0.1)	
	Undetermined spp.		7.5 (0.1)
	Stephanolepis cirrhifer		0.6 (< 0.1)
48	Sphyraenidae	7.6 (0.1)	
	Undetermined spp.		7.6 (0.1)

Table 2 (continued)

Rank	Family/Species	Total contribution Family (%)	Species (%)
49	Trichiuridae	7.5 (0.1)	
	Undetermined spp.		7.5 (0.1)
49	Diodontidae	7.5 (0.1)	
	Undetermined spp.		7.5 (0.1)
51	Scopelarchidae	7.2 (0.1)	
	Undetermined spp.		7.2 (0.1)
52	Evermannellidae	7.1 (0.1)	
	Undetermined spp.		7.1 (0.1)
52	Cirrhitidae	7.1 (0.1)	
	Undetermined spp.		7.1 (0.1)
54	Bythitidae	6.5 (0.1)	
	Undetermined spp.		6.5 (0.1)
55	Chiasmodontidae?	5.9 (0.1)	
	Undetermined spp.		5.9 (0.1)
56	Anguillidae	5.8 (0.1)	
	Undetermined spp.		5.8 (0.1)
57	Muraenesocidae	5.6 (0.1)	
	Undetermined spp.		5.6 (0.1)
58	Pleuronectidae	5.5 (0.1)	
	Undetermined spp.		5.5 (0.1)
59	Emmelichthyidae	5.4 (0.1)	
	Undetermined spp.		5.4 (0.1)
60	Ophichthidae	5.3 (0.1)	
	Undetermined spp.		5.3 (0.1)
61	Oneirodidae	5.1 (0.1)	
	Undetermined spp.		5.1 (0.1)
62	Muraenidae	5 (0.1)	
	Undetermined spp.		5 (0.1)
62	Tetraodontidae	5 (0.1)	
	Undetermined spp.		5 (0.1)
64	Fistulariidae	4.8 (0.1)	
	Undetermined spp.		4.8 (0.1)
65	Blenniidae	3.5 (< 0.1)	
	Undetermined spp.		0.7 (< 0.1)
	Nemophini		2.8 (< 0.1)
66	Haemulidae	3.3 (< 0.1)	
	Undetermined spp.		3.3 (< 0.1)
67	Malacosteidae	3.2 (< 0.1)	
	Undetermined spp.		3.2 (< 0.1)
68	Atherinidae	3.1 (< 0.1)	
	Undetermined spp.		3.1 (< 0.1)
69	Synanceidae	2.9 (< 0.1)	
	Undetermined sp.		2.9 (< 0.1)
70	Bramidae	2.8 (< 0.1)	
	Undetermined sp.		2.8 (< 0.1)
71	Belonidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
71	Malacanthidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
71	Acropomatidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
71	Platycephalidae	2.5 (< 0.1)	
	Undetermined sp.		2.5 (< 0.1)
75	Linophrynidae	1.9 (< 0.1)	
	Undetermined sp.		1.9 (< 0.1)
76	Kuhliidae	1.8 (< 0.1)	
	Undetermined sp.		1.8 (< 0.1)
76	Ammodytidae	1.8 (< 0.1)	
	Undetermined sp.		1.8 (< 0.1)
78	Giganturidae	1.7 (< 0.1)	
	Undetermined sp.		1.7 (< 0.1)
79	Istiophoridae	1.5 (< 0.1)	
	Undetermined spp.		1.5 (< 0.1)

Table 2 (continued)

Rank	Family/Species	Total contribution Family (%)	Species (%)
80	Caulophrynidae	1.4 (< 0.1)	
	Undetermined spp.		1.4 (< 0.1)
81	Scomberesocidae?	1.1 (< 0.1)	
	Undetermined spp.		1.1 (< 0.1)
82	Ipnopidae?	0.6 (< 0.1)	
	Undetermined spp.		0.6 (< 0.1)
82	Antennariidae	0.6 (< 0.1)	
	Histrio histrio		0.6 (< 0.1)
84	Triglidae	0.6 (< 0.1)	
	Undetermined spp.		0.6 (< 0.1)
85	Chlorophthalmidae	0.4 (< 0.1)	
	Undetermined spp.		0.4 (< 0.1)
86	Unidentified	1002.6 (10.9)	
	Total fish larvae	**7371.67 (100)**	
	Fish eggs	**11398.1**	

Results

Family and species composition

A total of 11398.1 eggs/1000 m^3 and a total of 7371.67 fish larvae/1000 m^3, representing 85 families, 19 genera, and 2 species, were collected from the 31 sampling stations in the South China Sea (west coast of Philippines) during 17 April to 9 May 1998 (Table 2). Unidentified larvae accounted for 10.9% of the total catch. These larvae could not be identified because they were either too small, damaged or not described. The Myctophidae was the most abundant family, comprising 31.0% of the total number of larvae, followed by the Gonostomatidae (10.6%), Bregmacerotidae (7.4%), Gobiidae (5.1%), Hemiramphidae (3.7%), Scombridae (2.9%), Labridae (2.5%), Carangidae (2.2%), Apogonidae (2.0%), Engraulidae (1.6%), Lutjanidae (1.6%), and Bothidae (1.2%).

Abundance of fish larvae and fish eggs

Total fish larvae were most abundant in the central region, followed by the north, and the south (Fig. 2). Within zones (distances offshore) the total number of larvae were most abundant at the inshore zone, followed by in the middle zone and the offshore zone (Fig. 2). However, total numbers of fish larvae did not significantly differ between regions or zones and there was no effect for the interaction term on the abundance of total fish larvae ($P > 0.05$ in all cases, Table 3).

There was no significant difference between regions or zones and no interaction of region and zone on the abundance of fish eggs ($P > 0.05$ in all cases, Table 3). However, there was a trend for the highest abundance of fish eggs to occur in the northern region, followed by the central region, with the southern region having lowest abundance (Fig. 3). Amongst zones, the highest concentration of fish eggs occurred inshore with the concentration decreasing towards the offshore zone. (Fig. 3).

Differences in larval and egg density due to tow type and day and night capture

In this study there were two tow types: just below the water surface and a double oblique tow. There did appear to be an effect of depth, as significantly fewer larvae were caught by surface tows than by double oblique tows (Fig. 4, $P < 0.0001$, Table 4). Time of sampling (day and night) appeared to affect the abundance of larvae as well. The larvae collected during the

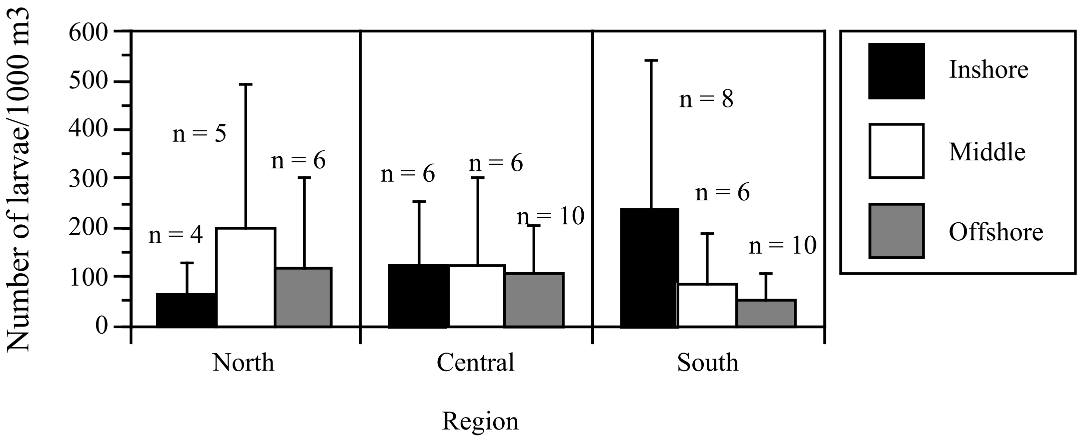

Figure 2. Mean abundance of total fish larvae at each region and zone collected during April/May 1998 in South China Sea (west coast of Philippines). Column charts show mean number of larvae/ 1000 m^3, vertical lines show standard deviation

Table 3. Results of ANOVAs. Z = zone of sampling (3 levels), R = region of sampling (3 levels).

Family **Significant factor**	**Number of stations included**	**d.f.**	**F**	**P**
Total fish larvae				
R	61	2	0.2142	> 0.05
Z	61	2	0.1713	> 0.05
R*Z	61	4	0.3022	> 0.05
Fish eggs				
R	61	2	0.2863	> 0.05
Z	61	2	0.2388	> 0.05
R*Z	61	4	0.5046	> 0.05

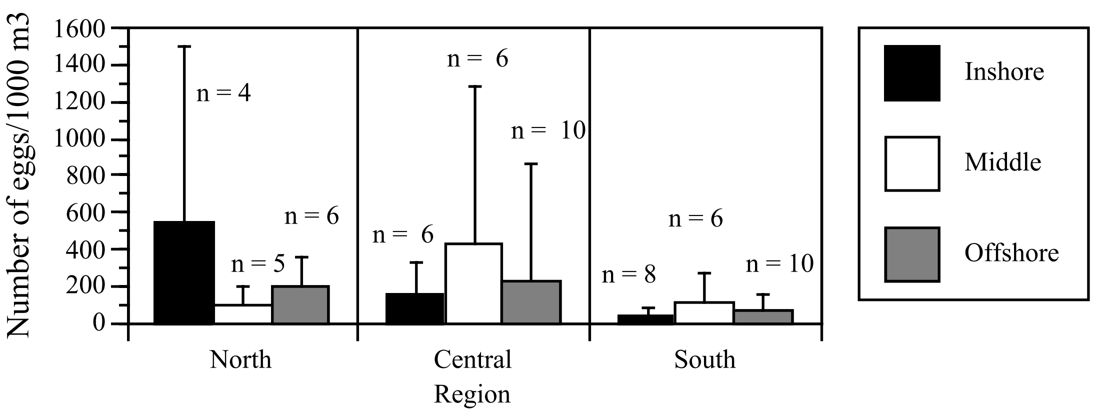

Figure 3. Mean abundance of fish eggs at each region and each zone collected during April/May 1998 in South China Sea (west coast of Philippines). Column charts show mean number of eggs/1000 m^3, vertical lines show standard deviation.

Table 4. Significant results of ANOVAs. Tow = towing type (2 levels; surface and double oblique tow), Time = time of day (2 levels; day and night).

Family Significant factor	Number of stations included	d.f.	F	P
Total fish larvae				
Tow	61	1	143.652	< 0.0001
Time	61	1	3.9132	0.05
Tow*Time	61	1	3.9187	0.05
Fish eggs				
Tow	61	1	7.2594	< 0.01
Time	61	1	7.7470	< 0.01
Tow*Time	61	1	0.6005	> 0.05

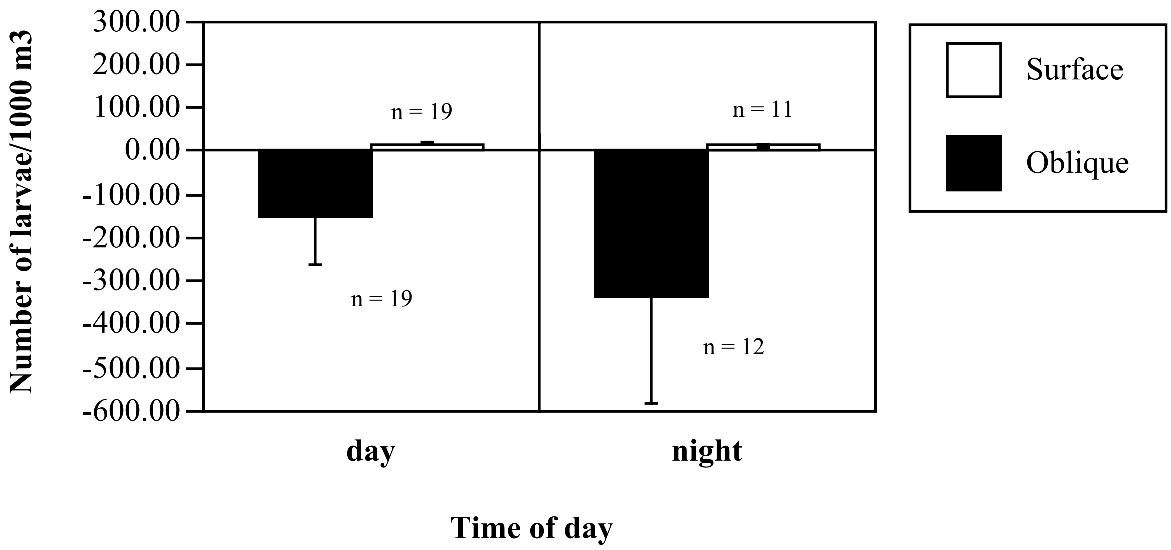

Fig. 4. Mean total larval abundace collected during night and day by surface and double oblique tows. Column charts indicate number of larvae, vertical lines indicate standard deviation.

night were more abundant than larvae caught during the day (Fig. 4, P = 0.05, Table 4). There also appeared to be an effect of the interaction of tow type and towing time on the abundance of total larvae (P = 0.05, Table 4).

There appeared to be an effect of tow type and towing time on abundance of fish eggs (P < 0.001, Table 4), but there was no effect of the interaction of tow type and towing time on fish eggs abundance (P > 0.05, Table 4). Fish eggs collected by surface tows were significantly more abundant than eggs collected by double oblique tows (Fig. 5). Likewise, fish eggs were more abundantly collected during the day than at night (Fig. 5).

Distribution of the ten most abundant families

The ten most abundant families of fish larvae in this study were found in different regions and zones (Table 5). The larvae of Hemiramphidae were found predominantly in the north. By contrast, the larvae of Myctophidae, Gonostomatiidae, and Scombridae were found mainly in the central region. Although the Scombridae were, in general, mostly found in the central region,

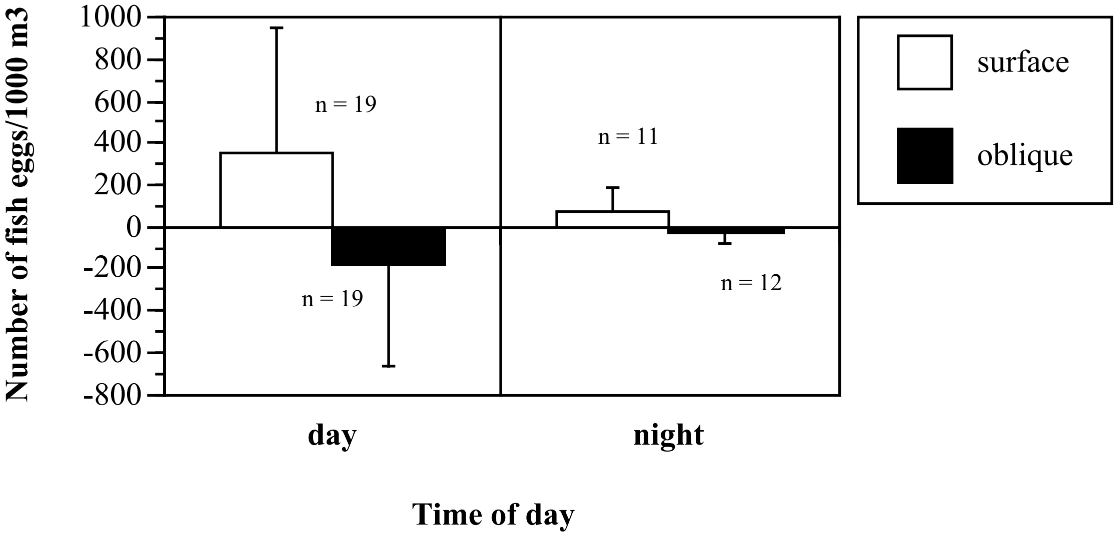

Fig. 5. Mean abundance of fish eggs during day and night by surface and double oblique tows collected during April/May 1998 in South China Sea (west coast of Phillippines). Column charts show number of fish eggs/1000 m^3, vertical lines indicate standard deviation.

the distribution of each species varied within this region. *Euthynnus* spp. and *Auxis* spp. were mostly found in the north but *Katsuwonus pelamis* occurred throughout the study area. The rest of ten most abundant families were found primarily in the south with exception of family Labridae which were found throughout the study area (Table 5).

Within zones, the Myctophidae and Gonostomatidae, occurred predominantly in the offshore zone, whereas the Bregmacerotidae, Gobiidae, Carangidae, and Apogonidae were found mainly at inshore stations. The Hemiramphidae, Labridae, and Engraulidae occurred mostly at middle zone while the Scombridae were found in similar numbers at middle and offshore zones. However, when considering each species separately, *Euthynnus* spp., *Katsuwonus pelamis* and undetermined tuna were found mostly at middle zone while *Auxis* spp. were predominantly found at inshore (Table 5).

The ten most abundant families were collected in greater numbers by double oblique tows than surface tows with exception of the Hemiramphidae, *Auxis* spp., and undetermined tuna (Table 5). This suggests that larvae mostly maintain in the deeper water column.

Abundance of tuna larvae (Family Scombridae)

Tuna larvae belonging to the Family Scombridae were found 201.8 larvae/1000 m^3, representing 4 genera, 1 species, and undetermined spp. (Table 2). There were no effects of region or zone on the number of tuna larvae ($P > 0.05$, Table 6). However, there was a trend of high abundance of tuna larvae occurring in the central region, followed by in the north, and the south (Fig. 6). Among zones, there was high abundance of tuna larvae found in the middle zone (Fig. 6). Interestingly, there was a significant interaction between region and zone affecting abundance of tuna larvae ($P > 0.01$, Table 6), which suggests the pattern was inconsistent throughout the sampling area.

Differences in tuna larval density due to tow type and day and night capture

The number of tuna larvae caught by surface and double oblique tows did not differ significantly ($P > 0.05$, Table 6). There was no significant effect of time of day on the abundance of tuna larvae ($P > 0.05$, Table 6), nor was there a significant interaction between tow type and time of day ($P > 0.05$, Table 6). However, there was a trend of high abundance occurring in double oblique tow sampling during the night (Fig. 7).

Table 5. Percentage of the ten most abundant families occurring at each zone (inshore, middle, and offshore), each region (north, central, and south), and at each tow type (surface tow and double oblique tow).

Rank	Family/Species	Zone			Region			Tow type	
		inshore (%)	middle (%)	offshore (%)	north (%)	central (%)	south (%)	surface (%)	oblique (%)
1	Myctophidae	25.20	31.11	43.69	24.16	51.43	24.41	2.36	97.64
2	Gonostomatidae	17.68	31.62	50.70	33.92	43.92	22.16	2.24	97.76
3	Bregmacerotidae	95.50	4.39	0.11	0.00	0.97	99.03	0.10	99.90
4	Gobiidae	71.79	14.96	13.25	3.83	26.96	68.41	2.99	97.01
5	Hemiramphidae	6.4	58.52	35.08	85.02	4.49	8.80	43.29	56.71
6	Scombridae	23.04	37.02	39.94	24.98	43.06	24.92	30.36	69.64
	Thunnus spp.	19.44	27.31	53.25	14.16	44.30	41.54	21.81	78.19
	Undetermined tuna	27.92	41.25	30.83	33.57	60.76	5.67	50.72	49.28
	Katsuwonus pelamis	21.92	56.39	21.69	38.47	21.54	39.83	15.80	84.20
	Euthynnus spp.	18.26	78.21	3.53	78.21	0	21.79	3.46	96.54
	Auxis spp.	100	0	0	100	0	0	60.78	39.22
7	Labridae	33.22	58.15	8.63	38.34	20.52	37.66	1.56	98.44
8	Carangidae	70.37	15.22	14.41	15.17	8.05	73.54	8.32	91.68
9	Apogonidae	89.65	7.88	2.47	8.56	4.74	86.70	2.40	97.60
10	Engraulidae	28.96	47.32	23.72	10.62	0.64	88.73	6.22	93.78

Table 6. Results of ANOVAs. R = region (3 levels), Z = zone (3 levels), Tow = tow type (3 levels), Time = time of day (2 levels).

Family Significant factor	**Number of stations included**	**d.f.**	**F**	**P**
Total tuna larvae				
R	61	2	0.4033	> 0.05
Z	61	2	2.2999	> 0.05
R*Z	61	4	4.5266	< 0.01
Tow	61	1	2.9597	> 0.05
Time	61	1	0.4661	> 0.05
Tow*Time	61	1	0.0115	> 0.05

Length-frequency distribution of tuna larvae

Tuna larvae caught in this study were preflexion, flexion, and postflexion stages of development. Most of the larvae collected were at the preflexion stage. Larvae ranged in length from 2.3 to 17.0 mm SL (n = 148 larvae, mean = 4.3 ± 1.9, Fig. 8). The flexion stage larvae collected in this study were generally 5.0 mm SL.

The size range and mean length of larvae at each region and zone is shown in Fig. 9. Tuna larvae caught in the north were larger than larvae caught in other two areas. Length of tuna larvae at each region were found to be significantly different ($P < 0.01$, Kruskal-Wallis test, n = 148, Table 7), but length of tuna larvae among zones did not appeared to differ ($P > 0.05$, n = 148, Kruskal-Wallis test, Table 7). However, there was a trend for larger larvae from the inshore zone. The interaction between region and zone on length of tuna larvae was not analysed due to lack of offshore larvae in the northern region.

Differences in size distribution due to tow type and day and night collection.

No differences in larval sizes were detected when comparing tows taken from the surface with tows taken from a depth of approximately 60 m ($P > 0.05$, Table 6, Fig. 10). On the other hand, there was a significant effect of towing time of day on the length of larvae ($P < 0.0001$, Table 7). The length of larvae caught at night appeared to be larger than those collected during the day (Fig. 10). The interaction between tow type and time of day was not found to affect length of larvae ($P > 0.05$, Table 7). Thus, differences in capture of large individuals between day and night tows were not ascribed to vertical migration of tuna larvae.

Discussion

Fish larval composition

The fish larval assemblage of the South China Sea was overwhelmingly dominated by the Myctophidae at the time collections were made for this study. The Gonostomatidae was the next most abundant group. Although adults of myctophids and gonostomatids are of no importance in the commercial or sport fisheries of the area, the larvae of these families are frequently a dominant component of the ichthyoplankton in many deep oceans. The major contribution made by the Myctophidae and the Gonostomatidae to the larval assemblage of this study area parallels the situation found in the eastern tropical Pacific (Ahlstrom, 1972). The myctophiform fishes are a mostly deep-water group (Leis and Rennis, 1983).

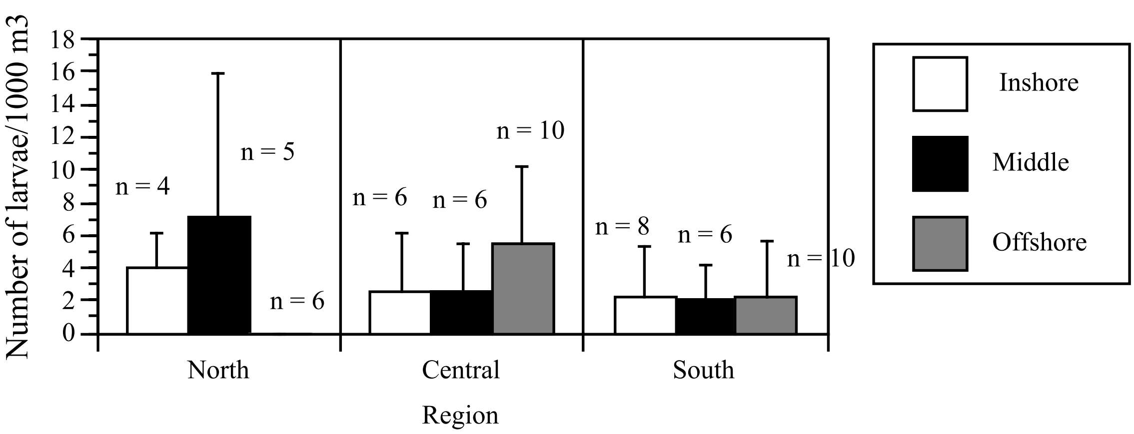

Fig.6. Mean abundance of tuna larvae (Scombridae) at each region and zone collected during April/ May 1998 in South China Sea (west coast of Philippines). Column charts show number of larvae/1000 m^3, vertical lines show standard deviation.

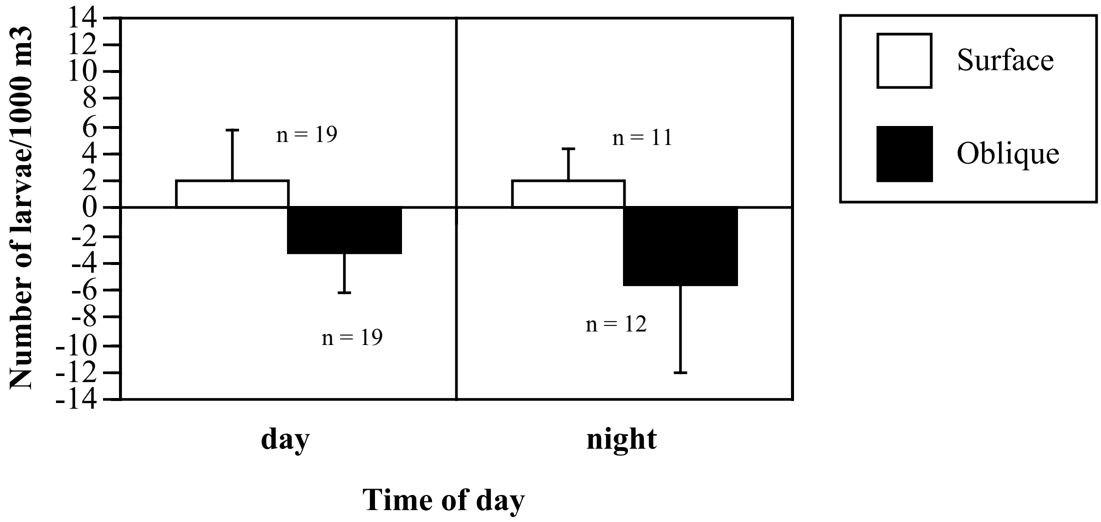

Fig. 7. Mean abundace of tuna larvae (Scombridae) during day and night collected by surface and double oblique tows during April/May 1998 in South China Sea (west coast of Philippines). Column charts indicate number of larvae/1000 m3, vertical lines show standard deviation.

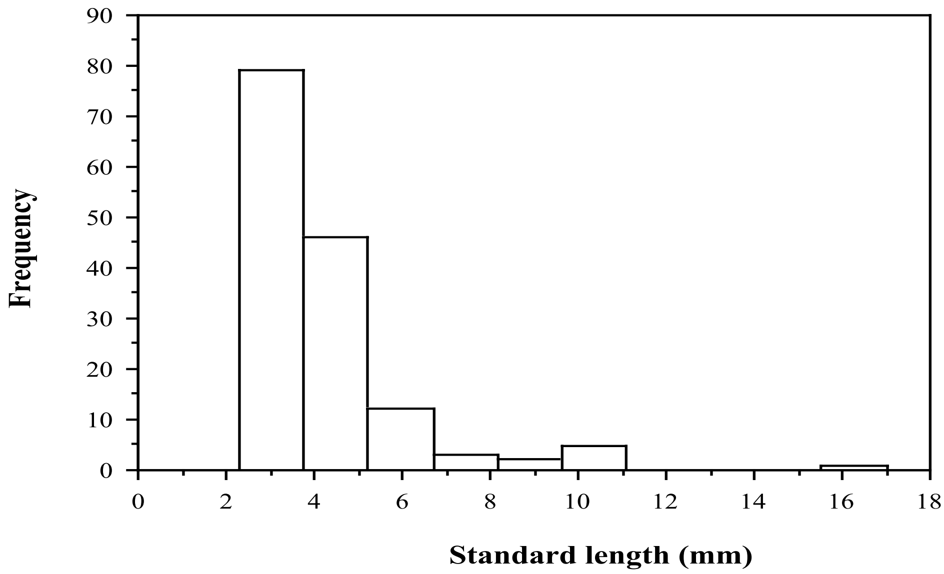

Fig. 8. Length-frequency distribution of tuna larvae (Scombridae) collected during April/May 1998 in South China Sea (west coast of Philippines). Column charts show frequency of larvae.

Table 7. Results of ANOVAs. R = region (3 levels), Z = zone (3 levels), Tow = tow type (3 levels), Time = time of day (2 levels)

Length of tuna larvae				
Significant factor	**Number of larvae included**	**d.f.**	**P**	
R	148	2	$\chi^2 = 10.8803$	< 0.01
Z	148	2	$\chi^2 = 0.1890$	> 0.05
R*Z	148	-	-	-
Tow	148	1	F = 0.0039	> 0.05
Time	148	1	F = 24.7653	< 0.0001
Tow*Time	148	1	F = 3.7984	> 0.05

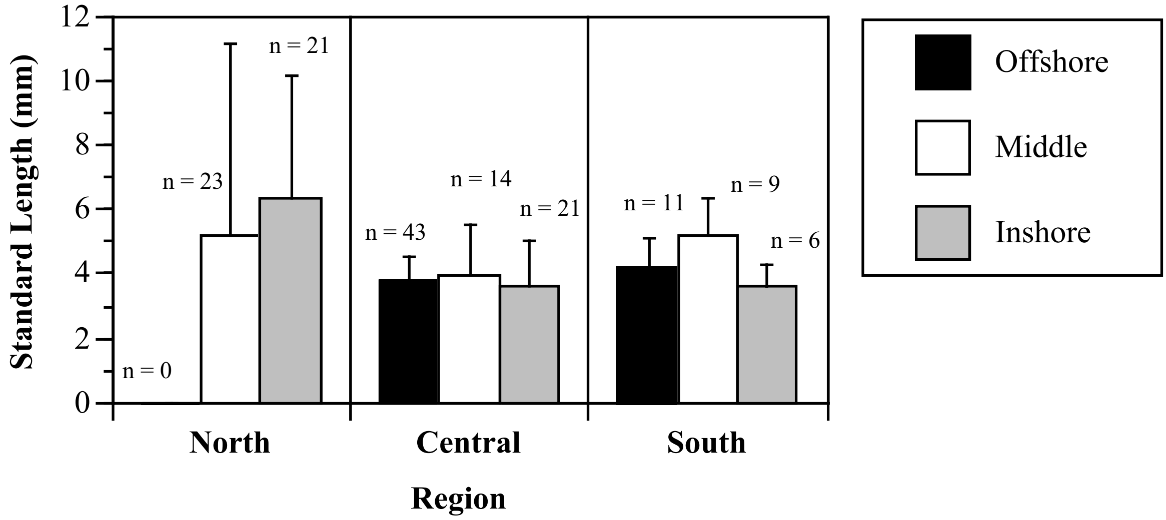

Fig. 9. Mean standard length of tuna larvae collected at each region and zone during April/May 1998 in South China Sea (west coast of Philippines). Column charts show standard length, vertical lines indicate standard deviation.

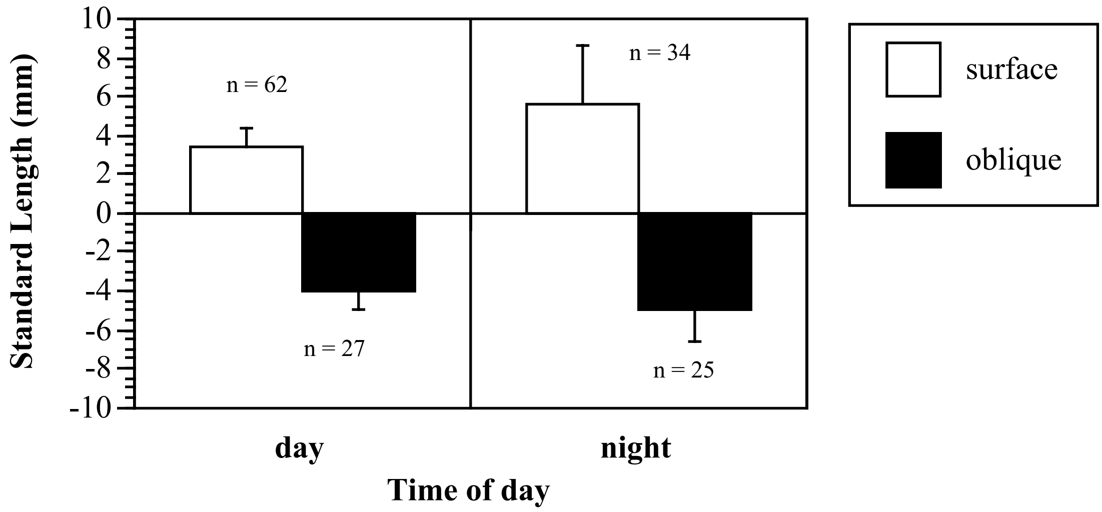

Fig. 10. Mean standard length of tuna larvae collected during day and night by surface and double oblique tows during April/May 1998 in South China Sea (west coast of Philippines). Column charts show mean standard length (mm), vertical lines show standard deviation.

Distribution of larvae

Of the three zones, there was no significant difference of larval fish abundance. Fish larvae appeared to be distributed throughout the study area. However, the inshore stations generally showed the highest numbers of fish larvae and the offshore the lowest.

There was no effect of region or zone on the abundance of fish eggs which suggests that fish eggs are distributed throughout the areas. However, fish eggs were found in high numbers at inshore stations in the northern region. This implies that it might be a spawning ground.

The larvae of the 10 most abundant fish families caught in the study area can be separated into three broad categories: (1) those for which the greatest concentrations were in the inshore zone, represented by the Bregmacerotidae, Gobiidae, Apogonidae, and the Carangidae; (2) those for which the greatest concentrations were in middle zone, represented by the Hemiramphidae, Labridae, and Engraulidae; (3) those for which the greatest concentrations were in the offshore zone, represented by the Myctophidae and Gonostomatidae. The high concentration of larvae in the inshore zone from the first group suggests that these fish may be coastal spawners. The last group of larvae are characterised as a marine deep-water group (Leis and Rennis, 1983).

More larvae were caught by double oblique tows than by surface tows during both day and night. This indicated that larvae did not migrate towards the surface at night which is similar to Ropke's (1989) finding. He found that the species of larvae sampled were deeper at night than during the day. These findings were opposite to other study in which most species appear to migrate towards the surface at night (Kendall and Naplin, 1981).

In this study, fish eggs were collected mainly by surface tows and this should be expected as fish eggs are often buoyant and tend to float towards the surface (Coombs, 1981; Coombs *et al*., 1990).

Abundance and distribution of tuna larvae

Tuna larvae occurred in low densities in this study which is similar to the findings of Wade (1951), Strasburg (1960), and Conand and Richards (1982). The low density of tuna larvae may result from not sampling at the correct depths. Tuna larvae were distributed throughout the study area, however, there appeared to be a trend of high abundance in the central and the north. Tunas require warm water for spawning and larval survival; consequently, the limits of larval distribution are governed largely by water temperature (Matsumoto *et al*, 1984). In the south, the water may be colder than the central and the northern regions, resulting in low larval densities in the south. Further study on the relationship between water temperature and abundance of tuna larvae is needed particularly in this study region.

Tuna larvae did not show diel vertical migration in this study as number of larvae did not significantly differ between oblique tows and surface tows. In addition, the number of larvae caught at night were not different from those caught during the day. This contradicts Matsumoto (1958), Strasburg (1960), Klawe (1963), Ueyanagi (1969), and Richards and Simmons (1971). They showed that skipjack tuna larvae generally are limited to the upper 50 m of water, that they undergo diel vertical migration, and that the vertical migration is most pronounced in the upper 30 m. All of these studies show that surface tows at night caught considerably more larvae than day tows. At a site in the eastern Indian Ocean, larval southern bluefin tuna moved towards the surface during daylight and descend at night, whilst at the same location, skipjack tuna larvae undertook the reverse migration (Davis *et al*., 1990).

When diel variations in vertical distribution correlated with the day/night cycle have been demonstrated, the amplitude of the vertical migration has often been shown to increase with larval size (Fortier and Leggett, 1984; Health *et al*., 1991). In the case of North Sea herring, larvae moved closer to the surface in daylight and closer to the sea bed at night with increasing length in the range 10-30 mm (Health *et al*., 1991). Those studies also contradict our findings. Large tuna larvae did not show vertical migration as similar length of larvae were found both surface and double oblique tows. However, larvae caught at night were larger than those caught during the day. This may due to net avoidance of larger larvae during the day (Heath, 1992).

Acknowledgements

We thank all crews of the SEAFDEC research vessel and all staff of SEAFDEC who worked at sea. This work was supported by a grant from Southeast Asian Fisheries Development Center (SEAFDEC). I would also like to thank Mr. Robert Gurney for critically editing the manuscript.

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Abundance and Distribution of Zooplankton in the South China Sea, Area III: Western Philippines

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ABSTARCT

A survey on the zooplankton in the waters of western Philippines was carried out from April 18 to May 9, 1998. The estimate of zooplankton biomass ranged from 0.92 mg/m^3 to 20.85 mg/m^3 with a mean of 5.70 mg/m^3. Maximum and minimum densities of zooplankton recorded were 4683/m^3 in station 16 and 446/m^3 in station 5, respectively. The zooplankton communities were comprised of 37 different categories of animal groups. Copepods were the most dominant group in zooplankton communities at all stations but their abundance varied from 5% to 43% of the total zooplankton.

Keywords: zooplankton, biomass, abundance, South China Sea, Western Philippines

Introduction

Zooplankton play an important role in marine ecosystem, mostly as consumers of microbial production, and by influencing the resources available to microbes by regenerating and excreting dissolved organic matter [Lalli and Parsons (1993)]. Zooplankton are also a good indicator of water quality conditions and habitat quality [Bay Journal (1995)]. Estimate of the fishery resources of the oceans can be made through the study of its zooplankton production.

This study on the abundance and distribution of zooplankton in the South China Sea, Area III: Western Philippines, under the Interdepartmental Collaborative Research Program of SEAFDEC was undertaken to obtain information on the distribution, abundance and biomass estimate of zooplankton in the study area. The related data on primary productivity and phytoplankton is reported separately.

Materials and Methods

Zooplankton sampling had been done at 31 oceanographic stations in the study area (Fig. 1) from April 18 to May 9, 1998. The sampling locations and depths of each station are shown in Table 1. Samples were collected at each station using a plankton net (mesh size =90µ, mouth diameter = 45cm., length = 125) hauled vertically from a depth of 60 meters to the surface. A calibrated flowmeter (Rigosha, Japan) was mounted at the center of the net to measure the water volume filtered by the net. Replicate samples of 500 ml were obtained from each station for abundance and biomass determination. All samples collected were concentrated and fixed with 4% formaldehyde solution.

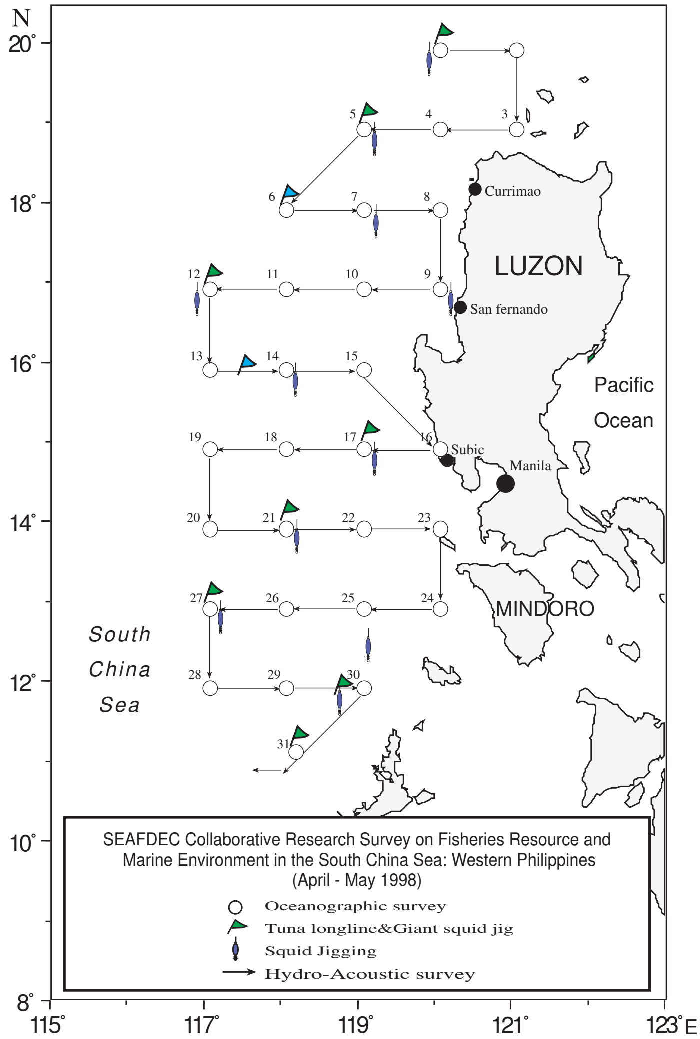

Fig. 1. Location of the sampling stations.

In determining zooplankton abundance and density, samples were subdivided into two groups, the >500µm and <500µm sizes. The organisms that were retained by the sieve were counted fully while those that passed through the sieve were subsampled. To subsample, a 25 µm size-sieve was used. The organisms that were retained in the 25µm mesh sieve were added with 100 ml of filtered seawater and stirred well to form a uniform distribution of the organisms. A one ml subsample was taken using a stempel pippette and placed into a Sedgewick-Rafter cell. The organisms were uniformly spread in the counting slide for microscopic observation with the aid of a needle. The counting of organisms was done in triplicates and performed under a light microscope. The zooplankton density, in individuals/m^3, as described by McManus (1993) in the Field Laboratory Manual on the Philippines Red Tide and Data Management was made:

$$\text{Organisms (m}^3\text{)} = \frac{\text{No. of organisms}}{\text{Subsample}} \times \text{Diltuted vol. (ml)} \; \frac{1}{\text{vol. filtd (m}^3\text{)}}$$

Determination of zooplankton biomass was conducted after a month of storing the samples at room temperature to allow maximal leaching of preservative. The samples were filtered on a pre-dried and pre-weighed filter paper. Zooplankton dry weight was obtained after oven-drying the concentrated samples at 60°C for 12 hours.

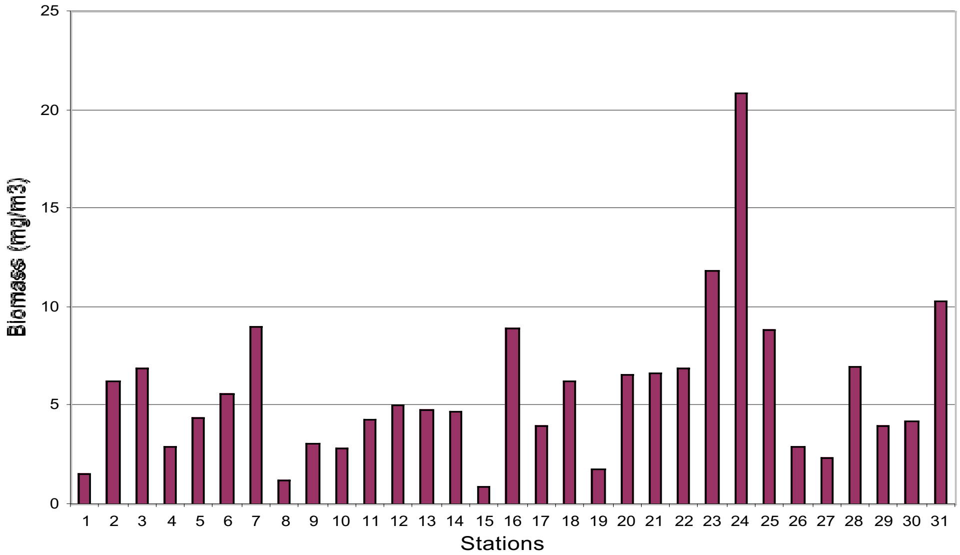

Fig. 2a. Zooplankton biomass.

Results

Zooplankton Biomass

The biomass estimates, using dry weight method, ranged from 0.92 to 20.85 mg dry wt/m^3 with an average of 5.70 mg dry wt/m^3 (Fig. 2a). The highest biomass of 20.85 mg dry wt/m^3 and the lowest biomass of 0.92 mg dry wt/m^3 were found along 13°00'07"N~119°58'06"E at station 24 off Mindoro Island and along 16°01'03"~119°00'35" at station 15 off Lingayen Gulf. The spatial distribution of biomass estimates of zooplankton in the whole area off western Philippines is shown in Fig. 2b. A zooplankton-rich patch which shares the highest biomass estimates of 20.85 mg dry wt/m^3 was observed at station 24 off Mindoro Island. The biomass estimates along coastal waters, particularly farther south (*viz*. stations 16, 23, 24, 25, 30, and 31) were considerably higher than those obtained along the coastal waters of northwestern Luzon (*viz*., stations 1, 4, 8, 9, 1, 15 and 17). Offshore waters of northwestern Luzon, approximately along 14°20'N and 116°~118°E, have relatively high biomass estimates ranging from <1~12 mg dry wt/m^3 than those of the coastal waters (Fig. 2a and b) except at stations 3 and 4 of the said area. Considerably high biomass estimates which ranged from 4 to 8 mg dry wt/m^3 occurred along 20°00'00"N~121°00'02"E at station 2 and along 19°01'05"N~121°00'04"E at station 3. Biomass estimates are quite variable in areas north off Palawan along 12°~13°N and 117°~119°E (station 26, 27, 28, 29, 30 and 31) which ranged from 1 to 12 mg dry wt/m^3. Station 31 off the coastal waters of Palawan yielded higher biomass estimates ranging from 8-12 mg dry wt/m^3.

Composition Abundance and Distribution of Zooplankton Community

Figure 3 showed a fairly comparable picture of the distribution and abundance of zooplankton community in the SCS, off western Philippines. The number of each group of zooplankton per station was expressed in individuals/m^3. The relatively high zooplankton counts in the survey area was due entirely to copepods (i.e., 87.37% of the total zooplankton, Fig. 4). The copepods, including its nauplii, could be grouped into three "sub-orders", viz: Calanoida, Harpacticoida and Cyclopoida. Of these, copepod nauplii was the most dominant sub-order ranging from 1 to 1559 individuals/m^3 in all stations. It appears that copepod nauplii are comparatively higher from the central to the southwestern parts than that of other parts of the

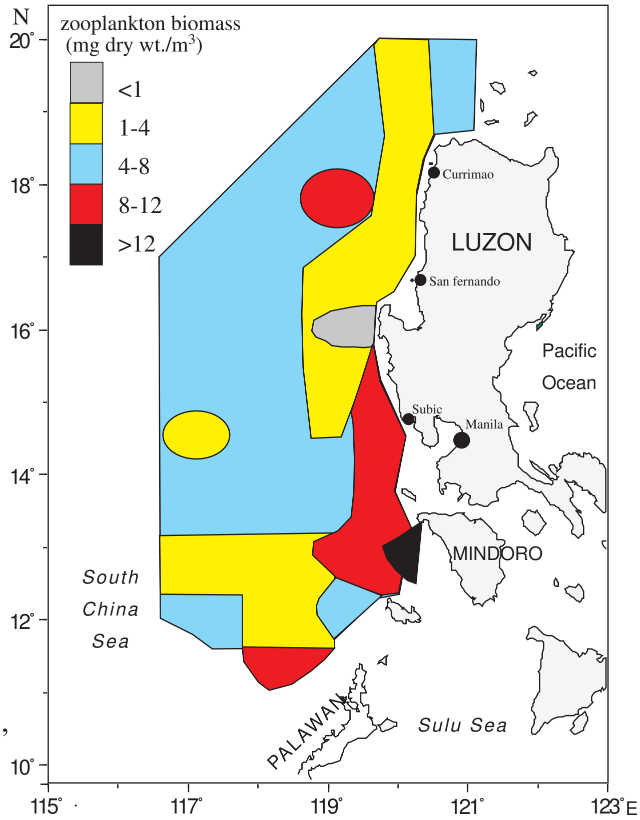

Fig. 2b. Distribution of zooplankton biomass, April-8-May9 1998.

Table 1. Position and depth of sampling stations in the study area.

Station No.	Latitude	Longitude	Actual depth(m)	Sampling depth (m)
1	19°59'02"	119°58'07"	3620	60
2	20°00'00"	121°00'02"	1434	60
3	19°01'05"	121°00'04"	vary	60
4	19°00'02"	120°00'04"	1100	60
5	19°00'02"	120°04'00"	3820	60
6	18°00'00"	118°00'00"	1830	60
7	18°00'03"	119°00'02"	1075	60
8	18°00'00"	120°00'00"	2955	60
9	17°00'00"	120°00'00"	1467	60
10	17°00'00"	119°00'00"	1851	60
11	17°00'00"	118°00'00"	3967	60
12	17°00'00"	117°00'00"	4020	60
13	16°00'03"	117°00'00"	3320	60
14	16°00'04"	118°00'07"	4034	60
15	16°01'03"	119°00'35"	3781	60
16	15°01'03"	120°00'04"	54	50
17	15°01'04"	118°57'04"	4657	60
18	15°00'00"	117°59'09"	936	60
19	14°59'06"	116°59'03"	1209	60
20	14°00'02"	116°59'05"	1677	60
21	14°04'02"	117°57'07"	1775	60
22	14°00'03"	118°59'09"	1820	60
23	14°01'06"	119°59'09"	2012	60
24	13°00'07"	119°58'06"	530	60
25	12°59'08"	118°59'00"	671	60
26	13°00'02"	117°58'09"	834	60
27	13°01'03"	116°59'01"	3810	60
28	12°00'34"	116°59'57"	vary	60
29	12°01'06"	118°00'00"	1143	60
30	11°59'09"	118°45'06"	1622	60
31	11°13'05"	118°03'01"	578	60

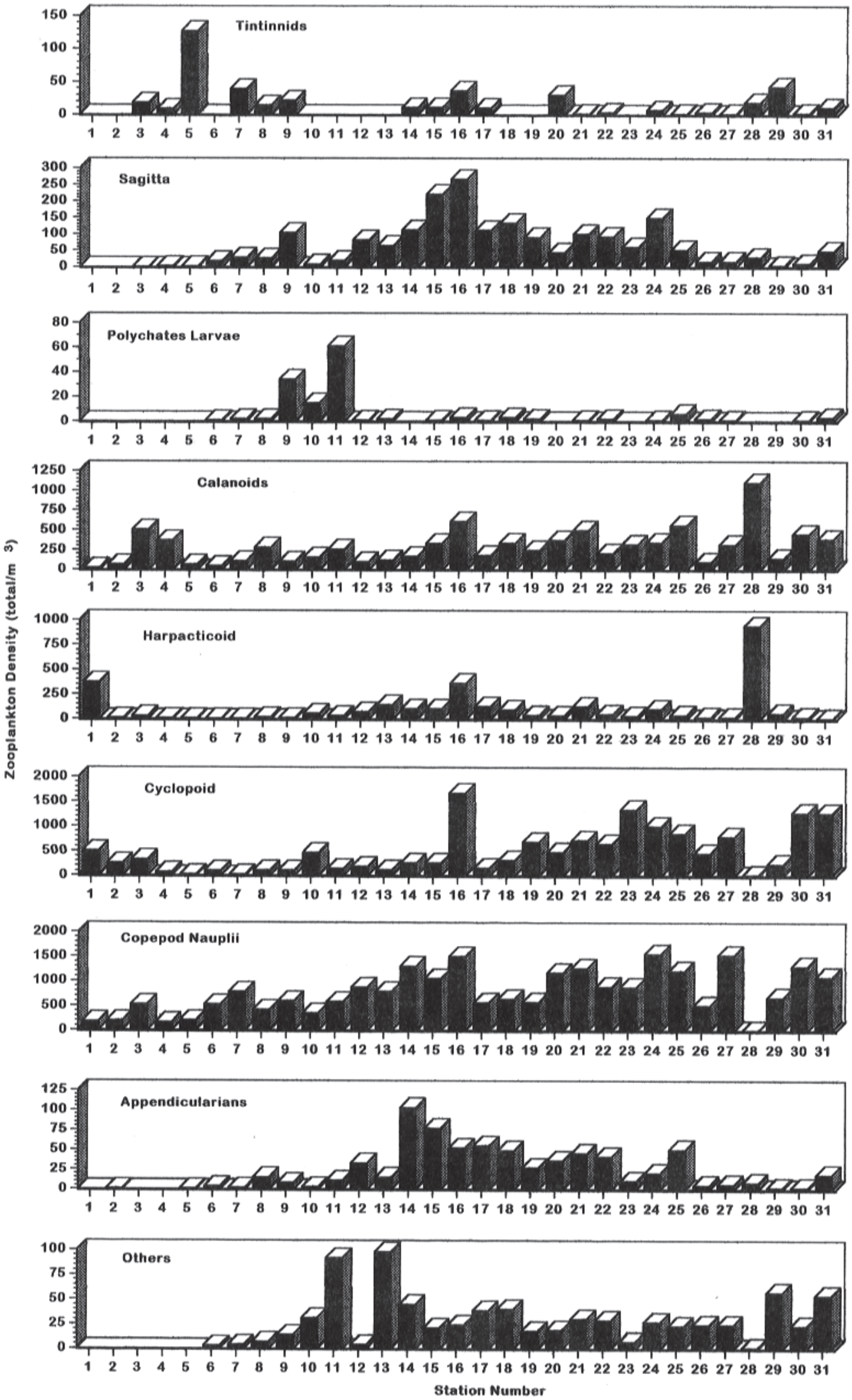

Fig. 3. Population density of the dominant zooplankton groups per station in the SCS, western Philippines (April 18 – May 9, 1998).

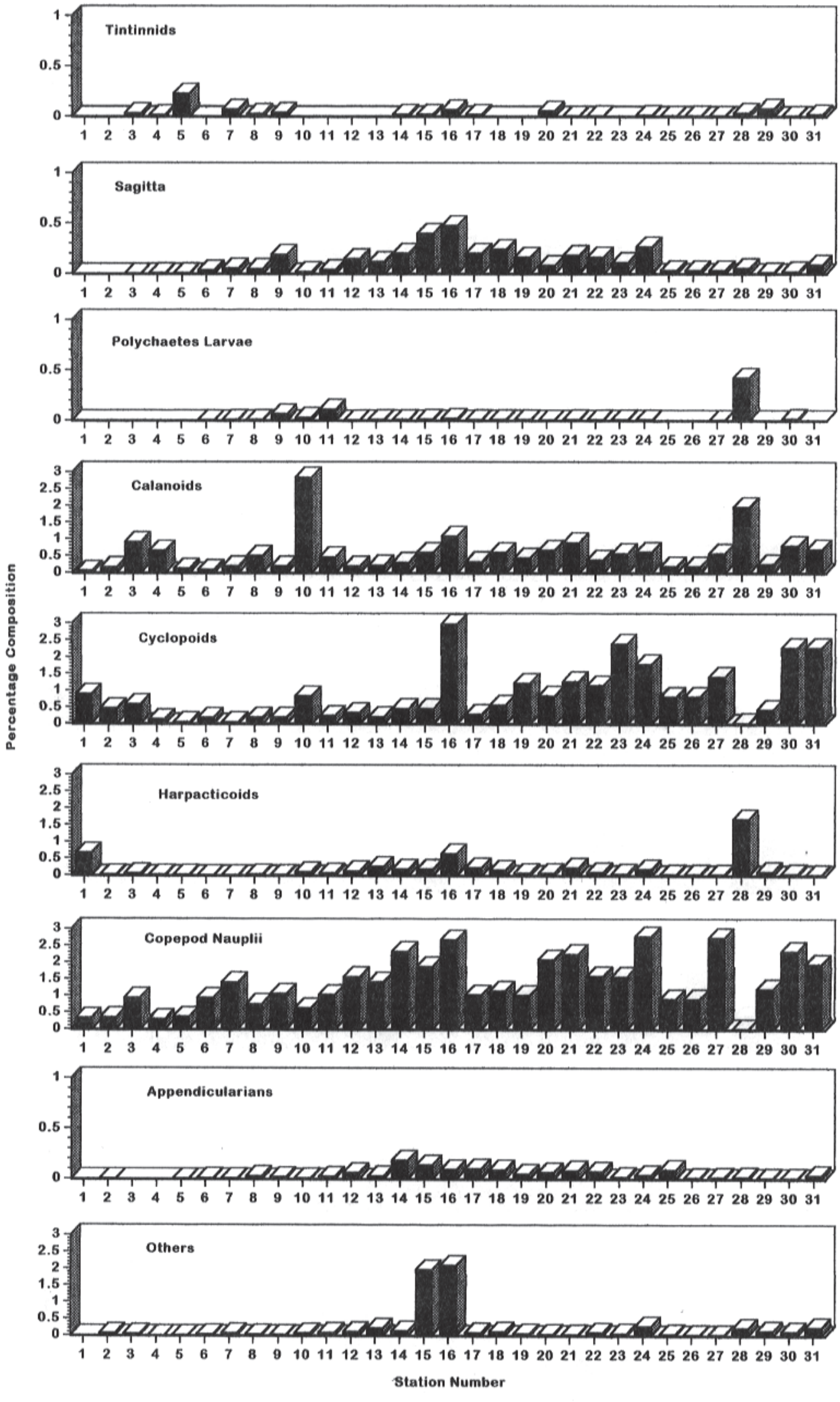

Fig. 4. Percentage composition of the dominant zooplankton group per station in the SCS, Area III: Western Philippines.

survey area. There are at least four major peaks of abundance identified for copepod nauplii in the area; one occurred in stations somewhere in the central part (stations 14, 15, and 16), another one at offshore stations about 120 nautical miles off Manila Bay (stations 20 and 21), another one along the coastal water (station 24) and about 180 nautical miles (station 25) off Mindoro Island, and the last one along the coast of Palawan (stations 30 and 31). Two maximum abundance of 1500 individuals/m^3 and 1559 individuals/m^3 occurred along the coastal waters off Subic (station 16) and off Mindoro Island (station 24), respectively; whereas, station 27 located offshore along 13°01'03"~116°59'01" also yielded maximum abundance of 1531 individuals/m^3 (Fig. 3).

Cyclopoida was the next dominant sub-order with counts ranging from 16 to1673 organisms/m^3 in all stations and constituted 27% of the total zooplankton (Fig. 5). As with copepod nauplii, counts of cyclopoids are comparatively low in the western Luzon than that of the southwestern part of the area (Fig. 3). Three major peaks of abundance for such organisms occurred in the following: one at station 16 in the central part yielding a maximum count of 1673 individuals/m^3; another one at stations 23 and 24 located off the mouth of Manila Bay and off Mindoro Island, with counts of 1343 individuals/m^3 and 1000 individuals/m^3, respectively; and the last one at stations 30 and 31 off Palawan coast, which have nearly the same counts of 1275 and 1274 individuals/m^3, respectively. The sub-order Cyclopoida is represented by the genera *Copilia, Corycaeus, Oithona, Oncaea, Pachysoma* and *Sapphirina.*

Sub-order Calanoida accounted for 16% of the total zooplankton with counts ranging from 16 to 1099 individuals/m^3 in all stations. Similarly, counts of calanoids are comparatively low, except that peak of abundance in stations 3 and 4, in the northwestern Luzon than that of the central and southwestern parts of the area. Three peaks of abundance for calanoids were observed as follows: two minor peaks: one at stations 3 and 4 in the northwestern Luzon, and another one at station 16 off Subic Bay; while one major peak of abundance with maximum count of 1099 individuals/m^3 occurred offshore at station 28 along 12°00'34"N~116°59'57"E. Sub-order Calanoida is represented by several genera; *viz., Acartia, Acrocalanus, Aetidues, Bradyidius,*

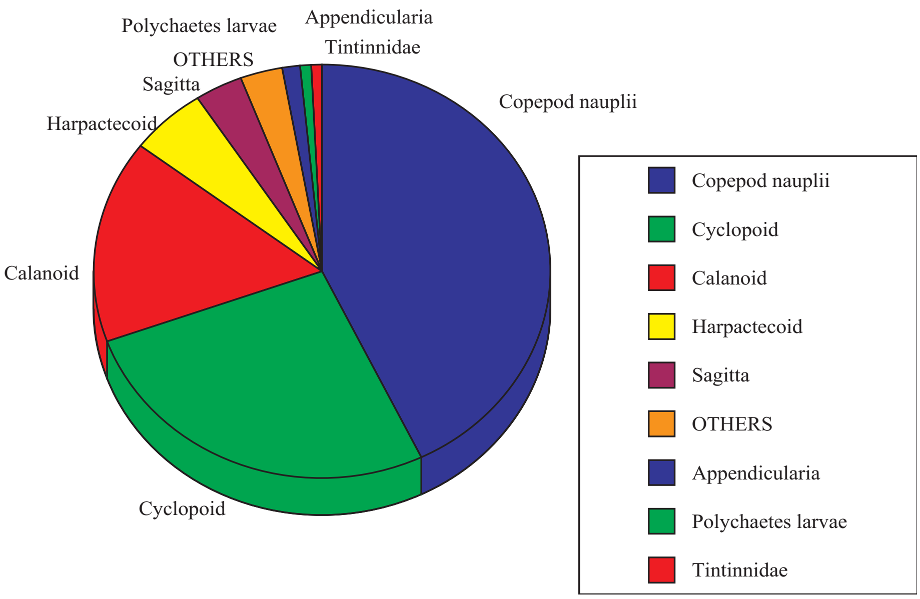

Fig. 5. Percentage composition of different zooplankton groups in the SCS, off western Philippines (April 18 – May 9, 1998)

Calanus, Candacia, Calanopia, Calocalanus, Centropages, Clausocalanus, Eucalanus, Euchaeta, Haloptilus, Lucicutia, Mecynocera, Paracalanus, Pleuromamma, Pontellina plumata, Pontellopsis, Pseudocalanus, Rhincalanus, Scolecithrix danae, Scolecithricella, Temora turbinata, Temora stylifera and *Temora discuadata*

Rare occurrence of sub-order Harpacticoida yielded relatively low counts ranging from 5 to 944 individuals/m^3 in all stations and represented only 5% of the total zooplankton. One major peak of abundance which do not exceed 1000 individuals/m^3 occurred offshore at station 28 along 12°00'34"N~116°59'57"E and two minor peaks which were found at station 1 in the northwestern most part of Luzon and station 16 off Subic Bay (Fig. 3). Sub-order Harpacticoida consisted mainly of four genera, *viz., Clytemnestra, Euterpina, Macrosetella* and *Microsetella.*

Sagitta is the only genus identified for phylum Chaetognatha in the entire area, which contributed only 3% of the total zooplankton. This resulted from the relatively low counts which ranged from 1 to 266 individuals/m^3 recorded in all stations. The organism is dominant in the central part of the area, that is particularly observed at stations 15 and 16 off Subic Bay having 221, and 266 individuals/m^3, respectively. It occurred also in fairly low counts in some stations particularly at station 9 off Lingayen Gulf and at station 24 off Mindoro Island.

Tintinnids, appendicularia and polychaetes larvae are relatively rare and contributed only 1% each of the total zooplankton. Other zooplankton sub-groups constituted 3% of the total zooplankton which represented in an order of abundance by foramineferans, gymnostomatidae, radiolaria, siphonophores, anthomedusae, leptomedusae, pteropods, heteropods, megastropods, gastropods, cladocera, ostracods, mysids, decapods and amphipods (Table 2).

Discussion

The range of total zooplankton counts (i.e., 446~4683 individuals/m^3) in the present study of SCS, off western Philippines are lower than those values previously reported for other waters of the ASEAN region and some tropical waters (Table 3). In comparison with the total number of zooplankton per m^3 obtained in Singapore Strait, for example, it is evident that the minimum average of approximately 14,000 individuals/m^3 and a maximum average of approximately 60, 000 individuals/m^3 [Tham *et al.* (1970)] are considerably higher than that of the present study. Results obtained by Tseng (1969) in Taiwan Strait was greater than that of the former. The methods used by Tham *et al.* (1970) and Tseng (1969) were by horizontal surface tows with different types of nets, whereas, the present study was by vertical haul of plankton net with mesh size of 90μ, mouth diameter of 45 cm and length of 125 cm. These facts showed that the method of sampling is very important in revealing the consistency of the distribution and abundance of zooplankton among areas.

The numerical abundance of zooplankton in the surveyed area does not correspond very well with the biomass estimates as compared with observation made at the east coast of Phuket Island, Southern Thailand, Andaman Sea, where the abundance of zooplankton corresponded very well with the biomass [Boonruang (1985)]. Figure 2b generally depicted a pattern of distribution of a much higher zooplankton biomass along the coastal waters farther south of western Philippines compared to those obtained along the coastal waters of northwestern Luzon. A patch of relatively high biomass estimates ranging from 8~>12 mg dry wt/m3 was evident

Table 2. List of Zooplankton Observed in the Study Area

Phylum	Subgroups	Common Genera
Protozoa	Tintinnidae	Codonellopis
		Cyttarocylis magna
		Cystonella trofortii
		Epiplocylis
		Eutintinnus
		Favella
		Parafavella
		Ptychocylis
		Parundella
		Rhabdonella
		Tintinnopsis
		Xystonella treforti
	Foraminifera	Globigerina
		Orbulina
	Gymnostomatidae	Porodon
	Radiolaria	Acanthometron pellucidum
		Anthocyrtidium cineraria
		Aulosphaera trigonopa
		Carocalyptra
		Collozum inerme
		Drysmosphaera polygonalis
		Eucecryphalus
		Eucyrtidium cienkowskii
		Eusyringium
		Pleurspis
		Pterocanium
		Sagena tenaria
		Sphaerozoum
Muggiaea		
		Sticholonche zanclea
Coelenterata	Siphonophores	Abylopsis
		Diphyes
	Anthomedusae	
	Leptomedusae	
Chaetognatha		Sagitta
Annelida	Polychaetes	Krohnia lepidota
		Lopadorrhynchus
		Naiades cantranii
		Pelagobia longicirrata
		Pontodora pelagica
		Rhynchonoreella gracilis
		Rhynchonoreella angelini
		Sagitella kowalewskii
		Travisiopsis lobifera
		Tomopteris
		Typhloscolex mulleri
		Vanadis grandis
		Vanadis minuta
	Polychaetes larvae	
Arthropoda	Calanoid	Acartia
		Acrocalanus
		Aetidues
		Bradyidius
		Calanus
		Candacia

Table 2. Continue

Phylum	Subgroups	Common Genera
		Calanopia
		Calocalanus
		Centropages
		Clausocalanus
		Eucalanus
		Euchaeta
		Haloptilus
		Lucicutia
		Mecynocera
		Paracalanus
		Pleuromamma
		Pontellina plumata
		Pontellopsis
		Pseudocalanus
		Rhincalanus
		Scolecithrix danae
		Scolecithricella
		Temora turbinata
		Temora stylifera
		Temora discuadata
		Undinopsis
	Cyclopoid	Copilia
		Corycaeus
		Oithona
		Oncaea
		Pachysoma
		Sapphirina
	Harpacticoid	Clytemnestra
		Euterpina
		Macrosetella
		Microsetella
	Copepod nauplii	
	Cladocera	Evadne
		Penilia avirostris
		Podon
	Ostracods	Conchoecia
	Mysids	
	Decapods	Lucifer
		Sergestes
	Amphipods	Hyperiidae
	Brachyuran megalopa	
	Brachyuranzoea	
	Pagurid (larvae)	
	Caridean (larvae)	
	Euphausiids	
	Isopods	
	Anomuran larvae	
	Fish larvae	
Fish eggs		
Mollusca	Pteropods	Cresies
		Cavolina
		Limacina
	Heteropods	Atlanta
	Megastropods	Janthina
	Gastropods larvae	
	Bivalves	
Chordata	Appendicularia	Oikopleura
		Fritillaria
	Salps	Salpa
		Thalia
	Doliolids	Doliolum
Echinodermata	Echinoderm larvae	
Aschelminthes	Rotifera	Brachionous

Table 3. Comparative estimates of zooplankton standing crop (numerical abundance and biomass among waters in SCS region)

Study Area	Methods	Standing Crop (Range of Total Counts)	Biomass	Source
Singapore Straits (1°12.9'N and 103°49.8'E) Depths: 11~14 m)	Horizontal surface tows of muslin net - Seasonal distribution was described -Period of collection: 03-1935~01-1936 - 30 min. of towing	14,396/m^3~58,949/m^3		Tham *et al.* (1990)
Nhatrang Bay, Vietnam (12°N 109°E)	Horizontal surface tows by Japanese made nylon nets #xx13 and #GG56 - Seasonal distribution was described - Period of Collection - 07-1970~06-1971	Only dominant zooplankton groups (*viz.*, Copepoida, Oikopleura, Chaetognaths, zoea) were reported 75~562/m^3	0.78~1.39 ml/m^3	Dao and Ngo-Anh (1972)
Northeast Seawaters of Taiwan	Two types of nets: (a) net of 45 cm diameter with mesh aperture 0.33 mm, GG 54 was used for 50-m depth to surface vertical hauls; and (b) 130 cm plankton and larval net (front section mennow net, rear section mesh aperture 0.33 mm, GG 54) was towed horizontally at a low speed from the right side of the vessel in the surface water layer for about 40 m.	Vertical haul: 398/m^3 Horizontal tow: 1449/m^3		Tseng (1970)
Southeastern Coast Of Taiwan		594/m^3		Huang (1983)
Southeaster of the South China Sea			7.03(±3.11)mg/m^3	Chark *et al.* (1987)
SCS, Western Philippines	Vertical haul of plankton net (mesh size=90µ; mouth diameter=45 cm and length=125 cm)	446~4683 individuals/m^3	0.92~20.85 mg dry wt/m^3	Present study

approximately along 12°~15°N and 119°~121°E (covering stations 16, 23, 24 and 25), a fact which may be attributed to a relatively high nutrient loads in these areas as pointed out in the work of Montojo (1998, this volume). Waters off Mindoro Island is featured by a highest zooplankton biomass of 20.85 mg dry wt/m^3. Likewise, in terms of numerical abundance, these particular areas, *i.e.,* off the coast of Subic, off the mouth of Manila Bay and off Mindoro Island (stations 16, 23, 24 and 25) demonstrated relatively high zooplankton population which ranged from 2670 individuals/m^3 to 4683 individuals/m^3. However, it could be noted that the highest total zooplankton of 4683 individuals/m3 occurred at station 16 off Subic Bay.

Offshore waters of northwestern Luzon (approximately along 14°20'N and 116°~118°E), on the other hand, established relatively high biomass estimates than that of the coastal waters except at stations 3 and 4 of the said area. Such condition could probably dealt with high zooplankton assemblage at homogenous water mass with relatively high salinity concentrations (i.e., 33.8‰~34.00 %o) at the water surface in the northwestern Luzon and near the entrance of Luzon Strait. This phenomenon was probably influenced by the monsoonal circulation pattern of the oceanic regime in the northeast side of the Pacific Ocean [Takenoute *et al.* (1970)] that converged with the northward longitudinal current of the SCS [Oniel and Eason (1982)] during the month of April. Likewise, induced water circulation from the southern part of SCS which caused water mass displacement from the Mindoro Strait during the month of May [O'niel and Eason (1982)], have probably contributed to zooplankton-rich patch in stations 16, 23, 24 and 25.

Variability of zooplankton biomass in areas north of Palawan along 12°~13°N and 117°~119°E (stations 26, 27, 28, 29, 30 and 31) which seems to coincide with variable numerical abundance of total zooplankton (Fig. 2b and 3), is probably associated with the multi current system in these areas as noted by several investigations carried out in the past [Wyrtki (1961), Takenuoti (1970), O'niel and Eason (1982)]. Unfortunately, data on water circulation pattern off the western Philippines was not obtained during the cruise and any further discussion on whether it influence the abundance and distribution of zooplankton population in the area would be pure speculation.

General observation made on the occurrence and abundance of the different zooplankton organisms which comprised 37 sub-groups showed that copepods form the major component and occurred throughout the study area. Looking at the graph at Fig. 3, the pattern of quantitative distribution of zooplankton in the entire area was dominated by copepods (87. 37% of the total zooplankton). Maximum peaks of abundance in coastal waters (i.e., in station 16 off Subic Bay, station 23 off the mouth of Manila Bay, station 24 off Mindoro Island, station 30 and 31 off Palawan), have been attributed to copepods, mainly comprised of copepod nauplii, Cyclopoida, Calanoida and Harpacticoida. Copepods also contributed to the maximum peaks of abundance at offshore waters (i.e., station 27) along 13°01'03"N~116°59'01"E and at station 28 along 12°00'34"N~116°59'57"E. Copepods are distributed throughout the world ocean and are one of the most important components of the plankton community [Ikeda (1977)]. They play a crucial role in the marine food chain, since they link with primary production to higher tropic levels and are important component in the diet of many fishes, seabirds and even whales. The copepods that include herbivores, carnivores and omnivores are said to play a significant role in the transformation of organic matter in marine pelagic ecosystem [Anraku and Omori (1963)]. As noted above, relatively high zooplankton population, which was dominated by copepods, was mostly confined along coastal waters, particularly off Subic Bay, off the mouth of Manila Bay and off Mindoro Island. This high zooplankton-rich patch also coincided with relatively high phytoplankton community in these areas as observed by Bajarias (1998, this volume). This high zooplankton abundance seems to follow the high phytoplankton concentrations in the area where the former can readily feed on the latter.

The plankton analyzed by Alvariño (1981) also showed that copepods were the dominant group in almost 80% of the collections made in the waters of California. Interestingly, this also conforms well with the present study wherein copepods constituted 87.37% of the total zooplankton in the entire sampling area. Alvariño (1981) further observed that the maximum abundance of copepods occurred in areas where there was an abundant anchovy larvae but never from localities with no anchovy larvae. Thus, it seems specially true for zooplankton to play a role as important link in the grazing food chain in marine ecosystem [Day *et al.,* (1989)]. Zooplankton production depends on primary and secondary production and is important in the estimation of the productivity of fish species and the fishery resources since zooplankton are fish food and can control fish recruitment and stocking success.

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Distribution of Planktonic Malacostraca and Cephalopod Paralarvae in the South China Sea, Area III: Western Philippines

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ABSTRACT

Zooplankton samples from 31 stations in the western Philippines water were collected by M.V. SEAFDEC on 7 April – 19 May 1998. Six major groups were identified: Euphausiacea, Natantia (Penaeidea and Caridea), Reptantia, Brachyura, Stomatopoda and cephalopod paralarvae. Three genera of Euphausiacea were found, they belong to one family: this group formed 25.1% - 90.9% of total taxonomic groups at different stations. The superfamily Penaeidea consisted of seven genera belong to four families. Caridea larvae were composed of 11 families including 19 genera. Retantia consisted of three infraorder: Stenopodidea, Thalassinidea and Parinuridea. The infraorder Parinuridea comprised two families: Palinulidae and Scyllaridae. Fourteen families of Brachyura larvae occurred in the study area. Stomatopoda was composed of three families including three genera. Cephalopoda paralarvae were presented in the plankton samples by six families representing eight genera. The maximum counts for malacostraca larvae and cephalopod paralarvae was observed at station 16. The present study reveals that some economic species such as *Penaeus* spp., *Parapenaeus* spp., *Panulirus* spp., *Scyllarus* spp., *Portunus* spp. and *Sthenoteuthis oualaniensis* were important components of the zooplankton assemblages in the western Philippines.

Key words: Euphausiacea, shrimp, Brachyura, phyllosoma, Stomatopoda, cephalopod, larvae, zooplankton

Introduction

Malacostraca larvae consist of seven major groups: Stomatopoda, Natantia(Penaeidea and Caridea), Reptantia, Anomura, Brachyura, Mysidacea and Euphausiacea. Despite their commercial importance, our knowledge of malacostraca larvae and cephalopod paralarvae from the Philippines waters is based mainly on general groups. The main objective of the present study is investigating the distribution, abundance and diversity information of some malacostraca larvae and cephalopod paralarvae from the western Philippines water and consideration of reproduction of these groups.

Materials and Methods

Zooplankton samples from 31 stations in the western Philippines water were collected by M.V. SEAFDEC on 7 April – 19 May 1998 (Table 1 & Fig. 1). Zooplankton was collected using 0.33 mm mesh net attached to 60 cm. diameter bongo frames. A flowmeter, attached within the aperture of the net, measured the amount of water filtered. At each station, a 30 minutes oblique tow of the bongo net was made with the ship speed was about 2 knots. The depth of the haul was 60 meters below the sea surface. Samples were preserved in 10 % buffered formalin-seawater immediately. In the laboratory, Euphausiacea, Natantia (Penaeidea and Caridea), Reptantia, Brachyura, Stomatopoda and cephalopod paralarvae were sorted out and identified to genus level.

The classification of Euphausiacea was based on Brinton (1975). The classification of shrimp larvae was based on Broad (1957), Cook (1965), Dobkin (1963), Gurney (1942), Heegaard (1966), Holthuis (1993), Kurata (1968), Kurata and Vanithchkul (1974), Paulinose (1979) and Williamson (1957, 1960, 1962, 1967[1], 1967[2], 1970 and 1976). The classification of phyllosoma larvae was based on Johnson (1971) and Radhakrishnan and Vijayakumaran (1993). The classification of Brachyura larvae was based on Rice (1980). The classification of stomatopod larvae was based on Dakin and Colefax (1940), Diaz (1998), Manning (1963) and Michel and Manning (1972). 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).

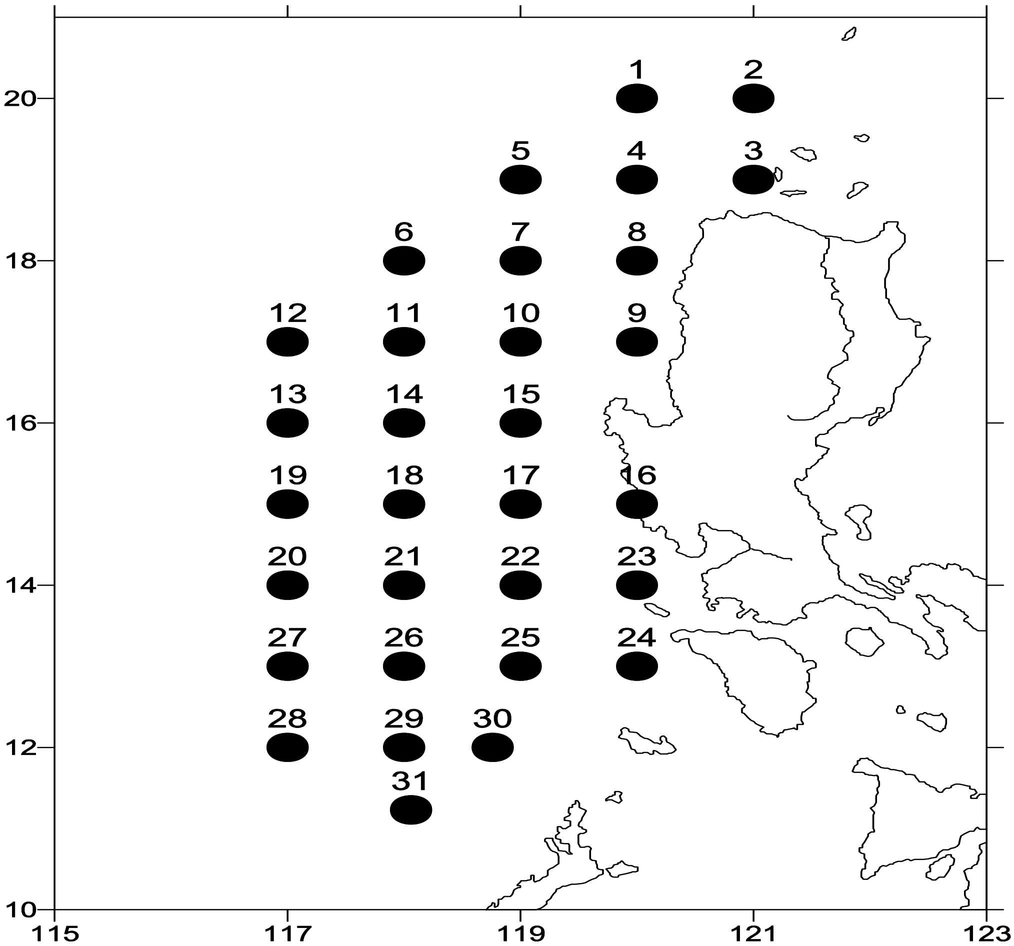

Fig. 1. Map of sampling stations in the western Philippines.

Table 1. Partial details of sampling stations

Station No.	Date	Local Time	Position Latitude	Longitude	Depth (m)
1	18-Apr-98	0700-0735	19˚59.2 N	119˚58.7 E	3620
2	18-Apr-98	2015-2044	20˚00.0 N	121˚00.2 E	1434
3	19-Apr-98	0431-0501	19˚01.5 N	121˚00.4 E	2565
4	19-Apr-98	1248-1316	19˚00.2 N	120˚00.4 E	1100
5	20-Apr-98	0708-0735	19˚00.2 N	120˚04.0 E	3820
6	21-Apr-98	2355-0024	18˚00.0 N	118˚00.0 E	1830
7	21-Apr-98	2024-2051	18˚00.3 N	119˚00.2 E	1180
8	22-Apr-98	0922-0949	18˚00.0 N	120˚00.0 E	2932
9	22-Apr-98	1615-1722	17˚00.0 N	120˚00.0 E	1505
10	25-Apr-98	0201-0230	17˚00.0 N	119˚00.0 E	1851
11	25-Apr-98	0922-0950	17˚00.0 N	118˚00.0 E	3967
12	25-Apr-98	1658-1727	17˚00.0 N	117˚00.0 E	4031
13	26-Apr-98	2043-2106	16˚00.3 N	117˚00.6 E	4113
14	27-Apr-98	0716-0735	16˚00.4 N	118˚00.7 E	4041
15	28-Apr-98	0604-0634	16˚01.3 N	119˚00.35 E	3646
16	28-Apr-98	1609-1639	15˚01.3 N	120˚00.4 E	59
17	29-Apr-98	0645-0616	15˚00.4 N	118˚57.4 E	4559
18	29-Apr-98	2017-2035	15˚00.0 N	117˚59.9 E	937
19	30-Apr-98	0327-0357	14˚59.6 N	116˚59.3 E	1206
20	30-Apr-98	1114-1145	14˚00.2 N	116˚59.5 E	1674
21	1-May-98	0546-0617	14˚04.2 N	117˚57.7 E	1777
22	1-May-98	2058-2027	14˚00.3 N	118˚59.9 E	1800
23	2-May-98	0430-0500	14˚01.6 N	119˚59.9 E	2185
24	4-May-98	1557-1627	13˚00.7 N	119˚58.6 E	710
25	5-May-98	2337-0006	12˚59.8 N	118˚59.0 E	440
26	5-May-98	0715-0734	13˚00.2 N	117˚58.9 E	822
27	5-May-98	1441-1510	13˚01.3 N	116˚59.1 E	1672
28	6-May-98	2033-2102	12˚00.34 N	116˚59.57 E	3810
29	7-May-98	0540-0611	12˚01.6 N	118˚00.0 E	1143
30	8-May-98	0608-0639	11˚59.9 N	118˚45.6 E	1922
31	9-May-98	0603-0636	11˚13.5 N	118˚03.1 E	544

Results

Distribution and abundance

Distribution and abundance of Euphausiacea, shrimp larvae, phyllosoma larvae, brachyura larvae, Stomatopoda larvae and cephalopod paralarvae were shown in Fig. 2-7.

Species composition

Cephalopoda and five major groups of malacostraca were identified. A total of Euphausiacea, Natantia, Reptantia, Brachyura, Stomatopoda and Cephalopoda representing 37 genera and 2 species was identified as shown in Table 2.

Euphausiacea

Euphausiacea composed of one family and three genera: *Thysanopoda tricuspidata*, *Euphausia* spp. and *Stylocheiron* spp. Abundance of Euphausiacea varies extensively; ranging from 500 - 17,197 individual/1000m^3. It showed highest concentration at station 23 (Table 3). Euphausiacea formed 25.1 % - 90.9 % of total taxonomic groups at different stations and was the most dominant component of the malacostraca and cephalopod larvae recorded (Table 10).

Penaeidea

The superfamily Penaeidea consisted of four families: Solenoceridae, Aristeidae, Penaeidae and Sergestidae. Family Solenoceridae was represented by only one genus *Solenocera* spp. This genus was found only at four stations in low density (3-270 individual/1000m^3). Family Aristeidae was found only one genus *Gennadas* spp. It occurred at all stations except station 18, but showed highest density at station 16 (216 individual/1000m^3). Family Penaidae was represented by *Penaeus* spp. and *Parapenaeus* spp. *Penaeus* spp. occurred at three stations (station 2, 23 and 25) and low number (2-3 individual/1000m^3). *Parapenaeus* spp. appeared at many stations that the highest concentration was at station 16 (216 individual/1000m^3). Family Sergestidae was represented by *Sergestes* spp., *Sergia* spp. and *Lucifer* spp. *Sergestes* spp. were found all over the studied area except station 28. The highest density occurred at station 5 (374 individual/ 1000m^3). *Sergia* spp. appeared in low number at station 6 and 7. *Lucifer* spp. were very common and formed 91 % of Penaeidea larvae. The highest density occurred at station 7 (4,388 individual/ 1000m^3). Abundance of Penaeidea varied from 288-4,851 individual/1000m^3. The highest concentration of Penaeidea larvae was at station 16 (Table 4). It formed 3.4% - 73.2% of all groups at different stations (Table 10).

Caridea

This group was composed of 12 families: Pasiphaeidae, Oplophoridae, Nematocarcinidae, Rhynchocinetidae, Anchistiodidae, Palaemonidae, Alphaeidae, Hippolytidae, Processidae, Pandalidae, Thalassocarididae and Amphionidae. The family Passiphaeidae was represented by *Leptochela* spp., which was found in most stations. The highest density was at station 23 with 966 individual/1000m^3. The family Oplophoridae, Nematocarcinidae and Processidae could not identified to genus level and densities of these families (in total) were only 3, 136 and 23 individual/ 1000m^3 respectively. The family Rhynchocinetidae was expressed by *Rhynchocinetes* spp. which was recorded in many stations but in low number (2-18 individual/1000m^3). The family Anchistiodidae was represented by *Anchistiodes* spp. This species was rare that found only at one station (3 individual/1000m^3). The family Palaemonidae was represented by two subfamilies:

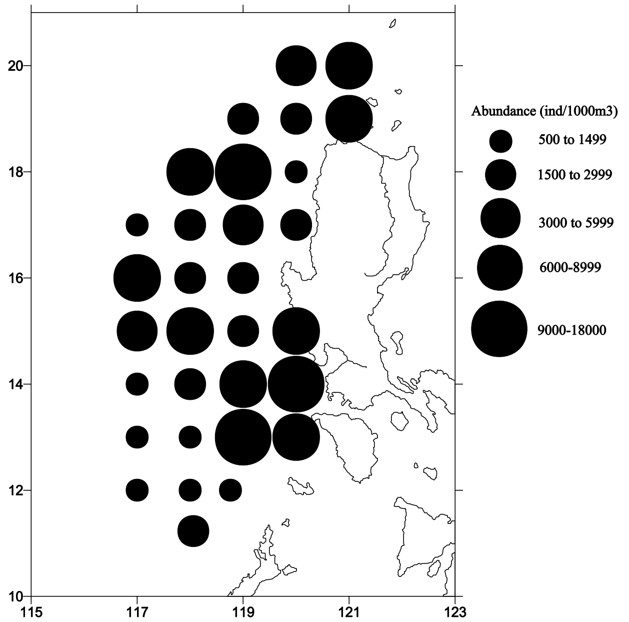

Fig. 2. Distribution and abundance of Euphausiacea in the western Philippines.

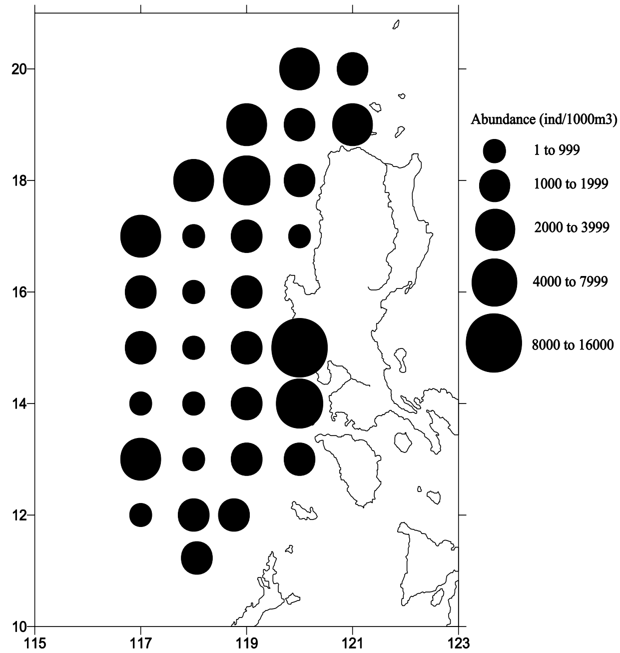

Fig. 3. Distribution and abundance of shrimp larvae in the western Philippines

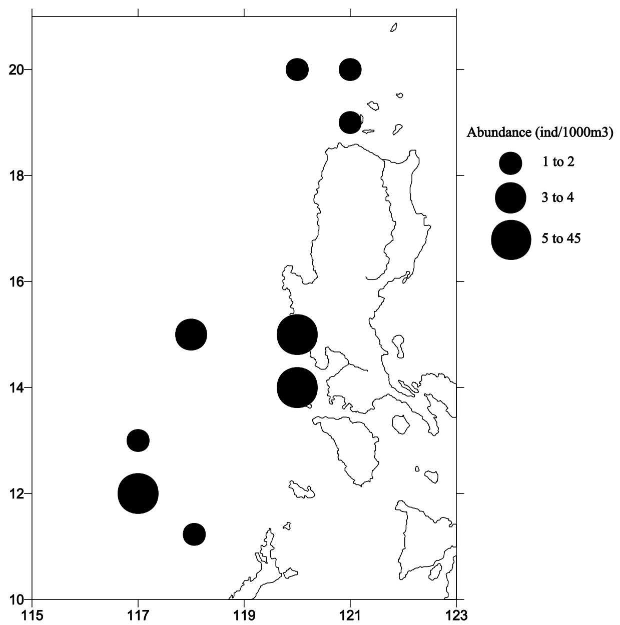

Fig. 4. Distribution and abundance of phyllosoma larvae in the western Philippines.

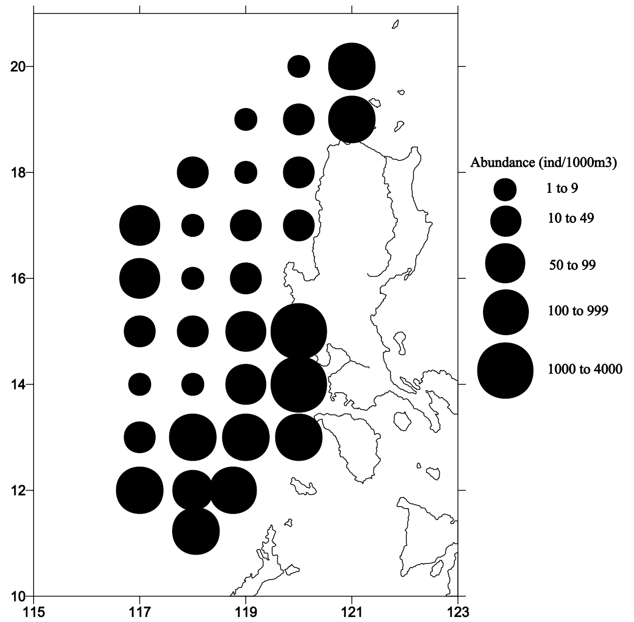

Fig. 5. Distribution and abundance of Brachyura larvae in the western Philippines

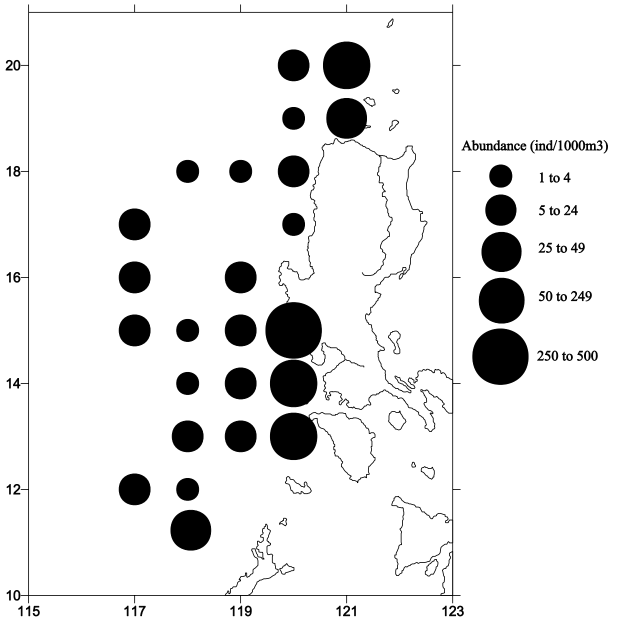

Fig. 6. Distribution and abundance of Stomatopod larvae in the western Philippines.

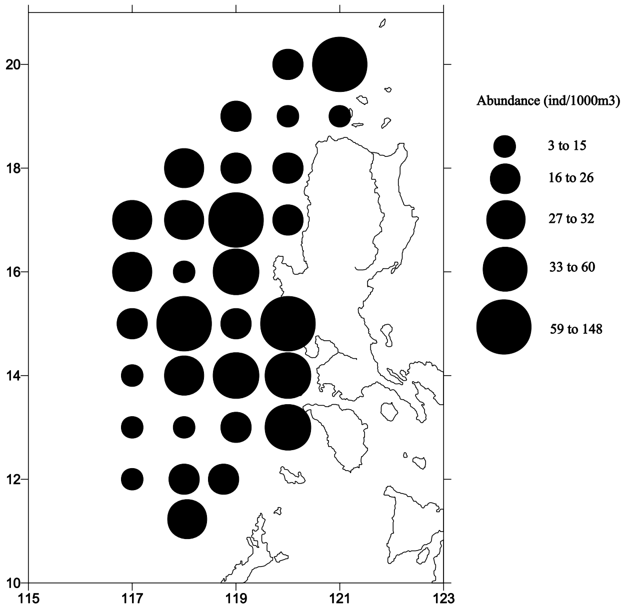

Fig. 7. Distribution and abundance of Cephalopod paralarvae in the western Philippines.

Palaemoninae and Pontaniinae. Subfamily Palaemoninae was expressed by *Palaemonetes* spp., *Retrocaris* spp., Palaemonid sp. 1, Palaemonid sp. 2 and Palaemonid sp. 3. Only Palaemonid sp. 2 occurred in many stations, the highest concentration was in station 16 (974 individual/1000m^3). While the other two species were rare in this study area. Subfamily: Pontoniinae was represented by *Mesocaris* spp. *Periclimenes* spp. and Pontoid larvae sp. 1. Both genera was found at all area that the highest density was recorded at station 16 (72 and 4093 individual/1000m^3 respectively).

The family Alphaeidae was represented by only one genus *Alpheus*. *Alpheus* spp. were found in the whole area in this study. The highest concentration of this genus occurred at station 16 (3,029 individual/1000m^3). The genus *Lysmata* of the family Hippolytidae was presented in many stations. The highest density was at station 16 with 343 individual/1000m^3. The family Pandalidae was represented at least three genera: *Heterocarpus* spp, *Plesionika* spp., *Stylopandalus* spp. and pandalid larvae sp. 1-5. Pandalidae was found in many stations but in low number. *Thalassocaris* spp. of the family Thalassocarididae was recorded at all stations except station 6 and 8. The highest density was at station 16 with 974 individual/1000m^3. *Amphion* spp. of the family Amphionidae occurred in some station in few numbers. Abundance of Caridea varied from 3-10,154 individual/1000m^3. The highest concentration of these larvae was at station 16 (Table 5). This group formed 0.2% - 36.8% of all groups at different stations (Table 10).

Reptantia

This group consisted of three infraorder: Stenopodidea, Thalassinidea and Parinuridea. The infraorder Stenopodidea was found only one family (Stenopodidae) and one genus (*Stenopus* spp.). This species appeared in many stations but in small numbers. The highest concentration of these larvae was at station 16 with 72 individual/1000m^3. The infraorder Thalassinidea could not identified to family level. Thalassinid larvae was found at two stations. It was very rare that occurred 0%-0.7% of all groups at different stations. The infraorder Palinuridea comprised two

Table 2 Taxonomic list of malacostraca larvae and cephalopod paralarvae in the western Philippines water during the period from 7 April – 19 May 1998 and frequency of occurrence: R= rare, average abundance < 10 ind. /1000m^3 , C = common , average abundance 10-100 ind./1000m^3 , VC=very common, average abundance > 100 ind./ 1000m^3

Taxonomic list	**frequency of occurrence**	**Taxonomic list**	**frequency of occurrence**
Euphausiacea		Macruma (Reptantia)	
Family: Euphausiidae		Stenopodidea	
Thysanopoda tricuspidata	*VC*	Family: Stenopodidae	
Euphausia spp.	VC	*Stenopus* spp.	R
Stylocheiron spp.	VC	Thalassinidea	
Macrura (Natantia)		Thalassinid larvae	R
Penaeidea		Palinuridea	
Family: Solenoceridae		Family: Palinuridae	
Solencera spp.	R	*Panulirus* spp.	R
Family: Aristeidae		Family: Scyllaridae	
Gennadas spp.	R	*Scyllarus* spp.	R
Family: Penaeidae		Brachyura	
Protozoea stage	R	Family: Dromiidae	R
Penaeus spp.	C	Family: Homolidae	R
Parapenaeus spp.	C	Family: Dorippidae	R
Family: Sergestidae		Family: Calappidae	R
Sergestes spp.	C	Family: Leucosiidae	R
Sergia spp.	R	Family: Raninidae	R
Lucifer spp.	VC	Family: Majidae	C
Caridea		Family: Parthenopidae	C
Family: Passiphaeidae		Family: Hymenosomatidae	C
Leptochela spp.	*VC*	Family: Corystidae	R
Family: Oplophoridae	R	Family: Cancridae	R
Family: Nematocarcinidae	R	Family: Portunidae	
Family: Rhynchocinetidae		*Portunus* spp.	VC
Rhynchocinetes spp.	R	Family: Xanthidae	C
Family: Anchistioididae		Family: Grapsidae	R
Anchistioides spp.	R	Stomatopoda	
Family: Palaemonidae		Family: Lysiosquilla	
Subfamily: Palaemoninae		*Lysiosquilla* spp.	R
Palaemonetes spp.	R	Family: Squillidae	
Retrocaris spp.	R	*Squilla* spp.	C
Subfamily: Pontoniinae		Family: Gonodactylidae	
Mesocaris spp.	C	*Gonodactylus* spp.	R
Periclimenes spp.	VC	Cephalopoda	
Family: Alphaeidae		Family: Enoploteuthidae	
Alpheus spp.	VC	*Enoploteuthis* spp.	C
Family: Hippolytidae		*Abralia* spp.	R
Lysmata spp.	C	Family: Ommastrepidae	
Family: Processidae	R	*Sthenoteuthis oualaniensis*	C
Family: Pandalidae		Family: Onychoteuthidae	
Heterocarpus spp.	R	*Onychoteuthis* spp.	R
Plesionika spp.	R	Family: Brachioteuthidae	
Stylopandalus spp.	R	*Brachioteuthis* spp.	R
Family: Thalassocarididae		Family: Cranchidae	
Thalassocaris spp.	C	Liocranchia spp.	R
Family: Amphionidae		*Leachia* spp.	R
Amphion spp.	R	Family: Octopodidae	

Table 3 Numbers of Euphausiacea (Family Euphausidae) per 1000 m^3 at 31 stations in the western Philippines water, during 7 April- 19 May 1998.

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Thysanopoda tricuspidata	424	306	96	0	16	32	157	0	0	225	7	50	657	153	138	111
Euphausiacea spp.	0	5870	2909	7	0	1579	3536	102	25	1660	0	0	2011	0	0	0
Stylocheiron spp.	0	387	703	715	1246	2715	2082	187	946	1055	1175	474	2339	879	1800	5874
euphausiid larvae	2583	1516	2685	1141	1614	3378	3772	383	970	1308	568	492	3611	1039	762	2355
Total	3007	8080	6394	1864	2876	7704	9548	672	1941	4249	1750	1015	8617	2071	2700	8340

	Stations															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	total
Thysanopoda tricuspidata	106	198	247	90	163	109	0	348	98	91	42	10	184	52	4	2371
Euphausiacea spp.	0	963	953	2	0	2258	8257	63	5067	0	0	20	0	0	13	17699
Stylocheiron spp.	908	1902	1129	225	1376	3210	2524	1774	1673	219	245	123	568	736	1430	22578
euphausiid larvae	536	3755	2681	183	744	2068	6416	3927	6986	337	423	884	738	563	444	28179
Total	1550	6818	5010	500	2283	7645	17197	6113	13824	647	710	1036	1490	1351	1891	70827

families: Palinuridae and Scyllaridae. The family Palinuridae was represented by *Panulirus* spp. This species was found at three stations in few number (2-3 individual/1000m^3). *Scyllarus* spp. of the family Scyllaridae was found in small numbers at 8 station ranging from 1-44 individual/ 1000m^3. The highest concentration of these larvae was at station 16 (Table 6). This group formed 0% - 0.2% of all groups at different stations (Table 10).

Brachyura

Larvae of fourteen brachyuran families were identified. A total of 9,303 individual/1000m^3 brachyuran larvae was record in this survey forming 4.3 % of the total larvae recorded. Only one larvae of Dromiidae were found at station 17. The larvae of Homolidae were found at three stations. The highest density was at station 16 with 29 individual/1000m^3. Dorippidae larvae occurred at three stations, number ranging from 6-29 individual/1000m^3. Larvae of Calappidae were presented in some stations in small numbers with the range 1-8 individual/1000m^3. The larvae of Leucosiidae were also found in some station. The highest density was found at station 16 with 103 individual/1000m^3. Raninidae larvae appeared in many stations, the highest density was at station 25 with 35 individual/1000m^3. Majidae larvae appeared in many stations. The highest concentration was at station 16 with 147 individual/1000m^3. Parthenopidae larvae appeared in some stations, the highest concentration was at station 24 with 160 individual/1000m^3. Hymenosomatidae larvae were found in many stations. The highest density was 1,921 individual/ 1000m^3 at station 16. Small number of Corystidae larvae were recorded in many stations. The highest density was found at station 24 with 102 individual/1000m^3. The genus Cancer of the family Cancridae occurred in some stations, the highest density was at station 16 with 29 individual/1000m^3. The genus *Portunus* of the family Portunidae was represented in most stations. The highest density was found at station 23 with 1,701 individual/1000m^3. Xanthidae larvae were common. The highest density was found at station 16 with 704 individual/1000m^3. Grapsidae larvae also occurred in some stations, the highest density was at station 24 with 36 individual/

Table 4 Numbers of Penaeidea larvae per 1000 m^3 at 31 stations in the western Philippines water, during 7 April – 19 May 1998 .

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fam. Soleniceridae																
Solenocera spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	270
Fam. Aristeidae																
Gennadas spp.	48	35	9	12	35	48	56	51	21	38	16	25	76	35	59	216
Fam. Penaeidae																
Protozoea stage	10	2	0	0	0	0	0	6	0	25	7	0	0	2	0	0
Penaeus spp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parapenaeus spp.	2	16	10	0	0	10	2	0	0	0	0	5	6	0	2	216
Fam. Sergestidae																
Sergestes spp.	104	88	87	38	374	142	177	79	128	97	30	89	63	38	68	72
Sergia spp.	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
Lucifer spp.	3753	850	1719	961	2091	1943	4388	964	491	1429	357	2742	1177	757	748	4075
Total	7660	1840	3542	1971	4591	4088	9014	2057	1132	2992	761	5603	2499	1587	1624	8926

	Stations															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Fam. Solenoceridae																
Solenocera spp.	0	0	0	0	0	3	5	0	0	0	0	18	0	0	6	270
Fam. Aristeidae																
Gennadas spp.	11	0	4	20	19	20	44	35	22	8	21	13	20	4	16	781
Fam. Penaeidae																
Protozoea stage	15	0	6	0	0	0	0	0	0	0	0	0	1	8	0	51
Penaeus spp.	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	2
Parapenaeus spp	36	82	34	26	37	90	143	69	54	14	52	0	23	24	43	2401
Sergestes spp.	36	82	34	26	37	90	143	69	54	14	52	0	23	24	43	1674
Sergia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Lucifer spp.	1001	374	1064	463	781	1107	2397	750	439	686	2270	251	1419	416	292	42154
Total	2055	831	2167	972	1618	2334	5038	1617	972	1400	4617	539	2886	869	654	88458

1000m^3. The highest concentration of Brachyura larvae was station 16, with 3563 individual/1000m^3 (Table 7). This group formed 0% - 22.1% of all groups at different stations (Table 10).

Stomatopoda

Stomatopoda was composed of three families: Lysiosquillidae, Squillidae, and Gonodactylidae. Family Lysiosquillidae was represented by *Lysiosquilla* spp. They were rare that the highest density was at station 23 with 28 individual/1000m^3. Family Squillidae was represented by *Squilla* spp. They were common. The highest density was at station 16 with 352 individual/1000m^3. Family Gonodactylidae was express by *Gonodactylus* spp. which appeared in six stations. . The highest density was observed at station 23 with 28 individual/1000m^3. The highest concentration of Stomatopoda larvae was observed at station 16, with 398 individual/1000m^3 (Table 8). This group formed 0% - 1.4 % of all groups at different stations (Table 10).

Table 5 Numbers of Caridea larvae per 1000 m^3 at 31 stations in the western Philippines water, during 7 April-19 May 1998.

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pasiphaeidae																
Leptochela spp.	2	28	13	2	5	3	35	0	2	0	2	2	0	0	3	399
Oplophoridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematocarcinidae	2	4	3	2	5	3	35	0	2	0	2	0	0	0	0	36
Rhynchocinetidae	2	0	0	0	2	2	0	0	0	2	0	5	6	0	17	18
Rhynchocinetes spp.																
Anchistioididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anchistioides spp.																
Palaemoninae	6	12	20	0	4	7	2	0	12	6	2	10	13	13	12	992
Palaemonites sp. 1	0	0	0	0	0	0	0	0	0	4	2	0	3	0	3	0
Palaemonites sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Retrocaris spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palaemonid sp. 1	2	0	1	0	0	0	0	0	0	0	0	0	0	2	2	18
Palaemonid sp. 2	4	12	19	0	4	7	2	0	12	2	0	10	9	11	7	974
Palaemonid sp. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pontoniinae	0	150	72	2	7	0	5	0	10	13	19	10	73	18	19	4165
Pontanid sp. 1	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesocaris spp.	0	18	9	0	2	0	0	0	2	2	0	0	13	3	7	72
Periclimenes spp.	0	122	63	2	5	0	5	0	8	11	19	10	60	14	12	4093
Alpheidae	12	213	170	10	4	5	2	3	19	13	9	36	127	11	42	3029
Alpheus sp. 1	0	30	6	0	2	0	0	0	6	4	0	2	3	0	0	0
Alpheus sp. 2	12	180	156	10	2	3	2	3	14	8	9	35	120	11	41	3029
Alpheus sp. 3	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0
Alpheus sp. 4	0	2	4	0	0	2	0	0	0	0	0	0	0	0	0	0
Alpheus sp. 5	0	2	3	0	0	0	0	0	0	0	0	0	0	0	2	0
Processidae	2	2	1	0	0	0	0	0	0	0	0	0	3	0	0	0
Hippolytidae																
Lysmata spp.	0	4	1	0	0	0	0	0	0	0	0	3	0	2	2	343
Pandalidae	0	0	1	0	0	3	2	0	0	2	0	2	0	0	2	180
Heterocarpus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plesionika spp.	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	180
Stylopandalus spp.	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Pandalid sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pandalid sp. 2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Pandalid sp. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pandalid sp. 4	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0
Pandalid sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalassocarididae																
Thalassocaris spp.	12	14	9	6	2	0	2	0	6	8	9	7	19	3	25	974
Amphionidae																
Amphion spp.	15	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0
caridean sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
caridean sp. 2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Total	52	428	291	22	29	24	87	3	50	44	44	74	240	46	123	10154

Table 5 Continued

	Stations															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Pasiphaeidae																
Leptochela spp.	4	8	0	2	2	5	966	45	811	6	0	119	1	10	806	3283
Oplophoridae	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Nematocarcinidae	3	8	0	2	2	0	0	0	5	4	0	3	1	0	14	95
Rhynchocinetidae																
Rhynchocinetes spp.	1	5	4	0	0	0	15	5	3	2	4	5	0	18	12	54
Anchistioididae																
Anchistioides spp.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Palaemoninae	8	27	4	0	8	28	69	5	35	24	9	23	8	34	43	1435
Palaemonites sp. 1	0	24	0	0	0	8	0	0	3	20	4	0	0	0	0	13
Palaemonites sp. 2	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Retrocaris spp.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Palaemonid sp. 1	0	0	0	0	8	10	30	4	3	2	0	5	4	14	29	25
Palaemonid sp. 2	7	3	4	0	0	10	34	2	27	0	5	18	4	20	14	1073
Palaemonid sp. 3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Pontoniinae	28	74	4	15	16	20	976	309	59	18	11	168	30	246	298	6834
Pontanid sp. 1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	11
Mesocaris spp.	9	64	2	0	2	3	69	7	3	0	0	8	1	24	19	127
Periclimenes spp.	19	11	2	13	14	18	907	302	57	18	11	161	29	222	279	4423
Alpheidae	28	11	13	7	10	49	1261	306	89	39	23	119	52	296	212	6220
Alpheus sp. 1	1	0	0	0	0	3	10	2	5	0	0	0	3	46	0	52
Alpheus sp. 2	27	11	13	7	10	46	1252	302	84	39	20	117	46	248	197	3635
Alpheus sp. 3	0	0	0	0	0	0	0	2	0	0	4	0	0	0	6	5
Alpheus sp. 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	8
Alpheus sp. 5	0	0	0	0	0	0	0	0	0	0	0	3	3	2	4	6
Processidae	1	0	2	4	2	0	0	0	0	0	2	0	1	2	0	23
Hippolytidae																
Lysmata spp.	1	0	0	4	3	0	15	7	3	2	4	5	0	8	8	354
Pandalidae	0	0	0	2	0	0	5	0	5	0	4	8	0	0	8	225
Heterocarpus spp.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Plesionika spp.	0	0	0	0	0	0	5	0	0	0	2	5	0	0	8	184
Stylopandalus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pandalid sp. 1	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Pandalid sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pandalid sp. 3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Pandalid sp. 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Pandalid sp.5	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Thalassocarididae																
Thalassocaris spp.	7	8	28	24	37	8	103	131	40	18	63	18	38	218	119	1096
Amphionidae																
Amphion spp.	0	3	2	0	5	0	0	2	0	2	5	0	7	0	0	19
caridean sp. 1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	18
caridean sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Total	82	143	58	62	83	113	3410	811	1054	114	123	472	139	830	1521	20728

Table 6 Numbers of Macruma (Reptantia) larvae per 1000 m^3 at 31 stations in the western Philippines water, during 7 April – 19 May 1998.

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Stenopidea																
Stenopus spp.	4	11	9	0	2	9	0	0	0	4	0	3	6	2	5	72
Thalassinidea																
Thalassinid larvae	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0
Palinuridae																
Panulirus spp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scyllaridae																
Scyllarus spp.	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	44
Total	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	44
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Stenopidea																
Stenopus spp.	1	3	0	0	8	5	39	18	13	2	4	13	3	2	27	265
Thalassinidea																
Thalassinid larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Palinuridae																
Panulirus spp.	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	6
Scyllaridae																
Scyllarus spp.	0	0	0	0	0	0	7	0	0	0	0	5	0	0	2	61
Total	0	3	0	0	0	0	7	0	0	0	2	5	0	0	2	67

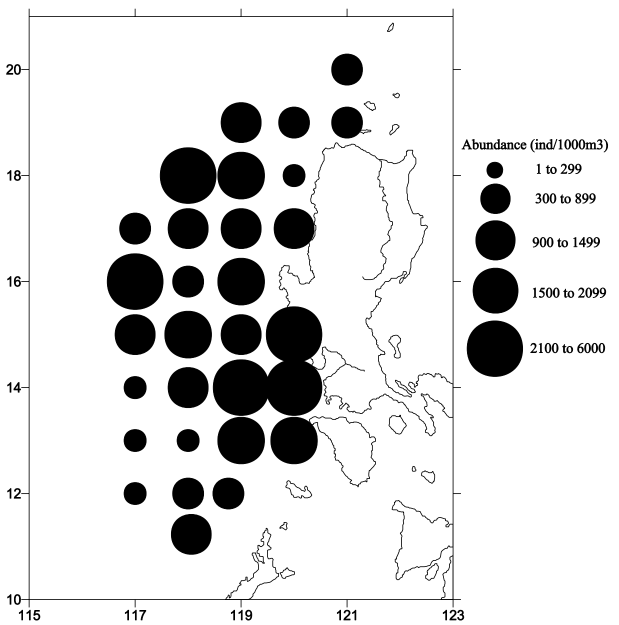

Fig. 8. Distribution and abundance of *Stylocheiron* sp. in the western Philippines.

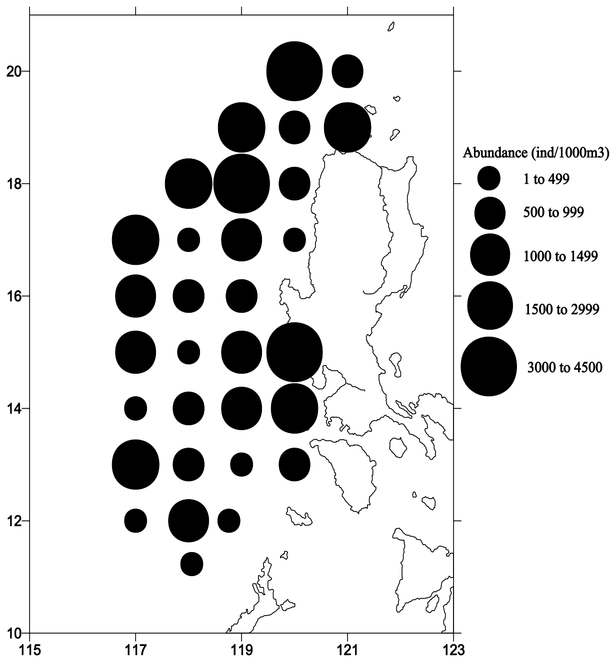

Fig. 9. Distribution and abundance of *Lucifer* sp. in the western Philippines.

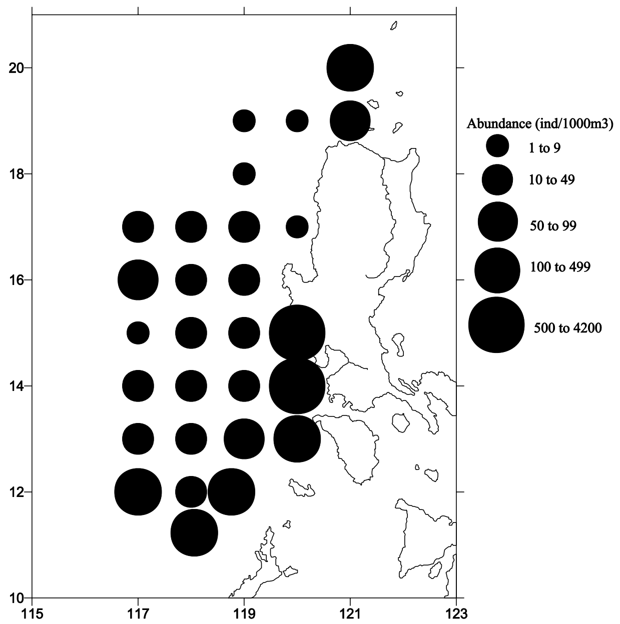

Fig. 10. Distribution and abundance of *Periclimenes* sp. in the western Philippines.

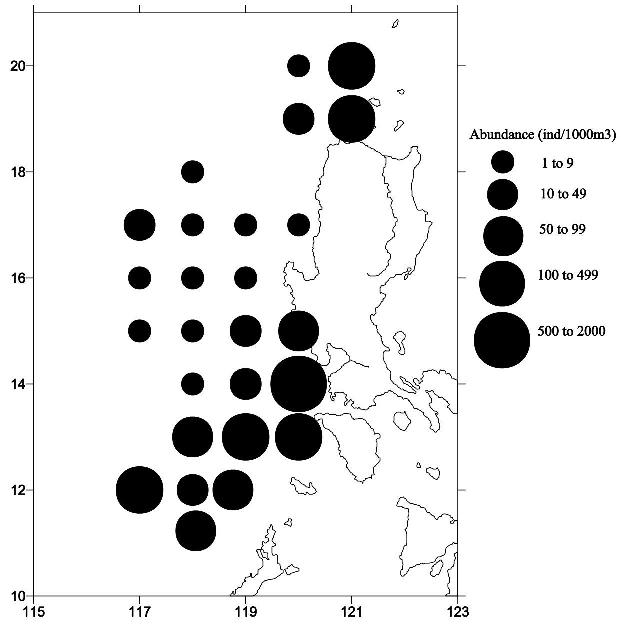

Fig. 11. Distribution and abundance of *Portunus* sp. in the western Phiippines.

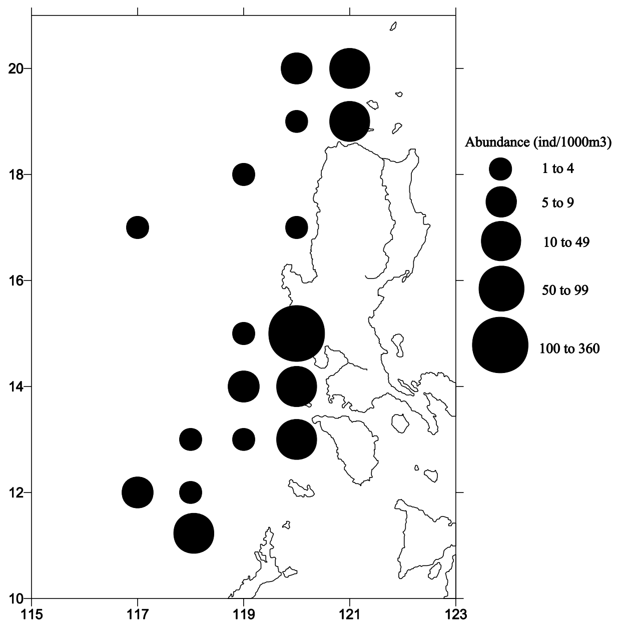

Fig. 12. Distribution and abundance of *Squilla* sp. in the western Philippines.

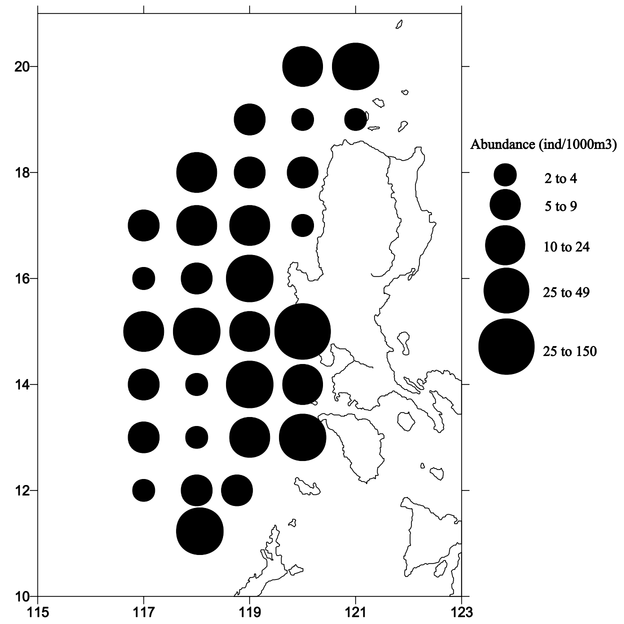

Fig.13.Distribution and abundance of *Enoploteuthis* sp. in the western Philippines.

Table 7 Numbers of Brachyura larvae per 1000 m^3 at 31 stations in the western Philippines water, during 7 April – 19 May 1998.

	Stations																														
St.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**Total**
Dromiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Homolidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	6	7	0	0	0	0	0	0	0	43
Dorippidae	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	29	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	42
Calappidae	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	4	0	0	0	0	7	8	0	0	5	0	2	0	30
Leucosiidae	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	103	0	0	0	0	0	0	6	15	5	0	0	3	4	2	4	149
Raninidae	4	2	1	2	0	3	7	11	6	0	0	13	9	0	2	0	1	0	6	2	0	0	6	22	35	12	2	5	0	6	0	159
Majidae	0	23	20	0	0	0	0	0	0	0	0	2	3	0	2	147	3	3	2	2	2	0	98	62	3	6	2	39	8	8	8	441
Parthenopidae	0	9	19	0	0	0	0	0	0	0	0	2	0	0	0	117	0	0	0	0	0	0	0	160	0	0	0	0	0	14	8	328
Hymenosomatidae	2	14	26	0	0	3	0	3	0	0	0	0	0	0	0	1921	0	0	0	0	0	5	104	152	8	0	0	18	0	4	10	2271
Corystidae	0	11	17	0	0	0	0	3	0	0	0	2	13	0	3	0	0	0	2	0	0	0	31	102	22	6	2	5	0	6	10	233
Crancridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	12	0	3	0	0	3	1	0	0	48
Portunidae	2	122	232	12	0	2	0	0	6	6	7	15	9	2	2	88	36	8	4	0	5	26	1701	279	148	88	0	350	46	79	92	3367
Xanthidae	0	16	6	2	0	5	2	0	2	29	2	3	3	2	7	704	12	5	9	2	2	8	209	40	24	0	2	80	8	44	21	1249
Grapsidae	0	5	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	3	0	36	0	0	0	0	0	4	2	58
unknown sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	0	0	0	0	0	0	0	10
unknown sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	31	11	0	0	0	0	0	0	0	71
unknown sp. 3	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	29	1	0	0	0	0	0	6	0	0	2	0	0	0	0	0	42
unknown sp . 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
unknown sp . 5	0	2	0	0	0	0	0	0	0	0	0	0	9	0	0	147	0	0	2	0	0	0	18	4	0	0	0	0	0	0	8	190
unknown sp . 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	3	0	2	2	15
Megalop sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Megalop sp. 2	0	12	3	0	2	0	0	0	2	4	0	5	3	2	7	44	0	0	11	2	0	8	37	22	22	14	4	8	1	2	0	213
Megalop sp. 3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Megalop sp. 4	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	5	12	11	5	0	0	0	0	2	0	40
Megalop sp. 5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	25	0	3	2	0	0	0	4	0	35
Megalop sp. 6	0	2	9	0	0	0	0	0	0	0	0	0	0	0	0	103	1	0	0	0	0	0	43	15	0	0	0	0	1	2	6	181
Megalop sp. 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	12
Megalop sp. 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Megalop sp. 9	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	5
Megalop sp. 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	2	8	17
Megalop sp. 11	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Total	8	227	336	18	2	14	9	17	17	42	9	55	54	5	24	3563	59	16	45	9	8	54	2371	957	294	129	11	518	71	182	179	9303

Table 8 Numbers of Stomapoda larvae per 1000 m^3 at 31 stations in the western Philippines water. During 7 April – 19 May 1998

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Lysiosquillidae																
Lysiosquilla sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
Lysiosquilld sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Lysiosquilld sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Squillidae																
Squilla spp.	6	46	27	2	0	0	2	0	2	0	0	2	0	0	2	352
Gonodactylidae																
Gonodactylus spp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Stomatopod sp.1	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Stomatopod sp. 2	0	0	1	0	0	2	0	3	0	0	0	2	0	0	2	0
Stomatopod sp. 3	2	11	12	0	0	0	0	3	0	0	0	2	9	0	2	2
Total	8	58	40	4	0	2	2	6	2	0	0	5	9	0	5	398

	Stations															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Lysiosquillidae																
Lysiosquilla sp.	0	0	0	0	0	0	28	16	0	0	0	0	0	0	0	61
Lysiosquilld sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Lysiosquilld sp. 2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Squillidae																
Squilla spp.	3	0	0	0	0	8	39	33	3	2	0	5	1	0	16	550
Gonodactylidae																
Gonodactylus spp.	0	0	0	0	0	0	28	20	0	0	0	2	0	0	4	65
Stomatopod sp. 1	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	12
Stomatopod sp. 2	0	3	2	0	0	3	2	5	5	0	0	0	1	0	10	41
Stomatopod sp. 3	4	0	2	0	3	3	2	5	5	6	0	0	0	0	0	72
Total	7	3	9	0	3	13	104	80	13	8	0	5	3	0	25	812

Cephalopoda

Paralarvae of six cephalopoda families were identified: Enoploteuthidae, Ommastrepidae, Onychoteuthidae, Brachioteuthidae, Cranchidae and Octopodidae. The family Enoploteuthidae was represented by *Enoploteuthis* spp. and *Abralia* spp. *Enoploteuthis* spp. was found all over the area, ranging from 2-137 individual/1000m^3, that highest density was observed at stations 16. While *Abralia* spp. occurred only at one station (St. 7) with 2 individual/1000m^3. The family Ommastrepidae was expressed by *Sthenoteuthis oualaniensis.* The paralarvae of *Sthenoteuthis oualaniensis* was found at almost every station except station 16 and 28. The highest density was observed at station 10 with 55 individual/1000m^3. *Onychoteuthis* spp. of the family Onychoteuthidae was very rare found at only two stations (4 individual/1000m^3). The family

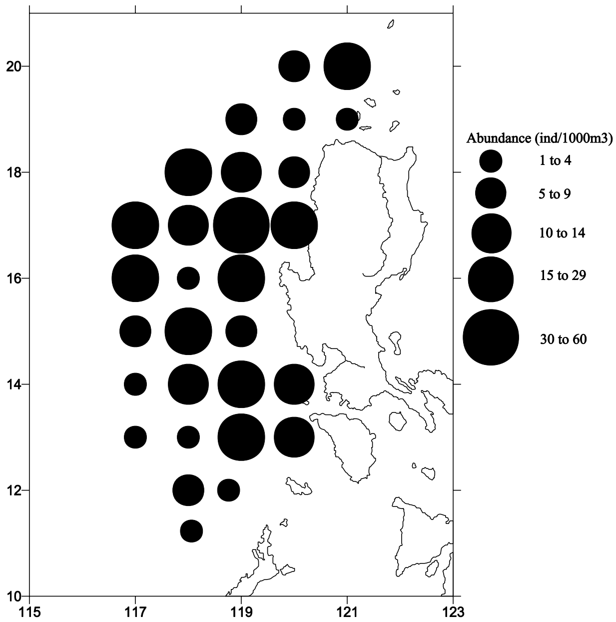

Fig. 14. Distribution and abundance of *Sthenoteuthis oualaniensis* in the western Philippines.

Table 9. Numbers of Cephalopod paralarvae per 1000 m^3 at 31 stations in the western Philippines water, during 7 April- 19 May 1998.

	Stations															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Enoploteuthidae																
Enoploteuthis spp.	10	44	4	4	7	10	5	6	2	19	19	8	3	5	25	137
Abralia spp.	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Ommastrepidae																
Stenoteuthis oualaniensis	6	16	3	2	7	22	14	6	17	55	12	20	22	3	19	0
Onychoteuthidae																
Onychoteuthis spp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Brachioteuthidae																
Brachioteuthis spp.	6	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0
Cranchidae																
Leachia spp.	0	0	0	2	0	0	0	0	2	0	2	0	0	0	3	0
Liocranchia spp.	0	0	0	2	2	0	5	0	2	0	2	0	0	0	0	2
Octopodidae																
Octopus type I	0	2	0	0	0	0	0	3	2	0	2	0	6	0	0	5
Octopus type II	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus type III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus type IV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown cephalopod sp. 1	0	5	0	0	7	9	0	3	2	0	2	5	0	2	12	0
Total	21	67	7	10	27	41	28	20	27	74	39	33	32	10	59	148

Table 9 (continued)

	Stations															
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	total
Enoploteuthidae																
Enoploteuthis spp.	13	37	11	7	3	28	22	38	11	4	7	3	5	8	29	534
Abralia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ommastrepidae																
Stenoteuthis oualaniensis	5	24	6	2	11	15	13	11	16	4	2	0	5	2	2	343
Onychoteuthidae																
Onychoteuthis spp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	5
Brachioteuthidae																
Brachioteuthis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Cranchidae																
Leachia spp.	0	0	2	0	5	3	15	0	0	0	0	0	4	2	0	40
Liocranchia spp.	0	0	0	0	6	0	0	0	0	0	0	0	1	2	0	24
Octopodidae																
Octopus type I	3	0	2	0	2	5	4	5	0	0	0	0	1	2	0	45
Octopus type II	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0	9
Octopus type III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Octopus type IV	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Unknown cephalopod sp.1	1	0	0	0	3	0	0	0	0	0	0	0	3	0	2	56
Total	23	61	21	9	30	54	59	58	27	8	9	3	20	16	33	1074

Table 10 Composition and percent abundance of important groups of malacostraca and cephalopod paralarvae recorded at each station during 7 April – 19 May 1998.

Station	Euphausiacea	Penaeidae	Caridea	Stenopidea	Thalassinidea	Parinuridea	Brachyura	Stomatopoda	Cephalopod
1	3007(42.9%)	3907(55.7%)	52 (0.7%)	4 (0.1%)	0	2 (0%)	8 (0.1%)	8 (0.1%)	21 (0.3%)
2	8080 (81.9%)	991 (10.0%)	428 (4.3%)	11 (0.1%)	0	2 (0%)	227 (2.3%)	58 (0.6%)	67 (0.7%)
3	6394 (71.8%)	1824 (20.5%)	291 (3.3%)	9 (0.1%)	1 (0%)	1 (0%)	336 (3.8%)	40 (0.4%)	7 (0.1%)
4	1864 (63.7%)	1010 (34.5%)	22 (0.8%)	0	0	0	18 (0.6%)	4 (0.1%)	10 (0.3%)
5	2876 (52.9%)	2500 (46.0%)	29 (0.5%)	2 (0%)	0	0	2 (0%)	0	27 (0.5%)
6	7704 (77.5%)	2145 (21.6%)	24 (0.2%)	9 (0.1%)	0	0	14(0.1%)	2	41 (0.4%)
7	9548 (66.8%)	87 (0.6%)	4626 (32.3%)	0	0	0	9 (0.1%)	2 (0%)	28 (0.2%)
8	672 (37.1%)	1094 (60.4%)	3 (0.2%)	0	0	0	17 (0.9%)	6 (0.3%)	20 (1.1%)
9	1941 (72.5%)	640 (23.9%)	50 (1.9%)	0	0	0	17 (0.6%)	2 (0.1%)	27 (1.0%)
10	4249(71.1%)	1564 (26.2%)	44 (0.7%)	4 (0.1%)	0	0	42 (0.7%)	0	74 (1.2%)
11	1750 (77.9%)	404 (18.0%)	44 (2.0%)	0	0	0	9 (0.4%)	0	39 (1.7%)
12	1015 (25.1%)	2861 (70.7%)	74 (1.8%)	3 (0.1%)	2 (0%)	0	55 (1.4%)	5 (0.1%)	33 (0.8%)
13	8617 (83.8%)	1322 (12.9%)	240 (2.3%)	6 (0.1%)	0	0	54 (0.5%)	9 (0.1%)	32 (0.3%)
14	2071 (69.9%)	830 (28.0%)	46 (1.6%)	2 (0.1%)	0	0	5 (0.2%)	0	10 (0.3%)
15	2700 (71.2%)	876 (23.1%)	123 (3.2%)	5 (0.1%)	0	0	24 (0.6%)	5 (0.1%)	59 (1.6%)
16	8340 (30.3%)	4851 (17.6%)	10154 (36.8%)	72 (0.3%)	0	44 (0.2%)	3563 (12.9%)	398 (1.4%)	148 (0.5%)
17	1550 (55.8%)	1054 (38.0%)	82 (3.0%)	1 (0%)	0	0	59 (2.1%)	7 (0.3%)	23 (0.8%)
18	6818 (90.9%)	457 (6.1%)	143 (1.9%)	3 (0%)	0	3 (0%)	16 (0.2%)	3 (0%)	61 (0.8%)
19	5010 (80.2%)	1103 (17.7%)	58 (0.9%)	0	0	0	45 (0.7%)	9 (0.1%)	21 (0.3%)
20	500 (45.9%)	509 (46.7%)	62 (5.7%)	0	0	0	9 (0.8%)	0	9 (0.8%)
21	2283 (70.2%)	837 (25.7%)	83 (2.6%)	8 (0.2%)	0	0	8 (0.2%)	3 (0.1%)	30 (0.9%)
22	7645 (83.9%)	1227 (13.5%)	113 (1.2%)	5 (0.1%)	0	0	54 (0.6%)	13 (0.1%)	54 (0.6%)
23	17197(66.6%)	2641 (10.2%)	3410 (13.2%)	39 (0.2%)	0	7	2371 (9.2%)	104 (0.4%)	59 0.2%)
24	6113 (68.6%)	868 (9.7%)	811 (9.1%)	18 (0.2%)	0	0	957 (10.7%)	80 (0.9%)	58 (0.7%)
25	13824 (87.7%)	533 (3.4%)	1054 (6.7%)	13 (0.1%)	0	0	294 (1.9%)	13 (0.1%)	27 (0.2%)
26	647 (39.9%)	713 (44.0%)	114 (7.0%)	2 (0.1%)	0	0	129 (8.0%)	8 (0.5%)	8 (0.5%)
27	710 (22.1%)	2347 (73.2%)	123 (3.8%)	4 (0.1%)	0	2 (0.1%)	11 (0.3%)	0.00%	9 (0.3%)
28	1036 (44.3%)	288 (12.3%)	472 (20.2%)	13 (0.6%)	0	5 (0.2%)	518 (22.1%)	5 (0.2%)	3 (0.1%)
29	1490 (46.7%)	1467 (45.9%)	139 (4.4%)	3 (0.1%)	0	0	71 (2.2%)	3 (0.1%)	20 (0.6%)
30	1351 (64.7%)	454 (21.7%)	83 (4.0%)	2 (0.1%)	0	0	182 (8.7%)	0.00%	16 (0.8%)
31	1891 (46.8%)	362 (9.0%)	1521 (37.6%)	27 (0.7%)	0	2 (0%)	179 (4.4%)	25 (0.6%)	33 (0.8%)
Total	138893 (63.9%)	46304 (21.3%)	20728 (9.5%)	265 (0.1%)	3 (0%)	67 (0%)	9303 (4.3%)	812 (0.4%)	1074 (0.5%)

Brachioteuthidae was represented by *Brachioteuthis* spp. It occurred at three stations, ranging from 2-6 individual/1000m^3. The family Cranchidae was expressed by *Liocranchia* sp. and *Leachia* spp. Both of them were appeared only in few stations. The highest density of *Liocranchia* spp. was at station 21 with 6 individual/1000m^3. The highest density of *Leachia* spp. was 15 individual/1000m^3 at station 23. The family Octopodidae was represented by *Octopus* type I-IV. This families was not common and was found in few number (0-12 individual/1000m^3). The highest concentration of Cephalopod paralarvae was found at station 16, with 1480 individual/ 1000m^3 (Table 9). This group formed 0.1% - 1.7 % of all groups at different stations (Table 10).

Discussion

The highest density of malacostraca larvae and cephalopod paralarvae was found at station 16 related to high density of shrimp larvae, phyllosoma larvae, brachyura larvae, stomatopoda larvae and cephalopod paralarvae. Whereas Euphausiacea appeared in highest density at station 23. This studied found some economic species such as *Penaeus* spp., *Parapenaeus* spp., *Panulirus* spp., *Scyllarus* spp., *Portunus* spp. and *Sthenoteuthis oualaniensis*. Moto (1986) reported some edible crustacean in the Philippines waters that most of them were found in inshore water where the depth was not more than 300 meters. Roper *et al* (1984) reported cephalopod of the world. He found 10 families and at least 25 species from the Philippines waters. In this study, 6 families and 11 species of cephalopod paralarvae were found. Holthuis (1980) reported shrimps and prawn of the world, he found 7 families and at least 20 species in this area. In this study, there were found shrimp larvae 16 families and 37 species. Holthuis (1991) also reported marine lobsters of the world, he found 24 species in the Philippines waters. In this study, 2 families and 2 species of phyllosoma larvae were reported. This investigation is the first study in quantitative and qualitative study of malacostraca larvae and cephalopod paralarvae in this area. It provides a background information for future long term study. At least, the result will be of use for the investigation about the breeding period and spawning area of certain malacostraca and cephalopod in western Philippines water.

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Species Composition, Abundance and Distribution of Phytoplankton in the Thermocline Layer in the South China Sea, Area III: Western Philippines

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ABSTRACT

Phytoplankton density, taxonomic composition and distribution in the thermocline layer were investigated to compare with those in the surface layer of 31 stations in the western Philippines during 17 April – 9 May 1998. The samples were collected from surface, thermocline depth (the beginning of thermocline), and chlorophyll maximum depth. In this study, thermocline depth and chlorophyll maximum depth were included in the thermocline layer. Three hundred and thirty-eight taxa, composed of 2 species of blue green alga, 144 species of diatoms and 168 species of dinoflagellates were identified. The occurrence of the species in each sampling depth were recorded. Phytoplankton densities at chlorophyll maximum depth were mostly highest among the sampling depths observed. The most abundance was 20,683 cells/l found at thermocline depth of station 24 due to the blooms of many diatom species. *Oscillatoria* (*Trichodesmium*) *erythraea* and *Chaetoceros lorenzianus* were dominant from surface through chlorophyll maximum depth. Seven species of diatoms presented as the dominant species only in the thermocline layer. The toxic dinoflagellates were found in low cell densities. Diversity and evenness indices of phytoplankton at chlorophyll maximum depth were high.

Keywords : phytoplankton, thermocline layer, chlorophyll maximum, South China Sea, western Philippines

Introduction

A study on distribution, abundance and species composition of phytoplankton in the South China Sea has been carried out since 1995 as one of the Interdepartmental Collaborative Research Program. The pattern of abundance, distribution of phytoplankton species and diversity indices were examined in the Area I (Gulf of Thailand and east coast of Peninsular Malaysia) and Area II (Sabah, Sarawak and Brunei Darussalam). The investigation of the Area III (Western Philippines) is focused on phytoplankton in the thermocline layer.

Very little works has been done about phytoplankton in the deep water layer especially thermocline zone in the South China Sea. Thermocline zone is the productive area and important for tuna fisheries. The thermocline ridges have been found to be the places where tunas aggregate, mainly due to the accumulation of forage organisms [Silas and Pillai (1982)]. Subsurface chlorophyll maxima (SCM) or deep chlorophyll maxima are usually found at the depths around or below the seasonal thermocline. Phytoplankton in this layer of the western North Pacific Ocean was found abundant and high diversity [Furuya and Marumo (1983)].

The purpose of this study is to describe species composition, abundance and distribution of phytoplankton in the thermocline layer (the beginning of thermocline depth and chlorophyll maximum depth) compare with those in the surface layer. Species diversity indices are also determined.

Materials and Methods

Sampling, counting and identification

The survey was carried out on board M.V. SEAFDEC during 7 April – 19 May 1998 in western Philippines. Phytoplankton were collected from 31 stations during 17 April – 9 May 1998 [Fig.1]. Ninety – two sea water samples were taken with Van Dorn water sampler from surface, the beginning of thermmocline or thermocline depth and chlorophyll maximum depth. The sampling depths were determined using ICTD record at each station. The water samples of 20 – 40 l were filtered through 20 µm 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 an electron microscope.

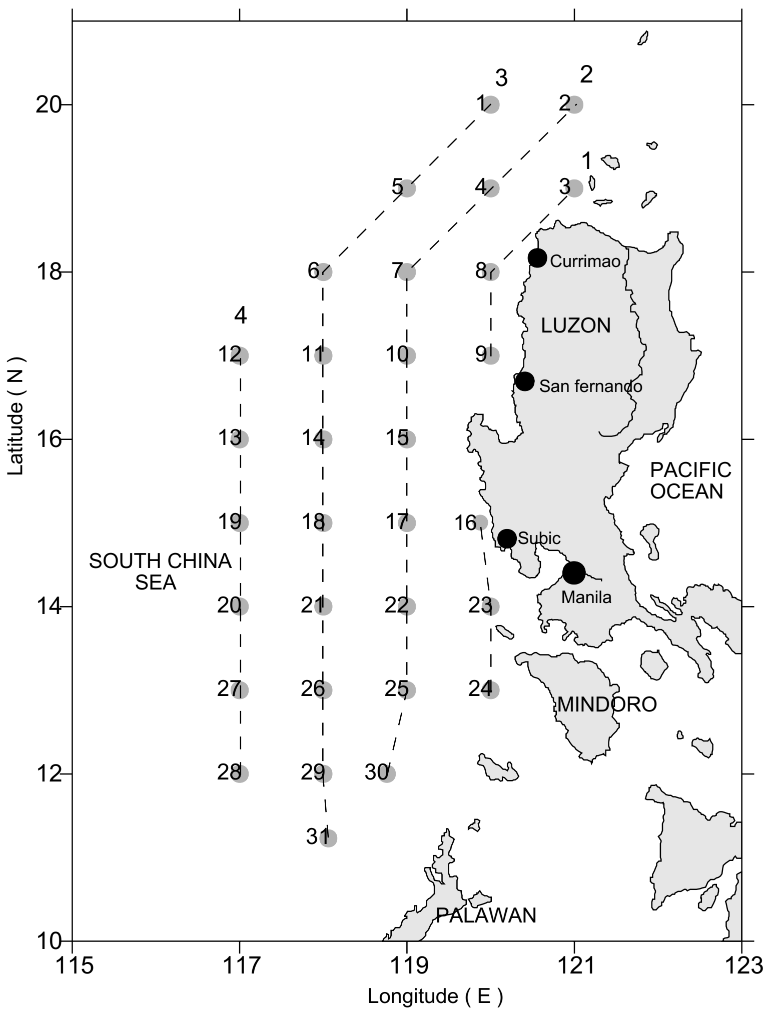

Fig. 1 Location of sampling stations

Statistical analysis

The richness index (R), diversity index (H′) and evenness index (E) were computed by the Menhinick index, Shannon index and the modified Hill's ratio respectively 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

From ICTD records, the mixed layer extended from the surface to ~ 10 – 75 m. Below the mixed layer, a sharp thermocline was found and extended to ~ 80 – 200 m. The chlorophyll maximum depths were observed below the beginning of thermocline. According to 4 lines of sampling stations in Fig.1, thermocline depths (the depths at the beginning of thermocline) and chlorophyll maximum depths of the line were considered separately. The ranges of thermocline depths of line 1 – 4 were 10 – 45 m, 20 – 50 m, 20 – 58 m and 18 – 75 m respectively. The chlorophyll maximum depths of those lines varied from 40 – 90 m, 60 – 100 m, 65 – 100 m and 80 – 100 m respectively [Table 1] while the sea depths were observed with relatively high variation [Fig. 2].

Identification

A total of 338 taxa were recorded in this study, composed of 2 genera including 2 species of blue green alga, 56 genera representing 144 species of diatoms, and 32 genera, 168 species of dinoflagellates [Table 2].

Abundance and distribution

Total phytoplankton densities in the surface layer were high near the coastal area of the western Philippines and decreased with distance from the coast [Fig.3]. Cell densities at station 13 & 14 were lowest (134 cells/l). The highest cell density in the surface layer was 1,386 cells/

Table 1 Ranges of depths, sampling depths and phytoplankton cell densities at 4 lines of sampling stations.

BG : Blue green algae

Line	Depth (m)	Sampling depth (m)	Total (cells /l)	BG (cells /l)	Diatom (cells /l)	Dinoflagellate (cells /l)
1	54 -2,955	S : 2 - 4	146 - 1,386	23 - 331	26 - 1,334	10 - 59
		Th : 10 - 45	145 - 20,683	32 - 1,605	57 - 20,309	25 - 187
		Ch : 40 - 90	219 - 1,752	0 - 33	56 - 1,744	7 - 53
2	671 - 4,657	S : 2 - 4	136 - 298	37 - 245	21 - 98	14 - 82
		Th : 20 - 55	147 - 494	37 - 440	10 - 172	28 - 83
		Ch : 60 - 100	368 - 516	0 - 92	342 - 486	10 - 46
3	555 - 4,034	S : 2 - 4	134 - 184	28 - 80	37 - 86	20 - 61
		Th : 20 - 58	148 - 233	0 - 124	48 - 133	20 - 66
		Ch : 65 - 100	339 - 2,623	0	204 - 2,618	5 - 60
4	720 - 4,042	S : 2 - 4	134 - 154	39 - 178	24 - 79	27 - 56
		Th : 18 - 75	163 - 321	5 - 224	49 - 135	26 - 59
		Ch : 80 -100	338 - 1,306	0 - 103	193 - 1,274	17 - 42

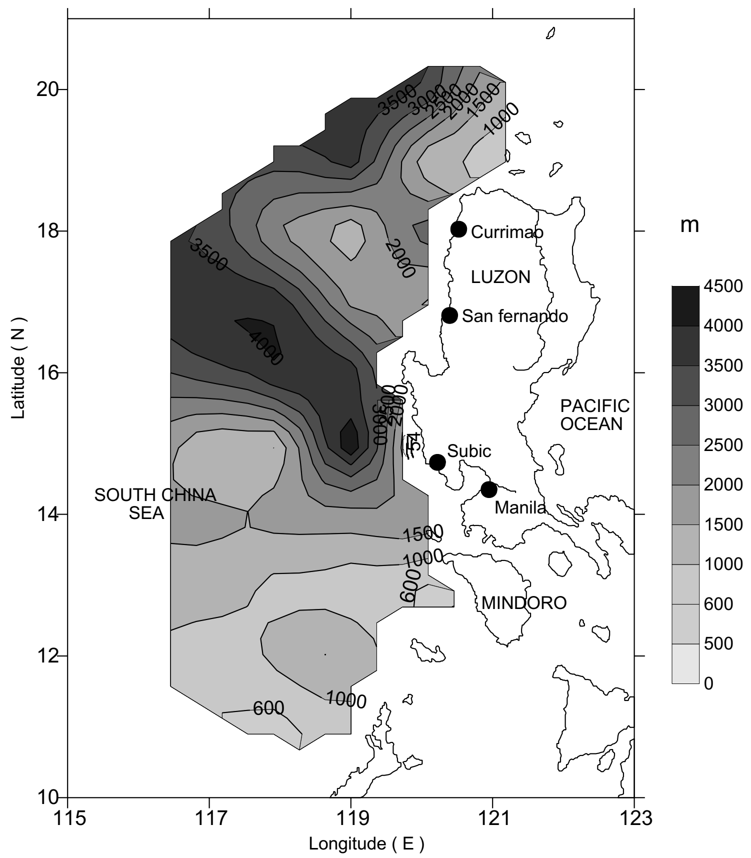

Fig. 2. Depth contour (m) of the study area.

Table 2. Taxonomic list and occurence of phytoplankton at different sampling levels.
S = Surface, Th = Thermocline depth, Ch = Chlorophyll maximum depth
x = present, xx = frequent, xxx = abundant

Specices	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)			
Actinocyclus spp.	x	x	x
Actinoptychus senarius (Ehrenberg) Ehrenberg	-	x	x
A. splendens (Shadbolt) Ralfs	x	x	x
Asterolampra marylandica Ehrenberg	xx	xx	xx
Asteromphalus elegans Greville	x	x	-
A. heptactis (Bre'bisson) Greville	xx	x	-
A. sarcophagus Wallich	-	x	x
Azpeitia africana (Janisch ex A. Schmidt) G. Fryxell & T.P. Watkins	-	x	xx
A. nodulifera (A. Schmidt) G. Fryxell & P.A. Sims	x	xx	xx
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	x	x
B. hyalinum Lauder	x	x	x
B. minus Karsten	x	x	x
Bleakeleya notata (Grunow) Round	-	x	-
Campylodiscus spp.	x	x	xx
Cerataulina bicornis (Ehrenberg) Hasle	x	x	x
C. pelagica (Cleve) Hendey	x	x	x
Chaetoceros aequatorialis Cleve	x	x	-
C. affinis Lauder	xx	xxx	xxx
C. affinis var. *willei* (Gran) Hustedt	xx	xx	xx
C. anastomosans Grunow	x	x	x
C. atlanticus Cleve	x	xx	xx
C. atlanticus var. *neapolitana* (Schroder) Hustedt	x	xx	xx
C. brevis Schütt	x	x	x
C. castracanei Karsten	-	x	-
C. coarctatus Lauder	xx	xx	xx
C. compressus Lauder	xx	xx	xx
C. convolutus Castracane	-	x	-
C. costatus Pavillard	x	x	x
C. curvisetus Cleve	x	-	-
C. dadayi Pavillard	xx	xx	xx
C. decipiens Cleve	x	x	x
C. denticulatus Lauder	x	xx	xx
C. didymus Ehrenberg	xxx	xx	x
C. diversus Cleve	xx	xx	xx
C. laevis Leuduger - Fortmorel	xx	xx	x
C. lorenzianus Grunow	xxx	xxx	xxx
C. messanensis Castracane	xx	xx	xxx
C. peruvianus Brigtwell	xx	xxx	xx
C. pseudocurvisetus Mangin	x	x	x
C. pseudodichaeta Ikari	xx	xx	xx

Table 2 **(Cont.)**

Specices	Sampling levels		
	S	Th	Ch
Chaetoceros radicans Schütt	-	xx	xx
C. rostratus Lauder	x	x	x
C. seiracanthus Gran	x	xx	xx
C. siamensis Ostenfeld	x	-	-
C. simplex Ostenfeld	x	xx	xx
C. socialis Lauder	x	x	-
C. subtilis Cleve	x	x	-
C. sumatranus Karsten	xx	xx	xx
C. tetrastichon Cleve	x	x	x
C. weissflogii Schütt	x	x	-
C. vanheurecki Gran	x	x	x
Climacodiam biconcavum Cleve	xx	xx	xx
C. frauenfeldianum Grunow	xx	xx	xx
Corethron hystrix Hensen	xx	xx	xx
Coscinodiscus argus Hensen	-	-	x
C. centralis Ehrenberg	x	x	x
C. concinnifromis Simonsen	-	x	-
C. concinnus W. Smith	x	x	x
C. gigas Ehrenberg	x	x	x
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. weilesii Gran & Angst	x	x	x
Cyclotella spp.	x	xx	xx
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin	x	x	x
Dactyliosolen antareticus Castracane	-	x	x
D. blavyanus (Bergon) Hasle	x	x	x
D. fragilissimus (Bergon) Hasle	-	x	x
Delphineis spp.	-	x	x
Diploneis spp.	-	x	x
Detonula pumila (Castracane) Gran	x	x	x
Ditylum brightwelii (West) Grunow	x	x	x
D. sol Grunow	x	xx	xx
Entomoneis spp.	x	x	x
Eucampia cornuta (Cleve) Grunow	x	x	x
E. zodiacus Ehrenberg	x	x	x
Fragilaria cylindrus Grunow	x	x	x
F. striatula Lyngbye	x	xx	xx
Fragilariopsis doliolus (Wallich) Medlin & Sims	x	xxx	xxx
Gossleriella tropica Schütt	x	xx	xx
Guinardia cylindrus (Cleve) Hasle	xx	xx	xx
G. flaccida (Castracane) H. peragallo	x	x	x
G. striata (Stolterfoth) Hasle	xx	xx	xx
Halicotheca thamensis (Shrubsole) Ricard	x	x	x
Haslea gigantea (Hustedt) Simonsen	xx	xx	xx
H. wawrikae (Hustedt) Simonsen	xx	xx	xx
Hemiaulus hauckii Grunow	xx	xx	xx
H. indicus Karsten	xx	xx	xx
H. membranacea Cleve	xx	xx	xx
H. sinensis Greville	xx	xx	xx
Hemidiscus cuneiformis Wallich	x	x	x
Lauderia annulata Gran	x	x	x
Leptocylindrus danicus Cleve	x	x	x
L. mediterraneus (H. Peragallo) Hasle	x	xx	xx

Table 2 **(Cont.)**

Specices	Sampling levels		
	S	Th	Ch
Lioloma delicatulum (Cupp) Hasle	x	xx	xx
L. elongatum (Grunow) Hasle	x	x	x
L. pacificum (Cupp) Hasle	-	xx	xx
Lithodesmium undulatum Ehrenberg	x	x	x
Meuniera membranacea (Cleve) P.C Silva	x	x	x
Nanoneis hasleae R.E. Norris	x	xx	xx
Navicula distans (W. Smith) Rafts	x	xx	xx
N. spp.	x	x	x
Neostreptotheca subindica Von Stosch	x	x	x
Nitzschia bicapitata Cleve	x	x	x
N. longgissima (Bre'bissn) Ralfs	x	x	x
N. spp.	x	x	x
Odontella longicruris (Greville)	-	x	-
O. mobiliensis (Bailey) Grunow	x	x	xx
O. sinensis (Greville) Grunow	x	x	x
Pachyneis gerlachii Simonsen	x	x	x
Palmeria hardmaniana Greville	x	x	x
P. ostenfeldii (Ostenfeld) van Stosch	-	x	x
Planktoniella blanda (A. Schmidt) Syvertsen & Hasle	x	xx	xx
P. sol (Wallich) Schütt	x	xx	xxx
Pleurosigma spp.	xx	xx	xx
Porosira denticulata Simonsen	-	x	x
Proboscia alata (Brightwell) Sundström	xx	xx	xx
Pseudoguinardia recta Von Stosch	x	x	x
Pseudo-nitzschia pseudodelicatissima (Hasle) Hasle	x	x	x
P. pungens (Grunow & Cleve) Hasle	xx	xx	xx
P. subpacifica (Hasle) Hasle	x	x	x
P. spp.	x	x	x
Pseudosolenia calcar - avis (Chultz) Sundström	xx	xxx	xx
Rhizosolenia acuminata (H. Peragallo) Gran	x	x	x
R. bergonii H. Peragallo	x	x	xx
R. castracanei var. *castracanei* H. Peragallo	x	x	xx
R. castracanei var. *neglecta* Sundström	-	x	x
R. clevei var. *clevei* Ostenfeld	xx	xx	xx
R. clevei var. *communis* Sundström	x	x	x
R. dayana H. peragallo	-	x	-
R. formosa H. Peragallo	x	x	x
R. hyalina Ostenfeld	x	x	x
R. imbricata Brightwell	x	x	x
R. ostenfeldii Sundström	-	-	x
R. robusta Norman	x	x	x
R. setigera Brightwell	x	xx	xx
R. styliformis Brigthwell	xx	xxx	xx
Stephanopyxis palmeriana (Greville) Grunow	x	x	x
Thalassionema bacillare (Heiden) Kolbe	-	x	xx
T. frauenfeldii (Grunow) Hallegraeff	xx	xxx	xxx
T. javanicum (Grunow) Hasle	x	xx	xx
T. nitzschioides (Grunow) Mereschkowsky	xx	xx	xx
T. pseudonitzschioides (Schuette & Schrader) Hasle	-	x	x
Thalssiothrix longissima Cleve & Grunow	x	xx	xx
T. gibberula Hasle	-	x	x
Thalassiosira eccentrica (Ehrenberg) Cleve	xx	xx	xx
T. leptopus (Grunow) Hasle & G. Fryxell	x	x	x
T. lineata Jouse'	x	x	x
T. oestrupii (Ostenfeld) Hasle	x	x	x

Table 2 **(Cont.)**

Specices	Sampling levels		
	S	Th	Ch
Thalassiosira subtilis (Ostenfeld) Gran	x	x	x
T. spp.	x	x	x
Tropidoneis sp.	-	x	x
Phylum Dinophyceae (Dinoflagellate)			
Alexandrium compressum (Fukuyo , Yoshida, & Inoue) Balech	x	-	-
A. fraterculus (Balech) Balech	x	-	-
A. leei Balech	x	-	-
A. tamarense (Lebour) Balech	x	x	-
A. tamiyavanichi Balech	xx	xx	xx
A. spp.	x	x	x
Amphidinium spp.	x	-	-
Amphisolenia bidentata Schroder	xx	xx	xx
A. globifera Stein	x	-	-
A. schauinslandii Lemmermann	x	x	-
A. trinax Schütt	-	x	-
Amylex triacantha (Jörgensen) Sournia	-	x	x
Balechina sp.	x	x	x
Ceratium arietinum Cleve	x	-	-
C. azoricum Cleve	x	x	-
C. belone Cleve	x	x	x
C. biceps Claparede & Lachmann	x	x	x
C. bigelowii Kofoid	-	-	x
C. boehmii Graham & Bronikosky	xx	xx	xx
C. candelabrum (Ehrenberg) Stein	xx	xx	xx
C. carriense Gourret	x	x	-
C. concillians Jörgensen	x	x	-
C. contortum Gourret	x	x	x
C. contortum var. *sultans* (Schröder) Jörgensen	-	-	x
C. declinatum (Karsten) Jörgensen	x	x	xx
C. deflexum (Kofoid) Jörgensen	x	x	-
C. dens Ostenfeld & Schmidt	x	x	x
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	xx	xx
C. gravidum Gourret	-	xx	x
C. hexacanthum Gourret	x	x	x
C. horridum (Cleve) Gran	xx	xx	xx
C. humile Jörgensen	xx	xx	xx
C. incisum (Karsten) Jörgensen	x	x	x
C. inflatum (Kofoid) Jörgensen	-	x	-
C. kofoidii Jörgensen	x	x	x
C. longipes (Bailey) Gran	x	x	x
C. limulus Gourret	x	-	-
C. lunula (Schimpe) Jörgensen	x	x	x
C. macroceros (Ehrenberg) Vanholf	x	x	-
C. massiliense (Gourret) Karsten	x	x	-
C. pentagonum Gourret	x	x	x
C. platycorne Daday	-	-	x
C. praelongum (Lemmermann) Kofoid	x	x	x
C. pulchellum Schroder	xx	xx	xx
C. ranipes Cleve	x	x	xx
C. schmidtii Jörgensen	xx	xx	xx
C. schroeteri Schroder	x	xx	xx

Table 2 (Cont.)

Specices	Sampling levels		
	S	Th	Ch
Ceratium symmetricum Pavillard	x	-	-
C. symmetricum var. *coarctatum* (Pavillard) Graham & Bron	-	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
C. vulture var. *japonicum* (Schröder) Jörgensen	-	x	-
Ceratocorys armata (Schütt) Kofoid	-	x	x
C. gorretii Paulsen	x	x	x
C. horrida Stein	xx	xx	xx
C. magna kofoid	-	-	x
Cladopyxis sp.	x	x	x
Citharisthes apsteinii Schütt	-	x	-
Citharisthes regius Stein	-	x	-
Corythodinium tesselatum (Stein) Loeblich Jr. & Loeblich	x	x	x
Dinophysis acuminata Claparede & Lachmann	x	x	-
D. caudata Saville - Kent	xx	xx	xx
D. exigua Kofoid & Skogsberg	-	x	-
D. hastata Stein	x	x	x
D. miles Cleve	x	x	xx
D. schuettii Murray & Whitting	x	xx	xx
D. uracantha Stein	-	x	x
Diplopsalis lenticulata Berg	xx	xx	xx
D. spp.	x	x	x
Diplopelta parva (Abe') Matsuoka	-	-	x
Diplopsalopsis orbicularis (Paulsen) Meunier	-	x	-
Fragilidium spp.	x	x	xx
Goniodoma polyedricum (Pouchet) Jörgensen	xx	xx	xx
Gonyaulax digitale (Pouchet) Jörgensen	x	x	x
G. fragilis (Schütt) Kofoid	-	x	x
G. glyphorhynchus Murry & Whitting	x	x	x
G. grindleyi Reinecke	-	x	-
G. hyalina Ostenfeld & Whitting	x	x	x
G. milneri (Murray & Whitting) Kofoid	-	-	x
G. pacifica Kofoid	-	x	x
G. polygramma Stein	xx	xx	xx
G. scrippsae Kofoid	xx	xx	xx
G . spinifera (Claparede & Lachmann) Diesing	xx	xx	xx
G. subulatum Kofoid & Michener	-	x	-
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	x
Heterocapsa spp.	x	x	x
Heterodinium blackmanii (Murray & Whitting) Kofoid	x	x	x
Histioneis micheilana Murray & Whitting	-	-	x
H. rigdenae Kofoid	-	x	x
H. sp.	x	x	x
Kofoidnium sp.	x	xx	x
Lingulodinium polyedrum (Stein) Dodge	x	x	x
Ornithocercus heteroporus Kofoid	-	x	x
O. magnificus Stein	x	xx	xx
O. quadratus Schütt	-	x	x
O. splendidus Schütt	-	x	x

Table 2 **(Cont.)**

Species	Sampling levels		
	S	Th	Ch
Ornithocercus steinii Schütt	-	x	x
O. thumii (A. Schmidt) Kofoid & Skogsberg	xx	xx	xx
Oxytoxum parvum Schiller	-	x	x
O. scolopax Stein	x	x	x
O. subulatum Kofoid	x	xx	xx
O. trubo Kofoid	-	x	-
Oxyphysis oxytoxides Kofoid	-	-	x
Palaephalacroma sp	-	x	x
Phaeopolykrikos hartmannii (Zimmerman) Matsuoka & Fukuyo	x	x	-
Phalacroma acutoides Balech	x	x	x
P. argus Stein	-	x	x
P. cuneus (Schütt) Abe'	x	x	-
P. doryphorum Stein	x	xx	xx
P. favus Kofoid & Michener	x	x	x
P. ovum Schütt	-	x	-
P. parvulum (Schütt) Jörgensen	-	x	x
P. rapa Stein	x	x	-
P. rotundatum (Claparede & Lachmann) Kofoid & Michener	x	xx	xx
P. rudgei Murry & Whitting	x	x	x
Podolampas bipes Stein	xx	xx	xx
P. palmipes Stein	xx	xx	xx
P. *spinifera* Okamura	xx	xx	xx
Polykrikos spp.	x	x	-
Preperidinium meunieri (Pavillard) Elbachter	x	xx	x
Prorocentrum balticum (Lohmann) Loeblich	-	x	-
P. compressum (Bailey) Abe' & Dodage	xx	xx	xx
P. concavum Fukuyo	-	-	x
P. emarginatum Fukuyo	-	-	xx
P. graclie Schütt	x	x	-
P. mexicanum Tafall	-	-	x
P. micans Ehrenberg	x	x	x
P. sigmoides Böhm	x	-	-
Protoceratium spinulosum (Murray & Whitting) Schiller	-	x	x
Protoperidinium abei (Abe') Balech	-	x	x
P. angustum P. Dangeard	-	-	x
P. brochii Kofoid & Swezy	-	x	-
P. conicum (Gran) Balech	xx	xx	xx
P. crassipes (Kofoid) Balech	xx	x	x
P. curtipes (Jörgensen) Balech	-	x	x
P. depressum (Baley) Balech	xx	xx	x
P. diabolus (Cleve) Balech	x	x	-
P. divergents (Ehrenberg) Balech	x	x	x
P. elegans (Cleve) Balech	xx	xx	x
P. excentricum (Paulsen) Balech	x	x	-
P. grande (Kofoid) Balech	x	x	x
P. hirobis (Abe') Balech	x	x	-
P. latispinum (Mangin) Balech	x	x	x
P. leonis (Pavillard) Balech	xx	x	-
P. minutum Kofoid	-	x	-
P. murrayi (Kofoid) Balech	x	x	-
P. nipponicum (Abe') Balech	x	x	-
P. oblongum (Aurivillius) Parke & Dodge	-	x	-
P. obtusum (Aurivillius) Parke & Dodge	-	x	-
P. oceanicum (Vanholf) Balech	x	x	x
P. ovum (Schiller) Balech	x	x	x

Table 2 **(Cont.)**

Specices	Sampling levels		
	S	Th	Ch
Protoperidinium pacificum Kofoid & Michener	xx	xx	xx
P. pallidum (Ostenfeld) Balech	x	x	x
P. pellucidum Bergh	x	x	x
P. pentagonum (Gran) Balech	x	x	x
P. quanerense (Schroder) Balech	xx	x	x
P. roseum Paulsen	-	x	x
P. solidicorne (Taylor)	x	x	-
P. spinulosum (Schiller) Balech	x	x	x
P. stenii (Jörgensen) Balech	x	xx	x
P. subinerme (Paulsen) Balech	x	x	x
P. tenuissimum Kofoid	-	-	x
P. thorianum (Paulsen) Balech	-	x	-
P. tristylum Stein	-	x	-
Pyrocystis fusiformis Wyville - Thomson ex Blachman	xx	xx	xx
P. hamulus Cleve	x	x	x
P. lunula species complex	xx	xx	xx
P. noctiluca Murray ex Haeckel	xx	xx	xx
Pyrophacus horologium Stein	x	x	-
P. steinii (Schiller) Wall & Dale	x	xx	-
Schuettiella mitra (Schütt) Balech	-	x	-
Scripsiella trochoidea (Stein) Balech	xx	xx	x
S. spp.	xx	xx	xx
Sinophysis sp.	x	x	-
Spiraulax kofoidii Graham	-	x	x
S. jolliffei Kofoid	-	x	-
Triposolenia truncata Kofoid	-	x	x
T. bicornis Kofoid	-	-	x

l observed at station 16. The distribution patterns of blue green algae, diatom and dinoflagellate in the surface layer are shown in Figs.4 – 6. Blue green algae was abundant near the coastal area of the uppermost part of the study area and near the Manila Bay. High cell density of diatom was found near the Subic Bay and at station off Mindoro, while dinoflagellate was found abundant in the upper part. The cell densities of total phytoplankton at 3 sampling depths shown in Fig.7 indicate that almost every high density of phytoplankton were observed at chlorophyll maximum depth except at station 24 where the density at thermocline depth was relatively high.

The ranges of phytoplankton density at different depths of each line are shown in Table 1. Cell densities of all groups (blue green algae, diatom and dinoflagellate) at thermocline depth in the line 1 varied considerably and the maximum cell counts of these groups were observed. Blue green algae was abundant from surface to thermocline depth and decreased in cell number at chlorophyll maximum depth. However, it was dominant at this depth in some stations [Fig. 10]. The exceptional high cell density (20,309 cells/ l) of diatom at thermocline depth of station 24 in the line 1 caused the density of phytoplankton higher than at chlorophyll maximum depth. In all other lines highest density were found at chlorophyll maximum depth, but dinoflagellate was most abundant at thermocline depth in all lines. The species number of diatom and dinoflagellate were highest at chlorophyll maximum depth and thermocline depth respectively [Table 3].

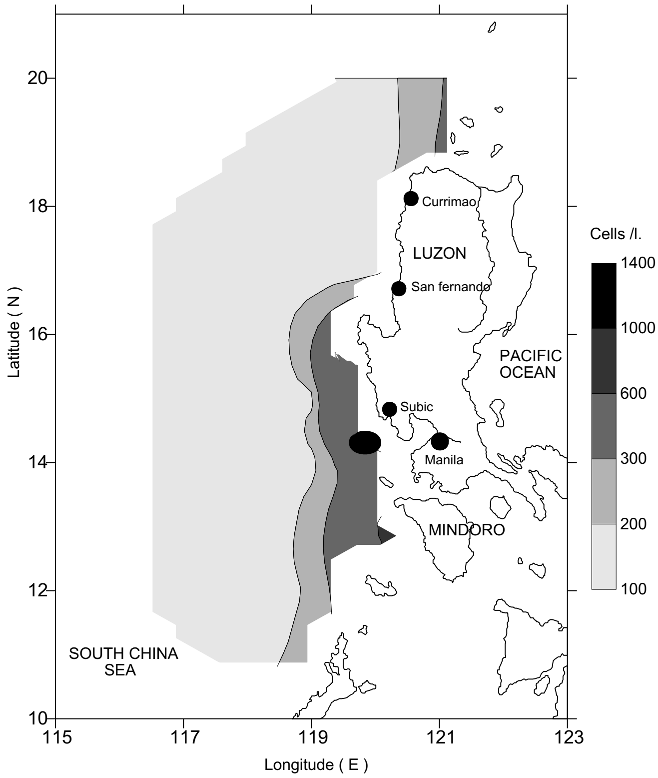

Fig. 3. Phytoplankton abundance at surface.

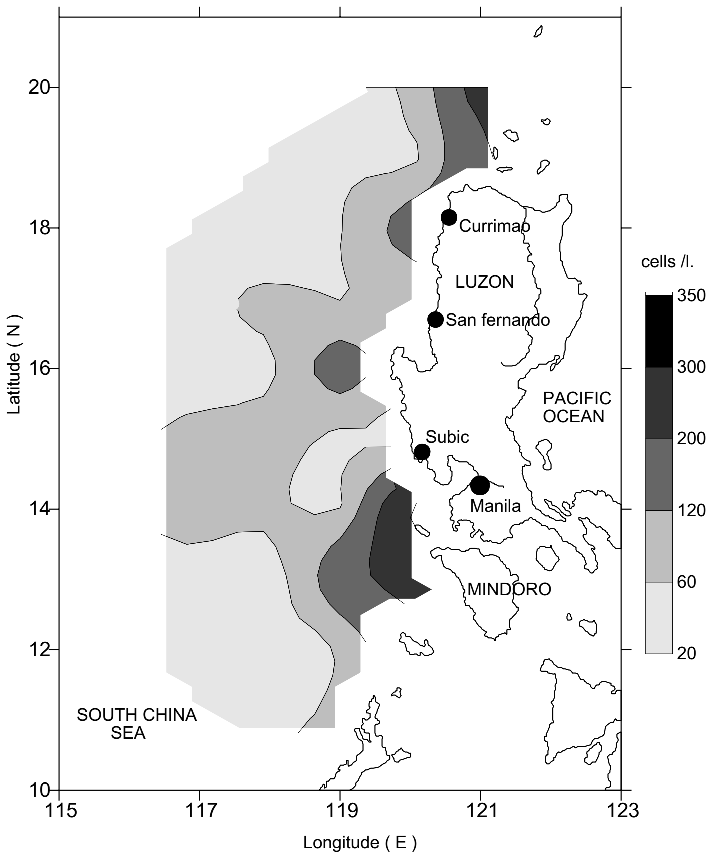

Fig. 4. Abundance of blue green algae at surface.

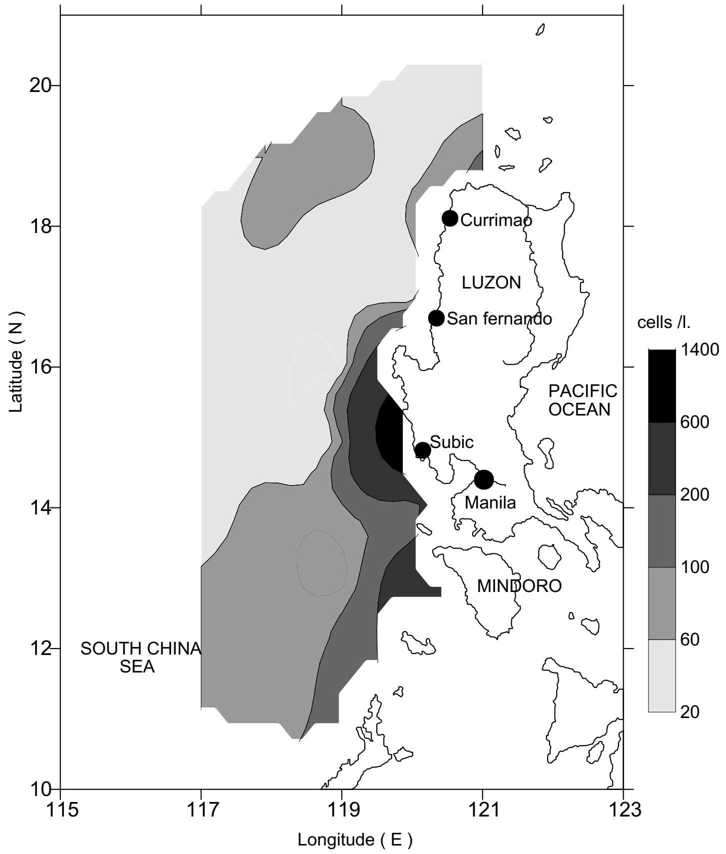

Fig. 5. Abundance of diatom at surface.

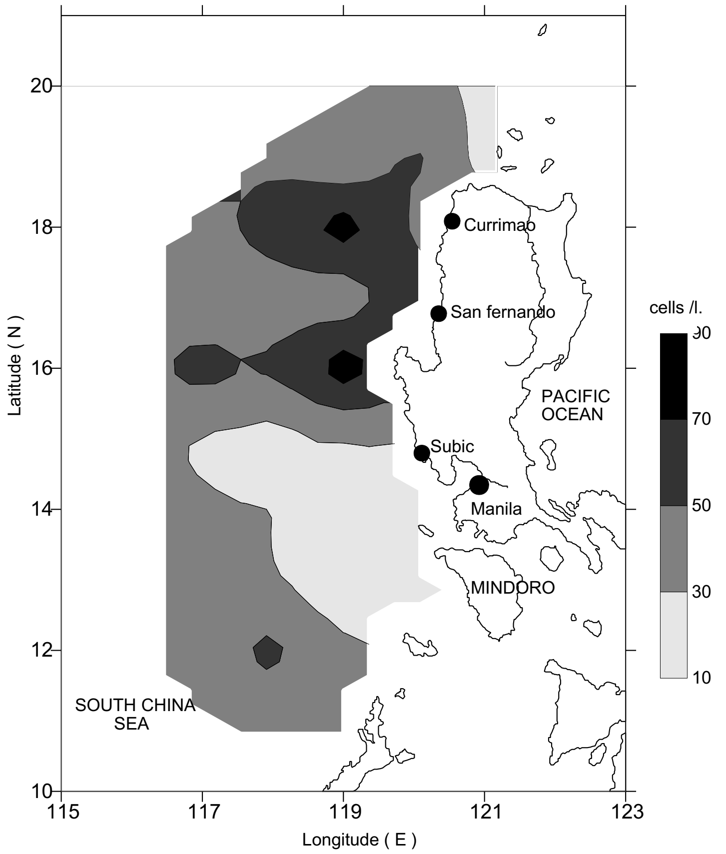

Fig. 6. Abundance of dinofagellate at surface.

Table 3 Phytoplankton species number, richness indices(R), diversity indices (H') and evenness indices (E) at 4 lines of sampling stations.

SD = Sampling depth S = Surface Th = Thermocline depth Ch = Chlorophyll maximum depth

Line	SD	Species number				R		H'		E	
		Diatom		Dinoflagellate							
	(m)	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
1	S	9 - 30	20	6 - 25	17	1.15 - 3.22	2.06	1.16 - 2.84	2.26	0.28 - 0.60	0.40
	Th	14 - 50	22	9 - 28	17	0.42 - 3.27	1.82	0.71 - 3.07	2.20	02.26 - 0.5[illegible]	0.43
	Ch	11 - 56	39	3 - 16	9	1.17 - 2.27	1.74	2.44 - 3.20	2.86	0.45 - 0.92	0.63
2	S	6 - 14	10	8 - 33	18	1.39 - 2.74	2.2	0.98 - 2.83	2.20	0.26 - 0.73	0.44
	Th	5 - 17	10	13 - 31	20	1.17 - 2.97	2.12	0.67 - 3.07	2.19	0.27 - 0.69	0.50
	Ch	19 - 43	29	5 - 15	8	1.29 - 2.62	1.96	2.55 - 3.33	2.94	0.54 - 0.81	0.61
3	S	8 - 12	11	9 - 22	15	1.47 - 2.83	2.16	2.16 - 3.31	2.57	0.37 - 0.72	0.58
	Th	9 - 17	13	7 - 28	17	1.30 - 2.29	2.37	1.88 - 3.09	2.54	0.33 - 0.73	0.54
	Ch	25 - 44	34	1 - 22	10	0.59 - 2.77	1.89	2.58 - 3.22	2.97	0.46 - 0.76	0.64
4	S	7 - 12	10	13 - 26	16	2.02 - 3.03	2.39	2.08 - 2.70	2.41	0.37 - 0.67	0.47
	Th	12 - 17	13	11 - 21	16	1.40 - 2.87	1.94	1.56 - 3.13	2.45	0.28 - 0.76	0.56
	Ch	28 - 43	35	6 - 17	11	1.38 - 2.56	1.76	2.81 - 3.25	3.03	0.46 - 0.75	0.66

Species occurrence at different sampling levels

Phytoplankton species mostly occurred from surface through chlorophyll maximum depth. Table 2 shows the occurrence of all species at surface, thermocline depth and chlorophyll maximum depth. *Oscillatoria* (*Trichodesmium*) *erythraea* and *Chaetoceros lorenzianus* were dominant in all sampling layers. Twenty-six species of diatom were not found in surface but presented below the mixed layer. Among these species, *Coscinodiscus argus*, *C. granii*, *C. reniformis* and *Rhizosolenia ostenfeldii* occerred only at the chlorophyll maximum depth. *Chaetoceros radicans* was never found at surface, but it was frequently found below the mixed layer through the chlorophyll maximum depth. Dinoflagellate species were not abundant at any sampling levels. The occurrences of many species related to sampling depths. The dinoflagellate that presented only at surface were *Alexandrium compressum*, *A. fraterculus*, *A. leei*, *Amphidinium* spp., *Amphisolenia globifera*, *Ceratium arietinum, C. limulus, C. symmetricum* and *Prorocentrum sigmoides*. There were 57 species occurred below the mixed layer.

Occurrence of dominant species

Only 2 species of phytoplankton, *Oscillatoria erythraea* and *Chaetoceros lorenzianus*, were dominant at surface. The first species dominated phytoplankton population and distributed to all over the study area except station 16 where the second species was dominant [Fig.8].

At thermocline depth, there were 7 species occurred as the dominant species [Fig.9]. The study area was mainly dominated by *Oscillatoria erythraea*. The other species, *Chaetoceros peruvianus*, *Fragilariopsis doliolus* and *Pseudoselenia calcar-avis*, were found predominantly at stations located in the upper part whereas *Chaetoceros lorenzianus*, *Rhizosolenia styliformis* and *Thalassionema frauenfeldii* were abundant in the lower part of the study area.

Six species comprised of *Oscillatoria erythaea*, *Chaetoceros lorenzianus*, *C. messanensis*, *Fragilariopsis doliolus*, *Planktoniella sol* and *Thalassionema frauenfeldii* presented with highest cell counts at chlorophyll maximum depth [Fig.10]. *Thalassionema frauenfeldii* was the dominant species observed at most of the sampling stations.

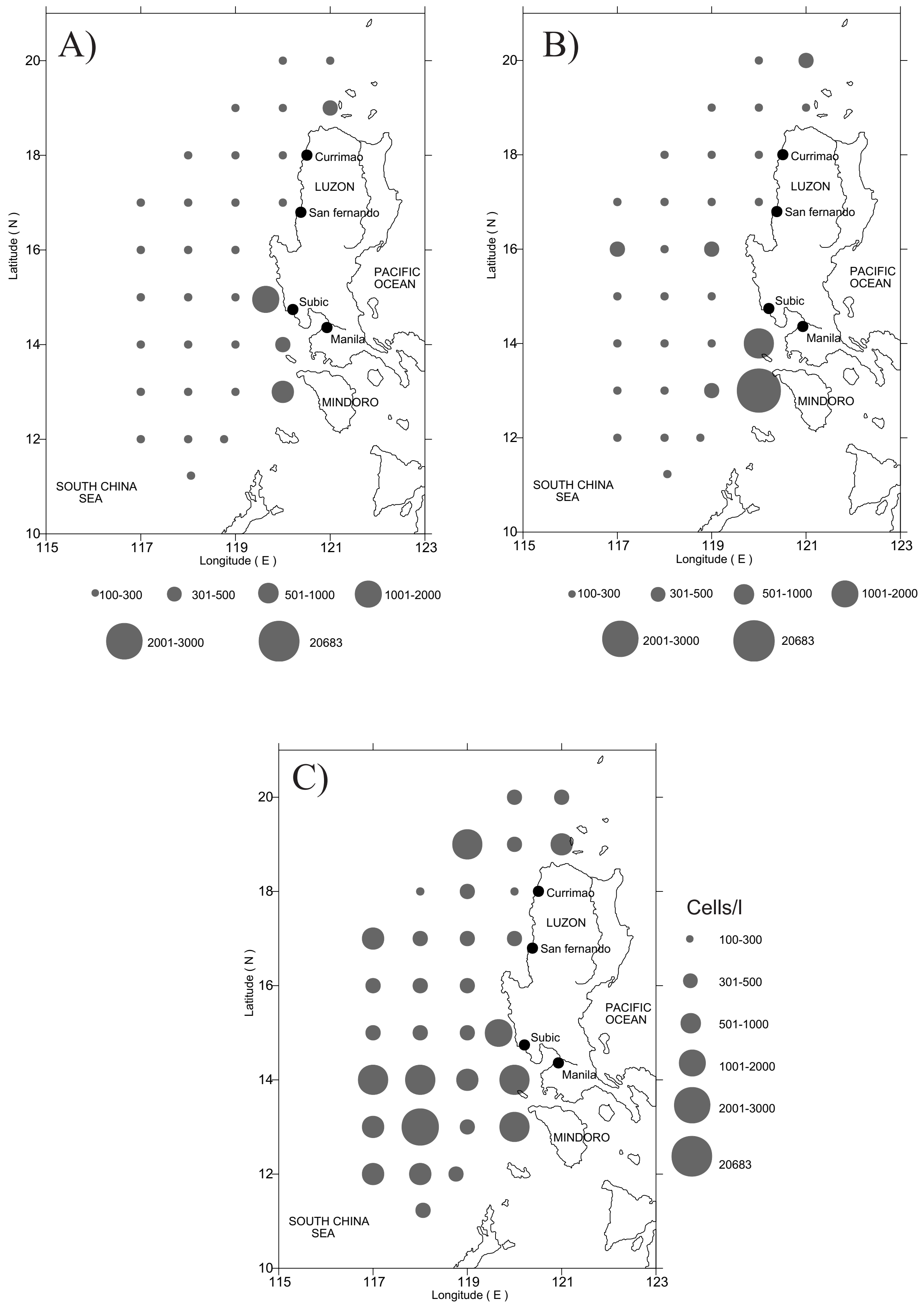

Fig. 7. Phytoplankton densities at different depths.
A: Surface , B: Thermocline depth, C: Chlorophyll maximum depth

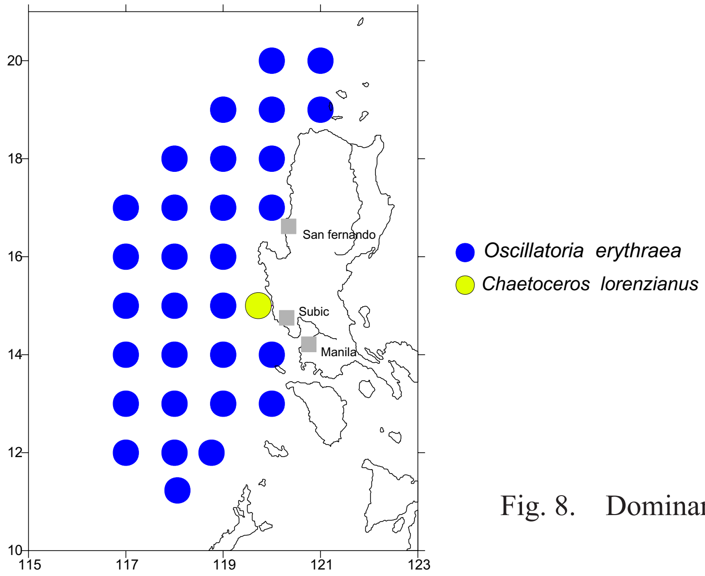

Fig. 8. Dominant species at surface

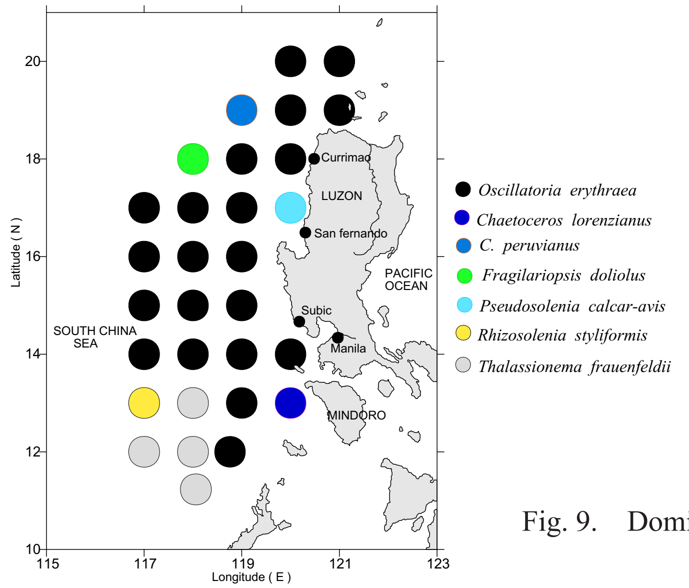

Fig. 9. Dominant species at thermocline depth.

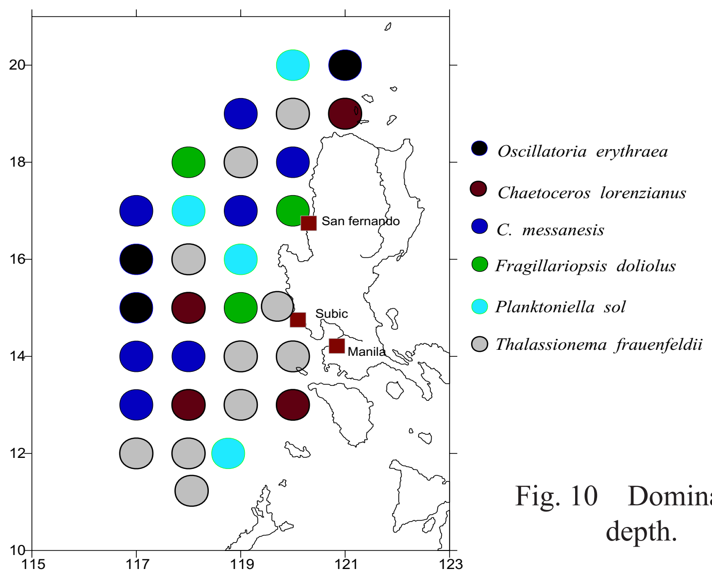

Fig. 10 Dominant species at chlorophyll maximum depth.

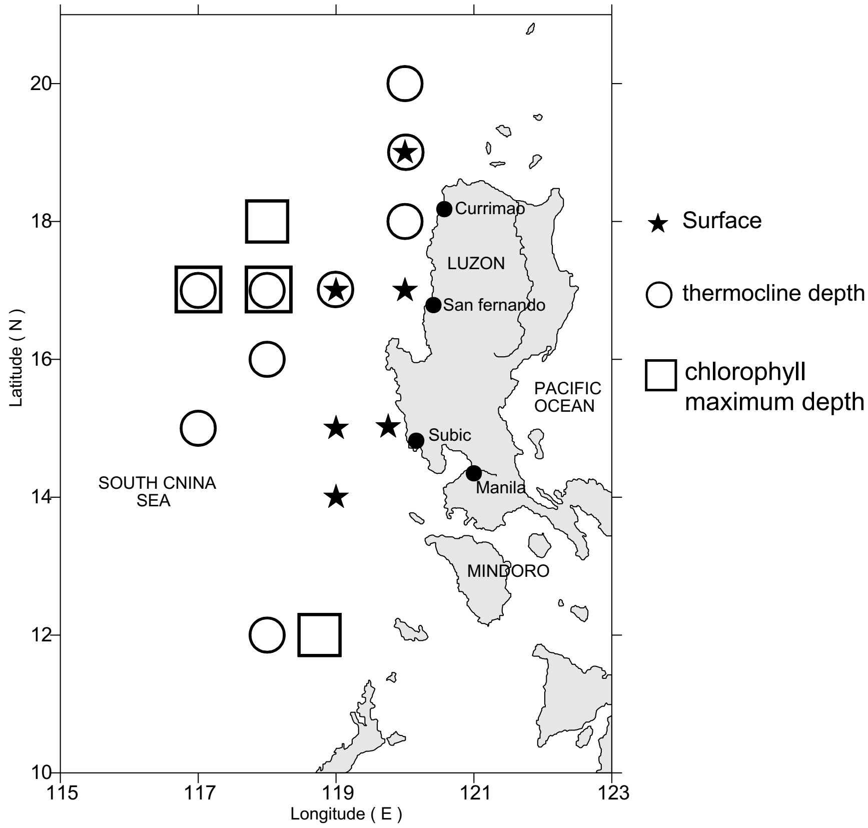

Fig. 11 Distribution of *Alexandium* spp (1-4 cells/l)

Occurrence of toxic dinoflagellate

Many species of toxic dinoflagellate were found in this survey. All of them occurred in low cell densities. *Alexandrium* was the selected genus to study its distribution which is shown in Fig.11. Highest cell count observed during this survey was 4 cells /l. This genus presented at surface of the stations near Luzon and distributed to the deeper layer of the farther stations.

Species diversity indices

The richness indices, diversity indices and evenness indices calculated from the entire list of taxa presented at surface, thermocline depth and chlorophyll maximum depth were summarized and shown in Table 3. The average richness indices of surface samples of all lines and those of sample taken from thermocline depth in lines 2 & 3 were high. The lowest value of each line was found at chlorophyll maximum depth. However, the lowest richness value was observed at thermocline depth of station 24. The average diversity index computed from the samples of each line was high at chlorophyll maximum depth and increased with distance from the coast. The average evenness indices were low at surface and increased through chlorophyll maximum depth of all sampling lines except line 3 that the average value of surface samples was rather high.

Discussion and Conclusion

The chlorophyll maximum is found in the thermocline, not always where the density gradient is greatest, but usually in a depth considerably lower [Saijo *et al*. (1969)]. In this area studied, both thermocline depth and chlorophyll maximum depth were in the thermocline layer.

The chlorophyll maximum depth varied from the level near the upper to the lower thermocline and mainly observed in the deeper level than those reported of the Area II [Boonyapiwat (1999 b)].

Phytoplankton density in the surface layer of the western Philippines (Area III) was rather low in comparison with those observed in the same period of the year in the Area I : Gulf of Thailand and east cost of Peninsular Malaysia [Boonyapiwat (1999 a)] and the Area II : Sabah, Sarawak and Brunei Darussalam [Boonyapiwat (1999 b)]. The Area I is the shallow water area and it has been known as a semi-enclosed sea where nutrients enrichment caused phytoplankton highly productive [Suvapepun *et al*. (1980)]. Although the sampling sites of the Area II and the present study area were both situated in the open sea, more abundance was found at surface and thermocline depth of the Area II but the cell density at chlorophyll maximum depth of this area was lower. This might be due to the difference of bottom topography of these areas. There are many elevations of the seafloor in the western Philippines waters. Then sea depths of this area varied considerably during sampling period. Furuya *et al*. (1995) investigated the effects of a seamount on phytoplankton production in the western Pacific Ocean and found high chlorophyll a patch in the subsurface chlorophyll maximum layer (SCM) above seamount. They concluded that the topography – current interactions above seamount induced perturbations in nutrients distribution and enhanced upward transport of nutrients into the bottom of euphotic zone. The enrichment was occasionally accompanied by elevated amounts of chlorophyll a downstream of the seamount. The increase was most pronounced in the SCM, but occasionally effects were observed near the surface [Furuya *et al*. (1995)]. The massive bloom of phytoplankton, observed at thermocline depth of station 24 where the seafloor was found elevated, might be caused by the process mentioned above.

Phytoplankton densities at chlorophyll maximum depth were mostly highest among the sampling depths observed. Olivieri (1983) investigated phytoplankton communities of the Cape Peninsula, South Africa and found that most of high cell concentrations corresponded with high level of chlorophyll a. High cell counts were also observed in the SCM in the western Pacific Ocean [Furuya and Marumo (1983)] and the suspended particles around this layer were richer in phytoplankton than those in the upper layers [Furuya (1990)].

The occurrence of phytoplankton species at 3 sampling depths seemed to be similar to those observed in the Area II and more taxa were found in the present study [Boonyapiwat (1999 b)]. *Chaetoceros affinis* var. *willei* presented from surface through the thermocline layer of all stations but it was not found in any sample of the Area I and Area II [Boonyapiwat (1999 a & 1999 b)].

The number of dominant species occurred in the present study area was rather low owing to the succession of *Oscillatoria erythraea* almost all the area during sampling period. All of dominant species (*Oscillatoria erythraea*, *Chaetoceros lorenzianus*, *C. messanensis*, *Fragilariopsis doliolus*, *Planktoniella sol* and *Thalassionema frauenfeldii*) found at chlorophyll maximum depth were similar to those in the Area II (Boonyapiwat, 1999 b). *Chaetoceros lorenzianus* was also reported as dominant species in the chlorophyll maximum layer of the East China Sea [Saijo *et al*. (1969)].

Toxic dinoflagellates recorded in this study were scarcely found. *Alexandrium* was a genus consisted of many toxic species [Balech (1995)]. One of them, *A. tamiyavanichi* was observed in lower cell concentration compared with that in the Area I and Area II [Boonyapiwat (1999 a & 1999 b)]. It might distributed throughout the South China Sea in this period of the year.

The diversity and evenness indices of phytoplankton in the chlorophyll maximum layer of the other regions were higher than those in the other layers. Boonyapiwat (1999 b) reported that diversity and evenness indices of phytoplankton from chlorophyll maximum layer of Sabah, Sarawak and Brunei Darussalam waters in May 1997 were high, in the range of 1.22 – 3.28 and 0.23 – 0.82, respectively. The values of the present study were slightly higher than in the Area II and diversity indices increased seaward. Furuya and Marumo (1983) noted that both diversity and evenness indices of the SCM samples collected from the western North Pacific Ocean were very high, > 4.0 and 0.8, respectively.

It is concluded that phytoplankton density in the western Philippines during April – May 1998 was rather low at surface and high in the thermocline layer (thermocline depth & chlorophyll maximum depth). The occurrence of some phytoplankton species were limited by depths. Toxic dinoflagellates presented from surface through the thermocline layer in low cell densities. At chlorophyll maximum depth, the richness index of phytoplankton was low but diversity and evenness index were high. The results of this investigation may benefit for the studies of marine ecology, red tides and marine fisheries of the Philippines and neighboring countries.

Acknowledgements

I wish to express my sincere thanks to Dr. Ken Furuya, the University of Tokyo, for providing literature and suggestions. Many thanks are due to Mr. Suchart Kaewmeejeen and Mr. Somchai Kamnoi for assistance with data analysis and preparing the manuscript.

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Subthermocline Chlorophyll Maxima in the South China Sea, Area III (Western Philippines)

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ABSTRACT

The subsurface chlorophyll maxima from 31 sampling stations in the South China Sea off Western Philippines were investigated. The extremely low concentration of chlorophyll ranged 0.001-0.104 µg/1 were observed. These values were thought to be a result of serious problem of samples storage for too long at -20°C. Shipboard analysis or improved storage strategy should be considered.

Introduction

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. Low concentration of chlorophyll in oligothrophic ocean at surface water is leas than 0.05 µg/1 while their characteristic maxima ranged 0.1-0.5 µg/1 at depth of 100-150 m. However, chlorophyll rich waters in estuaries, coastal seas, upwelling areas and continental shelf fronts have chlorolhyll concentration in the range of 1-10 µg/1. (Jeffrey and Mantoura, 1997

Primary production in the Gulf of Thailand and East Coast of Peninsular Malaysia in the South China Sea (Area I) was recently carried out by SEAFDEC in 1996. Musikasang *et al.,* (1999) reported that nearshore stations had highest daily primary production at depth of 2-6 meters while offshore stations sbpycnocline maxima were observed at depth of 25-50 m. The value of chlorophyll maxima at this depth is approximately 0.1 µg/1. Snidvongs (1999) studied the distribution and composition of photosynthetic pigments in the South China Sea in the areas off Sabah, Sarawak and Brunei Darussalam in 1997 and reported that subsurface chlorophyll maxima were observed at depth of 50-100 m. in Southeast Asian Waters where depth is deeper than 50 m. He also reported the range of chlorophyll a, b and c observed in the studied area were 0.01-0.77 µg/1, 0.01-0.32 µg/1 and 0.01-0.77 µg/1 respectively. Shamsudin *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 that chlorophyll a in the studied area ranged 0.00601-0.2569 µg/1. The subsurface chlorophyll maxima was observed at depth of about 60 m. Ichikawa (1990) reported that in the South China Sea off Sabah, the chlorophyll maxima was observed at depth of about 50 m. with a range of 0.14-0.43 µg/1. and concluded that the chlorophyll concentration in the area is comparable to those of productive North Pacific open waters and Equatorial upwelling waters.

The objective of the present study in to collect information on the distribution of chlorophyll in the South China Sea off Western Philippines and attempt to elucidate the over all chlorophyll distribution in the region in relation to marine fishery resources survey conducted by SEAFDEC member countries.

Material and Methods

Water samples were taken by Van Dorn water sampler at surface, seasanal thermocline (below the mixed layer), chloraphyll maxima depth and subchlorophyll maxima depth. The sampling depth followed ICTD record at each station. The chlorophyll maxima depth for all stations were well below seasonal thermocline depths. The water samples of 2-6 liters were collected and filtered through GF/F filters with diameter of 47 mm. Under vaccum pump not exceeding 150 mm. Hg (vaccum) in the dark place. Then the GF/F filters were kept in glass vials and store at -50°C in the research vessels. After returning to shore laboratory, the filters were kept at -20°C in the freezer until analysis was performed.

For extraction, GF/F filters were cut in a small pieces and grind in a glass hamogenizer with 2 ml DMF (Dimethylformamide) mixed with 0.5 M Ammonium Acetate (Furuya *et al.,* 1998) as the ion paring reagent and keep in refrigerator for ten minutes. Then, the crushed filters were centrifuged and the supernatant were filtered through a 0.2 µm PTFE filter (Sartorius). The mixing and filtaration was done immediately before injection. The 125 µl of the mixture was injected in to a Thermoseparation HPLC systems (a binary gradient pump, autosampler, UV detector, degasser) fitted with a 5 µm HICHROM S50DS (4.6x250mm.) HPLC grades reagents were used for all analysis. The pigment separated were identified on retention time of commercially available pigment (Chls a and b : Sigma U.S.A.). Chlorophyll were quantified by weight from peak area calibrated against that of the standard solution.

Results

Table 1 summarized the result of chlorophyll analysis in this study. The extremely low concentrations reflected that there might be some crucial problems in the analysis. The problems may concerned with water sampling volume, storage of GF/F filter, extraction and analysis by HPLC. Samples were collected during April 7- May 19, 1998. The samples were injected to HPLC on late December 1998. The prolong time for analysis was about 7-8 month. Thus, the GF/F were kept under –20° C for too long as mentioned by UNESCO (Mantoura *et. al.,* 1997) The delay in analysis was due to the malfunction of the HPLC system.

Thus storage of samples during the long cruise must be seriously considered as a drawback for a certain water quality parameter. Shipboard analysis of chlorophyll might the best but if not possible storage in liquid nitrogen is a good alternative.

Acknowledgement

The authors would like to thank the SEAFDEC for financial support. We also appreciate the help of the officers and crew of M.V. SEAFDEC for assisting in sample collection and M. Sopana Boonyapiwat for generous support of sharing Van Dorn water sampler. Appreciation is extended to Dr. Shettapong Meksumpun for providing chlorophyll standards.

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Table 1. Results of chlorophyll analysis in this study.

Stations	**Chlorophyll-a**				**Chlorophyll-b**			
	A	**B**	**C**	**D**	**A**	**B**	**C**	**D**
1	NS	-	-	-	NS	-	-	-
2	-	-	-	-	-	-	-	-
3	-	NS	-	-	-	NS	0.002	-
4	-	-	0.001	-	-	NS	0.004	-
5	-	-	-	-	-	-	-	-
6	-	-	0.003	-	-	-	0.002	-
7	-	-	0.002	-	-	-	0.006	-
8	-	-	0.001	-	-	-	0.003	-
9	-	-	-	-	-	-	-	-
10	-	0.002	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-
14	-	0.001	0.002	-	-	-	0.007	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	0.002	-
19	-	-	-	-	-	-	0.002	-
20	-	-	-	-	-	-	-	-
21	0.001	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-
24	-	-	0.005	NS	-	-	0.003	NS
25	-	-	0.008	-	-	-	0.006	-
26	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	0.002	-
28	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-
30	0.008	-	0.104	-	-	-	-	-
31	-	-	-	-	-	-	0.041	-

Remark: NS = NO SAMPLE; - = NON DETECT
A = SURFACE; B = SEASONAL THI
C = CHLOROPLIYLL MAXIMA; D = SUBCHLOROH

Phytoplankton in the Surface Layers of the South China Sea, Area III: Western Philippines

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ABSTRACT

Phytoplankton in the surface layers of South China Sea, Western Philippines were investigated for species composition, distribution and abundance.

Thirty one stations were sampled during the cruise of M/V SEAFDEC to South China Sea along latitudes 8° to 20°N and longitudes 115° to 121°E from April 15 to May 11,1998. In each station, water samples at the surface and at depths of 20, 40 and 60-m were collected by a 20-liters capacity Van-Dorn water sampler.

Results of the phytoplankton analysis yielded a total of 56 taxa. These included 3 species of blue-green algae; 1 genus of Chrysophytes; 32 genera of diatoms and 20 genera of dinoflagellates.

The phytoplankton assemblage was dominated by Bacillariophyceae or diatoms which accounted for 73% of the total standing stock. The top 5 most dominant representatives were *Chaetoceros spp* (962 cells/L); *Bacteriastrum spp* (587 cells/L); *Rhizosolenia spp* (349 cells/L); *Thalassiothrix spp* (314 cells/L) and *Leptocylindrus danicus* (162 cells/L). *Chaetoceros spp* occurred in almost all stations sampled.

Dinoflagellates ranked second in terms of abundance (16%) although they were sporadic and in smaller densities. The top 5 most dominant representatives were *Ceratium spp* (249 cells/L); *Podolampas spp* (91 cells/L); *Gonyaulax spp* (63 cells/L); *Dinophysis spp* (55 cells/L) and *Scrippsiella spp* (46 cells/L).

Blue-green algae or cyanophyceae accounted for 11% of the total standing crop and the most dominant species were *Pelagothrix clevei* (357 cells/L) and *Trichodesmium thiebautii* (153 cells/L).

Less than 1% of the total standing crop is attributed to Chrysophytes represented by *Dictyocha spp.*

Phytoplankton densities in the surface waters (0-m layer) was nominal compared to the other 3 strata/layers (20; 40 and 60-m). Phytoplankton densities increased with depth. Abundant concentrations of phytoplankton coincided with the fluorescence maxima and maximum concentrations of nutrients.

Trichodesmium thiebautii was dominant and formed patches in the surface and near-surface waters along the coast of northern Luzon or near the entrance of Luzon Strait where low water temperatures were recorded and high concentrations of dissolved nutrients were noted, while *Pelagothrix clevei* was also observed to form patches at the surface and near-surface waters along the southern coast near the entrance of Sulu Sea where low water temperatures were recorded and high salinities and maximum concentrations of dissolved nutrients were observed.

Abundant concentrations of diatoms composed mostly of several species of *Chaetoceros*; *Bacteriastrum; Rhizosolenia*; *Thalassiotrix* and *Leptocylindrus* were observed along and/or near

the coastlines, while in stations offshore, minimal density was noted.

Several species of dinoflagellates in low densities were observed in stations going offshore.

The paper closes with a brief discussion of the general distribution pattern exhibited by the phytoplankton.

Key words: Western Philippines: SCS, phytoplankton, species composition, abundance, distribution, surface layer

Introduction

Investigating the biological characteristics, particularly phytoplankton, of the waters off the northwest coast of the Philippines is necessary because the region is of paramount importance to the country's fisheries.

The waters off the northwest coast of the Philippines, which joins the South China Sea is characterized by the complex hydrography. There is the northward flowing warm current, the Kuroshio; equatorial current; southward contour current and eddies. The region is part and parcel of the South China Sea ecosystem. There are three important features of South China Sea which requires investigation. It harbors the highest marine biodiversity on earth. It is hypothesized to play a critical support system to surrounding shelf habitats by providing a rich source of pelagic propagules of fish and invertebrates [McManus (1994)]. South China Sea, like other large-scale bodies of water, interacts in the global ocean-atmosphere interactions to bring about climate variability. It is the largest marginal sea in the Indo-West Pacific region. The circulation pattern exhibits strong seasonal variability driven by the Asian Monsoon system (considered to be the strongest monsoon system in the world), and is influenced by the numerous island chains and archipelagos of Indonesia and Philippines, all of which partially isolates the South China Sea from the Western Pacific circulation regime [Wyrtki (1961)].

The region is less studied since it is exposed to the monsoons, hence oceanographic and biological information are scant. However, the area adjacent to southwest Taiwan is extensively studied. Chu (1982); Fan (1982) and Lin et al. (1986) as cited by Huang et al (1988) have extensively studied the movements of waters, while phytoplankton species and their distribution off southwestern Taiwan was reported by Huang (1986); Huang (1988) and Huang and Huang (1987) as cited by Huang et al. (1988). Phytoplankton taxonomy, distribution and occurrence along the coastal waters of northwestern Luzon was studied by Relon (1985).

Phytoplankton study in the waters off the northwest coast of the Philippines is necessary for a better understanding of the hydrographic feature and its influence on the organisms around the region. Estimates of the plankton abundance, distribution and productivity is essential to assess the overall status of the region.

The present study on phytoplankton obtained during the cruise of M/V SEAFDEC along latitudes 8º to 20ºN and longitudes 115º to 121ºE in April-May,1998, describes the species composition, distribution and abundance of phytoplankton in the surface layers. A brief discussion on the general vertical and horizontal distribution patterns exhibited by the phytoplankton is also presented.

Materials and Methods

Thirty one stations [Fig. 1] were surveyed during the cruise of M/V SEAFDEC on April 15 to May 11,1998. Water samples for physico-chemical analysis were collected by a rosette sampler with attached CTD. Temperature and salinity were recorded using CTD.

At each station, water samples at the surface and at depths of 20, 40, and 60-m were collected separately with a 20-liter capacity Van-Dorn water sampler. Twenty liters of water samples were filtered using a 20-µm mesh size net and 250-ml of the water sample were concentrated and stored in Nalgene plastic bottles. Phytoplankton samples were fixed with 10% formalin solution. Phytoplankton samples were examined under a light microscope and identification and enumeration were based on the works of [Fukuyo et al. (1994); Taylor (1979); Yamaji (1969); Subrahmanyan (1963) and Taylor (1963)].

Phytoplankton density estimations were done on a 1-ml aliquot part of the sample in a Sedgewick-rafter counting chamber. Cell density was determined and expressed in cells per liter. For blue-green algae, density was expressed in filaments per liter. The number of cells per liter is calculated after making an adjustment on the volume of water samples concentrated. The initial sample volume (V_1) was 20-liters which was filtered in a 20-µm mesh size net and then concentrated to 25-ml (V_2), from which a subsample of 1-ml (V_3) was taken.

The number of cells per liter is obtained by the formula:

$$\text{Number of cells/liter} = \frac{\text{number of cells counted X } (V_2/V_3)}{V_1}$$

where:

V_1 = initial sample volume (20-liters)
V_2 = concentrated sample
V_3 = subsample taken/analyzed

The mean density values of phytoplankton species were utilized for the computation of species diversity indices. The following formulae were used [Odum (1971]:

Shannon's Index of General Diversity:
$H = -\Sigma[\ (ni/N) \times \log (ni/N)$
where:
ni = mean density of each species
N = total density

Simpson's Index of Dominance:
$C = \Sigma(ni/N)2$
where:
ni = mean density of each species
N = total density values of all species

Pielou's Evenness Index:
$E = H/\log S$
where:
S = number of species
H = Shannon's index of general diversity

Phytoplankton were identified to genus level and whenever possible they were identified up to species level.

Vertical profiles of cell density and biomass (fluorescence) were plotted for comparison across stations and depths. Only 19 stations were utilized in the comparison since the fluorometer used in recording the fluorescence malfunctioned.

For composition analysis, dominant forms of phytoplankton were group into 3 categories:

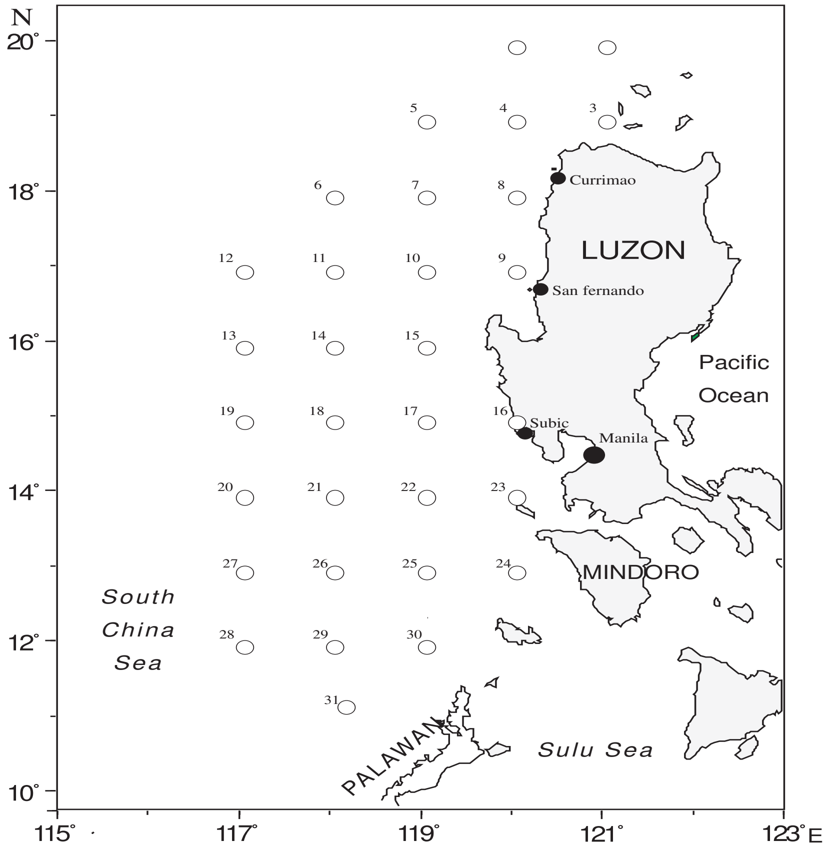


Fig. 1. Stations for phytoplankton sampling

Bacillariophyceae, Cyanophyceae and Dinophyceae. Vertical profiles of cell densities across depths in each station were prepared. Since the phytoplankton composition in the study area is highly diverse, and most of them occurred only in very small number/density, only the top 5 most dominant forms were included in the analysis/interpretation.

Results

Phytoplankton Assemblage

Table 1 presents the composition of phytoplankton found and identified from the 124 water samples collected during the cruise of M/V SEAFDEC in the South China Sea: Western Philippines from April 15 to May 12,1998. There were 4 classes identified, they are: Bacillariophyceae, Cyanophyceae, Chrysophyceae and Dinophyceae.

The assemblage of phytoplankton in the study area contained a total of 56 taxa. These included 3 species of blue-green algae; 1 genus of Chrysophytes; 32 genera of diatoms and 20 genera of dinoflagellates. Most of them are warm-water species and recorded as inhabitants of the Kuroshio of the East China Sea, and off Japan [Yamaji (1969)] and the South Western Indian Ocean [Taylor (1963)].

Relative abundance of phytoplankton in the region is shown in [Fig. 1a]. Likewise, the top 5 most dominant forms were presented in [Fig. 2].

Bacillariophyceae or diatoms accounted for 73% of the total standing crop. The top 5 most dominant representatives of diatoms were *Chaetoceros spp* (962 cells/L or 40%);

Bacteriastrum spp (587 cells/L or 25%); *Rhizosolenia spp* (349 cells/L or 15%); *Thalassiothrix spp* (314 cells/L or 13%) and *Leptocylindrus danicus* (162 cells/L or 7%).

Dinophyceae or dinoflagellates contributed 16% to the total standing crop of phytoplankton, and the top 5 most dominant were *Ceratium spp*(249 cells/L or 49%); *Podolampas spp* (91 cells/L or 18%); *Gonyaulax spp* (63 cells/L or 13%); *Dinophysis spp* (55 cells/L or 11%) and *Scrippsiella spp* (46 cells/L or 9%).

Cyanophyceae or blue-green algae accounted for 11% of the total standing crop and the most dominant species were *Pelagothrix clevei* (357 cells/L or 70%) and *Trichodesmium thiebautii* (153 cells/L or 30%).

Less than 1% of the total standing crop is attributed to Chrysophytes represented by *Dictyocha spp.*

Distribution

The vertical profiles of phytoplankton in the study area is illustrated in [Fig. 4] and [Fig. 3] shows the vertical distribution profiles of the top 5 most dominant representatives of phytoplankton.

Phytoplankton densities in the surface waters (0-m layer) was nominal compared to the other 3 strata/layers (20, 40 & 60-m). In all the 31 stations sampled, it was observed that phytoplankton density increases with depth. Phytoplankton density is greatest at the 60-m stratum/ layer where the maximum fluorescence is also noted.

The most significant component of the phytoplankton community is the diatoms or Bacillariophyceae. A well-defined pattern in the distribution of diatoms in the water column is observed. Concentrations of diatoms increased with depth with the greatest concentrations observed at depths between 20 and 40-m. Station adjacent to the coast of northern Luzon (Sta. 3) and stations near the coast south of Manila (Sta. 16, 23 &24) had high concentrations of

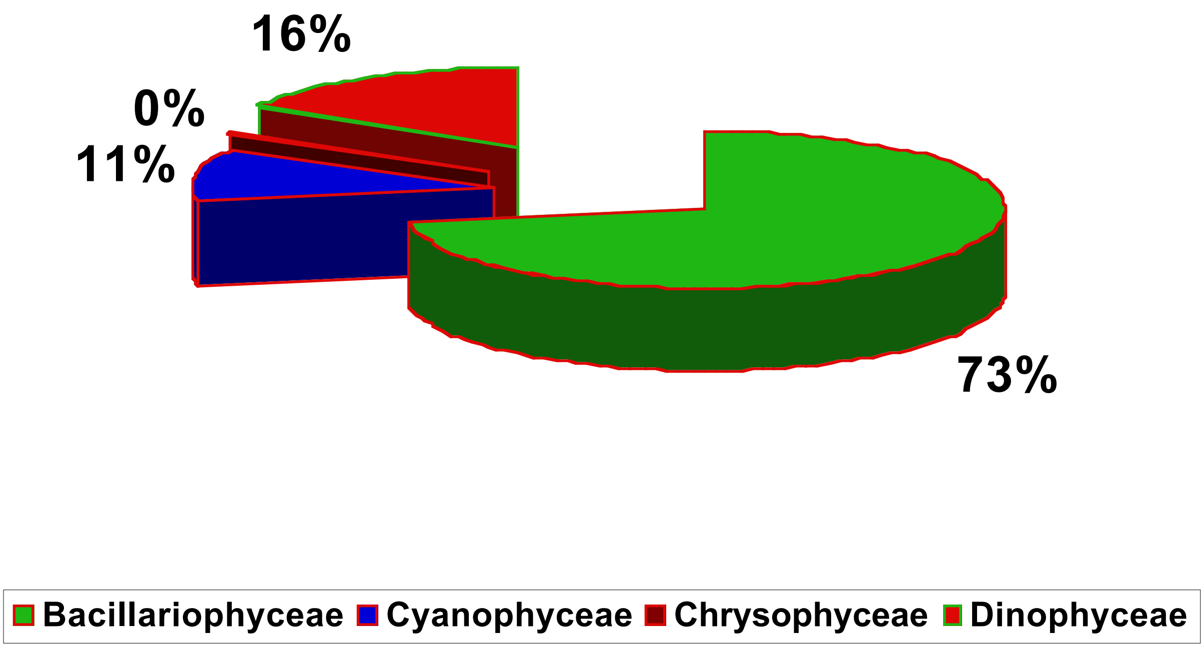


Fig. 1a. Relative abunadce of phytoplankton in the SCS: Western Philippines.

Table 1. List of Phytoplankton from the Surface Layer of South China Sea: Western Philippines, Apr-May,1998.

Division: Chrysophyta
Class : Bacillariophyceae
Order: Centrales
Family: Skeletonemaceae
1. Skeletonema spp
2. Stephanopyxis palmeriana

Family: Leptocylindraceae
1. Dactyliosolen mediterraneus
2. Leptocylindrus danicus
3. Guinardia flaccida

Family: Corethronaceae
1. Corethron pelagicum

Family: Thalassiosiraceae
1. Thalassiosira spp

Family: Coscinodiscaceae
1. Asterolampra marylandica
2. Asteromphalus cleavenus
3. Coscinodiscus spp
4. Planktoniella sol

Family: Rhizosoleniaceae
1. Rhizosolenia spp

Family: Bacteriastraceae
1. Bacteriastrum spp

Family: Chaetoceraceae
1. Chaetoceros spp

Family: Biddulphiaceae
1. Biddulphia spp
2. Cerataulina spp
3. Climacodinium spp
4. Ditylum sol
5. Eucampia zoodiacus
6. Hemiaulus spp
7. Streptotheca thamensis
8. Triceratium arcticum

Order: Pennales
Family: Fragilariaceae
1. Fragilaria spp
2. Thalassiothrix spp

Family: Tabellariaceae
1. Rhabdomena adriaticum

Family: Achnanthaceae
1. Coconeis pseudomargarita

Family: Naviculaceae
1. Amphipora gigantea
2. Amphora lineolata
3. Navicula spp
4. Pleurosigma spp

Family: Nitzschiaceae
1. Bacillaria paradoxa
2. Nitzschia spp

Division: Cyanophyta
Class: Cyanophyceae
Order: Nostocales
Family: Oscillatoriaceae
1. Trichodesmium thiebautii
2. Pelagothrix clevei

Family: Nostocaceae
1. Nostoc spp

Class: Chrysophyceae
Order: Dictyotales
Family: Dictyochaeae
1. Dictyocha spp

Division: Pyrrophyta
Class: Dinophyceae
Order: Prorocentrales
Family: Prorocentraceae
1. Prorocentrum spp

Order: Dinophysiales
Family: Amphisoleniaceae
1. Amphisolenia spp

Family: Dinophysiaceae
1. Dinophysis spp
2. Ornithocercus spp
3. Histioneis spp
4. Citharistes apstenii

Order: Peridiniales
Family: Pyrophacaceae
1. Pyrophacus spp

Family: Peridiniaceae
1. Diplopsalis sp.
2. Protoperidinium spp
3. Scrippsiella spp
4. Zygabikodinium lenticulatum

Family: Gonyaulacaceae
1. Amphidoma sp.
2. Gonyaulax spp

Family: Ceratocoryaceae
1. Ceratocorys spp

Family: Ceratiaceae
1. Ceratium spp

Family: Oxytoxaceae
1. Oxytoxum spp

Family: Cladopyxidaceae
1. Cladophyxis brachiolata

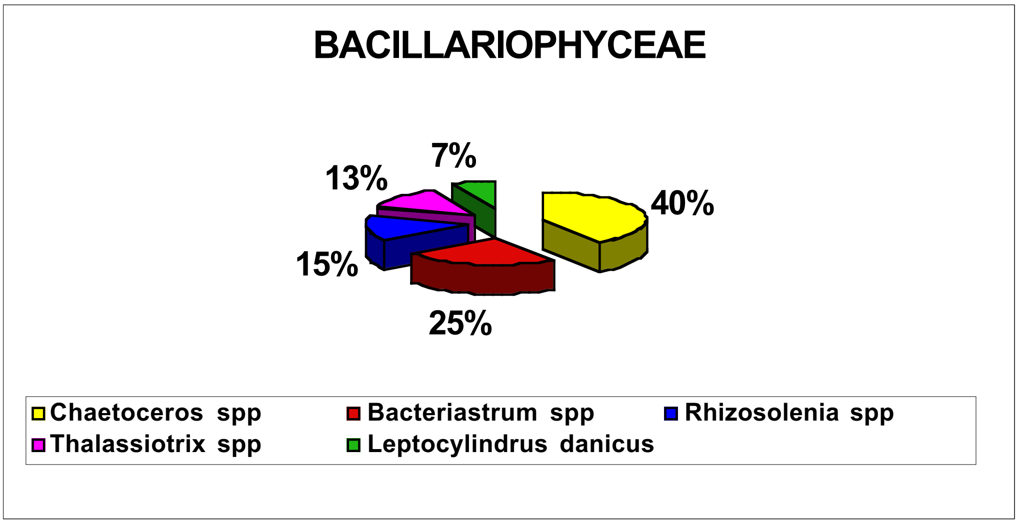
Family: Podolampadaceae
1. Podolampas spp

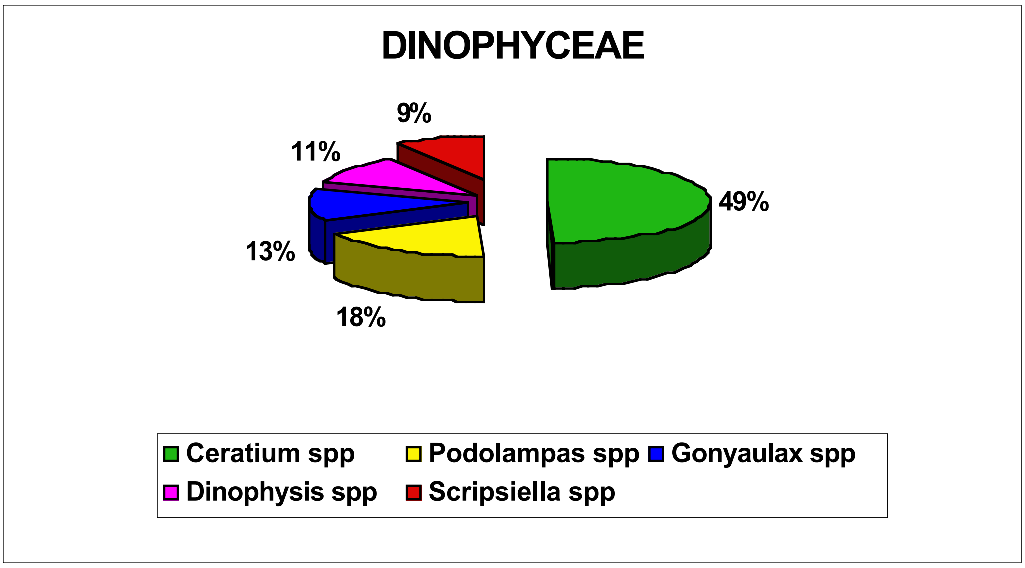
Family: Goniodomataceae
1. Goniodoma spp

Order: Phytodiniales
Family: Pyrocystaceae
1. Pyrocystis spp

Table 2. Phytoplankton Density in South China Sea: Western Philippines, Apr-May,1998.

STATION	BACILLARIOPHYCEAE				CYANOPHYCEAE				CHRYSOPHYCEAE				DINOPHYCEAE			
	0-m Cells/L	20-m Cells/L	40-m Cells/L	60-m Cells/L	0-m Cells/L	20-m Cells/L	40-m Cells/L	60-m Cells/L	0-m Cells/L	20-m Cells/L	40-m Cells/L	60-m Cells/L	0-m Cells/L	20-m Cells/L	40-m Cells/L	60-m Cells/L
1	13	53	15	9	0	23	25	0	0	0	0	3	15	30	20	24
2	7	0	380	229	180	39	0	0	0	0	3	0	32	4	62	24
3	68	105	14	135	12	0	0	0	0	0	0	0	17	35	20	6
4	24	42	36	234	9	0	2	0	0	2	0	2	17	27	32	12
5	18	27	77	282	0	0	0	0	2	0	0	0	23	26	14	0
6	30	57	8	84	0	0	0	0	2	0	0	0	26	23	6	12
7	9	24	211	148	0	0	0	15	0	0	0	0	27	14	11	12
8	19	30	2	111	11	0	0	10	0	0	0	0	25	32	14	6
9	10	14	7	30	12	0	7	0	0	0	0	0	28	24	18	16
10	2	5	37	62	23	0	0	0	0	0	0	0	21	22	37	23
11	13	7	0	111	0	0	0	0	0	0	0	0	33	17	12	20
12	6	50	45	3	0	0	3	0	0	0	0	0	12	31	21	8
13	40	18	4	4	28	0	61	0	0	0	0	2	17	30	29	32
14	10	60	151	9	2	0	0	6	0	0	0	0	49	23	49	9
15	3	48	15	146	0	0	23	0	0	0	0	0	9	6	8	25
16	477	1093	1210	779	0	6	0	12	0	0	0	0	28	33	63	15
17	11	13	67	28	0	0	19	34	0	0	0	0	25	31	33	12
18	8	0	3	9	0	0	128	0	0	0	0	0	46	12	23	8
19	0	20	28	27	0	5	0	31	0	0	0	0	6	24	57	14
20	7	6	6	0	0	5	0	0	0	2	2	0	30	55	19	14
21	19	14	13	2	2	18	0	0	0	0	0	2	25	18	18	16
22	2	20	0	32	0	30	40	31	0	0	0	0	26	20	32	15
23	43	248	145	446	110	270	382	0	4	4	0	0	8	55	28	29
24	277	264	1985	1187	0	335	0	20	0	0	15	0	39	88	18	16
25	5	3	18	67	28	6	9	0	0	0	0	0	9	12	9	18
26	24	16	3	280	4	0	0	0	0	0	0	0	49	24	23	15
27	6	12	18	6	9	0	0	0	0	0	0	0	98	35	31	26
28	9	23	40	67	0	11	3	0	0	0	0	0	12	24	21	6
29	17	7	15	0	0	0	9	0	0	0	0	11	30	24	31	26
30	19	6	169	11	0	0	5	2	0	0	0	0	60	8	9	17
31	63	3	54	39	0	0	0	0	0	0	0	0	44	9	17	9





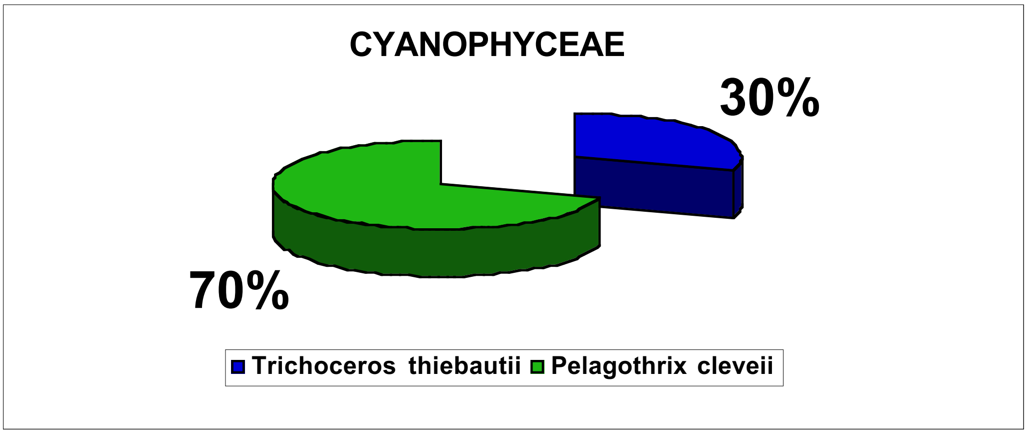


Fig. 2. Percentage composition of the top 5 most dominant representatives of phytoplankton in SCS: Western Philippines, Apr-May,1998.

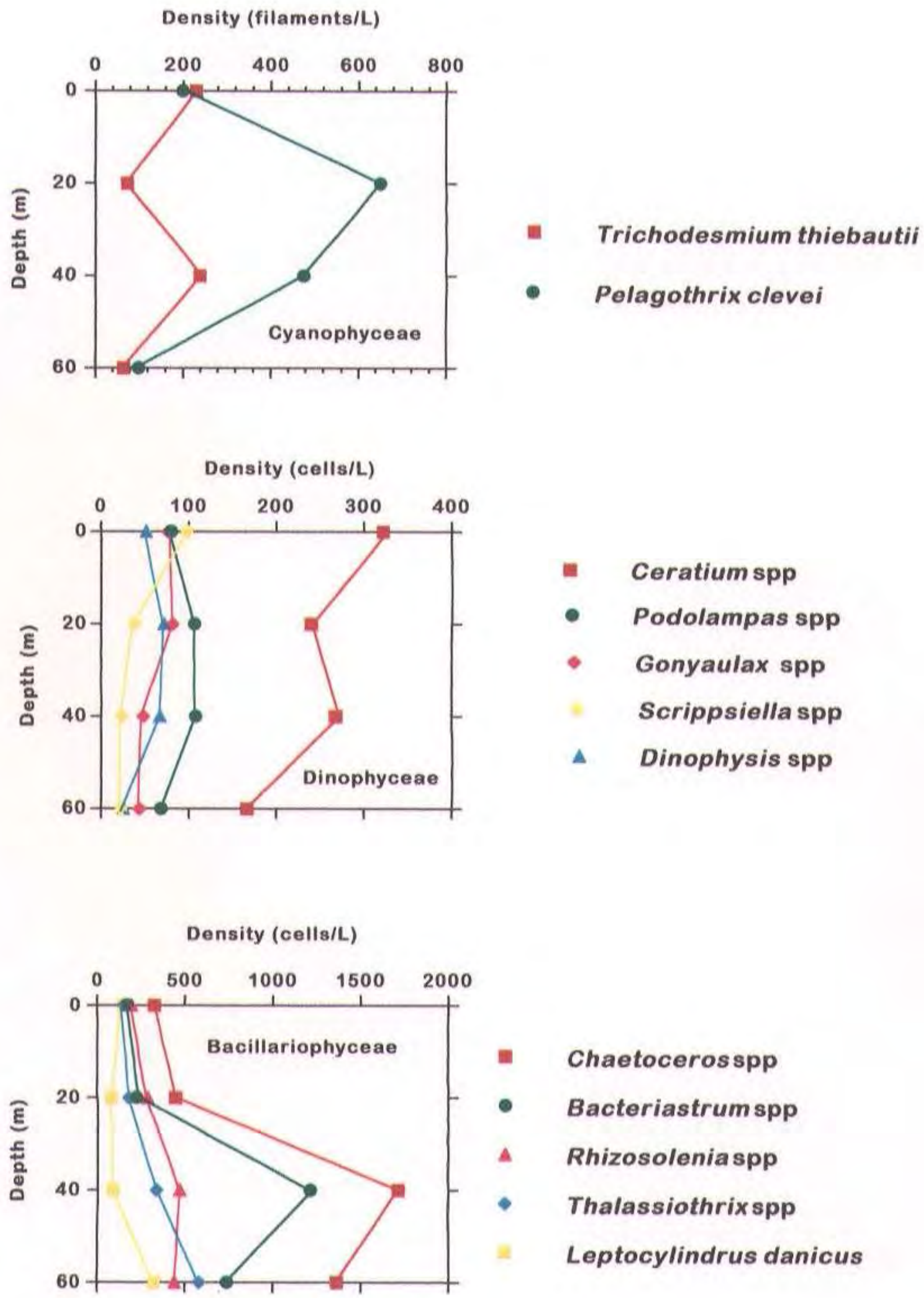


Fig. 3. Vertical distribution of the top 5 most dominant representatives of phytoplankton in SCS: Western Philippines, Apr-May,1998.

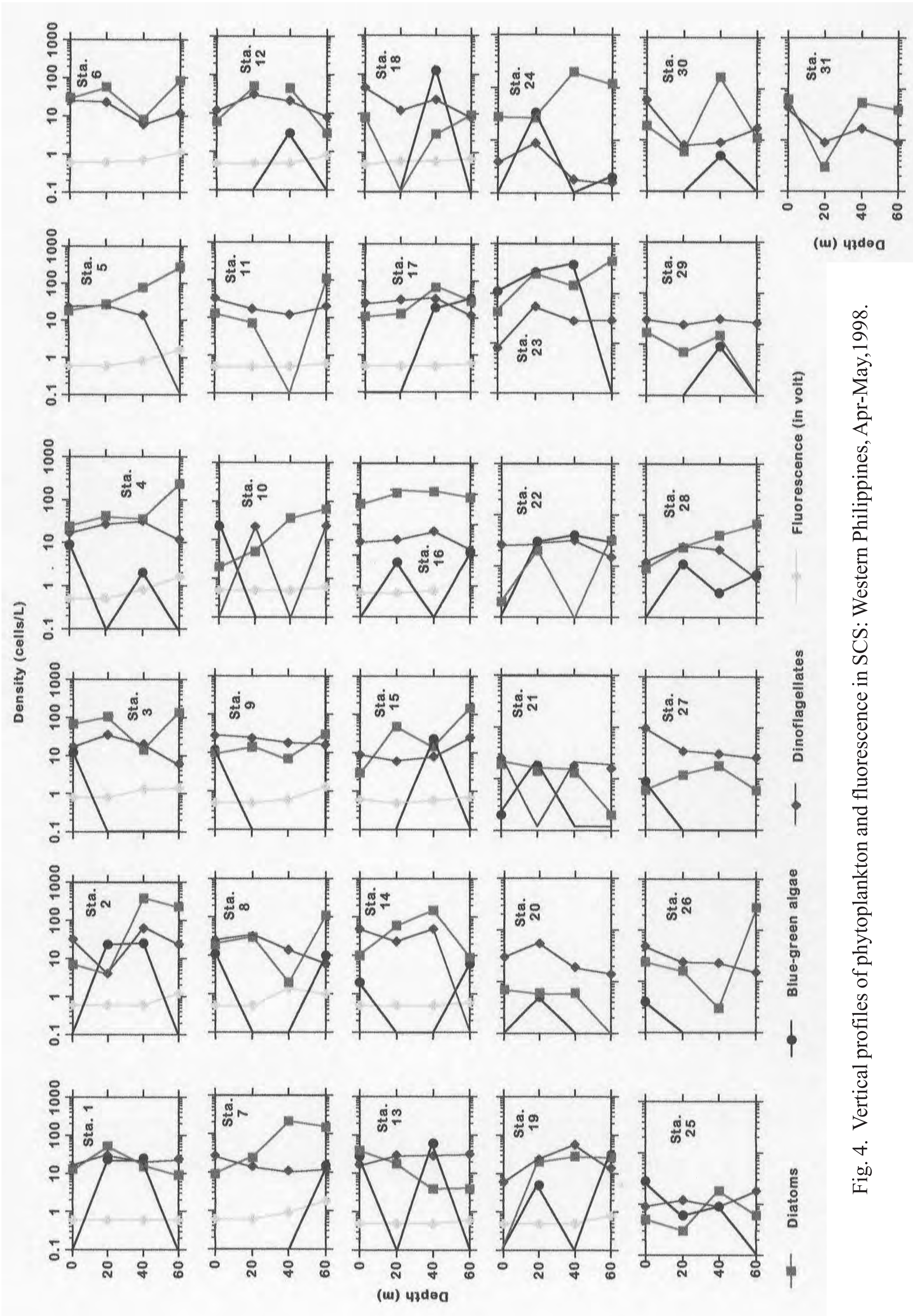


Fig. 4. Vertical profiles of phytoplankton and fluorescence in SCS: Western Philippines, Apr-May,1998.

diatoms with maximum cell densities recorded at the stations along the coast of Subic and near the coast south of Manila (Sta. 16 & 24) with cell densities of 1,210 cells/L and 1,985 cells/L, respectively. The most dominant forms of diatoms observed were *Rhizosolenia spp; Bacteriastrum spp* and *Chaetoceros spp*. They were abundant in almost all the stations, except at Sta. 15 which was dominated only by *Rhizosolenia spp*. *Chaetoceros spp* occurred in almost all the stations sampled with an average cell density of 1,363 cells/L, with the greatest density noted along the coast of Lubang Island (Sta. 24). *Chaetoceros spp; Bacteriastrum spp* and *Rhizosolenia spp* exhibited a similar pattern in the vertical distribution in the water column. Their cell concentrations increased with depth, with the maximum concentrations observed at 40-meters depth and at a depth of 60-m and below, it diminished. *Thalassiothrix spp* and *Leptocylindrus danicus* also exhibited a similar pattern. Cell concentrations increased with increasing depth with the highest concentrations recorded at 60-m layer.

Dinoflagellates or dinophyceae ranked second in terms of abundance (16%) among the phytoplankton community observed in the study area. They occurred sporadically in nominal densities. However, high cell density was noted in Sta. 30 and high concentrations occurred between depths of 20 and 40-m. Above and below these depths, concentration decreased.

Cyanophyceae or blue-green algae shared 11% in the total standing crop of the phytoplankton community. A distinct pattern in the distribution was noted. High concentrations were observed at 40-m, and below this depth, blue-green algae were absent. *Trichodesmium thiebautii* and *Pelagothrix clevei* both formed patches in the surface and near-surface waters. Abundant patches of *Trichodesmium thiebautii* were observed in the stations along the coast of northern Luzon (Stations 1 & 2), a region adjacent to the Kuroshio regime; while *Pelagothrix clevei* formed abundant patches in stations along the coast south of Manila (Stations 23 & 24).

Correlation of phytoplankton density and fluorescence across stations and depths were presented in Figure 4.

The highest fluorescence was registered at station 7 at a depth of 60-m and this was attributed to the abundant concentrations of diatoms.

Occurrence of diatoms in high densities were found between depths of 20 and 60-m, with the maxima observed between 40 and 60-m. A good correlation between cell densities and fluoresecence was noted.

Dinoflagellates in nominal concentration occurred sporadically in the study area, but a relatively higher concentration (180 cells/L) was recorded at station 30. There was no distinct relationship between dinoflagellates densities and fluorescence.

Diversity

Figure 5 shows the species diversity indices of the phytoplankton community. The average index of species diversity (i.e. Shannon index of general diversity) of phytoplankton in almost all stations were high, with the highest observed in Station 16 (4.52). The stations which registered low index of species diversity were 2, 15, 19, 21 & 25, with the lowest noted in Station 2. Meanwhile, low index of evenness was determined in stations where low index of species diversity occurred, with the lowest noted also in Station 2. The Shannon Index of General Diversity indicates the species richness in a given area. The higher the Shannon Index, the more species present, thus the higher biodiversity. Evenness, on the other hand, indicates the equitability of the species in terms of importance values (i.e. plankton densities) in the area. Higher evenness values suggest a more or less equal distribution of individuals across species, thus more diverse plankton community. Except for 2 stations, all the stations sampled have high biodiversity. The dominance index indicates the presence of dominant species, that is, the higher the dominance index, the lower the diversity. Only stations 2 & 21 have high index of dominance, with Station 21 showing the highest value (5.52). Higher values of dominance index in stations 2 & 21 were attributed to the dense patches of *Trichodesmium thiebautii* and *Pelagothrix clevei*, respectively.

Discussion

The standing stock of phytoplankton in the study area was 4,542 cells/L. The concentrations increased with depth, with the greatest concentrations observed at 60-m and increased toward the coast. Vertical and spatial heterogeneities were apparent.

Higher density of phytoplankton were observed at stations along and/or near the coast while low densities were noted at stations offshore and the standing stock of phytoplankton maxima usually occurred considerably at deeper strata (40-60-m). This condition is typical for tropical waters such as the Western Philippines: South China Sea.

Table 3 shows the comparison of chlorophyll-a determined from the different tropical waters.

[Marumo (1972)] determined the chlorophyll-a from South China Sea, Indian Ocean, Philippine Sea and Celebes Sea which ranged from 0.11-0.16 mg/m^3 ; 0.10-0.17 mg/m^3 ; and 0.10-0.27 mg/m^3 respectively. [Wauthy (1972)] calculated the chlorophyll-a of the waters North of New Guinea and the Chl-a ranged from 0.10-0.40 mg/m^3. Wauthy(1972) observed that the surface layer which is above the maxima, is typically poor offshore (<.10mg/m^3) and richer in the inland Bismark Sea with high values near New Guinea coast (>.40mg/m^3). On the other hand, the result of the present study is comparable to the findings of the above-cited authors, with the surface layer also typically poor offshore (.10 mg/m^3) and rich along the coast south of Manila (.18 mg/m^3).

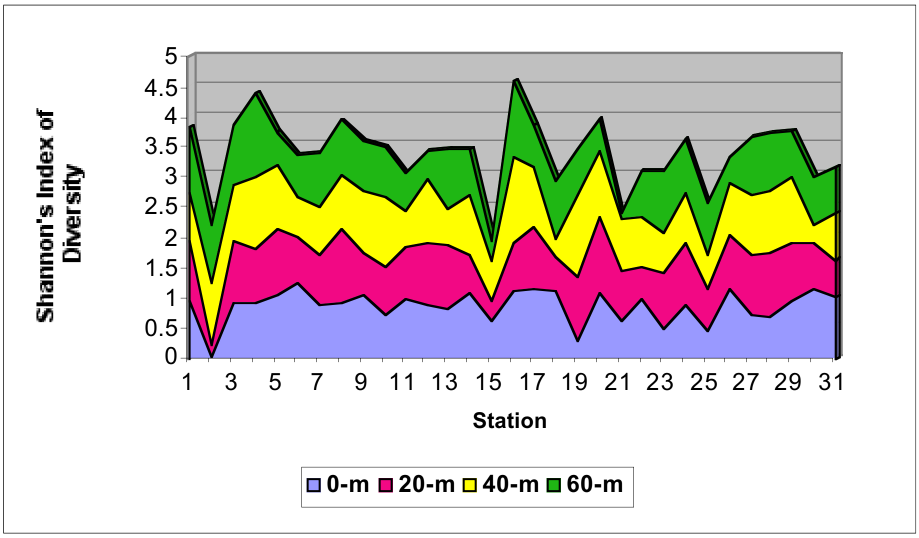
Spatial and temporal variations in plankton are seen to be strongly correlated with physical oceanographic processes and mediated by biological-physical interactions rather than purely biological forcing functions [Barnes, R.S.K. & R.N. Hughes (1968)]. Solar radiation and essential nutrient availability are the dominant physical factors that control phytoplankton production in the sea [Lalli, C.M. & T.R. Parsons (1993)].

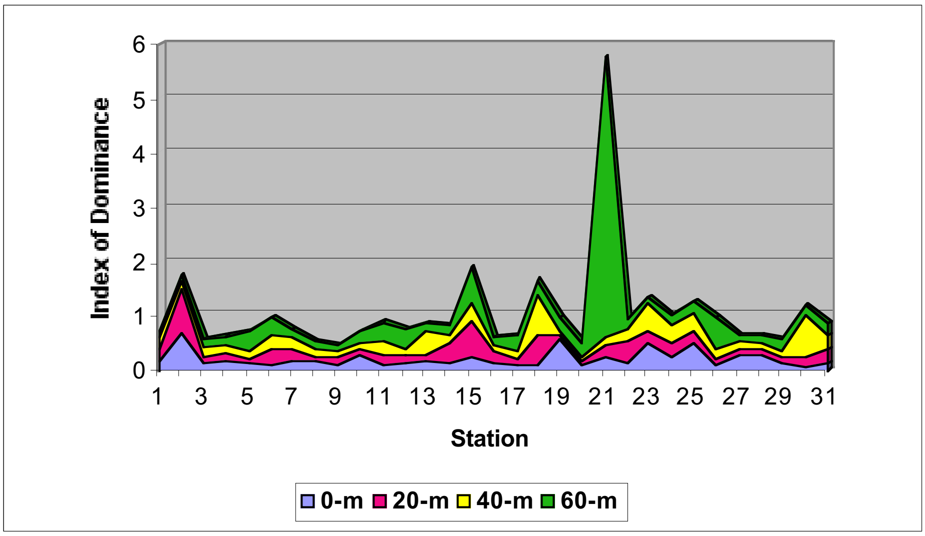
Dissolved nutrients in the study area were investigated by Montojo (this volume) and he found out that homogeneous water mass was almost devoid of nutrients particularly nitrate, nitrite and phosphate. Montojo (this volume) also observed that stations located near the entrance of Luzon Strait and Sulu Sea were rich in nutrients and the maxima were noted in these stations. Likewise, abundant concentrations of phytoplankton coincided with the high nutrient concentrations. High concentrations of phytoplankton were also found in stations where high concentrations of nutrients were observed.

The species composition of diatoms is similar to that reported by Huang (1986) and Relon (1985) off Southwestern Taiwan and coastal waters of Northern Luzon, respectively. Marumo (1972) studied the standing crop and phytoplankton community in the Southeast Asian Seas and his findings conformed to the findings of this present study.

Dense concentrations of phytoplankton, chiefly diatoms, were present at all inshore areas sampled.

In the northern coast, near the entrance of Luzon Strait, the population composed a pronounce admixture of oceanic species with the neritic subtropical and eurythermal species. Such species as *Trichodesmium thiebautii, Climacodinium spp, Eucampia zoodiacus* and *Ditylum sol,* common in subtropical waters were frequently present at stations close to the coast, presumably due to its close proximity to the Kuroshio regime. There was a marked spread of





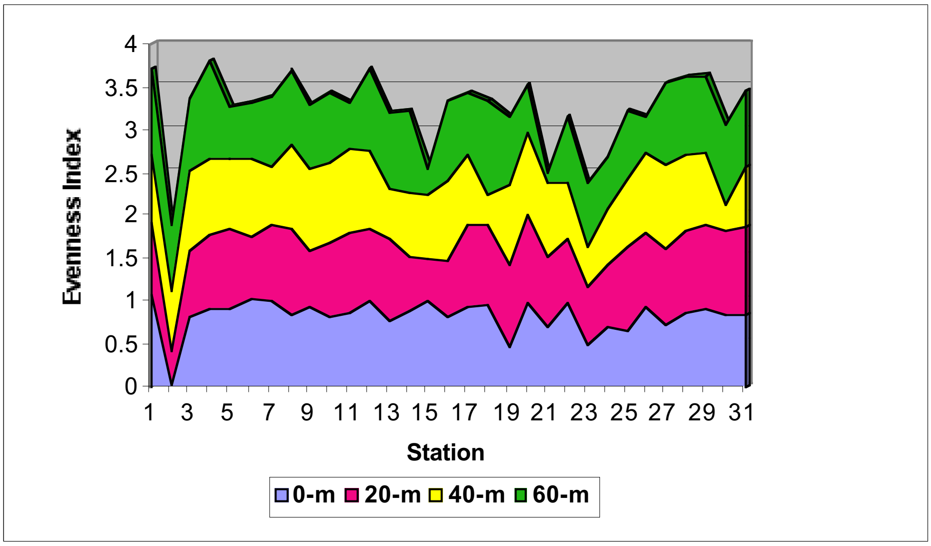


Fig. 5. Phytoplankton species diversity indices

Table 3. Cholorophyll-a obtained from various tropical waters.

AREA	Cholorophyll-a Values	SOURCE
South China Sea	0.11 – 0.16 mg/m^3	Marumo(1972)
Indian Ocean	0.16 mg/m^3	Marumo(1972)
Philippine Sea	0.10 – 0.17 mg/m	Marumo(1972)
Celebes Sea	0.10 – 0.27 mg/m^3	Marumo(1972)
North of New Guinea	0.10 – 0.40 mg/m^3	Wauthy(1972)
Western Philippines: SCS	0.10 – 0.18 mg/m^3	This study

neritic species from the region into the offshore areas. *Chaetoceros spp* was widely distributed in the whole area sampled. It was the most ubiquitous species recorded, being present in all the stations.

Dinoflagellates occurred in offshore areas of the region in smaller density.

The waters off Western Philippines is floristically interesting since the area is part of the South China Sea which is believed to harbor the highest marine biodiversity on earth. The break-up of the highly diverse circumglobal Tethys Sea during the early to mid-Cenozoic [McCoy & Heck (1976)], and speciation through allopatry and basin isolation [Greenfield (1968)] provide evolutionary explanation for some of the observed patterns of marine biodiversity in the region. Proximate mechanisms also exist to maintain this biodiversity in ecologically temporal scales. The island mass effect and retention mechanism imposed by reversing monsoonal winds allow for the maintenance of high diversity.

Acknowledgement

To the officers and crew of M/V SEAFDEC, to my friend Sopana, for sharing me some of her water samples and to my colleagues in BFAR, particularly to Mr. Dennis Candia for preparing my visuals, my sincerest thank you. Likewise, the efforts of Dr. Yasuwo Fukuyo in teaching me in phytoplankton identification and graphics preparation is greatly acknowledged.

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The Primary Productivity in the South China Sea, Area III: Western Philippines

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ABSTRACT

In this paper the relative concentrations and vertical distributions of primary production were investigated off Western Philippines of the South China Sea during tradewinds from April 15 to May 11, 1998. Primary productivity measurements were conducted using conventional "light-and-dark bottle" oxygen method. The net primary production estimates at ten (10) different stations established between 19° 59.2'N, 119° 58.7'E and 11° 13.5'N, 118° 03.1'E ranged from 0.10 ~ 1.53 g C $m^{-2} d^{-1}$. The result suggests that the present net production estimates in the area is remarkably higher than the estimates from other parts of the South China Sea (viz., northern coastal waters off Taiwan and southwestern parts of the SCS which included marine waters of Thailand, Indonesia and Malaysia). The highest primary production occurred at the upper 60-m well-mixed layer of station 1 in the northwesternmost part of the area. Results have shown that some other hydrographic and chemical parameters (viz., temperature, salinity, light and fluorescence) greatly complicate and may not coherent with the analyses of relative distribution and abundance of primary production in the area.

Key words: Primary production, vertical mixing and upwelling

Introduction

Despite the vast expanse of the South China Sea, little is known of its fisheries status, in general and its primary productivity status, in particular. The factor that has to be reckoned with, is that few ASEAN countries are equipped and capable to do high seas explorations, with the South China Sea (SCS) as a vast oceanic waters. It could be noted that offshore studies in the South China Sea have been less extensively documented than those of its coastal waters. Over the last decade, limited oceanographic studies dealing with the physical, chemical and biological characteristics of the northern coastal waters off Taiwan of the SCS (24°N 120°E ~ 26°N 123°E) were done in a series of expedition by Chinese researchers (Hung *et al*. 1980). Likewise, oceanographic studies, mostly at the coastal waters in the southwestern part of the SCS were carried out in Thailand (Andersen 1977, Limpsaichol and Poopeth 1984), Indonesia (Ilahude, 1978) and Malaysia (Shamsudin 1987, Shamsudin *et al.* 1988 and Shamsudin 1988). The results of these cruises provided some important information regarding the environmental factors affecting the primary productivities of these areas.

In particular, the status of water quality and fisheries in the South China Sea (SCS) off western Philippines has never been documented. There is no available information on aquatic biota, and the level of primary production in the area. Such data are important to evaluate the productivity of the area and its capacity as a fishing ground, before it could be considered as one of the major sources of fish and other fishery resources in the Philippines.

Phytoplankton is the principal source of organic material (primary production) in the sea and its importance was long recognized as the initial stage in the marine food chain. Primary productivity, in this study, was measured in terms of the quantity of carbon fixed. However, considering that the *in situ* method for assessing the actual carbon fixation in the water column needs too much time in a ship survey, the simulated on-board incubation experiment with oxygen method was used during the oceanographic cruise.

This study serves as a starting point in obtaining essential information about the relative distribution and level of primary productivity in relation to abundance of phytoplankton and some other hydrographic and chemical parameters (*viz.,* temperature, salinity, light and fluorescence) in the area. Specifically, the study was the first attempt to estimate the vertical profiles of primary production for the whole western Philippine waters. The results of this study offered the first data in support to the available fishery resources in the area.

Materials and Methods

The study was carried out from April 15 to May 11, 1998, in the South China Sea off Western Philippines on board M/V *SEAFDEC* as a third phase of the collaborative research program of Southeast Asian Fisheries Development Center (SEAFDEC) in the South China Sea. Out of 31 pre-established stations, ten stations (*i.e.,* Station Nos. 1, 5, 7, 10, 15, 17, 22, 25, 30 and 31) located between 19° 59.2'N, 119° 58.7'E and 11° 13.5'N, 118° 03.1'E, which represented the middle transect of the area were occupied for ten days (Figure 1). The water samples for primary productivity were collected at six fixed depths (*i.e.,* 0-m, 20-m, 40-m, 60-m, 80-m and 100-m depths) in the euphotic zone of each station by a Van Dorn twin-type water sampler of 20*l* x 2 capacity. Initially, the samples were filtered through a 0.3-mm mesh net to separate zooplankton component from phytoplankton. The samples were carefully siphoned into 3 types of BOD bottles, *viz.,* control, light and dark bottles. The oxygen content of the control bottle is fixed when the experiment commences while those of the paired bottles; one transparent and the other darkened were incubated in a lighted tub (dimensions: W=35 cm x H=45 cm x L=70 cm) of seawater on board the ship. Light and dark sample bottles were exposed to both overlying and underlying fluorescent lights of about 400 μmol photons m^{-2} s^{-1} during incubation. The distance of the incubated bottles from the overlying lights is about 40 cm. Quantitatively, light intensity at various levels in the tub with each designated depth was measured using light meter (Model: Light Quantum Meter with LI-193SA Spherical Quantum Sensor, 4Pi detector, LI-COR, Inc.). Dissolved oxygen contents of unincubated water samples were first determined. After incubation of the other water samples for 4 hours, the dissolved oxygen content was measured quantitatively by the Winkler titration method, in which, upon acidification causes the liberation of tri-valent iodine quantitatively equivalent to the amount of dissolved oxygen in the water sample. One-hundred ml of the acidified solution is then titrated with a standard sodium thiosulfate solution.

The hydrographic and chemical data used here were taken from the iCTD sampling during the survey. The parameters that were used in relation to primary productivity data analysis were selected as follows: temperature, salinity, light and amounts of fluorescence. Fluorescence was measured by the integrated CTD fluorometer at the same depths where primary productivities were observed.

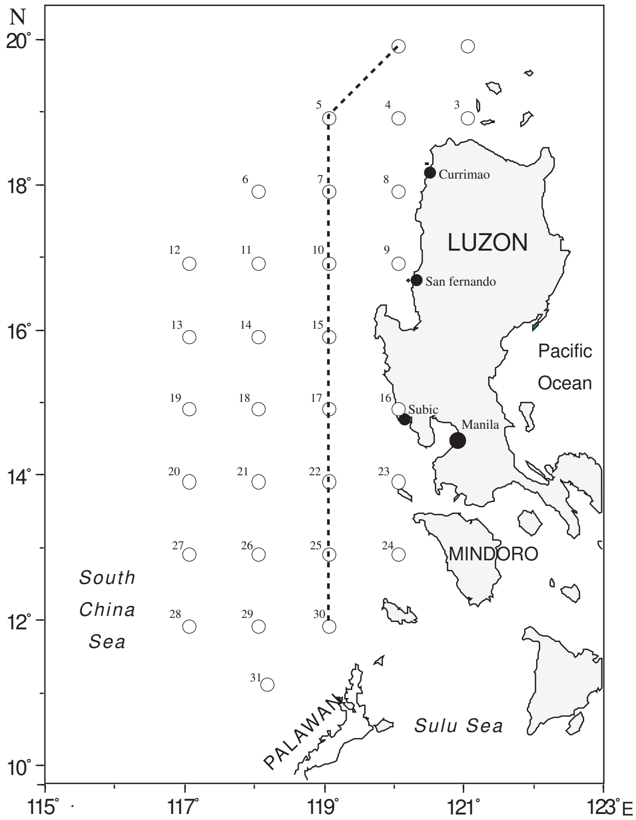

Fig. 1. Stations for oceanographic survey in the South China Sea, Area III: off Western Philippines.

Results

Vertical Distribution of Gross Primary Production

The results of gross primary productivity observations were presented in Figure 2a. The sampling area which was situated off the western part of the Philippines, have values ranging from 0.10 to 2.52 g C m^{-2} d^{-1}· The upper 60-m layer of station 1 in the northwestern part and of station 31 in the southwestern part yielded relatively high gross production. The highest gross production which were recorded in the upper 60-m layer of station 1 have values ranging from 1.4 to 2.52 g C m^{-2} d^{-1}.

Relatively low concentrations of gross production which ranged from 0 to 0.2 $gCm^{-2}d^{-1}$ were noted throughout the water column of stations 5 and 7 in the northwestern part, except at 60-m depth of station 5 where a value of 0.4 g Cm^{-2} d^{-1} was recorded.

Generally, going southward (*i.e.,* from stations 10 to 31) the gross production tends to increase. Fairly high gross production ranging from 0.33 to 0.61 g Cm^{-2} d^{-1} were recorded in the surface and sub-surface layers (0~20 m depths) of station 10, off Lingayen Gulf and station 15, off Cape Bolinao and these values gradually decreased with depths of both stations. Similar vertical profiles were observed at station 25 off Mindoro Island with gross production rates ranging from 0.19 to 0.88 g Cm^{-2} d^{-1} and at station 31 off Palawan which ranged from 0.44 to 1.13 g Cm^{-2} d^{-1}.

Stations 17 and 22, off Manila Bay in the central part, have relatively high gross production rates ranging from 0.1 to 1.01 g Cm^{-2} d^{-1} which increased with depths. Relatively high gross production with sub-surface maxima at 40 m depth was observed in station 30 off Calamian Group of Island.

Vertical Distribution of Respiration Rates

A decreasing trend of relatively high respiration rates which ranged from –1.13 to 2.23 g Cm^{-2} d^{-1} were observed in station 1 at the northwestern part. The highest value of 2.23 g Cm^{-2} d^{-1} was recorded at 20-m depth of this station.

Generally, almost all stations (stations 5, 7, 10, 15, 17, 22, 25, 30 and 31), except station 1, were characterized with fairly low uniform distribution throughout depths, which ranged from –0.12 to 1.09 g C m^{-2} d^{-1}. Remarkably high respiration rates were noted at 100-m depth of station 7 off Cape Bojeador and both at 80- and 100-m depths of station 22 off Manila Bay and station 31 off Palawan (Figure 2b). Moreover, the results showed that the oxygen concentrations in the dark bottles in the said depths turned out to be higher than the light bottles after four hours of incubation.

Vertical Distribution of Net Primary Production

Figure 2c shows the result of the vertical profile of net primary production in the area with values ranging from 0.1 to 1.53 g Cm^{-2} d^{-1}. Relatively high net productions were recorded throughout the water column of station 1 in the northwestern part with rates ranging from 0.21 to 1.53 g Cm^{-2} d^{-1}.

Relatively low net primary production, which ranged from 0.1 to 0.71 g Cm^{-2} d^{-1} were observed all throughout the water column of stations off northwestern Luzon (*i.e.,* stations 5, 7, 10 and 15). Going farther to the southwestern part (*i.e.,* from stations 17 onward), the net primary production tends to increase although it varies with depths at different stations. Net production rates seemed to increase with depths at station 17 off Subic Bay, whereas, stations situated off Manila Bay and Mindoro Island (*i.e.,* stations 22 and 25) and off Calamian Group and Palawan Islands (*i.e.,* stations 30 and 31) yielded net production rates that decreased with depths. On the other hand, maximum net production was found at 40-m depth of station 30 (Figure 2c).

Vertical Distribution of Phytoplankton

Figure 3a showed the vertical distribution and relative abundance of phytoplankton in the sampling area. Water masses with relatively high phytoplankton densities that ranged from 2,064 to 5,628 cells per liter of seawater predominated at the intermediate depths (between 40- and 70-m depths) of stations 5 and 7 in the northwestern part, at 60-m depth of station 15 off Cape Bolinao and at 40-m depth of stations 30 and 31 off Calamian Group and Palawan Islands in the southwestern part. Station 25, which is located off Mindoro Island in the southwestern part yielded relatively low phytoplankton densities all throughout its water column.

The highest phytoplankton density of 5,628 cells per liter was found in a water mass that lies at 60-m depth of station 5 in the northwestern part. Ironically, relatively low phytoplankton densities which ranged from 208 to 1,824 cells per liter were observed mostly from the surface to sub-surface layers (0- ~ 30-m depths) of all stations except the surface layer of stations 30 and 31, which yielded high phytoplankton densities (Figure 3a).

Vertical Distribution of Fluorescence

The results of fluorescence observation varies among stations with values ranging from 0.096 ~ 1.98 volts. Relatively high fluorescence occurred at about 40- to 100-m depths of

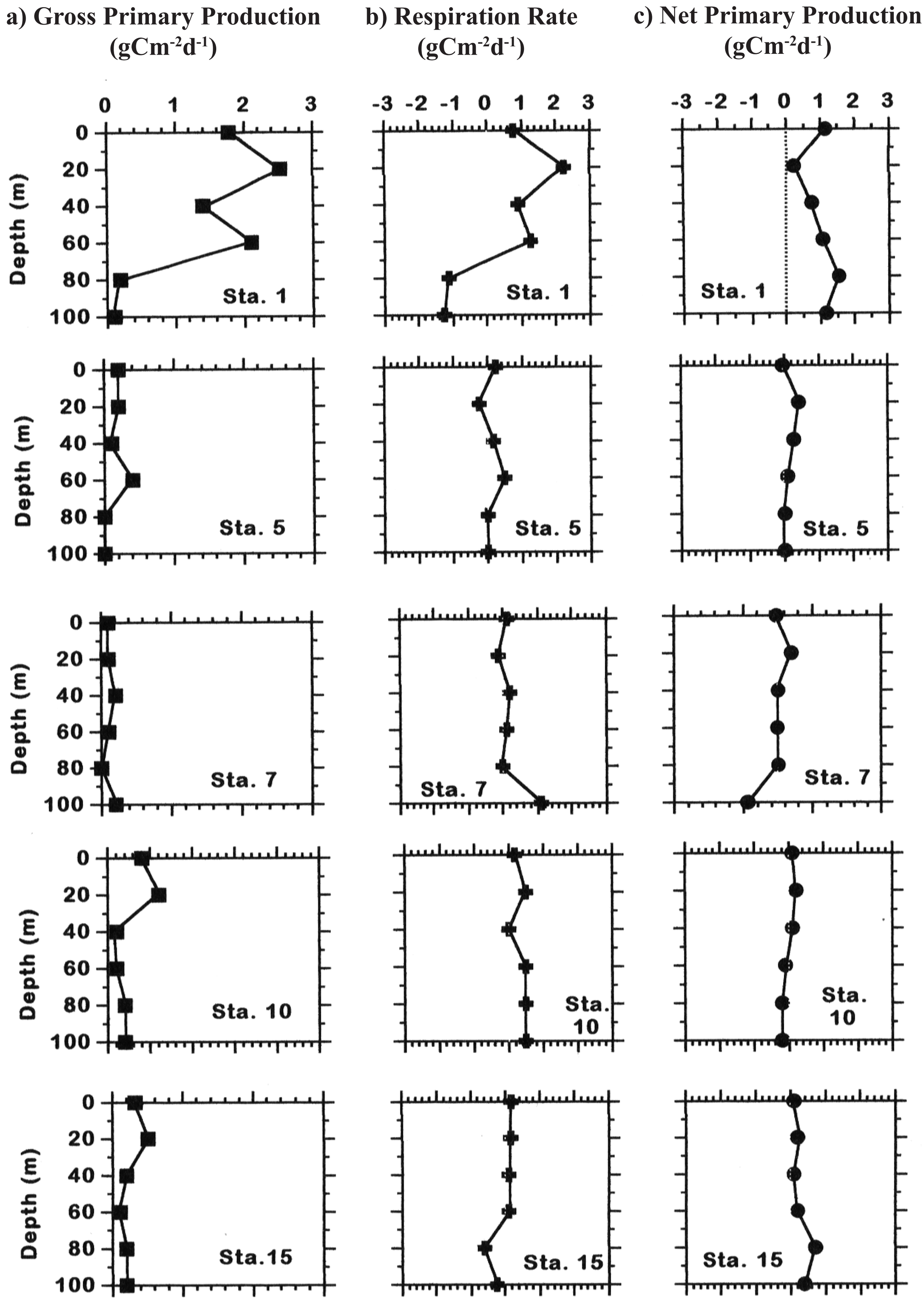

Fig. 2/1. Vertical profiles of primary production (gross, respiration and net production) at various depths of different stations in the SCS, off Western Philippines (M/S *SEAFDEC,* Apr. 15-May 11, 1998).

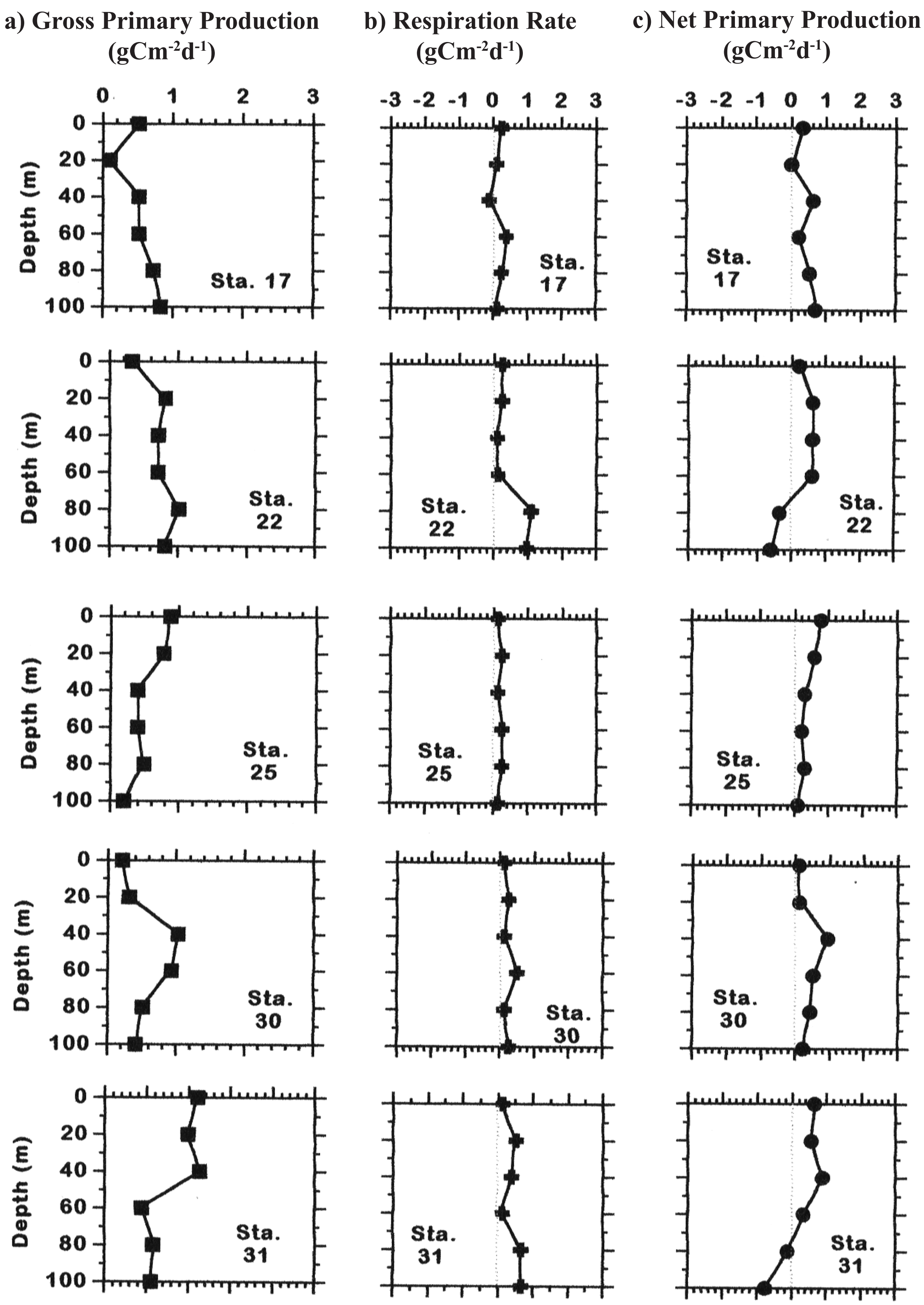

Fig. 2/2. Vertical profiles of primary production (gross, respiration and net production) at various depths of different stations in the SCS, off Western Philippines (M/S *SEAFDEC,* Apr. 15-May 11, 1998).

stations 5 and 7 and spread to deeper layer (100 m) of stations contiguous in the northwestern Luzon (*i.e.,* stations 1, 5, 7 and 10) and station 15 in the central part (Figure 3b).

A ring-like water mass, which occurred at 40- to 100-m depths of station 7, yielded the highest, range of fluorescence from 1.04 to 1.98 volts. Generally, sampling stations situated off northwestern and central Luzon of the area (*viz.,* Stations 1, 5, 7, 10, 15 and 17) have increased amount of fluorescence at increasing depths. The magnitude of variability of fluorescence tends to decrease going farther southward (*i.e.,* from stations 17 to 31, Figure 3b). The stations at the southwestern part showed uniform distribution of relatively low amounts of fluorescence.

Vertical Distribution of Temperatures

Temperature values that were obtained in the area during the survey ranged from 17.58°C to 31.02°C. A thermally-homogeneous layer of >27.0°C ~ >28.0°C down to about 60 m depth occurred at station 1 in the northwesternmost part (Figure 3c). Under the homogeneous layer lies the relatively cold-water masses where the temperature decreased from >26.0°C at about 80 m to >23.0°C at 100-m depth.

Upwelling occurred between stations 5 and 10 at the northwestern part where the thickness of the homogeneous layer that was described at station 1 decreased to about 20 m deep with a colder water mass ranging from >27.0°C to >28.0°C. The upwelling causes the water mass to rise up to about 20 m as indicated by the 27.0°C isotherm, which showed the thermocline layer between 40-m and 60-m depths between stations 7 off Cape Bojeador and at station 10 off Lingayen Gulf where the temperature decreased from 27.0°C at 40 m to >23.0°C at 60 m.

A warm water mass with temperatures ranging from >29.0°C to 30.0°C occupies the upper 30 m layer of several stations contiguous from the northwestern Luzon (*i.e.,* stations 10, 15 and 17) to southwestern part area (*i.e.,* stations 22, 25, 30 and 31). The highest temperature of >30.0°C occurred at the upper 20 m of station 15 off Cape Bolinao, station 22 off Manila Bay, station 25 off Mindoro Island, station 30 off Calamian Group Is. and station 31 off Palawan. Moreover, relatively cold-water masses between stations 15 and 17 off Cape Bolinao and Subic Bay in the central part are sinking, which temperature decreased from >28.0°C at 40 m to <23.0°C at 100 m.

Relatively cold-water masses which temperatures decreased from >28.0°C at about 30 m to >18.0°C at 100-m depths were observed from station 22 off Manila Bay to the southwestern part (*i.e.,* stations 25, 30 and 31, respectively, Figure 3c).

Vertical Distribution of Salinity

A water mass of relatively low salinity (<33.90‰ ~ >34.00‰) occupies the upper 60 m of the homogeneous layer at station 1 in the northwestern part (Figure 3d). The same feature with the temperature distribution that is the presence of upwelling between stations 5 and 7 in the northwestern part can be noted in the salinity distribution. It consists of salinity concentrations that increased from >34.10‰ at about 5 m to 34.70‰ at 100 m. The sinking of relatively low salinity-water mass with values ranging from 33.70‰ to 34.40‰ occurred between stations 10 and 22 off Lingayen Gulf and Manila Bay, respectively. Apparently, a tongue-like water mass that occurred at the upper 40-m layer between stations 15 and 22 off Cape Bolinao and Manila Bay, respectively, yielded the lowest salinity concentrations ranging from <33.70‰ to <33.90‰.

Different forms of water masses with relatively high salinity values were observed at stations in the southwestern part of the area. A ring-like water mass that occurred between the

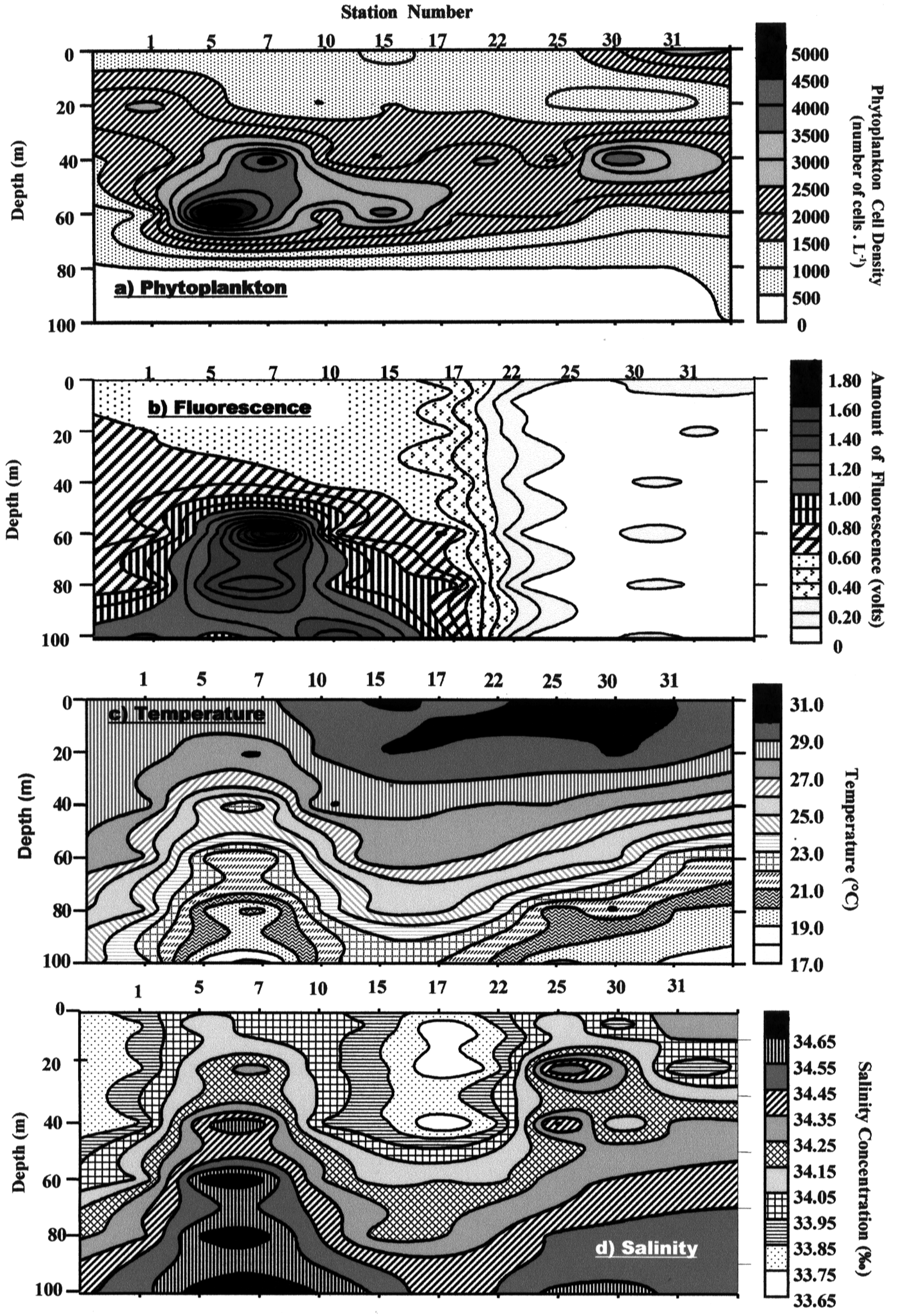

Fig. 3. Vertical profiles of (a) phytoplankton cells, (b) fluorescence intensity, (c) temperature, and (d) salinity concentrations at various depths of different stations in the SCS, off Western Philippines (M/V *SEAFDEC*, Apr. 15-May 11, 1998).

surface layer and 40-m depths of stations 25 off Mindoro Island, station 30 off Calamian Group Is. and station 31 off Palawan, have high salinity values ranging from 34.1 ‰ to 34.4 ‰ (Figure 3d).

In Situ Vertical Light Attenuation and Simulated Light On Board Incubation

The actual light data in few selected stations, where light measurements during daytime observations were possible, were used and simulated during on board incubation experiments. Analyses of the results have shown that the *in situ* surface insulation and vertical attenuation within the water column in the SCS off western Philippines vary from 3,419 μmol photons m^{-2} s^{-1} at 0-m depth to 0.084 μmol photons m^{-2} s^{-1} at 100-m depth. Each station showed different light intensities, which vary enough to explain the magnitude of variability observed in primary productivity in the area.

Moreover, the light simulated during on board incubation was standardized at about 400μmol photons m^{-2} s^{-1}. The vertical profiles of the simulated light intensities vary among stations, which ranged from 1.01 to 431.30 μmol photons m^{-2} s^{-1} (Figure 4).

Discussion

The net primary production in the South China Sea, Area III: off western Philippines between 19° 59.2'N, 119° 58.7'E and 11° 13.5'N, 118° 03.1'N ranged from -0.1 ~ 1.53 g C m^{-2} d^{-1}. These estimates are generally higher than previous estimates reported for other waters of the ASEAN and tropical regions (Table 1). The present estimates showed that the primary production in this area is higher than that of the northern coast off Taiwan of the SCS, which yielded 0.90 ~ 1.11 g C m^{-2} d^{-1} (Hung *et al.* 1980). Small variation of only 0.42 g C m^{-2} d^{-1} was noted. However, a great difference is obvious if one considers to compare the present estimates of primary production than among other regions of the South China Sea such as in the west coast off Phuket Island and at the Andaman Sea, Thailand (*i.e.,* 0.023 ~ 0.085 g C m^{-2} d^{-1}, Andersen 1977, Limpsaichol and Poopetch 1984); off Southern Makassar Strait, Indonesia (*i.e.,* 0.4 ~ 0.7 mg m^{-3} Chl-*a*, Ilahude 1978); and off the Sarawak waters of Malaysia (*i.e.,* 0.43 g C m^{-2} d^{-1}, Shamsudin 1988). The comparison of different results which were shown in Table 1 are not viable because of the different methods of sampling that were used by those authors. These facts showed that the method of sampling is very important in revealing the consistency of the level of primary productivity among areas.

The variations in vertical profiles of primary productivity in the area did not seem correlated with any precise light intensity obtained during the incubation experiment on board the ship. Primary production obtained from the incubated bottles at a series of depths in a lighted tub, exhibit characteristic patterns of photosynthetic rate with depth in relation to the vertical distribution of simulated light. Net primary production obtained at the water surface of most station display a pronounced light inhibition with maximum photosynthetic rates occurring below the surface (Figure 4a & c). On the other hand, the light regime in the top water layers of stations 1 and 25 are seemingly favorable for phytoplankton photosynthesis. Specific observation, however, showed that high primary productivity in station 1 off northwestern Luzon, station 17 off Subic Bay, station 22 off Manila Bay, station 25 off Mindoro Island, stations 30 and 31 off Palawan, appear to occur in response to relatively high vertical light intensities obtained at various light levels in the tub of seawater (Fig. 4a & c). Relatively high net primary production

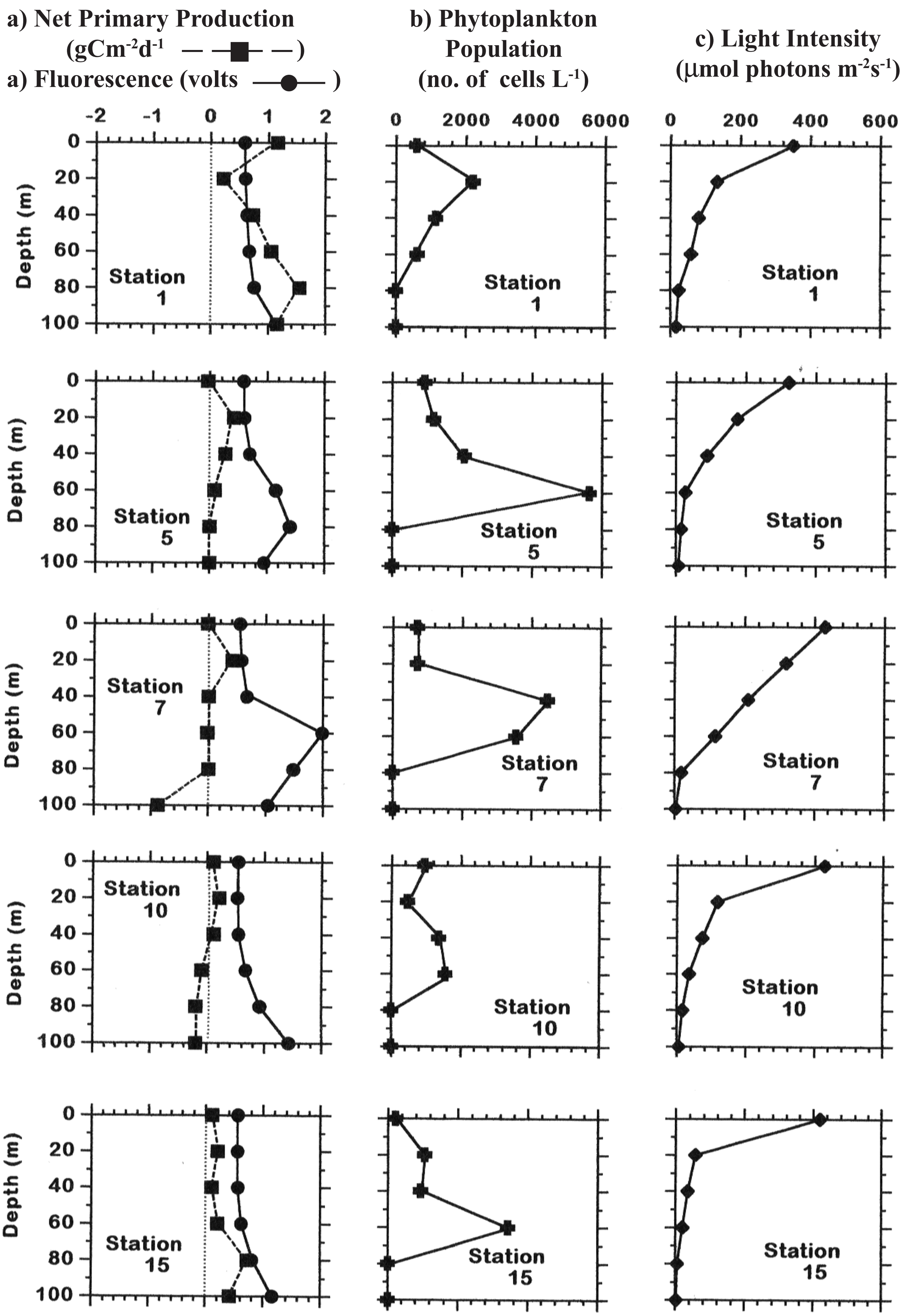

Fig. 4/1. Vertical profiles of (a) net primary production and (c) light intensity obtained during on board incubation and the *in situ* vertical profiles of (a) fluorescence and (b) phytoplankton cell density at various depths of different stations in the SCS, off Western Philippines (M/V *SEAFDEC,* Apr. 15-May 11, 1998).

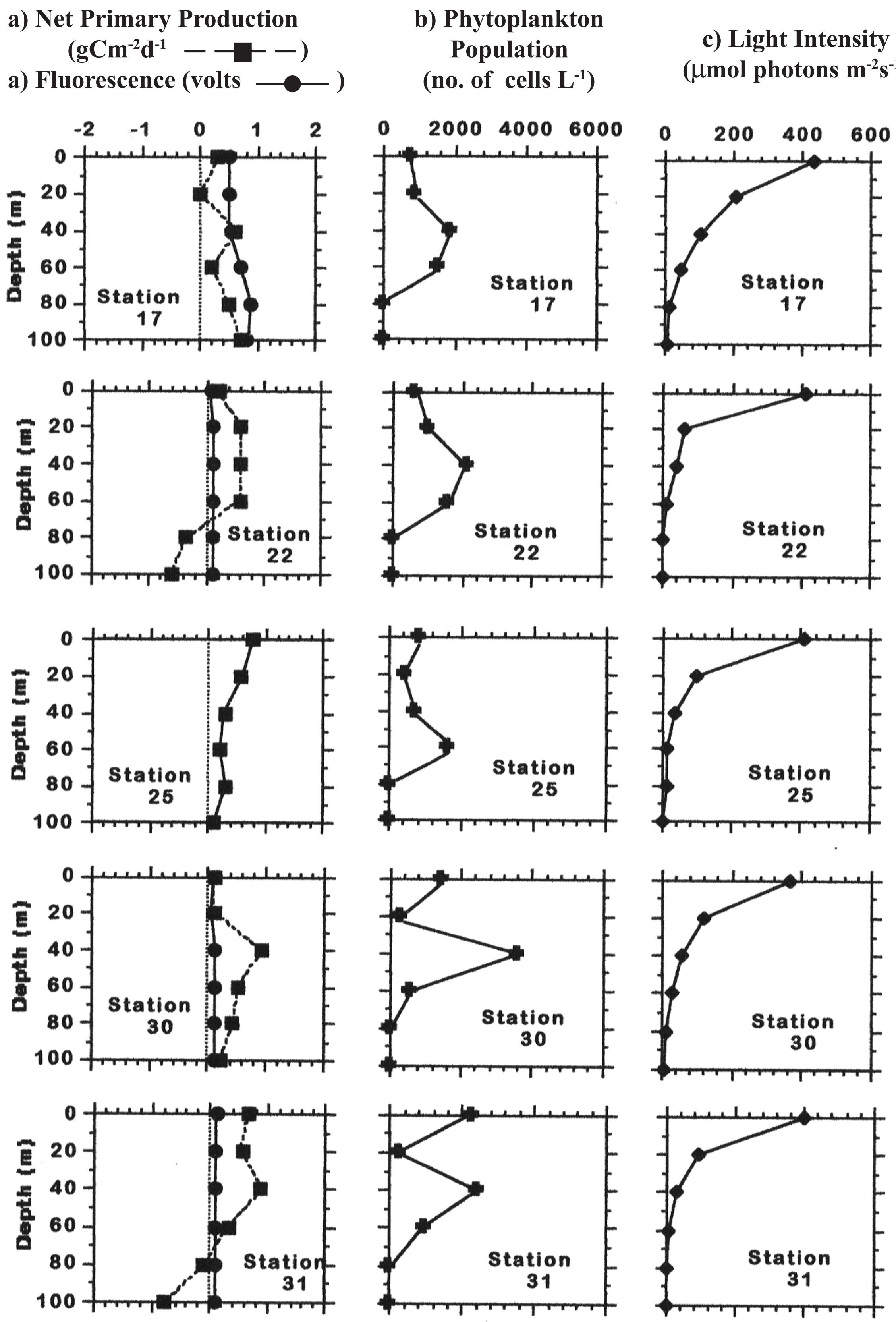

Fig. 4/2. Vertical profiles of (a) net primary production and (c) light intensity obtained during on board incubation and the *in situ* vertical profiles of (a) fluorescence and (b) phytoplankton cell density at various depths of different stations in the SCS, off Western Philippines (M/V *SEAFDEC,* Apr. 15-May 11, 1998).

Table 1. Comparative estimates of net primary productivity among regions of South China Sea (SCS).

Waters of the ASEAN & other Tropical Regions	Methods	Daily Production Estimates (g C $m^{-2} d^{-1}$)	Source
Northern Coast off Taiwan	*In situ* C-14	0.90~1.11 g C $m^{-2} d^{-1}$	Hung *et al.* (1980)
West Coast off Phuket Island, Thailand	*In situ* C-14	0.023~0.085 g C $m^{-2} d^{-1}$	Andersen (1977), Limpsaichol and Poopetch (1984)
Off Southern Makassar Strait, Indonesia	Chlorophyll method	0.4~0.7 mg m^{-3} Chl-*a*	Ilahude (1978)
Off the Sarawak Waters, Malaysia		0.43 g C $m^{-2} d^{-1}$	Shamsudin (1987)
Five areas of western tropical and sub-tropical Pacific Ocean	Both *in situ* and simulated *in situ* using C-14		Taniguchi and Kawamura (1970)
a) Kuroshio Counter Current	a) *In situ* ----------------- b) Simulated *in situ* ----	0.16 g C $m^{-2} d^{-1}$ (0.44~0.45mg $Cm^{-3} hr^{-1}$)	
b) North Equatorial Current	a) *In situ* ---------------- b) Simulated *in situ* ---	0.08~0.09 g C $m^{-2} d^{-1}$ (0.07~0.28mg $Cm^{-3} hr^{-1}$)	
c) Equatorial Counter Current	a) *In situ* ---------------- b) Simulated *in situ* ----	0.19 g C $m^{-2} d^{-1}$ (0.07~0.58 mg $Cm^{-3} hr^{-1}$)	
d) South Equatorial Current	a) *In situ* ---------------- c) Simulated *in situ* ----	0.27~0.31 g C $m^{-2} d^{-1}$ (0.29~1.49 mg $Cm^{-3} hr^{-1}$)	
e) North Fiji Islands	a) *In situ* ---------------- b) S imulated *in situ* ---	- (0.12~0.61 mg $Cm^{-3} hr^{-1}$)	
Kuroshio and its adjacent area	C-14 incubation by using 3 different techniques as follows: a) *In situ* -------------- b) Simulated *in situ* – c) Water tank in ship laboratory	0.1~0.2 g C $m^{-2} d^{-1}$ in high sea areas 0.2~0.4 g C $m^{-2} d^{-1}$ in the coastal waters -	Saijo *et al.* (1970)
Off Western Philippines	Light-and-Dark Oxygen Bottle using light simulated incubation	0.10~1.53 g C $m^{-2} d^{-1}$	Present study

were recorded in these areas with light intensities ranging from 100.0 μmol photons $m^{-2} s^{-1}$ at 40-m depth to 5.16 μmol photons $m^{-2} s^{-1}$ at about 60~80-m depths. Such range of irradiance in the tub of seawater could probably be less saturated for phytoplankton cells to begin photosynthesis. Thus, the high levels of primary productivity probably indicate an actively photosynthesizing activity of phytoplankton under such light intensities in the area (Fig. 4a and c). At one instance, the condition of high light attenuation that was demonstrated at *in situ* observation for prevailing bright sunlight, clear sky, calm weather and vertical mixing. Vertical mixing is also important in regulating the availability of light for phytoplankton productivity. It enhances primary production by simultaneous downward diffusion of light attenuation throughout the mixed water column, which allow phytoplankton cells to use for photosynthesis [Day, Jr. *et al.* (1989)].

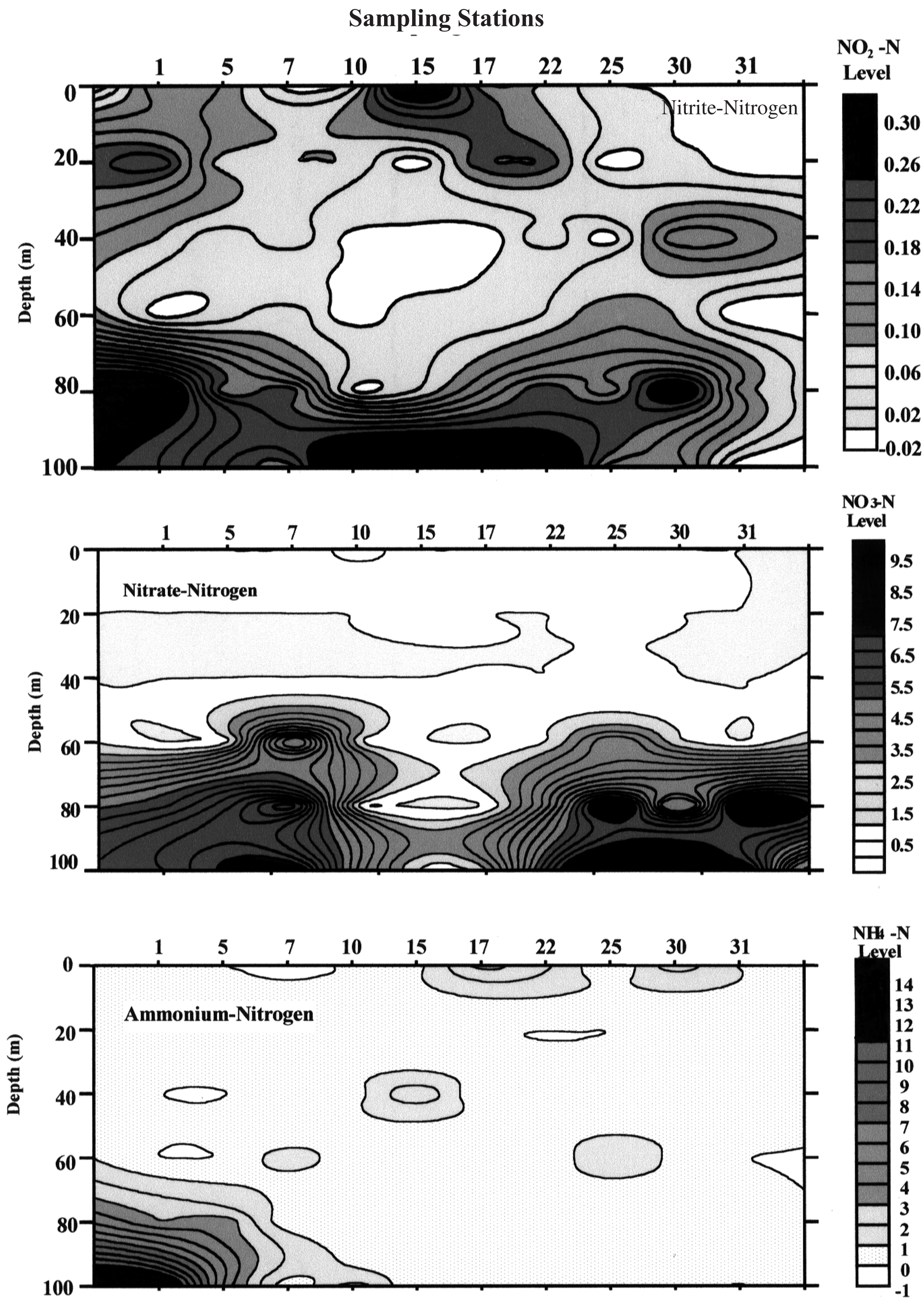

Fig. 5. Vertical profiles of nitrogen-ion (nitrite-, nitrate- and ammonium-) concentrations at various depths of different stations in the SCS, off Western Philippines (M/V *SEAFDEC*, Apr. 15-May 11, 1998).

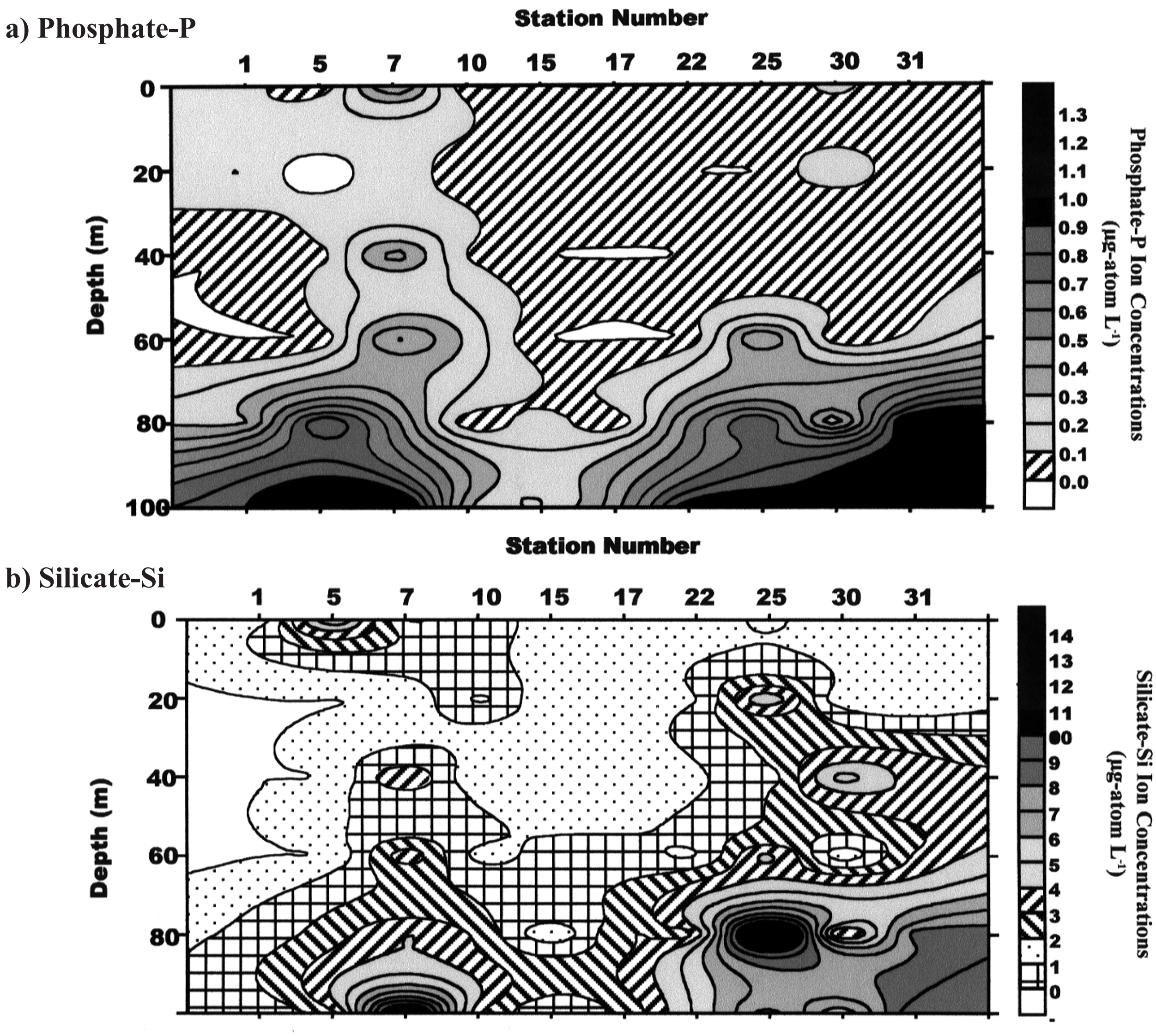

Fig. 6. Vertical profiles of phosphate- and silicate-ions concentration at various depths of different stations in the SCS, off Western Philippines (M/V *SEAFDEC*, Apr. 15-May 11, 1998).

The high net primary productivity values, which ranged from 0.21 to 1.53 g C m^{-2} d^{-1} at station 1 in the northwestern most part is associated with vertical mixing as noted by the homogeneous layer of cold water masses as indicated by 27.0°C ~ 28.0°C at the upper 60 m layer and a relatively low salinity concentrations which ranged from 33.90‰ to >34.00‰ (Figures 3c~d and 4a) in the area. The turbulent water circulation from the northeast side of the Pacific Ocean [Takenoute (1970)] causes the vertical mixing along the northwestern Luzon (station 1, 19° 59.2'N, 119° 58.7'E) that converged with the northward longitudinal current of the SCS during the month of April [O'Niel and Eason (1982] and [Wyrtki (1961)] had probably contributed also to the relatively high net primary production in the area. Likewise, during the month of May, the water circulation induced by the southwest monsoonal surface current from the Mindoro Strait and from the southern part of the SCS [Wyrtki (1961)] had probably contributed also to the relatively high net primary production at station 17 off Subic Bay, station 22 off the mouth of Manila Bay, station 25 off Mindoro Island, and stations 30 and 31 off Palawan. Unfortunately, data on water circulation pattern off the western Philippines was not obtained during the cruise and any further discussion on whether it affects the distribution of primary production in the area would be pure speculation. Consideration can also be given to the direct or indirect influence of vertical mixing to the nutrient enrichment (*viz.,* nitrite contents) throughout the water column of station 1 (Fig. 5, data taken from work of Montojo as part of this collaborative study), thereby enhancing phytoplankton productivity in the area [Oudot and Morin (1987)].

The amount of fluorescence in the water has been measured for an equivalent amount in lieu of chlorophyll contents of phytoplankton in marine areas. Fluorescence is a property closely associated with the chlorophyll molecule. Chlorophyll, like many other organic molecules, possesses the ability to fluoresce (Lorenzen, 1966). The results in this study revealed that there is no satisfactory explanation in relating the relative abundance and distributions of primary productions with degree of fluorescence and the number of phytoplankton cells in different stations (Figs. 4a & b). The amount of fluorescence is somewhat higher in the northwestern and central Luzon. Generally, fluorescence attributed to chlorophyll pigments of phytoplankton has no correlation with the distribution and abundance of primary production in the area. It could be noted that the high amounts of fluorescence spread between 40- and 100-m depths of stations 5 and 7 also coincided with the highest number of phytoplankton cells in the area (Figs. 4a & b, phytoplankton data was taken from the work of Bajarias as part of this collaborative study). This parameter do not affect, to any great extent, to the distribution of primary production in the area (Figures 4a & b). On the other hand, such peak in fluorescence and numbers of phytoplankton cells could probably be the effect of upwelling that was observed between stations 5 and 7 in the northwestern Luzon (Figs. 3a & b). Likewise, upwelling causes the rise of deeper water with relatively high nutrient (*viz.,* nitrate-, phosphate- and silicate-ions) levels from 100-m depth to about 50~60-m depths that probably support the phytoplankton abundance in these areas (Figs. 5 and 6). Bauerfeind (1986) and Ilahude (1978) stress the importance of upwelling on the hydrology, in general, and productivity, in particular, in tropical and equatorial waters also. Upwelling is a powerful, but complex, factor affecting productivity in marine areas. Results, however, have shown that the occurrence of upwelling in this area (between stations 5 and 7) yielded no direct links with primary productivity although both high amounts of fluorescence and number of phytoplankton cells at depths between 40- and 60-m depths showed linkage to the effect of upwelling.

To focus on probable factors that control primary production in the SCS, off western Philippines, detailed series of meteorological, hydrological and chemical measurements are needed. The difficulty in obtaining consistency in primary productivity measurements results, in part, from a very crude method of simulation experiments. In lieu of the most commonly used C-14 method, which was restricted during the survey, an on-board incubation experiment with the light-and-dark bottle oxygen method was used. The type of method and the considerations of other laboratory equipment and facilities (such as incubators with controllable temperatures and light source) are critical in obtaining accurate primary productivity measurements. Further study of the same objectives may help to refine our methodologies which may enable us to obtain accurate primary productivity measurement and to enable us to understand which invironmental factor will dominate/control their variable distribution in the area.

Acknowledgement

We wish to acknowledge the assistance we have received from a number of persons in the course of developing this paper and during the M/V *SEAFDEC* oceanographic cruise in the SCS, off Western Philippines: in particular, Dr. Anond Snidvongs, Chulalongkorn University, Thailand and Mr. Cielito L. Gonzales, Philippine Technical Coordinator for the collaborative research program who have helped us with technical advice; to our colleagues in BFAR's Oceanography Section, Mr. Juan Relox, Jr., and Mr. Ulysses Montojo who assisted in the collection of water samples. Gratitude is further expressed to the support of Steering Committee for giving us the opportunity to conduct this research work. The work was funded and carried out as part of the third SEAFDEC's collaborative research program in the South China Sea (SCS).

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Dissolved Nutrients in the South China Sea, Area III: Western Philippines

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ABSTRACT

This paper discusses the distribution of dissolved nutrients and the hydrology of the first 100 m depth of Western Philippines, South China Sea (SCS). The object of the study was to understand variations in the distribution of these parameters by comparing the results of the April-May 1998 survey to previous studies made in the SCS and the Pacific side of Philippine waters. Water samples at different sampling depths (surface, 20, 40, 60, 80 and 100 m) were collected from 31 oceanic stations, from 11º-20ºN and 117º-121ºE. Results of this study confirmed that the chemical and hydrological profiles in SCS were similar but the range of values obtained for different parameters were dependent on the seasonal and spatial variations. The higher average temperature observed relative to the previous summer data may be attributed to the El Niño phenomenon. The mixed layer was deeper compared to the NE monsoon data. Conversely, western and eastern Luzon waters demonstrated differences in hydrological profile, except for the surface temperature, which was almost similar to the 1967-68 Pacific waters summer data. Among the nutrients investigated, phosphate and nitrate demonstrated a direct relationship with temperature, salinity and dissolved oxygen, from the surface down to 100 m depth. The behavior of phosphate and nitrate can be evaluated in terms of their hydrological structure in contrast to the more reactive silicate and nitrite ions.

Key words: dissolved nutrients, hydrology, South China Sea, Western Luzon, Northwestern Palawan.

Introduction

Assessment of the nutrient regime of an aquatic system is the first step in understanding the fishery dynamics of the area. As defined by Furnas (1992) nutrients refers to the material currency of energy flow and structural form in a biological system. These include inorganic compounds of nitrogen (N, in the form of nitrite and nitrate ion), phosphorous (P in the form of phosphate ion) and to a lesser degree, silicon (Si, in the form of silicate ion).

Dissolved nutrients are of prime interest because they are synthesized and utilized by phytoplankton in the aquatic community. N and P, in particular, are involved in soft tissue formation (e.g., synthesizers of ATP and cell membrane), while silicon on the other hand, is a hard tissue builder (e.g., enhances the bloom of silicoflagellates and diatoms) [Sommer (1994)].

The survey area covered part of the Philippines' Exclusive Economic Zone (EEZ) and the South China Sea (SCS). The whole area is a part of the Southeast Asian (SEA) Seas that contribute almost 11 % of the world's marine catch [Weidenbach and Lindenfelsen (1983)]. The region's richness in marine fisheries is due to its favorable physical and chemical characteristics [Weidenbach and Lindenfelsen (1983)].

There were several investigations carried out in the past regarding hydrological and nutrient concentrations of the area and its adjacent waters. [Wrytki (1961), Watts (1970), Uda et al. (1972), Han (1982), Zhiging et al. (1983), Law et al. (1987), Saleh et al. (1986), Toshihiro et al. (1987) and Gong et al. (1992)].

The purpose of this paper is to provide an update on the spatial distribution of nutrients, as well as their relationship to some of the hydrological parameters (e.g., dissolved oxygen (D.O.), salinity (S) and temperature (o), and to compare the data with previous investigations done in the area and the Pacific waters of the Philippines.

Methods

An oceanographic survey was conducted in the South China Sea, Area III (western Philippines) using the research vessel MV SEAFDEC in April and May 1998 occupying 31 survey stations [Fig. 1].

Salinity, D.O and temperature, were measured at 1 m intervals at every station using a CTD-Rosette (Falmouth Scientific Instrument). Niskin bottles of 2.5 l capacity (General Oceanics Inc.) attached to a Rosette sampler were used in the sample collection. Samples were taken at 20

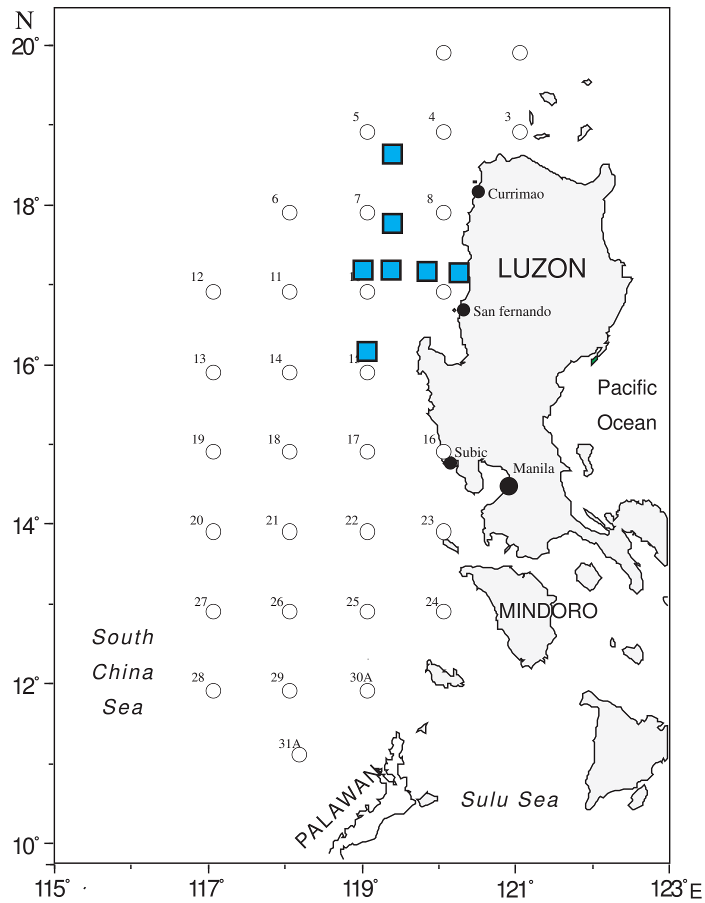

Fig. 1. The oceanographic and sampling locations for nutrients in the Western Philippines, SCS from April 18 – May 4, 1998. (■) refers to stations surveyed in December 16-30, 1990.

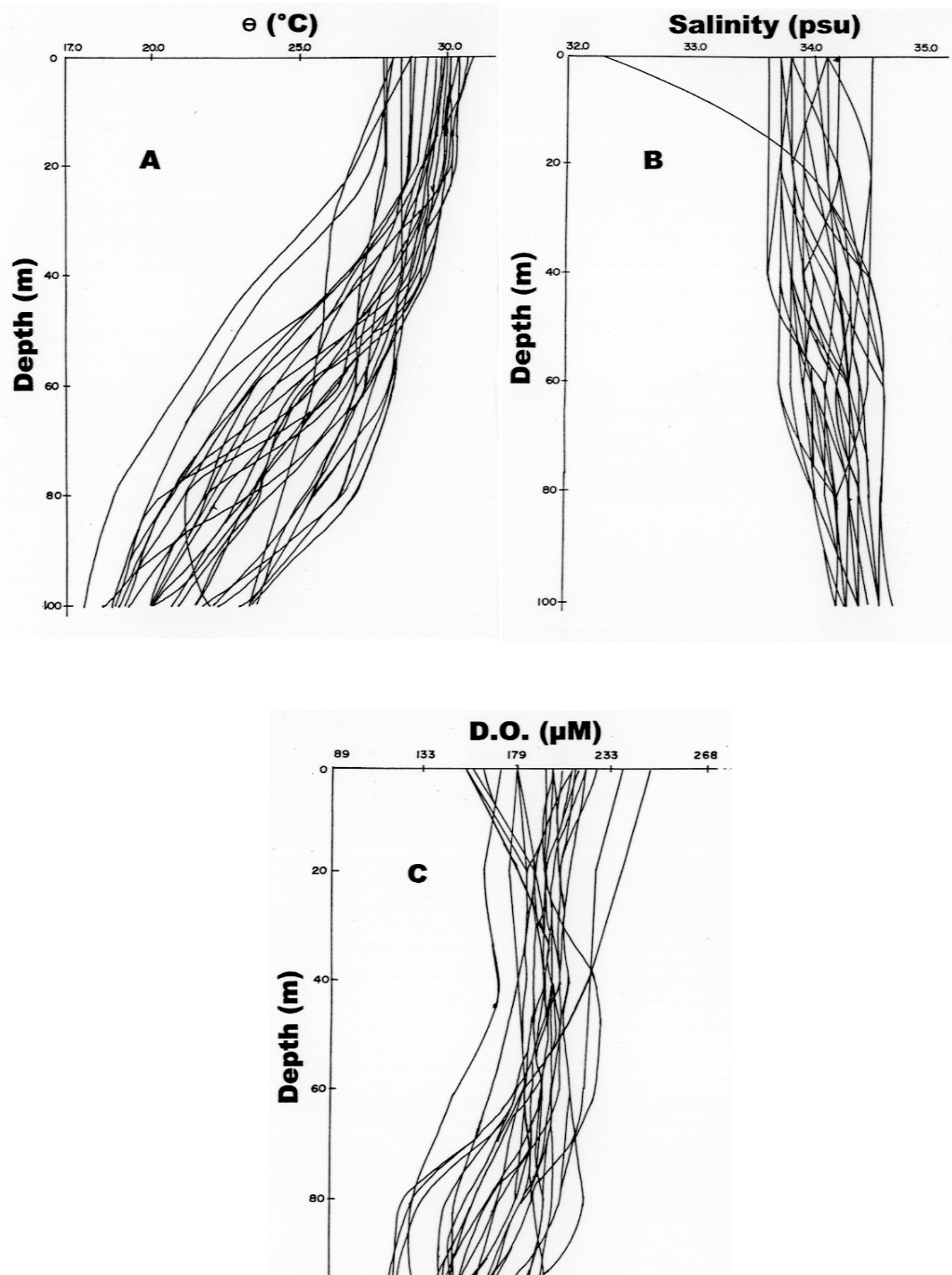

Fig. 2. Vertical profiles of (A) temperature, (B) salinity and (C) D.O. in Western Philippines, SCS from surface to 100 m depth.

m intervals from the surface down to 100 m.

Subsamples of 125 ml each were pressure filtered (< 1.0 atm) through Whatman GF/F glass fiber filters (nominal pore size: 0.7 µm) into previously acid-cleaned polyethylene tubes for dissolved nitrate, nitrite, phosphate and silicate determinations. Sample containers were rinsed twice with sample water before filling them with 125 ml of the subsample. Samples to be used for analysis were double packed with plastic bags and were frozen [IOC Manual Guide (1993)].

Nutrient analyses were undertaken using the standard colorimetric methods [Parsons and Strickland (1972)] at the Bureau of Fisheries and Aquatic Resources (BFAR) ocean laboratory in Manila. Isopleths and line graphs of nutrient concentration, temperature, D.O. and salinity at stations along 6 depths (20 m interval) were drawn. Comparative charts and scatter diagrams were plotted to illustrate the interrelations among the parameters under investigation. Statistical computations were done using the Strategic Application Software (SAS). ‘

Results

The concentrations of four nutrient parameters from the surface down to 100 m depth were as follows: nil-10.50 µM for NO3-N; nil-0.33 µM for NO2-N; nil-1.40 µM for PO4-P; and nil-38.00 µM for SiO3-Si.

Both the nutrient’s horizontal and vertical profiles showed variations in their spatial distribution in the water column. Isolines clearly showed the concentration variations in the area, particularly in the northwestern Luzon and Mindoro Strait.

Hydrological Profile

Fig. 2A-C shows the vertical profiles of θ, S and D.O. in the first 100 m. The hydrological structure showed that the mixed layer was from 10 to 60 m in the survey area although according to Gong et al. (1992) it was at 15 to 30 m in December 1990. Vertical profiles of temperature demonstrated uniformity in the surface layer (s.d.: ±0.85), and greater variations at subsurface layers, particularly at 80 m, wherein the standard deviation (s.d.) was at its maximum value of ±2.18. Of all the locations surveyed, water temperature was generally lower at the entrance of Luzon Strait.

Except for Station 16, which is located 3 nautical miles from the Zambales coastline, salinity was more or less the same in the entire 100 m depth. The observed maximum salinity value range was less than 1 psu, whereas the s.d. value from the surface to 100 m depth ranged from ±0.12 to ±0.35 .

The D.O. profile was almost similar in all stations. The oxygen minimum concentration was recorded at 40 m depth with mean and s.d. values of 198.66±0.24 µM while maximum variations were located at 80 m depth with mean and s.d. values of 175.89 µM and ±0.55 µM, respectively. This variation in D.O. level was observed at northwestern Luzon and west of Mindoro Island.

The horizontal profiles in Fig. 3 illustrates a minimum surface water temperature that prevailed over the water mass at 15°N, 120°E and 18°-20°N, 119°E . This trend persisted up to 20 m with a slight increase in s.d. and mean value of ±0.94 and 29.18 °C. A warm tongue-like water mass was found at 40 m depth, 16° to 17°N, 119°E. The cooler water mass from the north converged with the relatively warmer waters that came from the outer zone extending downward at 12°N. The average water temperature for this layer was at 27.73±1.39 °C. At 60 m depth, the average water temperature was slightly lower at 25.40±1.97 °C with a warmer water mass now located at 15°-16°N, 117°E while cooler water mass still persisted at 18°N, 119°E. At 80 m

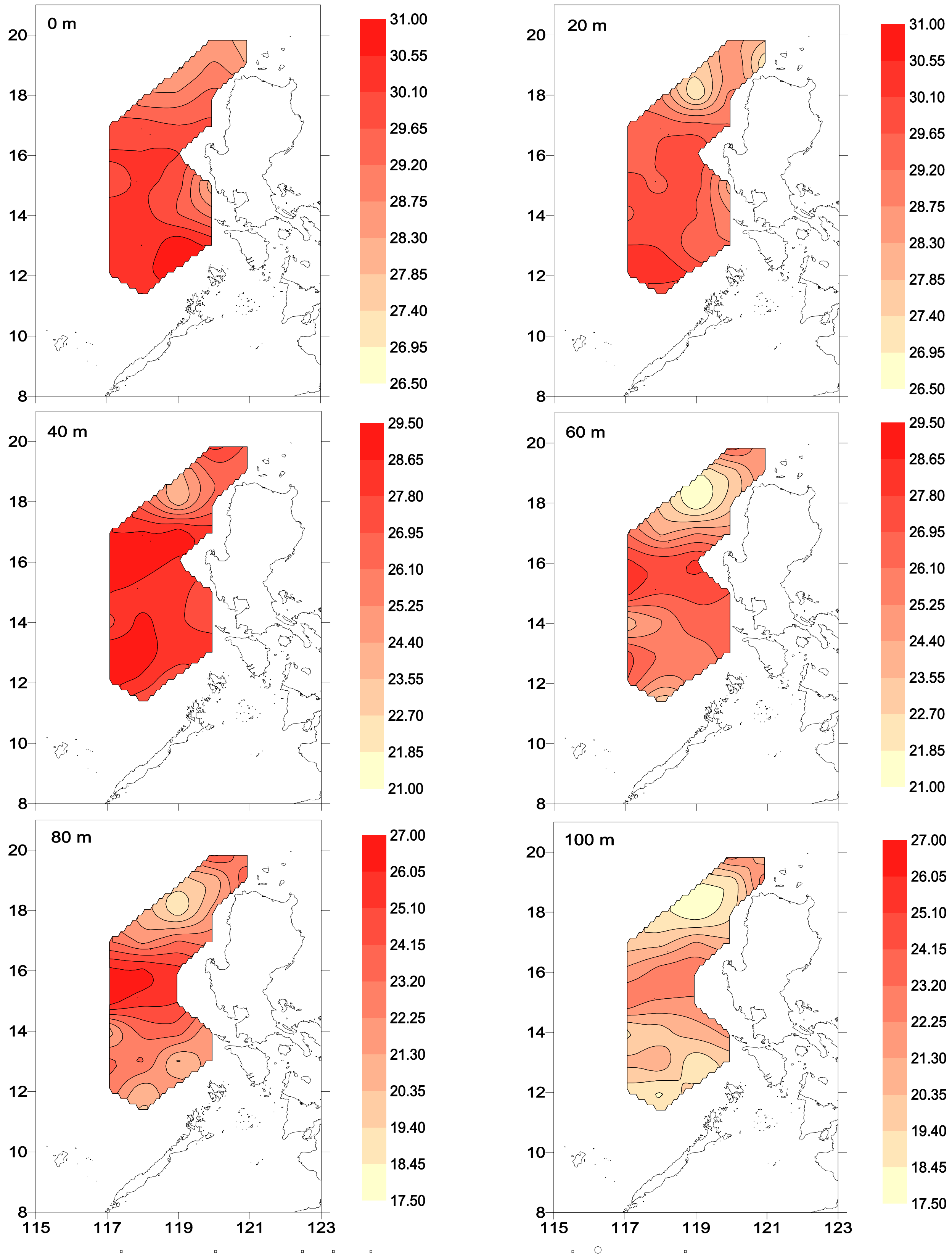

Fig. 3. Horizontal distribution of temperature in °C at various depths.

depth where the highest variation was recorded, moderately higher temperature continued to persist off Zambales coast with mean value of 22.76 °C in this water layer, while at 100 m depth, cooler water mass prevailed over the entire survey area (mean: 20.42 and s.d. ±1.72 °C).

The horizontal salinity profile shown in Fig. 4 demonstrated the surface water as an almost homogenous water mass (33.90±0.35 psu), except for slightly more saline water near the entrance of Luzon Strait and the Sulu Sea. At 20 m depth, the slightly saline condition of the water mass continued to prevail over northwestern Luzon up to 17°N and Mindoro Strait, with an average salinity of 33.97±0.23 psu. However, salinity level increased with an average value of 34.09±0.28 psu at 40 m depth. In this layer, water masses from outer zones converged with the lower salinity water mass off Lingayen Gulf, and the more saline water mass from the Sulu Sea. The same higher salinity level existed at 60 m depth (34.29±0.24 psu) situated over northwestern Luzon and northern Palawan and encompassed by a less saline water mass located, off Zambales and Pangasinan coasts. Water at 80 and 100 m had salinity that was almost uniform with mean values at 34.42±0.18 and 34.54±. 0.12 psu, respectively.

Fig. 5 shows the horizontal profile of D.O. at various depths. Generally, higher values were observed at the surface (198.66±45 µM), with maximum values at 13°N, 118°E and 11°N, 118°E. Lower concentrations were observed over the water mass originating from the north (17°-18°N, 119°-120°E), Zambales coast (15°N, 120°E) and at 14°N, 117°E. The trend persisted in different locations up to 20 m depth with a slightly lower mean value of 196.43±0.29 µM. There was a minimal increase of subsurface concentration of D.O. at 40 m depth with the maximum level observed at 12°-13°N, 118°-119°E. At 60 m depth, lower values persisted at 14°N, 117°E, and at 17°-18°N, 118°-119°E, a relatively higher concentration was evident at 13°N, 118°E. In this layer, the recorded mean value of 194.20±0.32 µM. At 80 m depth, significant reduction in D.O. level was established with an average of 175.89±0.55 µM. Similar to the shallower layers, low D.O. concentrations continued to persist at 14°, 117°E, 12°N, 118°E and 18°N, 118°E while higher concentrations were evident at northern Palawan, off central Luzon and Balintang Channel. There was a continuous reduction of D.O. level (mean : 153.12±0.50 µM), at 100 m depth .

Nutrient Profiles

Figs. 6A-D shows the vertical profile of NO_3-N, NO_2-N, PO_4-P and SiO_3-Si. Except for nitrite, the three nutrients demonstrated abrupt increases in concentration below the mixed layer. The homogeneous water mass was almost devoid of nutrients particularly with nitrate, nitrite and phosphate. Of the 31 stations surveyed, nitrate values can be grouped into four sets namely: stations with significant increase at 60 m, 80 m, 100 m and those with insignificant changes in concentration level. Phosphate profiles were similar to nitrate, except in Station 7. Silicate, on the other hand, showed a localized increased in concentration at various depths in different stations. The maximum increase in concentration was noted in stations located near Luzon Strait and the Sulu Sea entrance.

The horizontal profiles of nitrate in Fig. 7 show the surface water to have a relatively low nitrate concentration (range 0.84, mean: 0.11 µM). However, this nutrient was present at offshore waters (117°-118°E, 14°- 15°N) and near the Zambales coast, while below detection limit for the rest of the stations. Nitrate was also prevalent at 20 m off Cape Bolinao (16°N, 119°E) and near the entrance of Manila Bay (Station 23), but practically nil value was observed from 17° to 20°N latitude. It was also present at 40 m along the latitudinal zones (13°, 14°N), perpendicular to Manila Bay, followed by an abrupt increase in concentration on the northwestern Luzon at 60 m (range: 6.85, mean: 0.64 µM). Waters coming from Sulu Sea was observed to have a relatively

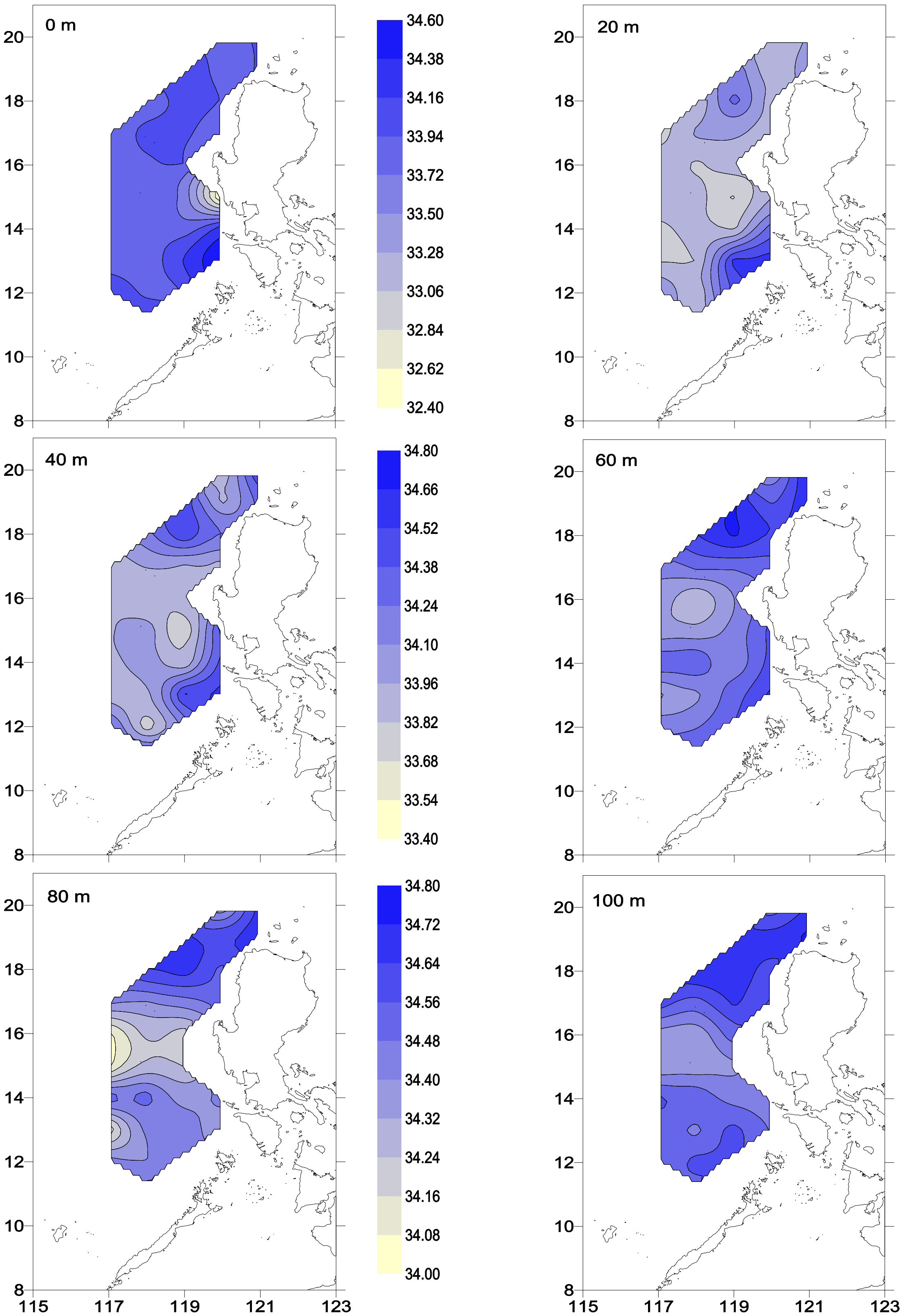

Fig. 4. Horizontal distribution of salinity in psu at various depths.

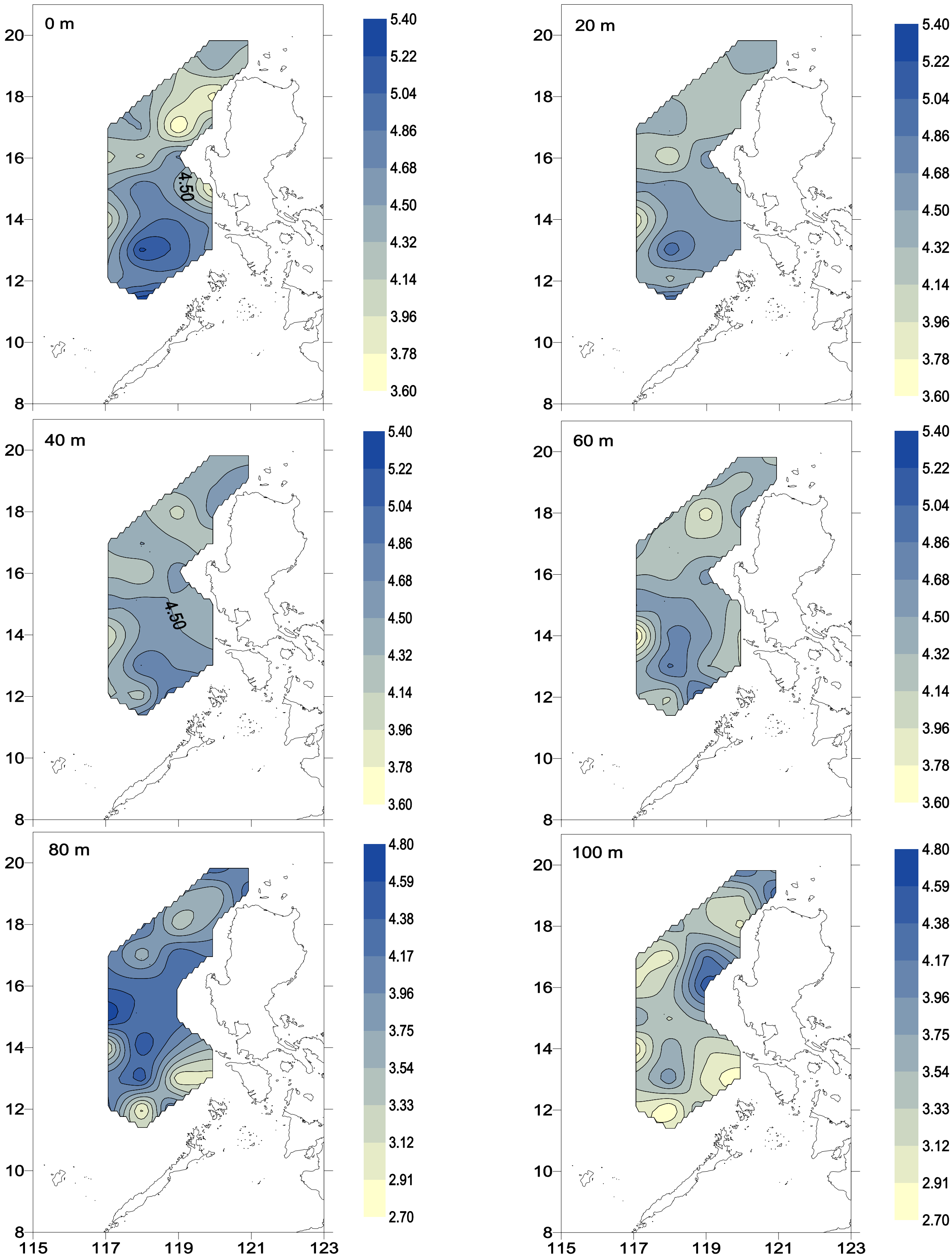

Fig. 5. Horizontal distribution of D.O. in µM at various depths.

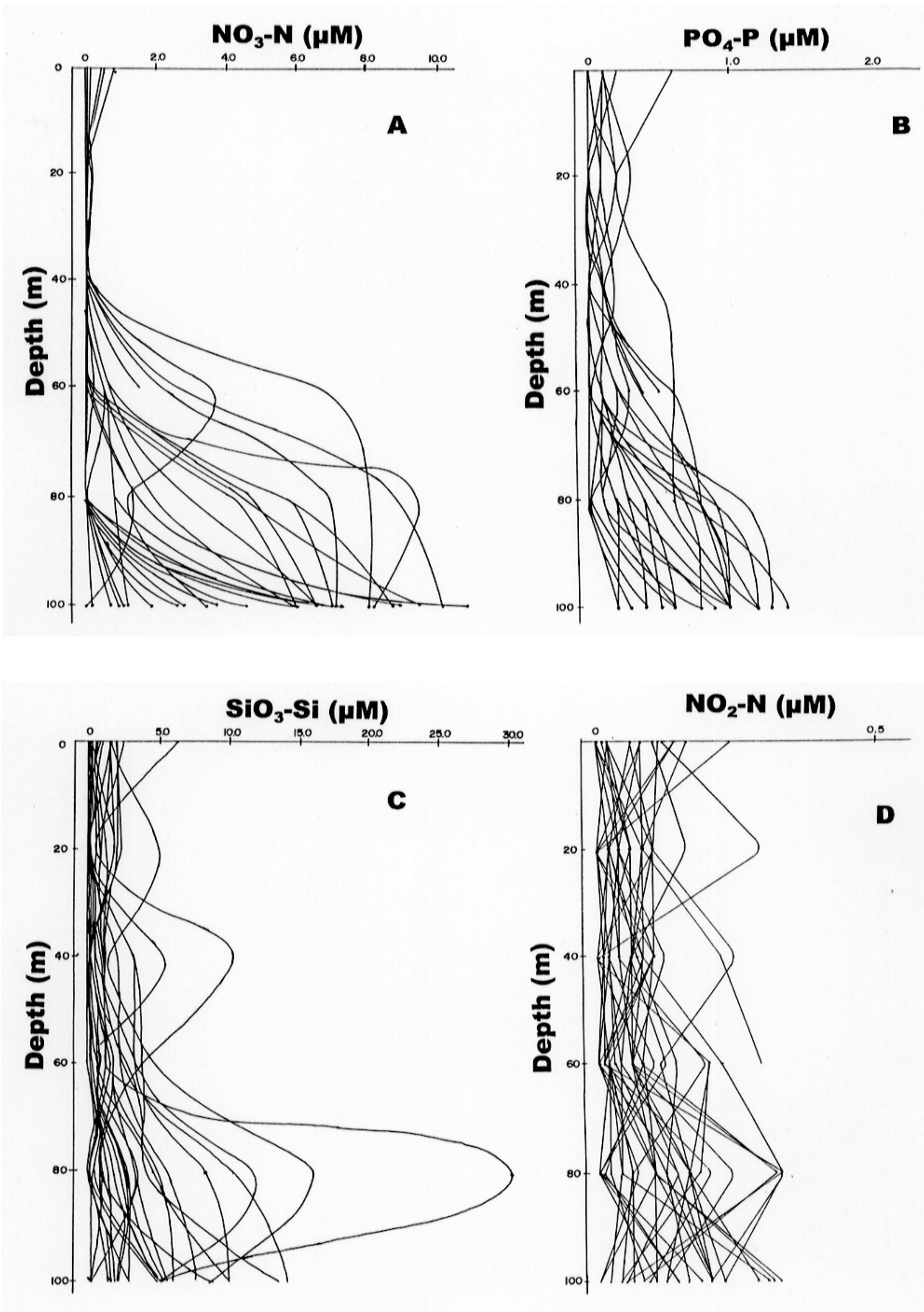

Fig. 6. Vertical profiles of (A) NO_3-N, (B) NO_2-N, (C) PO_4-P and (D) SiO_3-Si in Western Philippines.

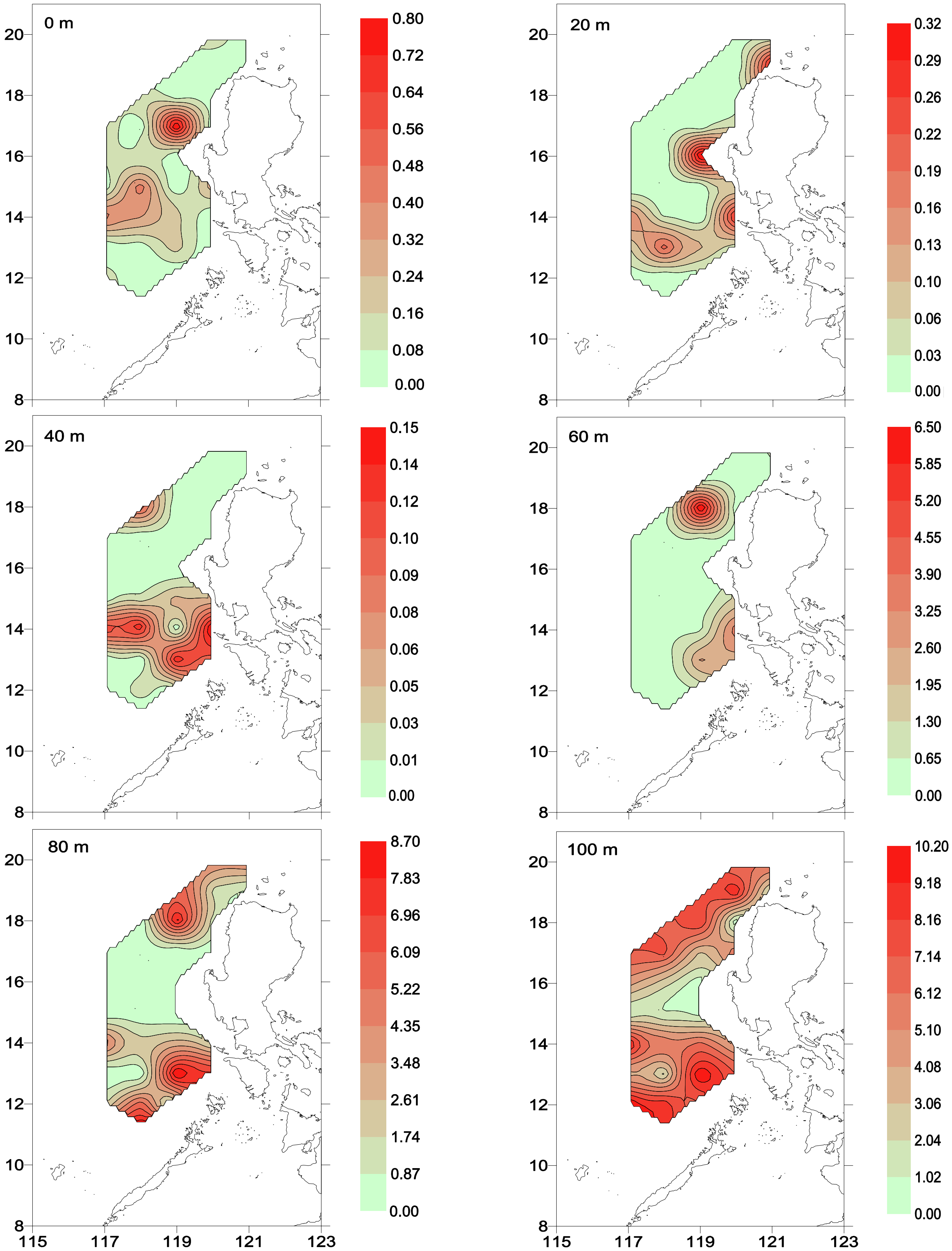

Fig.7. Horizontal distribution of NO_3-N in µM at various depths.

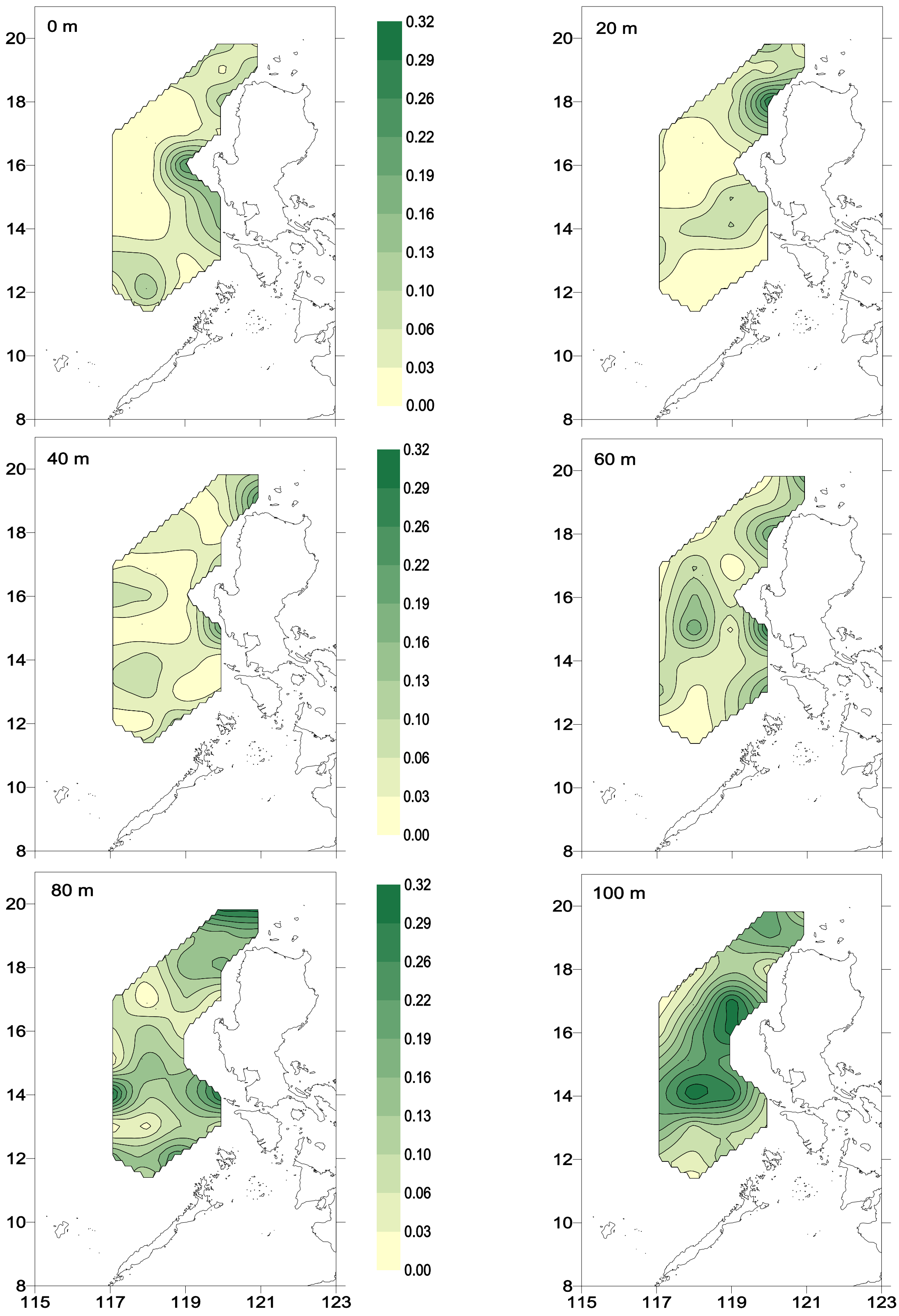

Fig. 8. Horizontal distribution of NO_2-N in μM at various depths.

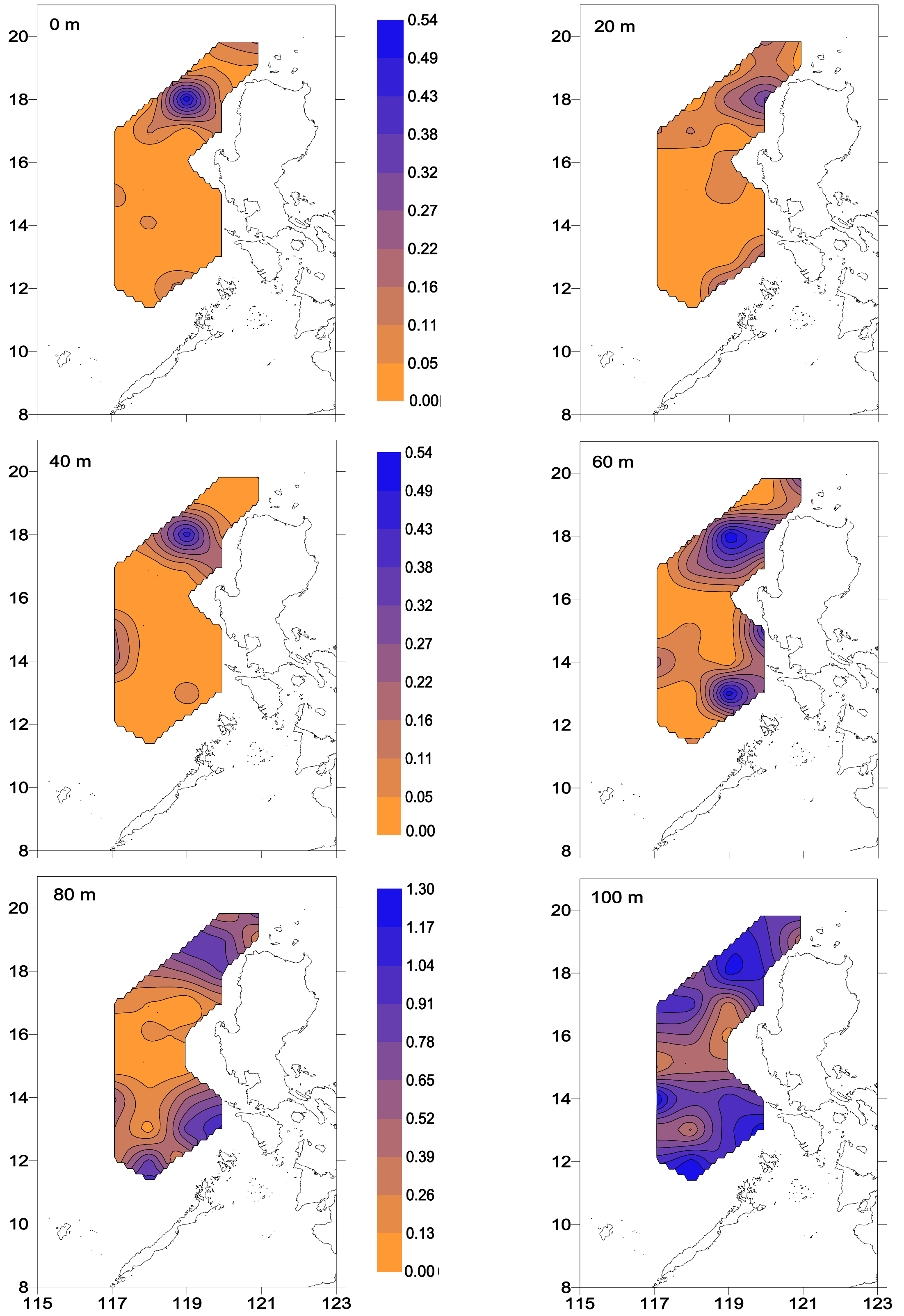

Fig. 9. Horizontal distribution of PO_4-P in µM at various depths.

higher in nitrates. Consequently, the 80 m depth, nitrate-rich northwest excursion from Sulu Sea and Luzon Strait continued to persist (range: 8.96, mean: 2.32 µM), while the middle part of this layer (15° to 17°N, 117° to 120°E) has a concentration below detection limit for said nutrient. At 100 m depth, dissolved nitrate had a mean value of 5.15 µM and a range of 10.32 µM.

Nitrite ion [Fig. 8] was almost uniformly distributed from the surface up to 100 m depth. In the surface layer, dissolved nitrite near the shore area had a range of 0.24 µM and a mean of 0.05 µM. At 40 m depth, it had only minimal values in all the stations surveyed (range: 0.25, mean: 0.03 µM). The range and mean nitrite values at various depths were as follows: 0.30 and 0.06 µM at 20 m, 0.22 and 0.07 µM at 60 m, 0.33 and 0.13 µM at 80 m and 0.32 and 0.14 µM at 100 m depth.

Similar to nitrate, phosphate ion concentrations, as shown in Fig. 9, were relatively higher in the water mass off northwestern Luzon at all depths investigated while the rest of the stations in the surface layer, 20 m, and 40 m depths were almost devoid of this nutrient. The range and mean values obtained were: 0.55 and 0.05 µM at the surface, 0.34 and 0.06 µM at 20 m depth, and 0.48 and 0.05 µM at 40 m depth. Phosphate concentrations significantly increased at 60 m depth (range: 0.55, mean: 0.12 µM) with three diverging zones, 18°N, 119°E, at 14°N, 117°E and 13°N, 119°E, respectively. Moreover, at 80 and 100 m depth, the phosphate concentration continued to increase with maximum values of 1.08 and 1.40 µM and mean values of 0.42 and 0.82 µM, respectively.

Fig.10 shows dissolved silicate profiles in the study area. Surface layer water mass demonstrated relatively high values (range: 6.31, mean: 0.72 µM), particularly at 19°N, 119°E extending longitudinally southward up to 15°N, converging with water mass containing minimum silicate from the center and at 13°N, 119°E as well as at 14°N, 117°E. The same trend was observed at 20 m depth, specifically, at the northwestern part of Mindoro Island and nearshore of northwestern Luzon (range: 5.04, mean: 0.67 µM). Meanwhile, at 40 m depth, silicate levels in areas off northwestern Luzon and the Sulu Sea entrance remained higher (range: 1.35, mean: 1.20 µM). At 60 m, silicate–rich water (range: 4.65, mean: 1.34 µM) were observed (15°N, 119°E and 117°E, 14°N together with 16°N-18°N, 119°E). At deeper waters, silicate level significantly increased with range and mean values of 38.85 and 4.43 µM at 80 m depth, and 14.19 and 5.04 µM at 100 m depth respectively.

Figs. 11-15 shows the average nutrient as well as the hydrological profiles (continuous line) of the 1998 survey compared to the data from the previous investigations of Gong et al. (1992) and Watts, (1970). The first was the result of the oceanographic cruise in the SCS on December 1990, while the later data were obtained from 19° to 20°N and 113° to 116°E during the summer of 1967-68 [Watts (1970)].

θ - Nutrient Relationship

Fig. 11A-D shows the nutrient concentration as a function of temperature. In Fig. 11A, nitrate results in the 1998 survey obtained minimal values of ≤ 0.05 µM from 31°C to 27.0°C. An inverse relationship was observed below this temperature as both previous data demonstrated a significant increase in nitrate concentration as temperature decreases. At initial temperature range, no correlation was established by Watt while the same temperature range was absent in the water mass investigated by Gong et al. (1992). But for the 1990 northeast monsoon data, a very high concentration gradient from 27° to 24.5 °C, from this point until 17 °C, minimum change in concentration was observed.

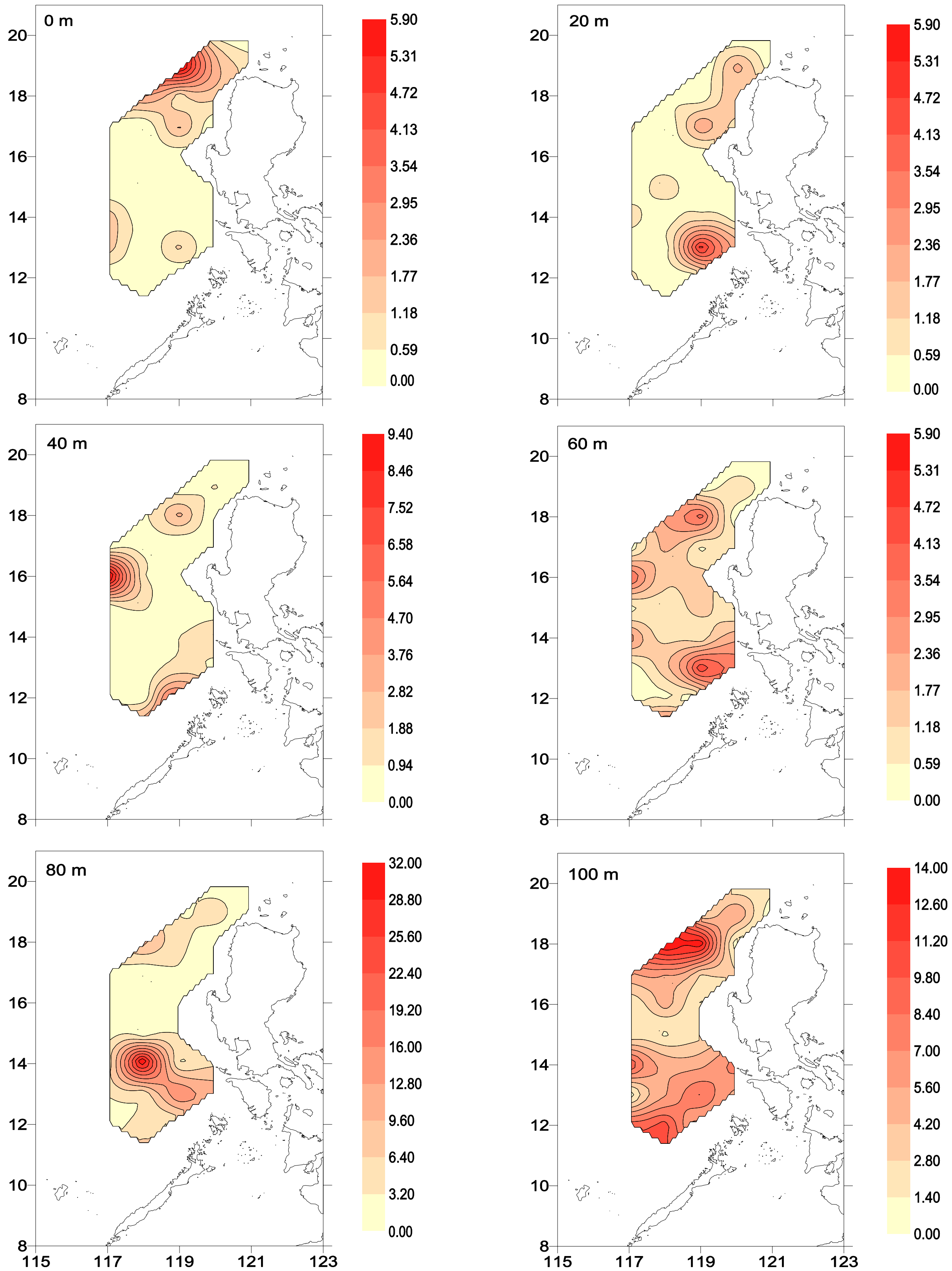

Fig. 10. Horizontal distribution of SiO_3-Si in μM at various depths.

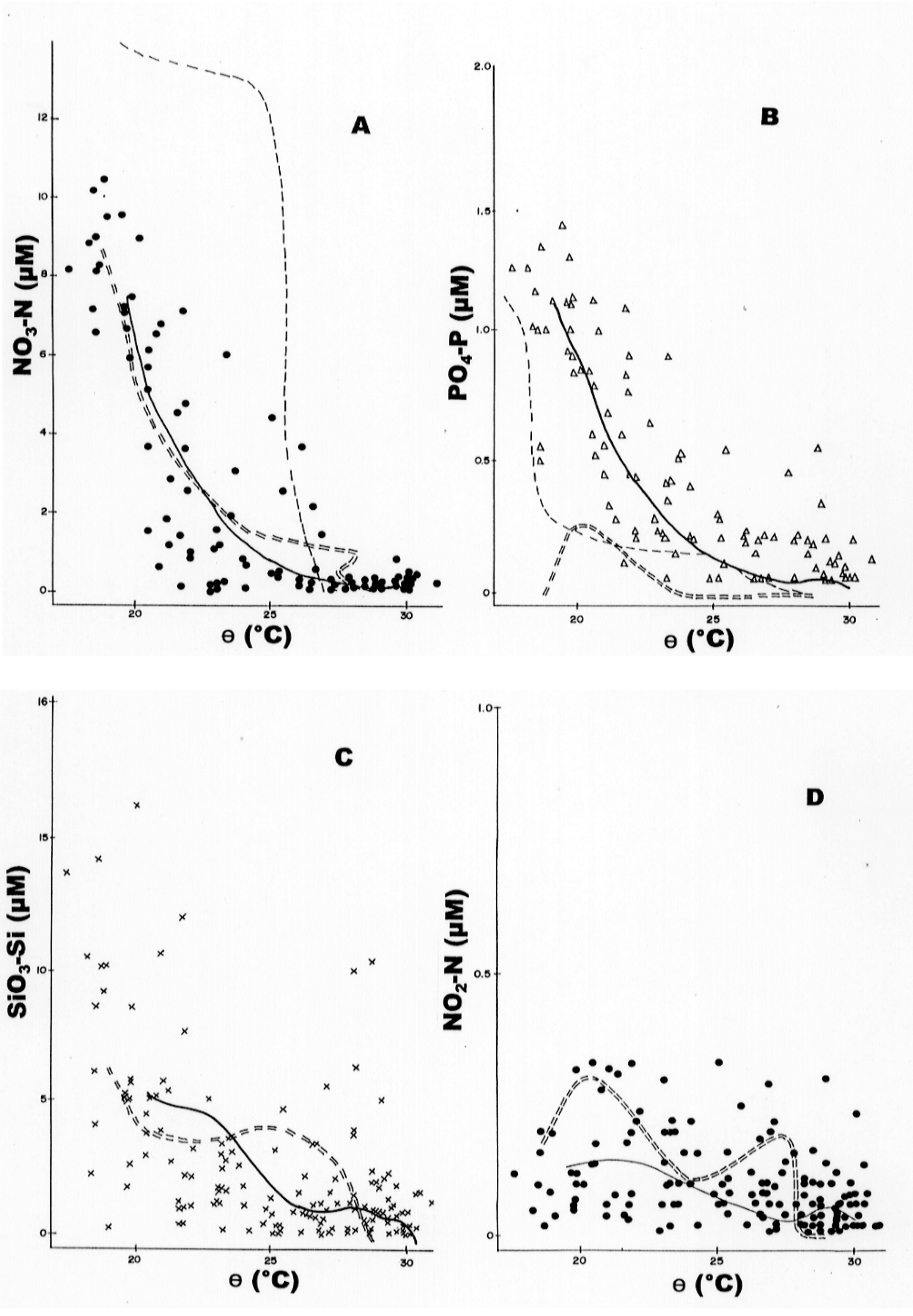

Fig. 11. Comparative profiles of o-nutrient relationships: (A) θ- NO_3-N, (B) θ-PO_4-P, (C) θ-SiO_3-Si and (D) θ-NO_2-N. (—) refer to 1998 summer average result, (- -) refer to December 1990 and (= =) for summer of 1967-68.

The θ - phosphate relationship in Fig. 11B shows a relation that is inversely proportional. This trend was similar to what Gong et al. (1992) established in the 1990 data.

The θ - silicate relationship [Fig. 11C] shows a multi-modal peak for both lines presented. This profile demonstrated an absence of a direct relationship for this nutrient with temperature in the first 100 m depth. The θ-nitrite plot in Figure 11D followed the same trend.

Salinity-Nutrient Relation

Fig.12a-d shows salinity as a function of nutrient concentration. The nitrate profile [Fig. 12A) shows a similar line structure for the three surveys, except for the summer data, wherein a minor peak was evident in nitrate concentration of <1.0 μM at corresponding salinity values of 33.7 to 34.0 psu. Gong et al. (1992) obtained relatively higher nitrate concentrations at this salinity range. A similar increase in concentration (from 1.0 μM and above) was observed at 33.75 psu (NE monsoon) and 34.58 psu (summer data).

The 1998 and 1990 surveys show similar salinity-phosphate profile [Fig.12B], while the 1967-68 results demonstrated an almost nil value at 34.5 psu.

For salinity and silicate relationship [Figure 12C], a lesser degree of association was obtained based on the two summer results, but in general, the concentration of silicate ion increased with salinity. The nitrite-salinity profile [Figure 12D] shows an almost insignificant correlation.

D.O.-Nutrient Relationship

D.O.-nitrate relationship in Fig.13A, shows a nearly uniform initial concentration of nitrate (≤05 μM) at 192.0 to 205.0 μM of D.O. in all the three surveys conducted. The present average data demonstrated a constant increase in nitrate concentration with decreasing D.O. level. The December 1990 data showed significant increase in nitrate concentration at 205.0 μM in relation to a much lower D.O. level of 174.0 μM. Watts (1970) obtained no trend for NO3-N concentration at a relatively higher D.O. level (190 to 205 μM). Lower than this value a constant increase in nitrate concentration was observed.

The D.O.-phosphate plot [Fig. 13B] was almost similar to nitrate. There was a uniform increase in phosphate level with decreasing D.O. level. There was a single-broken line that shows a curvilinear behavior contrary to the data obtained by Watts (1990) with almost no relationship.

Based on the silicate and nitrite-D.O. graph [Fig. 13C-D], both nutrients showed no direct correlation in the two studies made. However, silicate concentration generally increased with depth.

Discussion

SEAFDEC's 1998 survey of the Western Philippines, SCS, established similarities in the physico-chemical profile but also demonstrated differences in seasonal and spatial values relative to the previous studies conducted.

Figs.14A-D shows the comparative profile of temperature, salinity and D.O in different occasions in the SCS and the eastern Philippine waters. The temperature profile [Figure 14A] of SCS showed parallelism compared to the Pacific side with average values that were generally higher compared to previous results. Only at 40 and 100 m depths , the results obtained by Watts (1970), were close to the average values and were within the s.d. range of the present study. The profile obtained in the first 40 m depth was almost similar with the eastern Philippines'

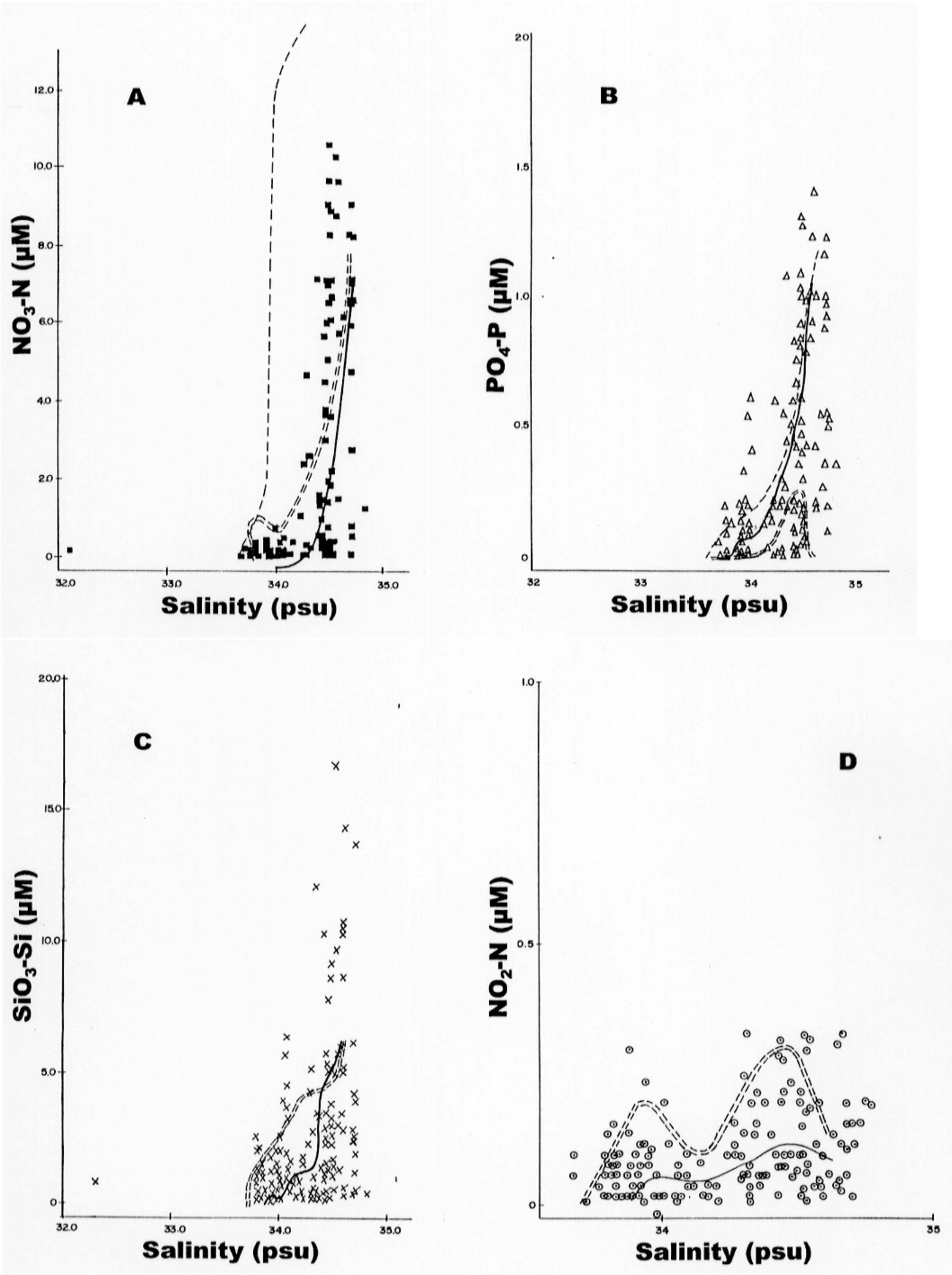

Fig. 12. Comparative profiles of S-nutrient relationships: (A) S-NO_3-N, (B) S-PO_4-P, (C) S-SiO_3-Si and (D) NO_2-N. (—) refer to 1998 summer average results, (- -) refer to December 1990 and (= =) for summer of 1967-68.

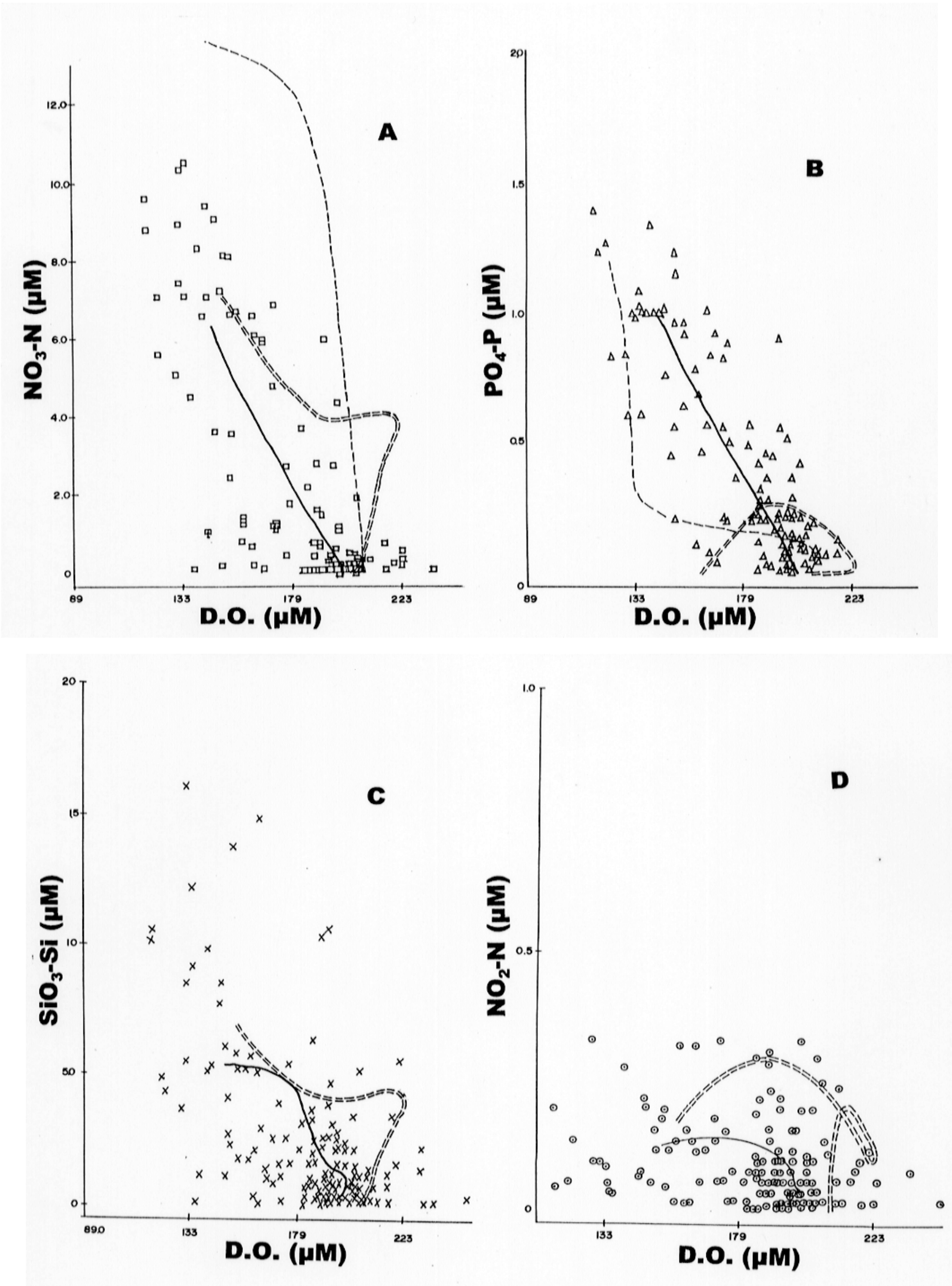

Fig. 13. Comparative profiles of D.O.-nutrient relationships: (A) D.O.-NO_3-N, (B) D.O.-PO_4-P, (C) D.O.-SiO_3-Si and (D) D.O.-NO_2-N. (—) refer to 1998 summer average results, (- -) refer to December 1990 and (= =) for summer of 1967-68.

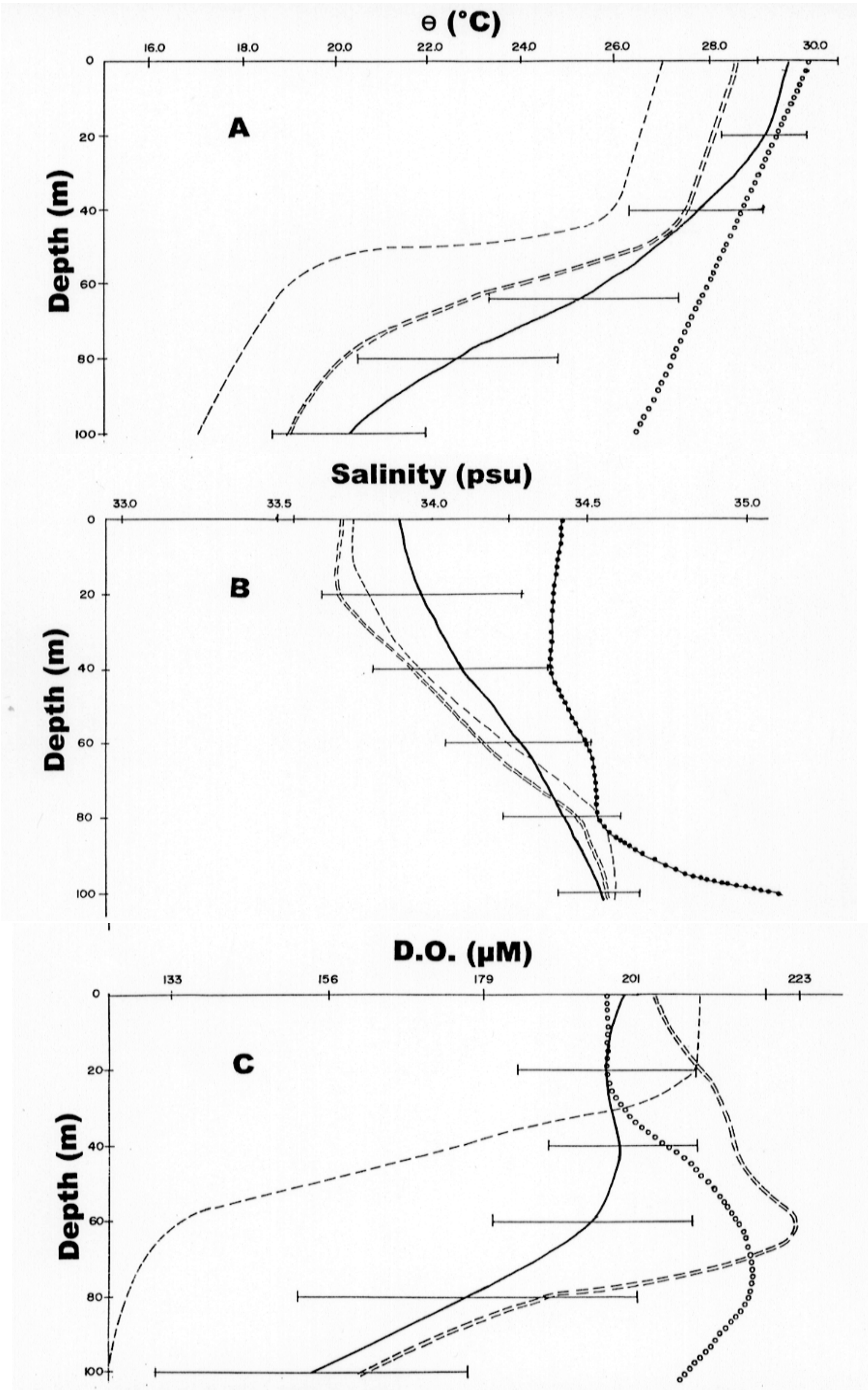

Fig. 14. The vertical profiles of (A) θ, (B) S and (C) D.O. in different occasions. (—) refer to 1998 summer average results, (- -) refer to December 1990, (= =) refer to summer 1967-68 and (….) refer to Eastern Luzon Waters. The horizontal bars represent the s.d. range of the latest data.

temperature structure from 10° to 20°N Manansala (1970). The higher temperature values obtained in the latest survey as compared to historical data being considered in this study was probably due to the global warming brought about by the 1998 El Niño phenomenon as well as a reflection of local and seasonal variations [(Gong et al. (1992)].

Salinity [Fig. 14B] on the other hand, demonstrated a slight variation but were still within the range of values of the SCS data. However, the SCS profiles were different compared to the more saline Pacific waters. During the survey, the higher salinity level of the surface water may be due to higher evaporation rate in the area during the summer season [Wyrtki (1961)]. Gong et al. (1992) suggested that there was no significant surface water mass intrusion coming from the Pacific Ocean due to extreme values in salinity.

For D.O. [Fig. 14C], average values at the first 20 meters were almost similar; however, there were significant differences observed below this depth level. There was reduction in D.O. level along SCS at lower depths compared with the Pacific profile. These difference at the subsurface layers can be due to subsurface water currents as reported by Watts (1970).

The nutrient levels in the area were also quantified and compared to previous studies [Fig.15]. The nitrate and phosphate data demonstrated similar trends while the point for comparison for nitrite and silicate profile cannot be established except with depth. The profile of nutrients particularly for N and P in the first 100 m depth was a function of the mixed layer in which abrupt increased in concentration was observed, usually from 10 to 60 m depth. Except for P, the 1998 cruise obtained the lowest stocks of nutrients in the area.

The tropical oceanic waters such as the SCS generally have a deficiency in nutrients especially during summer time [Furnas ,1992]. This concept was demonstrated clearly by the present results in comparison with Gong et al, (1992), who made the survey during the northeast monsoon. The latter survey obtained a significant level of nitrate at shallower mixed layer compared to the present and 1967-68 summer data. Nitrite and silicate ions increased with depth but no specific trends were obtained [Fig. 15C-D].

In comparison to other studies, Zhiging and Feiyong (1983) reported that the central waters of SCS (110°-118°E, 12°-15°N) demonstrated a tropical behavior [Furnas, (1992]. The horizontal distribution of dissolved Si and P were more or less uniform, with decreasing trends in concentration from SE to NW. The vertical profile on the other hand, from surface down to 1000 m depth was similar to that of the Pacific Ocean. The range was from nil to 3.1 µM for P and nil to 182.14 µM for Si. There were higher values at 100 m and 1000 m with homogenous water mass beyond 1000 m depth [Han (1982)].

In the southwestern part of SCS, values obtained [Toshihiro et al., 1987] for nitrate and nitrite were generally lower in comparison with the current results. P on the other hand, was higher compared to the present value. In Sarawak waters [Saleh et al. (1986)], the average nitrate concentration was 200 % greater than the present values and nitrate was slightly higher at 0.37 µM. Further SW in western peninsular Thailand (97°E, 9°N), both N and P values were lower compared to Area III, with nitrite registered a nil value [Limpsaicol (1978)].

Horizontal distribution of nutrients showed a relatively higher concentration which was evident off northwestern Luzon (17°-20°N, 118°-120°E) and off western Mindoro Is (12°-14°N, 117°-120°E). This phenomenon was attributed to the seasonal oceanic regimes typical in tropical areas like the South China Sea. In the first location, there was significant level of nutrients through eddy formation caused by the turbulence from the Pacific Ocean in the north [Takenoute (1970)] and converging with the northward longitudinal current of the SCS [O'Niel and Eason (1982)] during the month of April. O'Neil and Eason (1982) further discussed that in the month of May, this concurrent water mass displacement from Mindoro Strait as well as from the

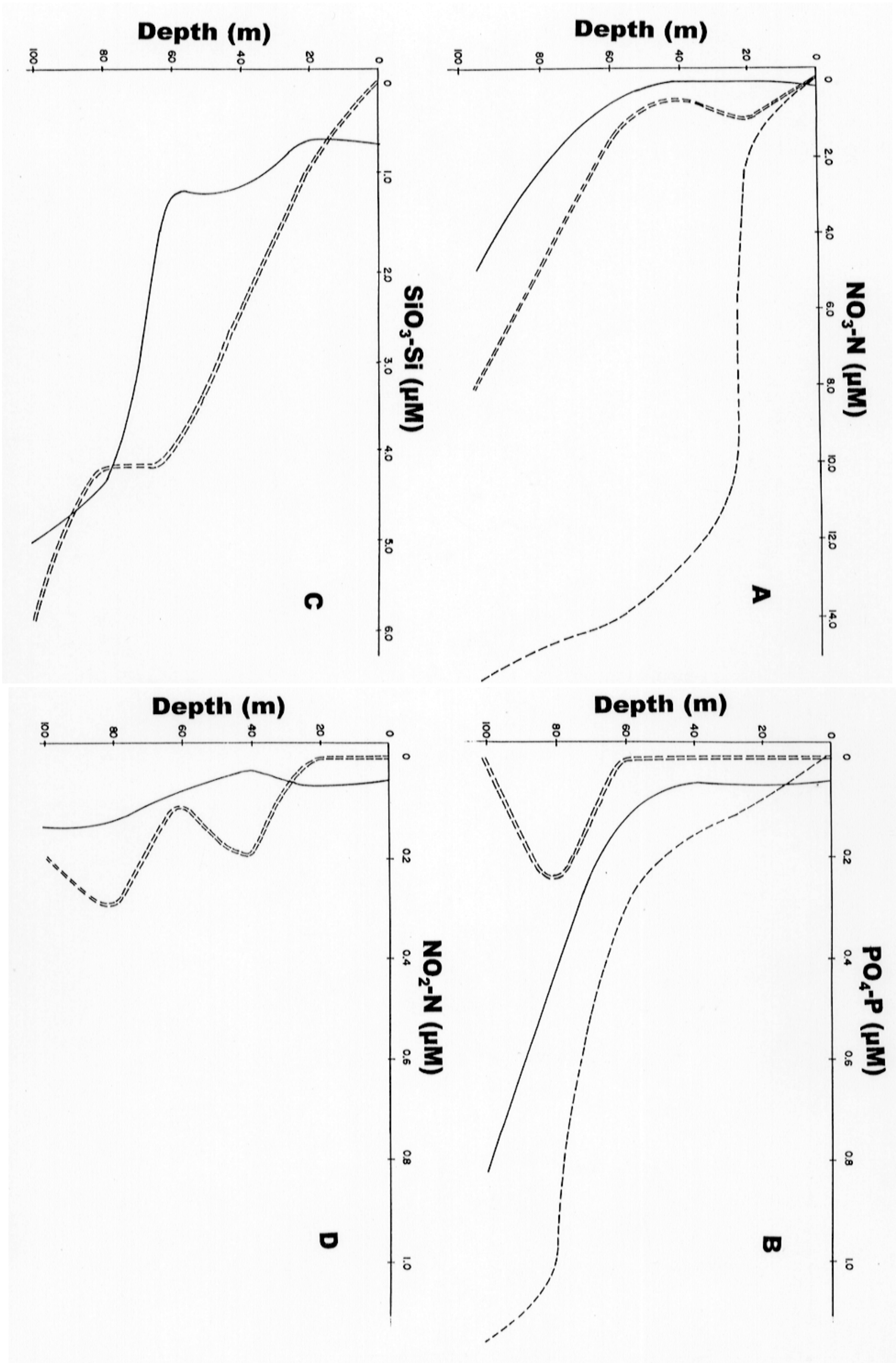

Fig. 15. The vertical profiles of (A) NO_3-N, (B) PO_4-P, (C) SiO_3-Si and (D) NO_2-N, in different occasions. (—) refer to 1998 summer average results, (- -) refer to December 1990 and (= =) for summer of 1967-68.

southern part of SCS, induced water circulation.

However, the absence of water circulation, off Zambales coast (15° and 16°N latitude) was the reason for the minimum nutrient and salinity (32.0 psu) levels, which could be a reason for its different water mass as reported by Uda et al. (1972).

Finally, the chemical hydrography from 11°-20°N and 117°-121°E, within 100 m confirmed similarities in hydrological structure though the values obtained were different as a result of different mixed layers due to current regimes, seasonal changes as well as the El Niño phenomenon. The present study also observed contrasts and similarities in temperature, salinity and D.O. between SCS and the Pacific side of the Philippine waters. Their hydrological profiles were different except for the surface D.O and temperature which were most likely due to the above cited phenomenon. The spatial and seasonal variability in the mixed layer area was attributed to fact that the SCS, particularly in the northeastern Luzon and northern Palawan are the converging zones of multi current system [Wyrtki (1961), Takenuoti (1970), and O'Niel and Eason (1982)]. The comparison made by Gong et al. (1992) confirmed that during NE monsoon, the area has a shallower mixed layer. At the same time, the area had relatively high nutrient stocks. Nutrient distribution was also dependent with hydrology particularly the nitrate and phosphate ion concentrations. These ions showed a direct relationship with hydrology based on several studies while silicate and nitrite failed to demonstrate direct relationship except with depth for silicates.

Also, it is possible that upwelling occurs in the location off northwestern Luzon, based on the hydro-chemical characteristics cited above. However, the finding is not yet conclusive and needs further verification to elucidate the seasonal water dynamics in the area.

Acknowledgement

The author would like to thank the staff of BFAR: Messrs Cielito L.Gonzales, Juan R. Relox, Jr., Valeriano M. Borja and Miss Fe Farida A. Bajarias of the Oceanography Section for their technical advice and assistance in sample collection, preparation and transport. I am also grateful to the help extended by the FEU Chemistry students in the analyses of samples and to Ms. Ma. Jesusa J. Avenido of NHI for her helpful comments in the preparation of this manuscripts.

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Nanoplankton Distribution and Abundance in the South China Sea, Area III: Waters of Western

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ABSTRACT

A collaborative cruise in the South China Sea in the waters of the South China Sea off the Western Philippines was conducted in the post-monsoon (April and May, 1998) periods on board MV SEAFDEC. The nanoplankton (including the smaller microplanktonic species) from 31 sampling stations consisted of more than 200 taxa comprising predominantly of nanodiatom (>150 species), Prymnesiophyta (>48 species), Dinoflagellata (>30 species) and Prasinophyta (>18 species). Among the minute plankton collected, three species of nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous Prymnesiophyta species were present. The dominant pennate diatom comprised of *Synedra parasitica, Fragilaria brevistriate, Diploneis crabro* and *Neodenticula* sp., all of which were <20µm in size. The central diatom comprised of *Cyclotella striata, C. meneghiniana* and *Stephenopyxis palmeriana*. The genera of *Synedra, 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 dominant Prymnesiophyta species (mostly small flagellate cells) comprised genera of *Distephanus, Thalassomonas, Coccolithus, Protosphaera* and *Cryptochrysis*; 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, Coccolithus, Minidiscus* and *Thalassiossira* had a wide range of species. The class Heptophyceae comprising of the three families namely; Prymnesiaceae (*Chrysochromulina* sp.), Coccolithaceae (*Oolithotus fragilis, Coccolithus pelagicus*) and Gephyrocapsaceae (*Emiliania huxlegi, Gephyrocapysa oceanica*) had high cell densities (ranging from 1×10^5 L^{-1} – 5×10^5 L^{-1}) especially in the nearshore waters. The total nanoplankton population (ranging from 3.1×10^5 to 2.47×10^5 L^{-1}) 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. Blooms of *Pyrodinim bahamense* and *Protoperidinium* sp. (to a limited extend) occurred during the study period.

Key words : algae, dinoflagellate, nanoplankton, Philippines, South China Sea

Introduction

It is well know fact that nanoplankton study has not been emphasized and given priority due its minute size and difficulty in identifying; however, this should not lead to its neglect since in many waters it is responsible for more than 50% biomass carbon fixation and production in the ocean than the more immediate obvious microplankton whose size is much bigger.

Only a few studies of plankton (especially the minute nanoplankton) and other related parameters were carried out in the Malaysian waters in the South China Sea. Studies by Chua and Chong (1973) in the Malacca Straits 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 species community structure, distribution and abundance of plankton in such waters had been lacking. Studies by Shamsudin *et al.* (1987) in the South China Sea around the coasts of Johore, Terengganu and Kelantan found that majority of the phytoplankton found were diatoms which comprise of numerous species of *Bacteriastrum, Chaetoceros, Rhizosolenia* and *Pleurosigma*. The blue green, *Trichodesmium erythraeum* was found in abundance in tropical waters (Chua & Chong, 1973). Studied on plankton (Chua & Chong, 1973; 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 (including the lower size range of the microplankton having <50 μm) community structure has been analysed during the post-monsoon study period (April/May 1998) in the western Philippines waters of the South China Sea. The species communtiy structure patterns, distribution, composition and species abundance at various study sectors of the South China Sea were analysed.

Method

Study Area

The study area cover an area which extends from the northern tip of Philippines (19° 59.2' N; 119° 58.7' E) to the south near the Palawan island (11° 13.5' N; 118° 3.1' E) of the South China Sea. The estimated study area is ca 6000 nautical square miles covering the economic exclusive zone (EEZ) of Philippines sea of the South China Sea. The sea cruise track followed a zig-zag manner starting from the northern coastal Philippines waters and ended up at the southern end of Philippines waters covering a total of 31 sampling stations.

Sampling Method & Preparation

The research survey was carried out during the cruise survey in April/May 1998 covering thirty one stations. Water sampler (twin 10 L sampler, Jitts 1964) was used to collect water sample from the depth of the Maximum Chlorophyll Layer (MCL). The MCL was predetermined during the hydro-acoustic survey which is carried out simultaneously. The water sampel (5*l*) was first filtered through a 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 3% glutaraldehyde buffered with 0.01 M phosphate (pH = 7.8), 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; Hallegraeff, 1984). 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% formaline 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 & McIntyre (1977), Gaardner & Heindel (1977) and Heimdal & Gaarder (1980, 1981).

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:

$$\mathbf{H = -\sum P_i \log_2 P_i}, \quad \text{where } P_i = n_i/N$$

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)

$J = H/\log_2 S$; where S is the number of species

Statistical Analysis

One way analysis of variance can be employed 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 $\mathbf{Cj = j / (a + b - j)}$

(ii) Sorensen $\mathbf{Cs = 2j / (a+b)}$

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). Subsequenthy 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). The basic principle of UPGA is derived from comparing the coefficient of similarity between pairs of habitats in the community of various sampling stations under study.

Results

The nanoplankton (including the smaller microplanktonic species with the size range of 5 - 50 µm) from 31 sampling stations comprising of more than 200 taxa consisting predominantly of nanodiatom (>150 species), Prymnesiophyta (>48 species), Dinoflagellata (>30 species), Cryptophyta (>20 species) and Prasinophyta (>18 species) was collected from the Philippines waters of the South China Sea. Among the minute plankton collected were three species of nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous Prymnesiophyta species (Table 1).

Dominant Nanoplankton Species Encountered

The three nanodiatom species of *Minidiscus* were centrale diatom while the other forms consisted of the genera *Navicula, Thalassiosira, Fragilaria, Diploneis, Synedra, Cyclotella, Stephosnopyxis, Pseudo-nitzschia* and *Chaetoceros* including those belonging to the minute species whose size range were between 5-50µm (Table 1). Some of the know *Navicula* species consisted of *Navicula grevileana, N. schonkenii, N. fucicola* and *N. pseudanglica* var. *signata;* while the *Thalassiosira* species comprised of *Thalassiosira tenera, T. climatosphaera, T. oestrupii* var. *ventrickae* and *T. pacifica*. Among the nanodiatom, 10 genera were new records in the Philippines waters during the study period.

The dinoflagellate consisted of a wide range of species of *Gyrodinium, Pyrodinium, Gonyaulax, Scrippsiella, Protoperidinium, Protoceratium, Ceratocorys, Oxytoxum* and *Alexandrium*; many of which were in the cyst forms found especially in the coastal waters (especially Subic Bay). The coastal and intermediate Philippines waters contained significantly higher cell concentrations of *Protoperidinium* sp. and *Pyrodinium bahamense*; these species have the potential to form blooms or red tides. The presence of the dinoflagellate species of *Ceratium, Protoperidinium* and *Alexandrium* were detected in considerable amounts at coastal and intermediate Philippines waters of the South China Sea.

Emiliania huxlegi and *Oolithotus fragilis* were found in considerable concentrations with values of 1.2×10^5 and 1.1×10^5 L^{-1} respectively. *Coccolithus pelagicus* and *Chrysochromulina* sp. were present in smaller quantities ($<0.24 \times 10^4$ L^{-1}) (Table 2). Related genera belonging to Haptophyceae comprising of Prymnesiaceae (*Chrysochromularia* sp.); Coccolithceae (*Coccolithus pelagicus, Oolithotus fragidis*); Gephyrocapsaceae (*Gephyrocapsa oceanica*); Rhabdophaeraceae (*Discosphaera tubifira*); Helicosphaeraceae (*Helisosphaera carteri, H. pavimentum*), Rhabdosphaeraceae (*Acanthoica quattrospina, Discosphaera tubifera, Rhabdosphaera claviger*); Syracosphaeraceae (*Coneosphaera molischii, Syracosphaera pulichra, Umbellosphaera irregularis, U. tenuis*) and Halopappaceae (*Florisphaera profunda, Haloppapus* sp.) were also present.

Distribution and Concentration of Nanoplankton in Areal Sectors

The map from Fig. 1 shows the various sampling stations during the cruise survey in the Philippines waters of the South Chine Sea. The population in the offshore waters toward the north and western parts of the Philippines waters was sparse (3.1×10^4 to 1.03×10^5 L^{-1}) while the coastal waters ranged between 1.8×10^5 to 2.4×10^5 L^{-1} (Fig. 2a). The distribution of the different nanoplankton dominant species in the Philippines waters are also shown (Fig. 2b). Species of the genera *Gymnodinium, Oxytoxum, Emiliania, Minidiscua* and *Thalassiosira* were dominant in coastal waters (especially Subic bay); while species of *Fragilaria* and *Syracosphaera* were present in offshore waters. The minute pennate nanodiatom *Synedra* and *Fragilaria* were found in the western offshore waters (Stations 12, 13, 19) while the centrale diatom *Cyclotella* and *Thalassiosira* were dominant in nearshore and intermediate Philippines waters (Stations 8,

Table 2. The distribution and estimated cell density of the major species of Class Heptophyceae in the Philippines waters during the April/May 1998 cruise survey.

Class : Haptophyceae Family:	Taxanomic species	* Sectors in Philippines waters	Total cell x 10^5 density Nos. L^{-1}
1. Prymnesiaceae	*Chrysochromulina* sp.	North (midshore)	0.4
2. Coccolithaceae	*Coccolithus pelagicus* (Wallich) Schutter *Oolithotus fragilus* (Lohmann) Rainhardt	South West (nearshore)	0.7
3. Gephyrocapaceae	*Gephyrocapsa oceanica* (Kamptner) *Emiliania huxlegi* (Lohmann)	Subic Bay (nearshore)	1.6
4. Helicosphaeraceae	*H. helicosphaera carteri* Kamptner *H. pavimentum* Okada	North west (offshore)	1.1
5. Rhabdosphaeraceae	*Acanthoica quattrospina* Lohmann *Discosphaera tubifera* Ostefild *Rhabdosphaera claviger* Murray	North west (offshore)	1.2
6. Syracosphaeraceae	*Caneosphaera molischii* Gaarder *Syracosphaera nodosa* Kamptner *S. pulchra* Lohmann *Umbellosphaera irregularis* Poasche *U. tenuis* Paasche	Subic Bay (nearshore)	1.2
7. Halopappaceae	*Florisphaera profunda* Paasche	Western (offshore)	1.4

* Sectors containing more than 1 station.

16, 23) (Fig. 2.1a & b).

The pennate diatom *Synedra* (especially *S. parasitica* A. Boyer) was present in considerable quantities (ca 9 x 10^4 L^{-1}) in the south west offshore waters while the pennate *Fragilaria* (especially *F. brevistriata* A. Boyer) was concentrated in the western offshore Philippines waters of the South China Sea. The centrale diatom *Thalassiosira* (*T. tenera, T. punctigera, T. oestrupii* var venrickae)) and *Cyclotella* (*C. striata*) were dominant in the coastal waters adjacent to the Subic bay (Fig. 2.2a & b). The dinoflagellate, *Gymnodinium* sp. (especially *G. maguelomense*) and *Pyrodinuim bahamense* were especially important along the coast of western Luzon and the adjacent waters of Subic bay respectively (Fig. 2.3a & b). The diatom *Navicula* sp. and the dinoflagellate *Oxytoxum mileri* were distributed toward the north of Subic bay (Fig. 2.4a & b). The centrale nanodiatom species of *Minisdiscus* (*M. comicus, M. childensis, M. trioculatus*) were concentrated in the vacinity of the Subic bay while *Cryptochrysis* species were found in coastal regions especially toward the Southern part of the Philippines waters (Fig. 2.5a & b). Other minute diatom (*Coscinodiscus* sp., *Diploneis crabro, Stephanopyxis palmeriana*) and the

Table 3. Species assemblage or association in the Philippines waters of the South China Sea during the cruise survey (April/May 1998).

Group	Species association		
	Diatom	**Coccolithophoridacea e**	**Dinoflagellate**
A	***Synedra parasita***	***Oolithotus fragilus***	***Protoperidinium* sp.**
B	***Diploneis crabro*** ***Navicula* sp.** ***Cyclotella striata*** ***Manidiscus* sp.** ***Thalassiosira* sp.**	**-**	***Gymnodinium* sp.**
C	***Stephanopyxis palmeriana***	***Penthospahera* sp.** ***Chrysochromulina* sp.** ***Florisphaera* sp.**	**Gonyaulax sp.**
D	***Fragilaria* sp.**	***Discosphaera* sp.** ***Caneosphaera* sp.** ***Acanthoica* sp.**	**-**
E	**-**	***Emiliana* sp.** ***Helicosphaera* sp.** ***Umbellasphaera* sp.** ***Syracosphaera* sp.**	**-**
F	**-**	**-**	***Alexandrium* sp.** ***Pyrodinium bahamense***

flagellate (*Thalassomonas* sp., *Tetraselmis* sp.) were distributed along the coastal areas. The dinoflagellate *Protoperidinium, Gonyaulax* and *Alexandrium* species were also encountered in the coastal regions around Subic bay and Manila bay during the cruise survey.

The Gephyrocapsaceae (especially *Emiliana huxlegi*) and the Syracosphaeraceae (mostly *Syracophaera nodosa*) belonging to the class Haptophyceae were present in the western offshore waters with mean values of 1.7 x 10^5 and 1.2 x 10^4 cells L^{-1} respectively (Fig. 2.6a & b).

3.3 Nanoplankton Assemblage and Association

The dendrogram from Fig. 3.1 (Table 3) illustrates that the nanoplankton species during the cruise survey comprised of at least six species assemblages or associations in cluster analysis on species sampled from the nearshore, midshore and offshore stations according to their preference on environmental conditions using the Unweighted Pair Group Average (UPGA) Pearsons Index analyses. The species assemblages consisted of group A (*Synedra parasitica, Protoperidinium* sp., *Oolithotus fragilus*); group B (*Diploneis crabro, Navicula* sp., *Cyclotella striata, Minidiscus* sp., *Gymnodinium* sp., *Thalassiosira* sp.); group C (*Stephanopyxis palmeriana, Penthosphaera* sp., *Chrysochromulina* sp., *Gonyaulax* sp., *Florisphaera* sp.); group D (*Discosphaera* sp., *Caneosphaera* sp., *Acanthoica* sp., *Fragilaria* sp); group E (*Emiliania* sp., *Helicosphaera* sp., *Umbellasphaera* sp., *Syracosphaera* sp); group F (*Alexandrium* sp.,

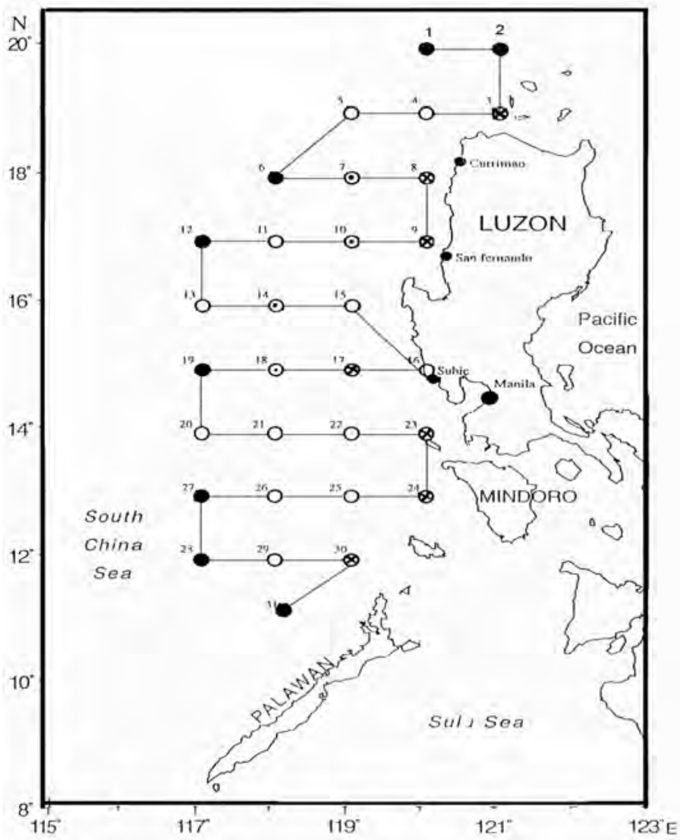

Fig. 1. The map showing the sampling stations in the Philippines waters of the South China Sea.

Pyrodinium bahamense).

Sampling stations can be grouped into at least 5 sectors with respect to their similarities in species composition using cluster analyses by mean of the Unweighted Pair Group Average (UPGA) Pearson Index analyses (Fig. 3.2). The identified sectors in the Philippines water of the South China Sea comprised of a) Eastern nearshore waters, b) Intermediate midshore waters, c) western offshore waters, d) Northern Philippines waters and e) Southern Philippines waters. The mean population densities at various stations of the 5 sectors (data from various stations from each sector were pooled together) were significantly high along the nearshore region during the study period with values ranging from 1.1 x 10^5 to 2.2 x 10^5 L^{-1}. Subic bay coastal waters sector had the highest values. The trend in the mean densities at the 5 sectors was inversely proportional to the distance from the coast; the values were much lower furthest away from the coast ranging from 0.05 x 10^5 to 0.2 x 10^5 L^{-1}. The diversity index H values ranged from 0.42 to 2.94 with high values in the region around the nearby and offshore stations (St. 14 to St. 21) of the Subic bay during the study period (Fig. 4). The J evenness index values were usually directly proportional to the H values.

Discussion

Semina and Tarkhova (1972) recorded close to 1000 species of phytoplankton, mainly of diatoms and dinoflagellates in the Pacific Ocean. The only other conspicuous marine microplanktonic forms are the spherical green cells belonging to the 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

Table 1. The distribution and estimated cell density of dominant nanoplankton in the Philippines waters during the April/May 1998 cruise survey.

	Species	* Sectors in Philippines waters	Total cell x 10^5 density Nos. L^{-1}
1. Centrale Diatom	*Minidiscus* sp. *M. comicus* Takano *M. chilensis* Rivera et Koch *M. trioculatus* Hasle	Subic bay (nearshore)	1.7
	Thalassiosira sp. *T. oestrupii* Hasle *T. punctigera* Hasle	Subic bay (nearshore)	2.4
	T. tenera Proschkina- Lavrenko *Cyclotella* sp. *Cyclotella striata* Grunow *C. meneghiniang* Kutzing *Stephanopyxis palmeriana* Kutz *Chaetoceros* sp.	Northern (offshore)	2.1
2. Pennate Diatom	*Synedra parasitica* A. Boyer	Subic bay (nearshore)	0.9
	Fragilaria brevistriata A. Boyer *Diploneis crabro* Ehr. *Neodenticula seminae* Akiba *Pseudo-nitzschia multistriata* Takano	Western (offshore)	0.9
	Navicula sp. *Navicula fucicola* Taasen *N. grevilleana* Hendey *N. pseudainglica* var. *signata* Hustedt	Subic Bay (South)	1.2
3. Dinoflagellate	*Gymnodium maguelomense* Biecheler *Gyrodonium* sp.	Subic Bay	4.2
	Pyrodinium bahamense Plate	Subic Bay	1.9
	Protoperidinium sp.	Subic Bay	1.1
	Protoceratium sp. *Ceratium* sp.	Subic Bay	1.2
4. Flagellate	*Gonyaulax* sp. *Scrippsiella* sp. *Ceratocorys* sp. *Alexandrium* sp.	Subic Bay	0.2
	Oxytoxum sp.	Subic Bay	1.6
	Crypochrysis sp. *Thalassomonas* sp. *Tetraselmis* sp.	Subic Bay	1.7

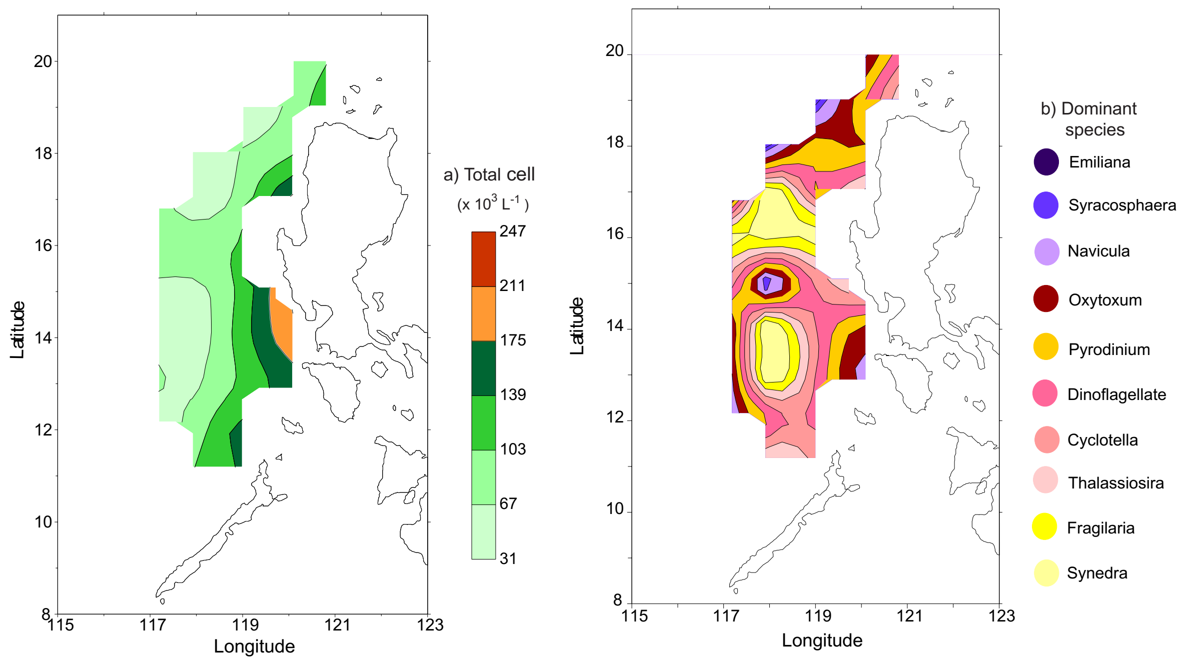

Fig. 2. a) Total cell density (x 10^3 L^{-1}) and b) Dominant nanoplankton species (10^4-10^5 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

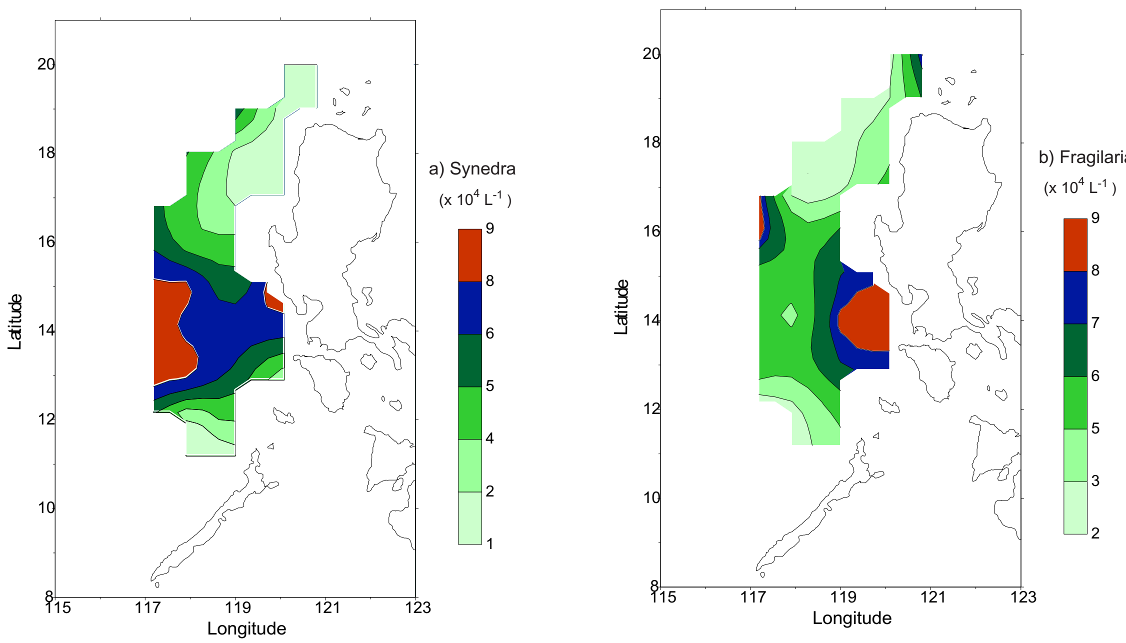

Fig. 2.1. Distribution of the genera (a) *Synedra* (x 10^4 L^{-1}) and (b) *Fragilaria* (10^4 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

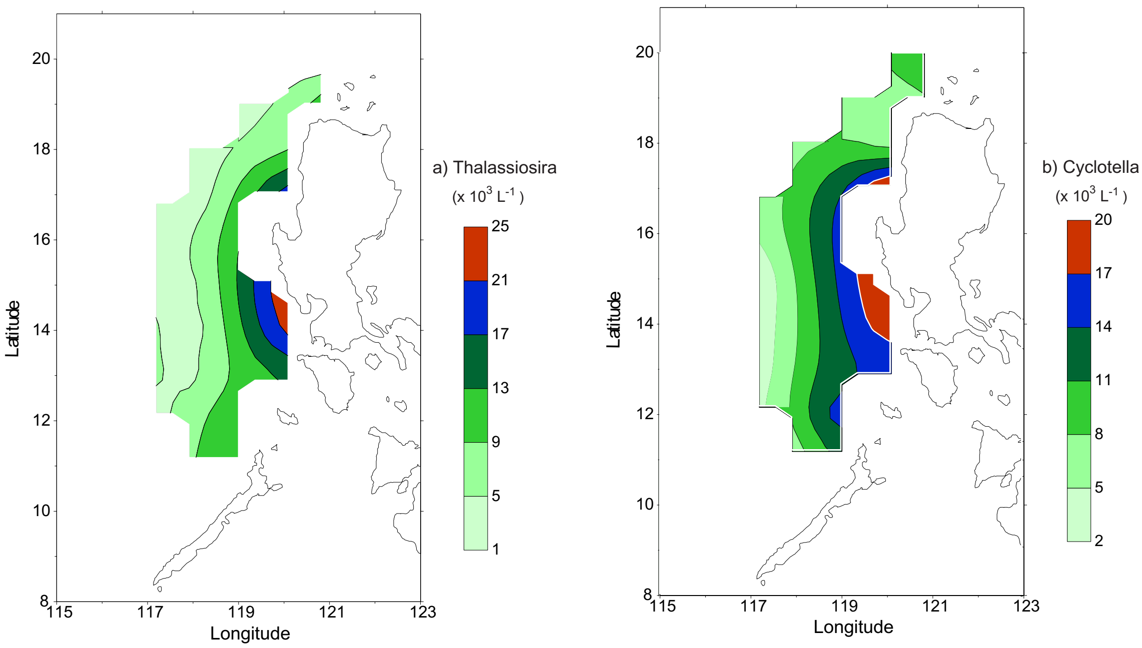

Fig. 2.2. Distribution of the genera (a)Thalassiosira(x 10^2 L^{-1}) and (b) Cyclotella(10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

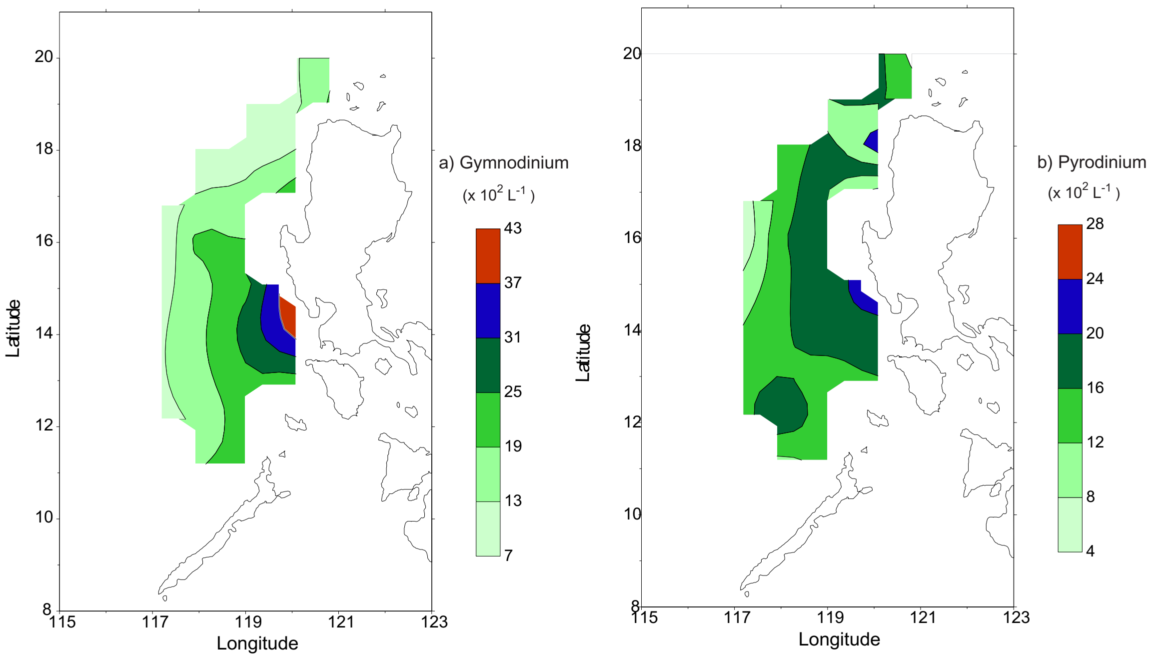

Fig. 2.3. Distribution of the genera (a) Gymnodinium (x 10^2 L^{-1}) and (b) Pyrodinium(10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

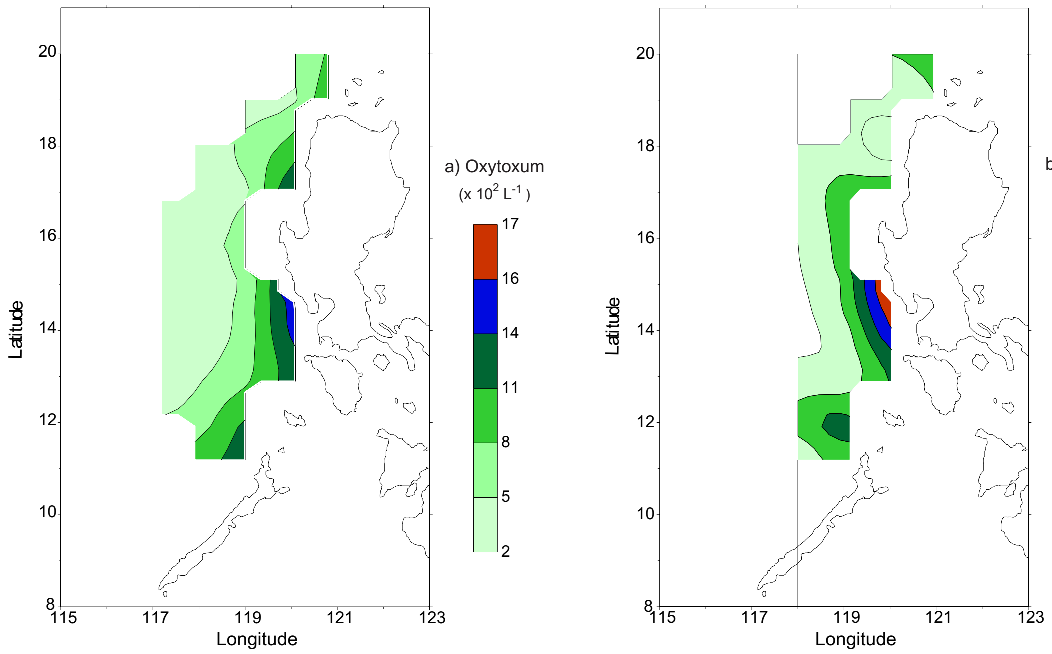

Fig. 2.4. Distribution of the genera (a) Oxytoxum (x 10^2 L^{-1}) and (b) Navicula (10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

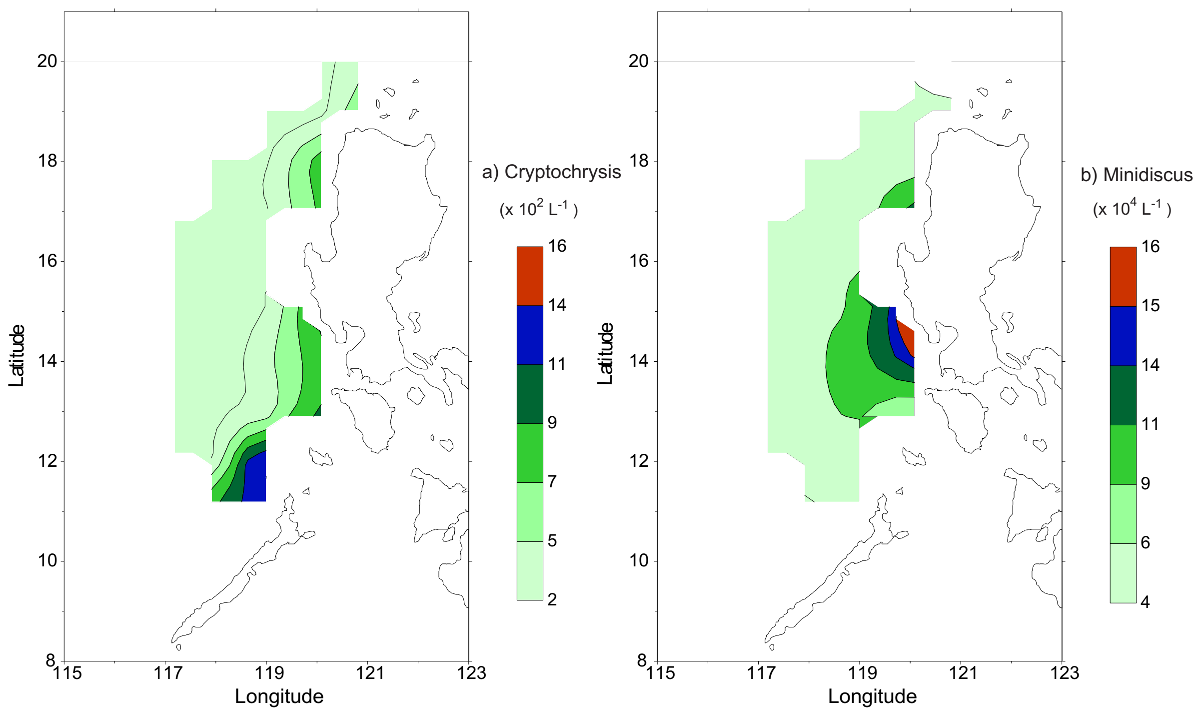

Fig. 2.5 . Distribution of the genera (a) Cryptochrysis (x 10^2 L^{-1}) and (b) Minidiscus (10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

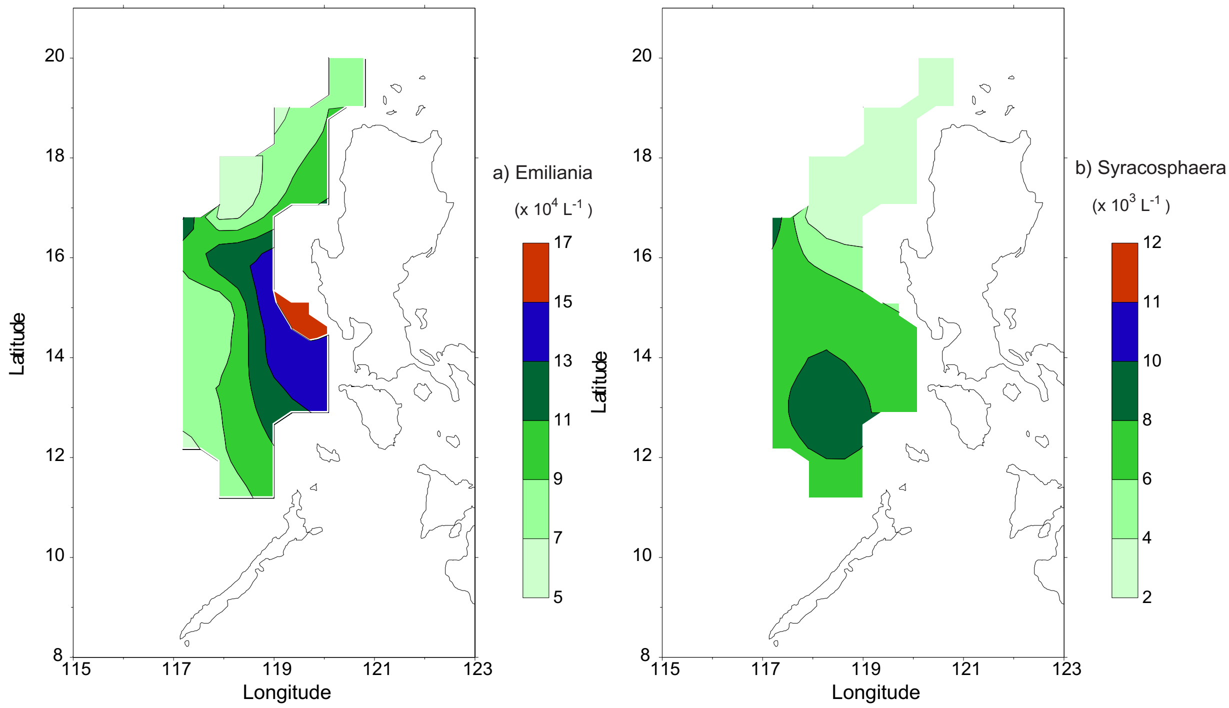

Fig. 2.6. Distribution of the genera (a) Emiliania (x 10^2 L^{-1}) and (b) Syracosphaera (10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

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. 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 microplankton species will predominate and thus effect or influence the number of species or the even distribution of individual species. A few small diatoms, dinoflagellates and other groups (e.g. *Dictyocha*) occur in the marine nanoplankton but detailed studies are still needed. During the present survey *Dictyocha* sp. was not encountered; however, Coccolithophoridaceae was well represented.

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 of close to 200 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.

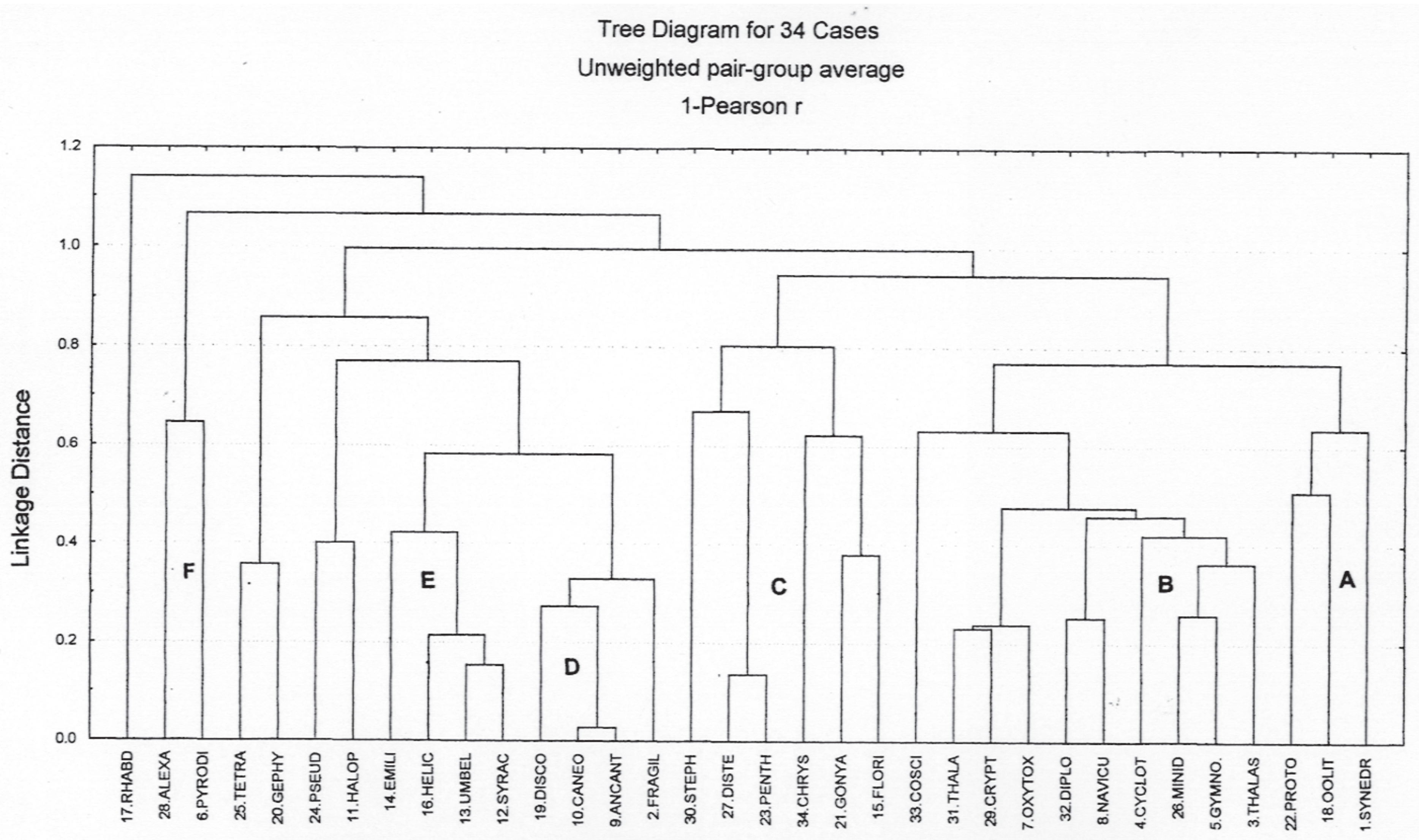

Fig. 3.1 The dendrogram showing the aggregation & association of nanoplankton species in the Philippines waters of the South China Sea (April/May 1998)

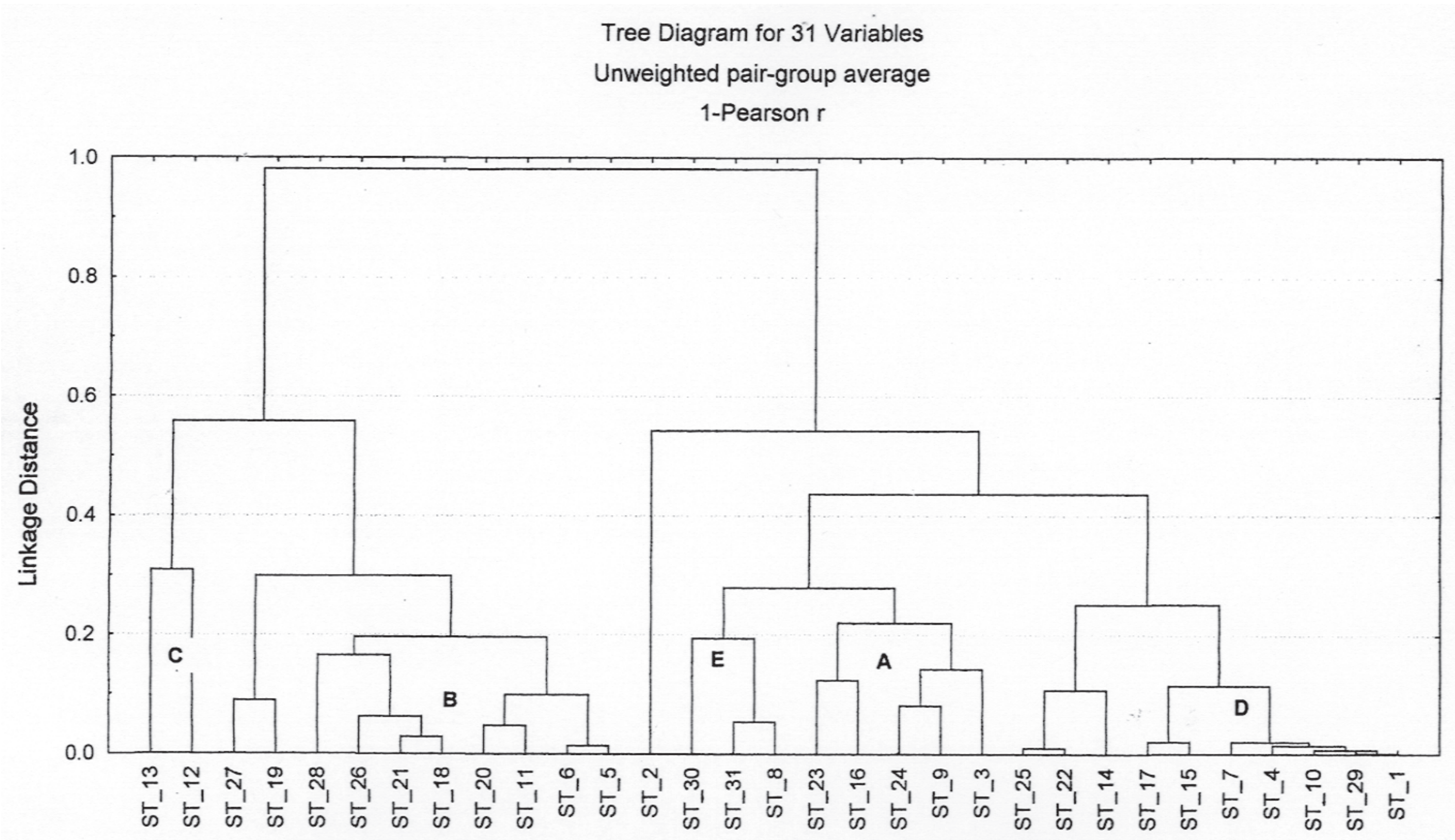

Fig. 3.2 The dendrogram showing the aggregation & association of sampling stations with similar community structure in the Philippines waters of the South China Sea (April/May 1998)

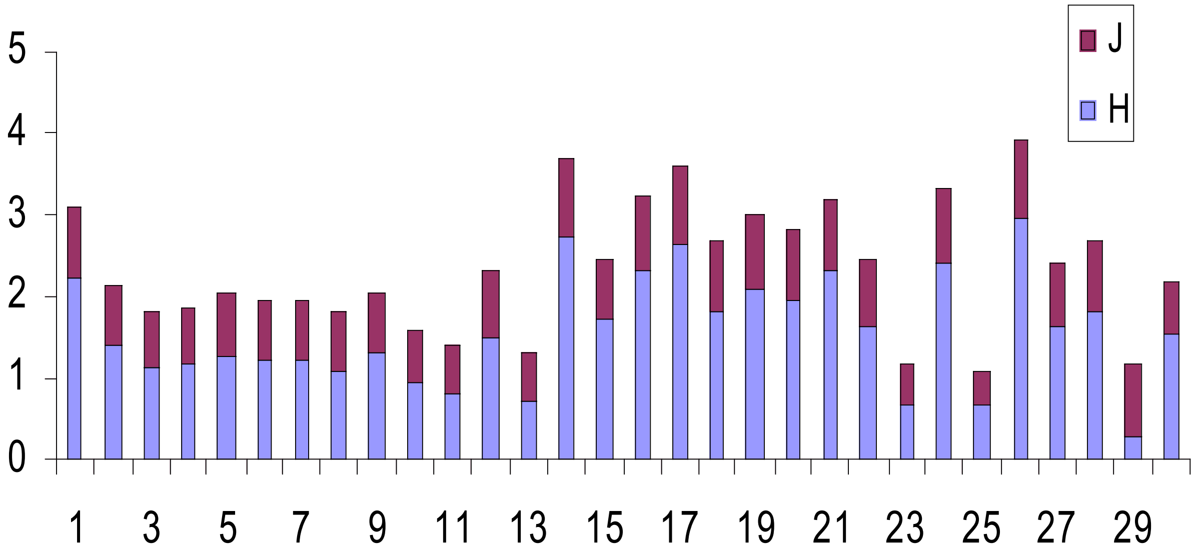

Fig. 4. The diversity (H) and eveness (J) indices of various station in the Philippines waters of the South China Sea during (April/May 1998).

On an annual basis 70-80% (total carbon 78 – 82 g C m^{-2}) was attributed to the nanoplankton. McCarthy *et al.*(1974) found that over a two year study in Chesapeake Bay the nanoplankton (in this case species passing through a 35 µm 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 *et al.*, 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 (MeCarthy *et al.* 1974, Hulbert *et al.* 1960).

Acknowledgement

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 (Universiti Putra Malaysia (UPM) Terengganu, Kuala Terengganu Malaysia) for her help in mapping out the microplankton population and for typing this manuscript.

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Characteristics of Water in the South China Sea, Area III: Western Philippines

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ABSTRACT

The characteristics of water in the South China Sea from latitude 11° N to 20°N and longitude 117°E to 121°E during 18 April to 8 May 1998 have been studied using Integrated CTD instruments onboard MV. SEAFDEC. It was found that there are six watermasses in the study area and there is upwelling off coast of northern Luzon Island at from the surface down to 200-meters. The water properties are influenced both by northeast and southwest monsoon winds as the duration of survey are during the transitional period, also by outflow from shore. The strong thermocline, halocline and pycnocline are present all over the area.

Introduction

This study is a part of the Interdepartmental Collaborative Research Program in the South China Sea area continuously carried out since 1995. The main objective is to collect and analyze the information necessary for management through collaboration among Southeast Asian Fisheries Development countries and other organizations concerned.

The survey was conducted by MV. SEAFDEC between 18 April and 8 May 1998 using 31 stations off the coast of the Philippines (Figure 1). The study area covers from latitude 11° N to 20° N and longitude 117° E to 121° E, which is about 272,000 square kilometers. The maximum depth reaching to about 5000 m. (Figure 2). The area covers the deep area of the South China Sea (SCS).

The Philippines separates the South China Sea from the Pacific Ocean with a steep continental slope and practically no continental shelf. The sea is connected to the Pacific Ocean by the Luzon Strait, the deepest and widest part having a sill depth of about 2,000 m. There are two narrow, shallow passages to the north and south of Palawan Island connecting the South China Sea to the Sulu Sea.

There are several studies indicating that the major circulation and variability of the water properties field in the South China Sea is driven by the monsoon winds (Shaw and Chao (1994), Nasir *et al.* (1997), Uu and Brankart (1997) and *etc*.). In the SCS, the wind prior to September is dominated by the southeast monsoon. The northeast monsoon begins to appear north of 20° N in September while south of that latitude, the southwest monsoon still prevails. The northeast monsoon is expanding southward against and decreasing the southwest monsoon in October. In December the northeast monsoon reaches its maximum strength and covers the entire SCS in December. The end of the northeast monsoon is in April. The southwest monsoon first appears in the central parts of the South China Sea in May and expands over the entire basin during July and August.

Another circulation pattern is the Kuroshio intrusion through the Luzon Strait below 100

m. and Pacific intrusion at depths between 1,500 and 2,000 m. This circulation pattern is significant only along the northern areas of the SCS and coincides with the appearance of the northeast monsoon (Uu and Brankart 1997)

This survey period is in the transition between northeast and southwest monsoon. At that time the survey the northern part was influenced by the northeast monsoon while the southern part was dominated by the southwest monsoon.

D.V. Uu and J. -M. Brankart, 1997 indicated watermasses in SCS from the analysis of a three – dimensional thermohaline structure where there are two types of water. The first permanent and the second seasonal. There are four permanent masses, two masses in the upper mixed layer: Open Sea Water (OSW) and the continental shelf waters (CSW). The third is exhibits maximum salinity water (MSW) and the fourth is deep water (DW). The seasonal masses exist only during some parts of the season. There are two seasonal watermasses in the SCS. The first is the water of the northern part of the open sea during winter (Northern open sea during winter, NOSW). The second is a water mass from the Pacific Ocean (POW).

The particular objective of this project is to find the characteristics of the water in the study area during the survey period and to provide principal data to other researchers in the collaborative survey-working group.

Methods

Hydrographic data were collected using the onboard Falmouth Integrated CTD instrument with conductivity, temperature, pressures, dissolved oxygen, fluorescence and pH sensors. (In this paper the fluorescence and pH data was excluded) According to the manufacturer's specification, the instrument has an accuracy of ±0.003 mmhn. , ± 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. Dissolved oxygen in the water samples was determined by a modification of the Winkler procedure (Parsons, Maita and Lalli, 1984) for the calibration of dissolved oxygen data. The oxygen calibration procedures are given in the catalogue of oceanographic data, area III: off the West Coast of the Philippines. Calibration of conductivity, temperature and pressure sensors were not performed due to the lack of a suitable precision calibration instrument. The CTD unit was last sent for calibration and deck testing by the manufacturer in April 1997.

Because of the length of the armored sea cable, the maximum depth for CTD casting was limited to a depth of about 1500 meters. The efficiency of the oxygen sensor is limited for 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 averaged at every 1 dbar interval using the FSI post acquisition data analysis software.

Because sea conditions vary such that the start point for measurement is problematic, the start point was taken as being 10 meters.

Results and discussions

Temperature distribution

The sea surface temperature of the area is increases from 28.0° c in the higher latitudes to 30.9 °c at the lower latitudes. The exceptions are at the station off the northern coast of Luzon

Island near stations. 5, 7 and 10 and the station near the passage between the South China Sea and Sulu Sea, these stations show a lower temperature than other stations in the survey pattern at the same latitude (Figure 3). At 500 m., the temperature gradient decreases from the surface down while the pattern of temperature distribution remains the same (Figure 4). The distribution of temperature at 1000 m. is homogeneous all over the area. (Figure 5). The characteristics of the temperature at 10, 500,1000 and 1500 are 28.45-30.4 °c, 8.1-8.6 °c, 4.3-4.45 °c and 2.8-2.9 °c respectively (Figure 6,7 and 8). The strongly defined thermocline, which is a character of equatorial water, is present at between 30-150 m depth. At the shallow stations, the thermocline is still present but shallower and narrower than the deeper areas.

Salinity distribution

The interval of sea surface salinity in the study area is 33.7-34.6 p.s.u. Salinity distributions at the northern part near station 5,7 and 10 are higher than in adjacent areas where it was found to be about 0.1-0.2 p.s.u. The highest surface salinity area was found near the passage between the South China Sea and Sulu Sea. The lowest was located near the shore off the middle of Luzon island and in the vicinity of station 27, 29 and 30, which may be the influence of less saline water from Manila bay and Palawan Island. (Figure 3,10 and 11). Small salinity gradients were found at 500 m. and 1000 m. depth (Figure 4 and 5). The halocline zone that is present between 20-150 m., and which resembles the thermocline zone being at similar depths. There is an exception in the area, which has the highest sea surface salinity at the upper layers and a shallow halocline. The intrusion from Sulu Sea may have an influence on this area.

There is a maximum salinity layer between about 100-200 meter depth, which is a characteristic of the equatorial regions (Figure 6,7,8,9,10 and11). Salinity profiles (Rojana-anawat *et.al, 1998*) show that the upper limit of the halocline zone is below the mixing zone and the lower limit is at the highest salinity depth. The sea at 10, 500, 1000 and 1500 are dominated by water at 33.8-34.2 p.s.u. , 34.4-34.5 p.s.u. , 34.6-34.7 p.s.u. and 34.6 p.s.u. respectively.

Density distribution

The distribution of sea surface density can be described roughly by starting that the value of sigma theta ($\sigma\theta$) and are in the range of 20.6-21.7 kg/m^3. As the density depends upon by temperature and salinity, the highest density areas were found at the surface near stations 5,7 and 10 and around stations 23 and 24 and had a lower temperature and higher salinity than the nearby waters (Figure 3). Density distribution at 500 m. and 1000 m. are shown in figures 4 and 5, respectively. The pycnocline was also found at all stations at similar depth to the thermocline and halocline. The characteristics of sigma theta at 10, 500, 1,000 and 1,500m.depth are 20.8-21.6 kg/m^3, 26.7-26.8 kg/m^3, 27.4 kg/m^3 and 27.6 kg/m^3 respectively. Vertical cross sections of sigma theta are shown in Figures 6,7,8,9,10 and 11.

Oxygen distribution

Lower concentrations of dissolved oxygen were found at the surface in the northern part of the area while at the southern part it was found to be a little higher (Figure 3). The high oxygen concentrations were present in the upper layers from the surface down to about 100 m. The occurrence of oxyclines are at about 80-120 meter from (Figures 6,7,8,9,10 and 11). Lower oxygen concentrations at the upper layer of water was found between station 5,7 and 10 (Figure 6).

Watermasses

The characteristics of the watermasses are identified following the study of D.V. Uu and J.M. Brakart (1997) and the watermasses of the Pacific Ocean (Pickard and Emery, 1990).
The upper mixed layer of the area during the survey period, open sea watermass, (OSW) occupied about 85% of the surface area and at about 0-30 m. depth (Figures 3,6,7 and 8). The open sea watermass was characterized by salinity between 33.5 –34 p.s.u. , and temperatures between 27-30 °c.

The depths between 50-100 m. are dominated by the mixed water between the northern open sea during winter (NOSW) and the Pacific Ocean water (POW). This coincides with the study of D.V. Uu and J. -M. (1997) that postulates that at the end of the winter monsoon of northeastern part of the SCS, the surface occupied by NOSW decreases with the decrease of the northeast monsoon and mixes with the POW until the summer monsoon. This was confirmed during this survey. NOSW was characterized by temperatures of less than 25 °c to about 23 °c and salinity variations from 34.0 to 34.5 p.s.u. , while temperature and salinity of the POW are about 25-27 °c and 34.0-35.0 kg/m^3 respectively. In the areas of stations 2 and 3, which are at the passage between the SCS and the Pacific Ocean, these are dominated by NOSW indicated by high salinity.

The maximum salinity water (MSW) which was indicated by temperature between 15-17 c and salinity from 34.5 – 35.0 p.s.u., at about 100-200 m. depth.
Beneath the MSW to about 1000 m. is the location of the mixing water between North Pacific Intermediate Water and Pacific Equatorial Water with temperatures of about 5-13 °c, salinity from 34-35 p.s.u. The T-S diagram of station no.2 (Figures 12 and 13) shows the difference from the others by having the lowest minimum salinity (34.42 p.s.u.) at about 500 m. this means that this area is dominated by the North Pacific Intermediate water, which is evident from the salinity minimum.

The last watermass is the deepwater (DW) with temperatures varying from 2-5 °c, and salinity between 34-35 p.s.u. at depths below 1000 m.

Table 1. Characteristics of the water masses.

Watermass	Salinity (p.s.u.)	Temperature (°c)	Depth (m)
Open sea water (OSW)	33.5-34.0	27-30	0-30
Northern open sea during winter (NOSW)	34.0-34.5	23-25	50-100
Pacific Ocean water (POW)	34.0-35.0	25-27	50-100
Maximum salinity water (MSW)	34.5-35.0	15-17	100-200
Mixing of north Pacific intermediate water and Pacific equatorial water			34.0-35.0
5-13	200-1000		
Deep sea water (DW)	34.0-35.0	2-5	<1000

*The table was modified from the study of D.V. Uu and J.M. Brankart 1997

Upwelling

The occurrence of cooler and more saline water at the surface between stations 5,7 and 10 (Figure 3) indicate that this area is influenced by upwelling, which generally is the reason for the high biological productivity. This was emphasized by the vertical distribution of water properties shown in figure 4, which has an influence on the area from the surface down to about 200 meters. It is in agreement with the study of P. –T. Shaw and S. –Y. Chao (1994) that there is upwelling at the eastern boundary of the South China Sea while downwelling is present off the coast of Vietnam during the northeast monsoon period.

Conclusion

1. There was an occurrence of upwelling at the northern part of the area during the survey period, which may be an influence of the northern monsoon wind.
2. The strong thermocline halocline and pycnocline, narrow mixing layer and the maximum salinity layer at about 100-200 meter depth are the dominant characteristics of the waters in the area.
3. The properties of the water during the survey period influenced by the transition between the northeast monsoon and southwest monsoon wind and outflow from the shore.
4. There is unusual water with lower temperatures, higher salinities and concentration of dissolved oxygen and with a narrower halocline at the station near the passage between the South China Sea and the Sulu Sea. This water may be influenced by the Sulu Sea waters.
5. Six watermasses were found during the survey period.

Acknowledgements

The authors would like to thank Mr. Wirote Laongmanee for his efforts in the graphic presentation of data. We would like to thank MV. SEAFDEC crew members for their help during field survey. The authors are grateful to Dr. Somboon Siriraksophon for his comments on the manuscript and to Mr. Rupert Elstow for his edition the language of the paper.

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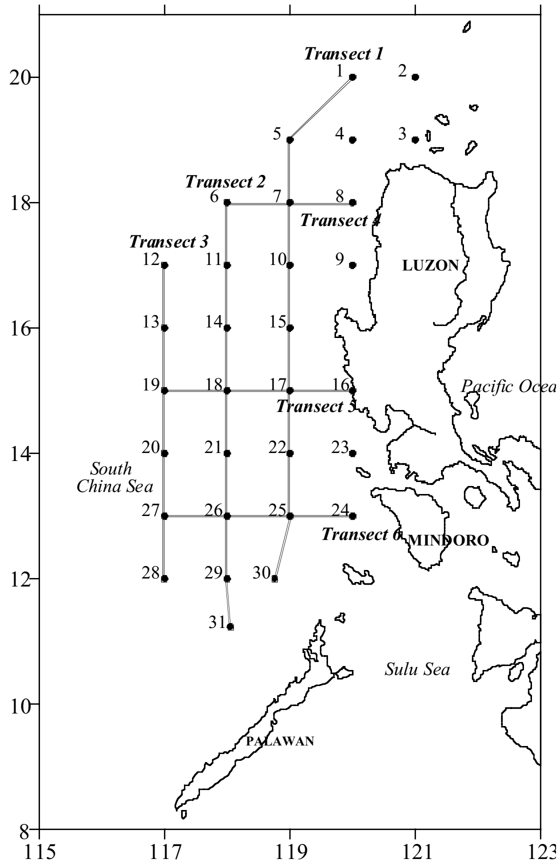

Fig. 1. All sampling station and six selected transects.

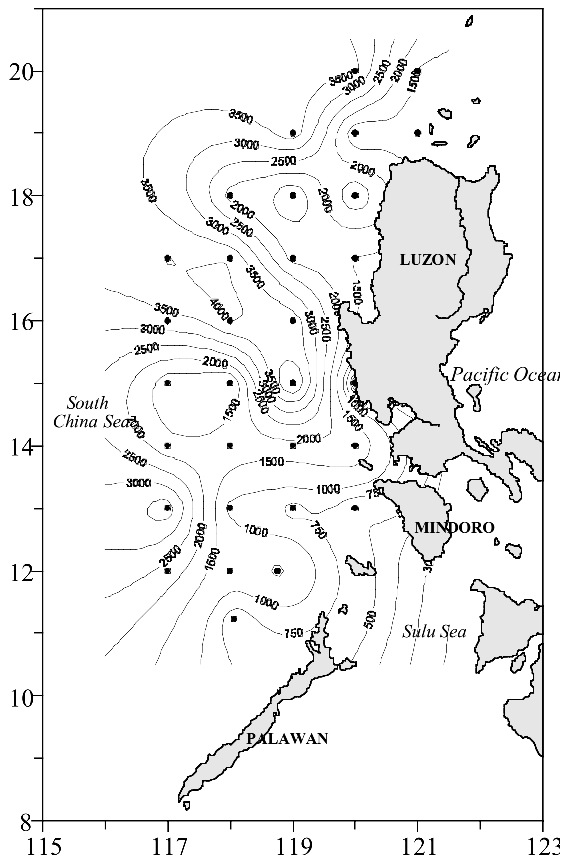

Fig. 2. Depth contour (m) of the study area.

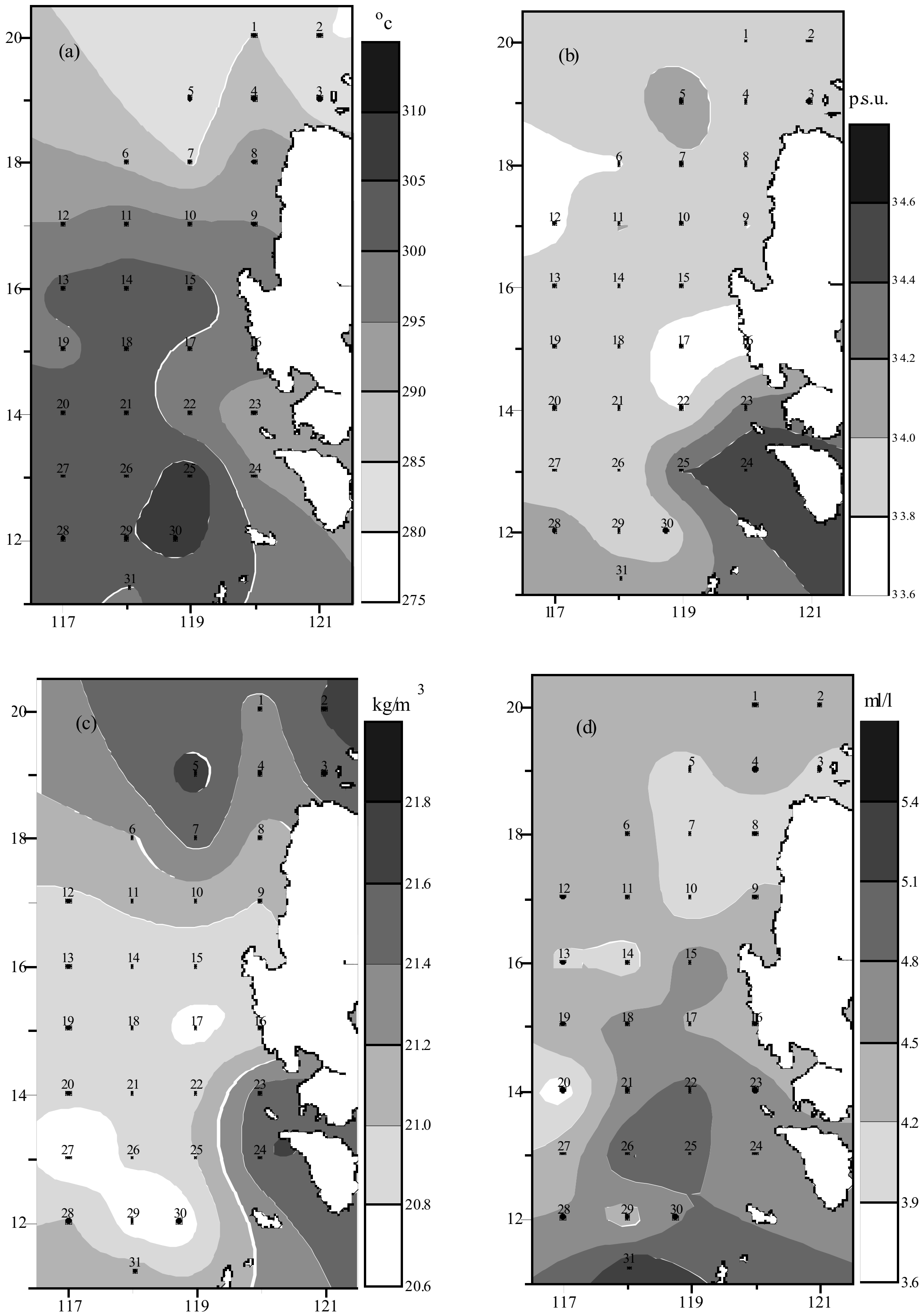

Fig. 3. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m^3) and dissolve oxygen (ml/l) at surface (10 m.).

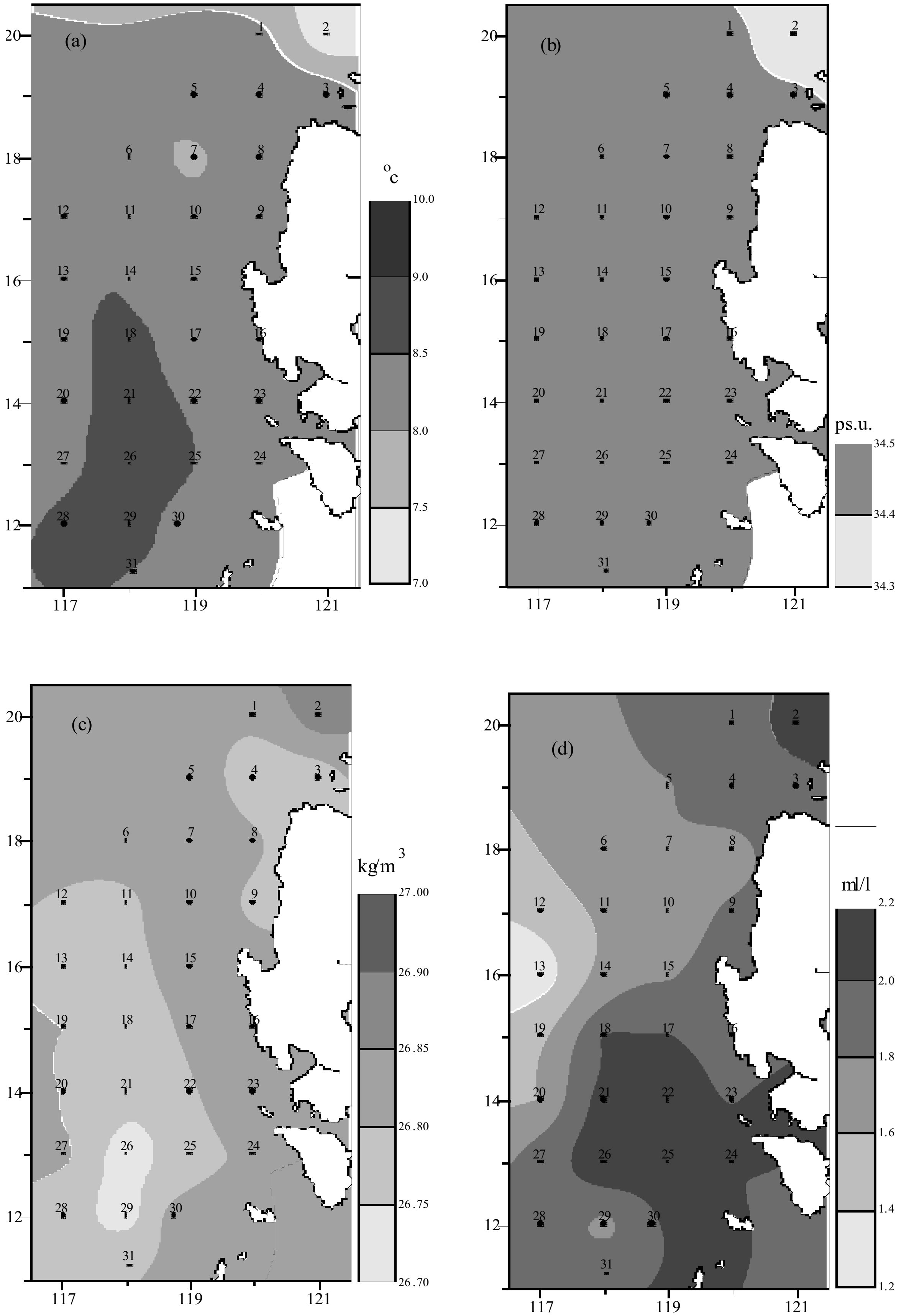

Fig. 4. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m^3) and dissolve oxygen (ml/l) at 500m.

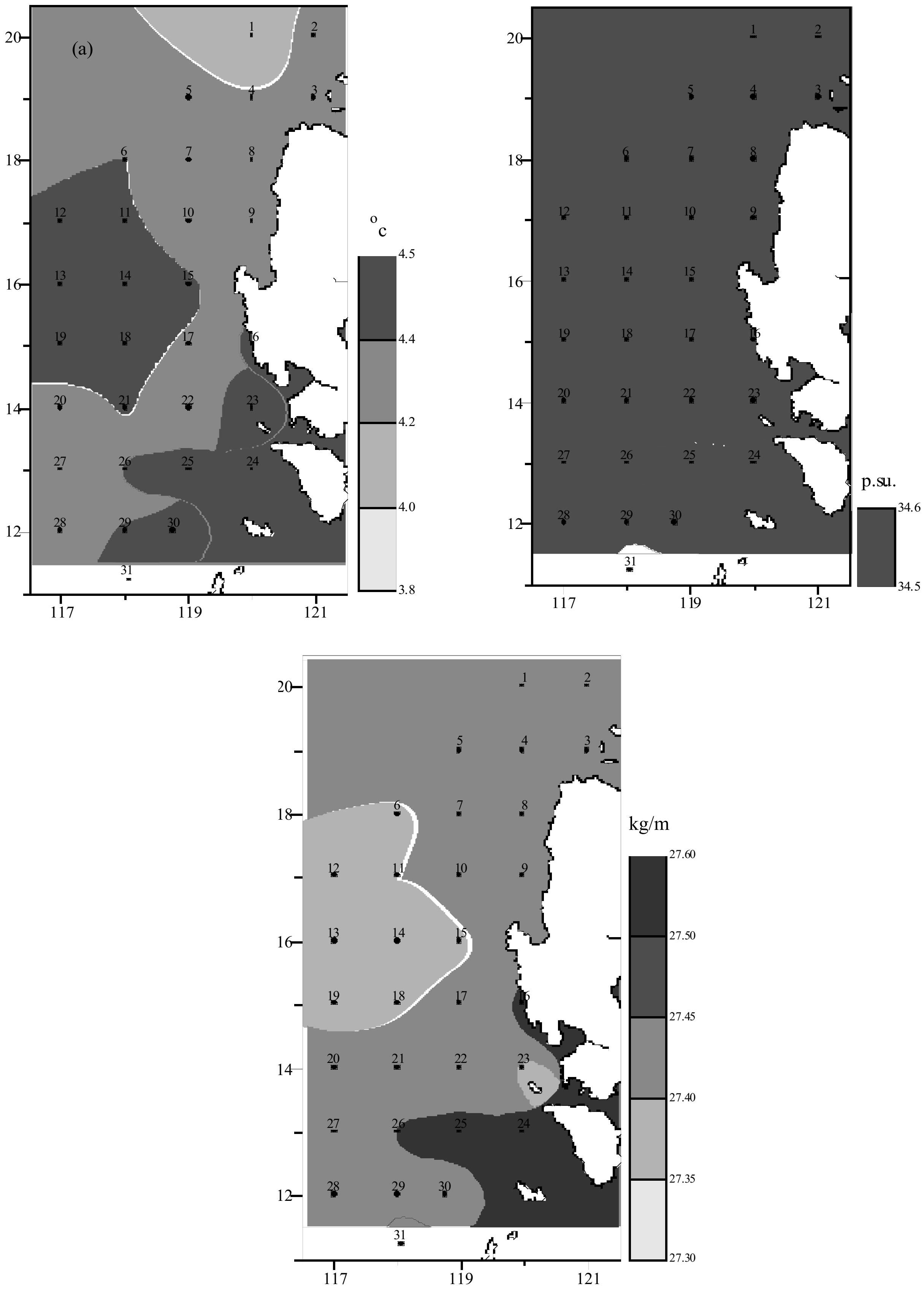

Fig. 5. Distribution of temperature (°c), salinity (p.s.u.) and density (kg/m^3) at 1000 m.

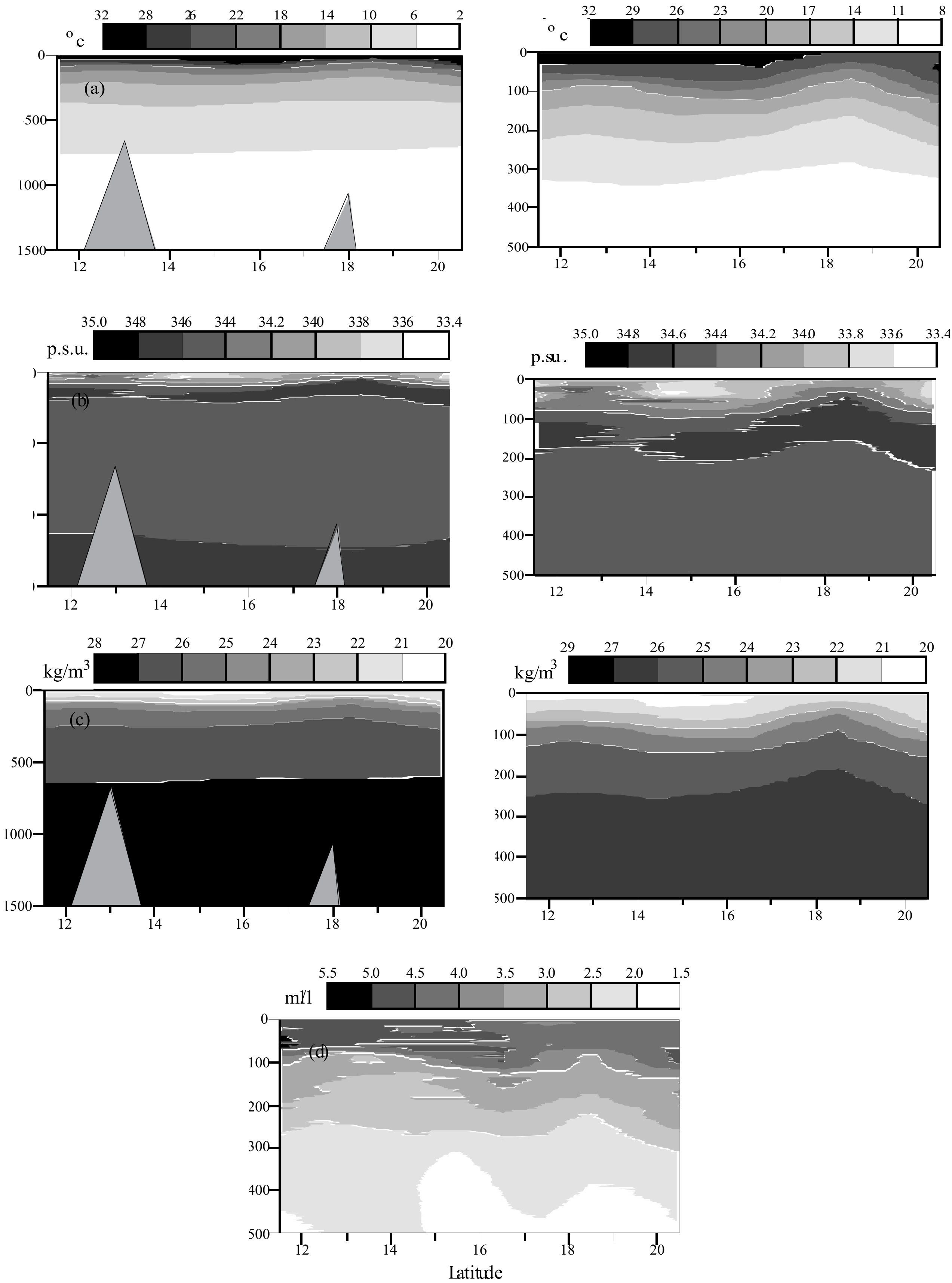

Fig. 6. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m^3) and dissolve oxygen (ml/l) from sea surface to 500 m. and 1500 m. along transect 1.

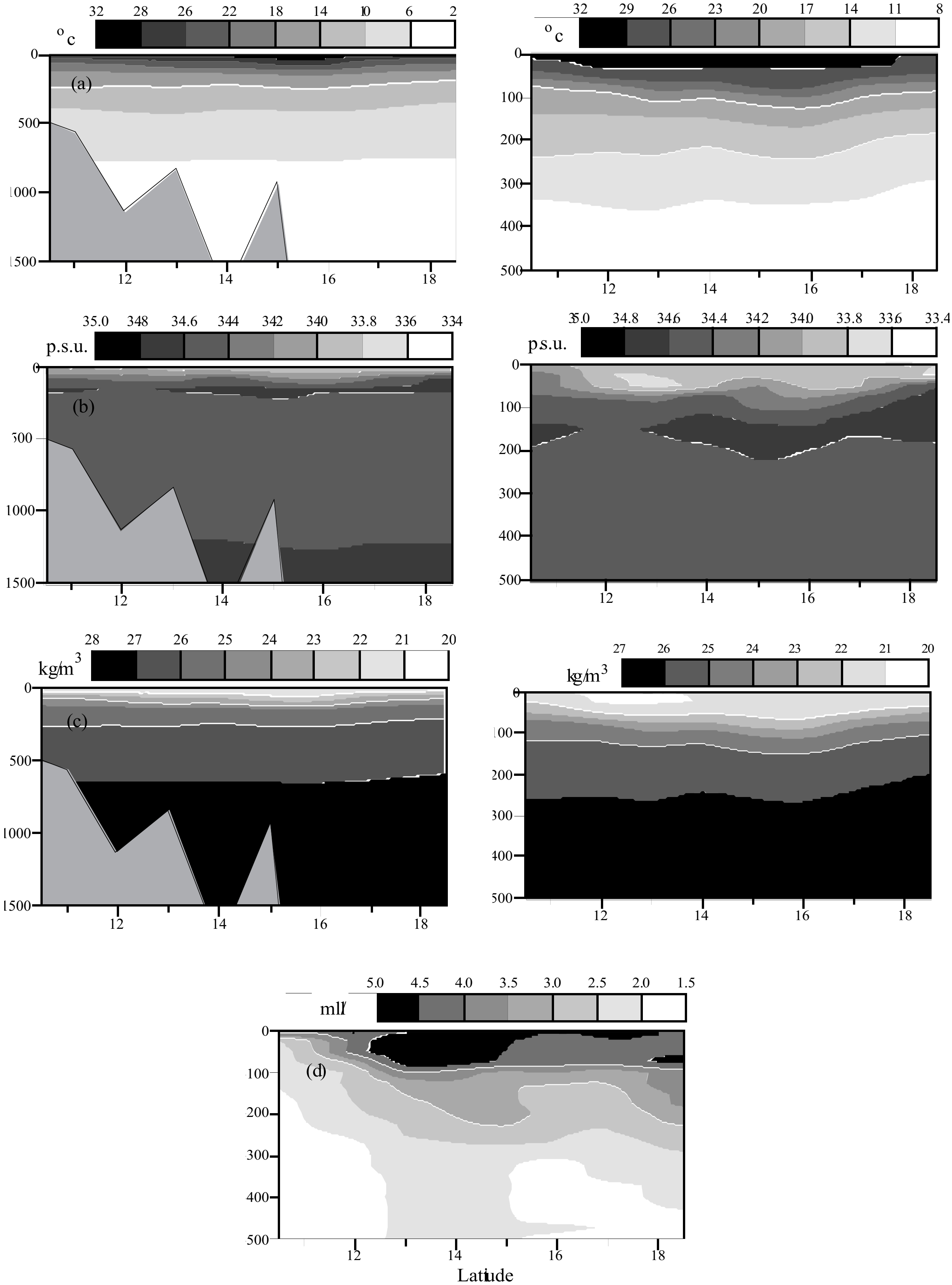

Fig. 7. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m³) and dissolve oxygen (ml/l) from sea surface to 500 m. and 1500 m. along transect 2.

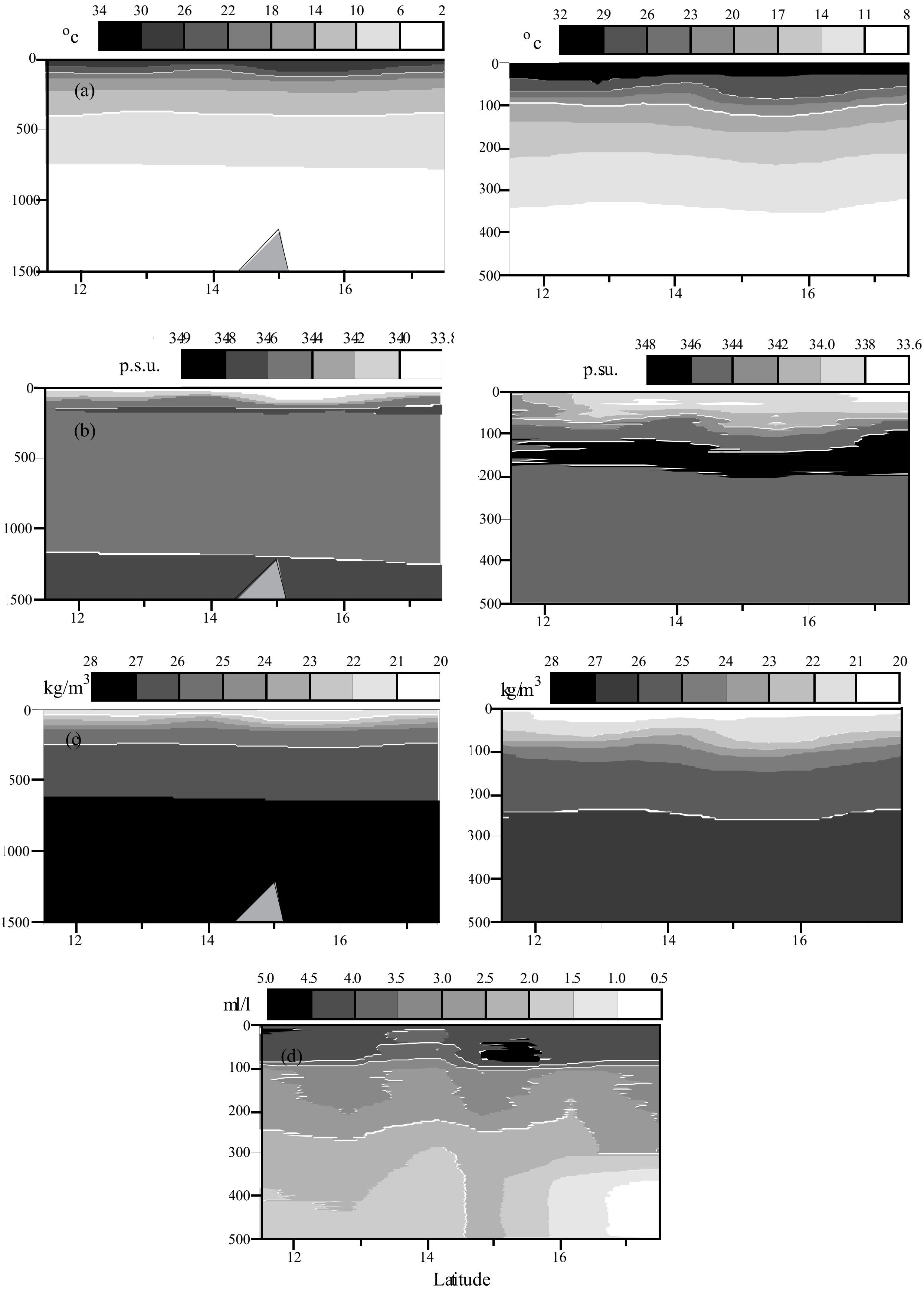

Fig. 8. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m³) and dissolve oxygen (ml/l) from sea surface to 500 m. and 1500 m. along transect 3.

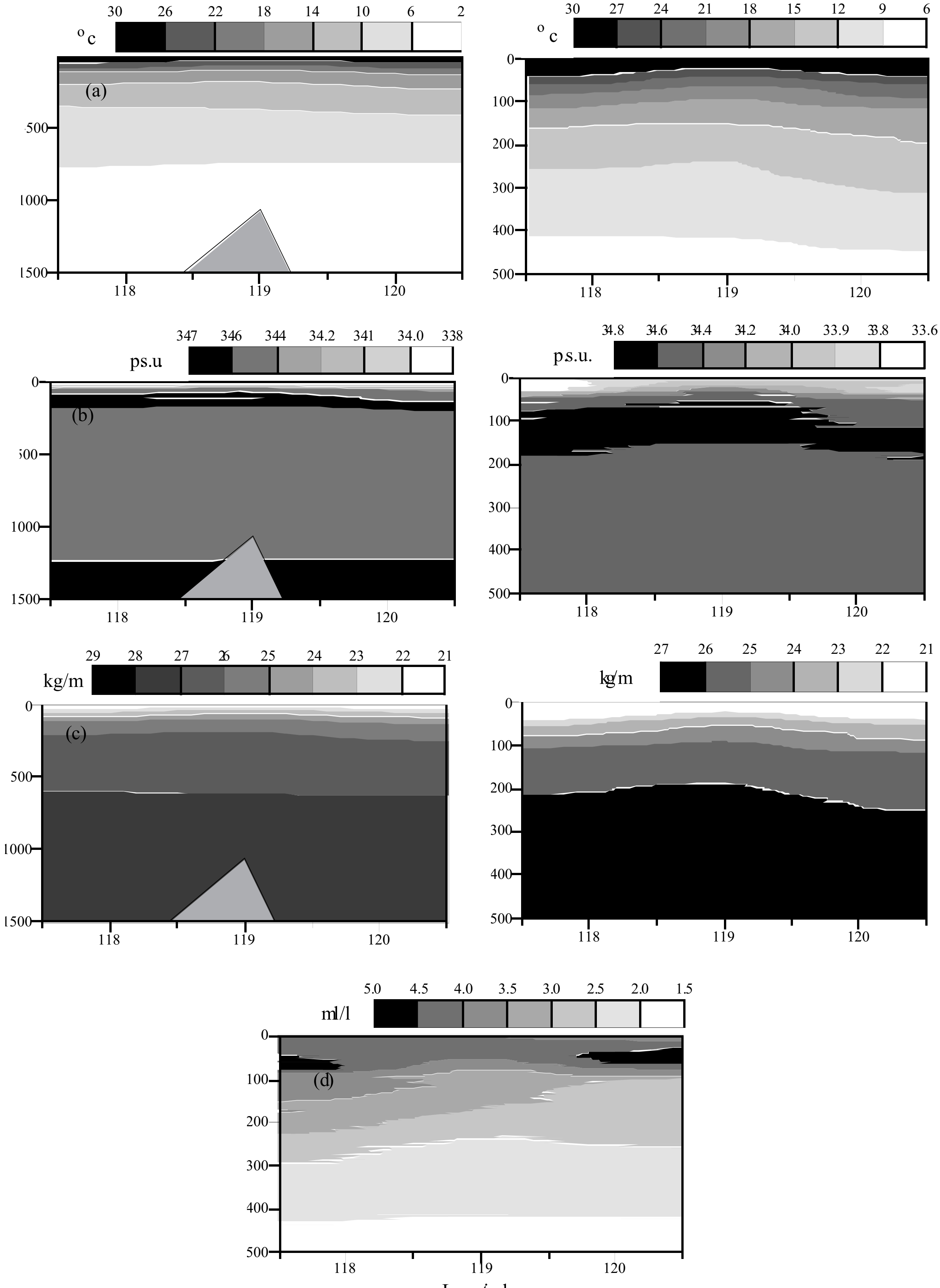

Fig. 9. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m^3) and dissolve oxygen (ml/l) from sea surface to 500 m. and 1500 m. along transect 4.

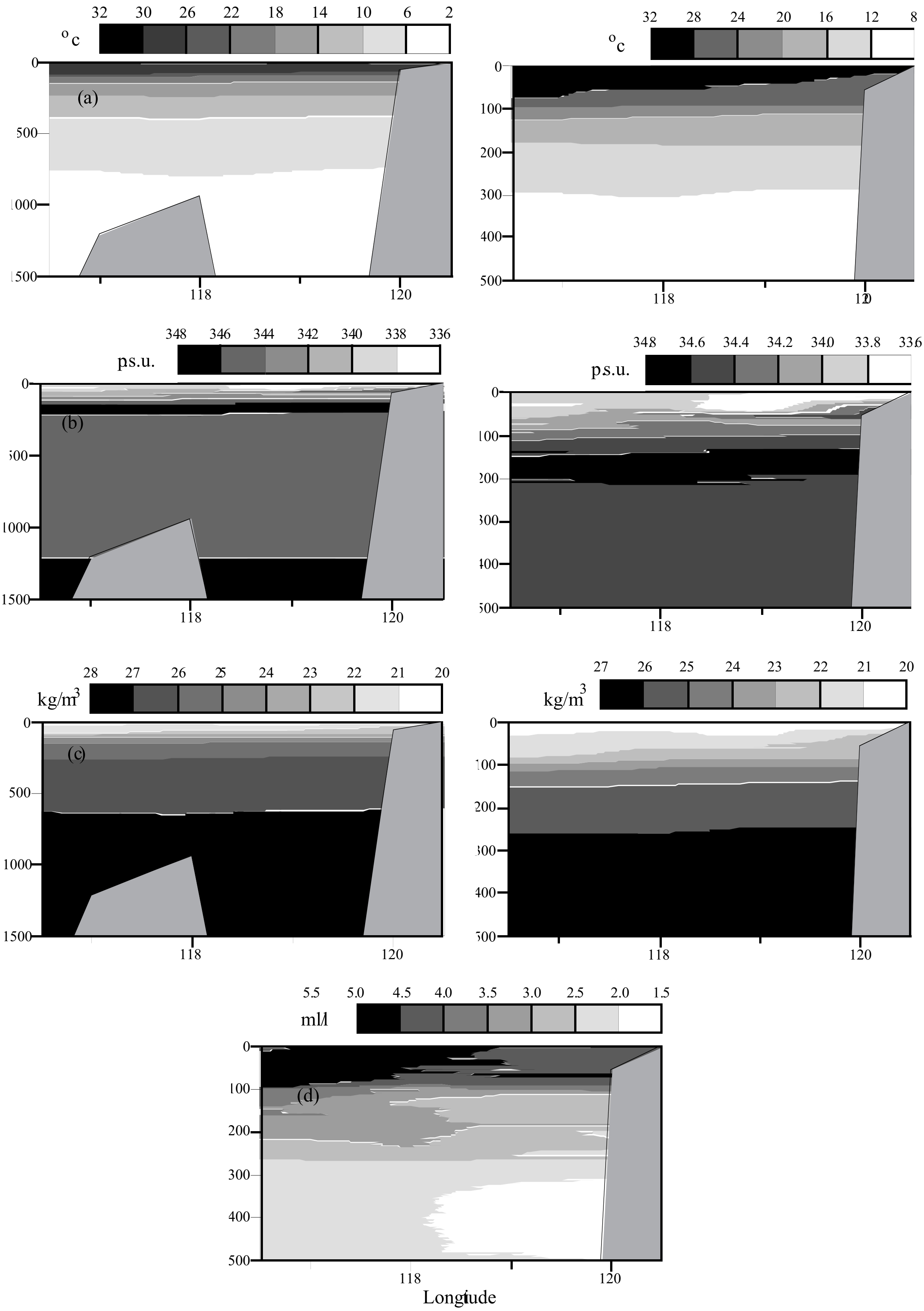

Fig. 10. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m³) and dissolve oxygen (ml/l) from sea surface to 500 m. and 1500 m. along transect 5.

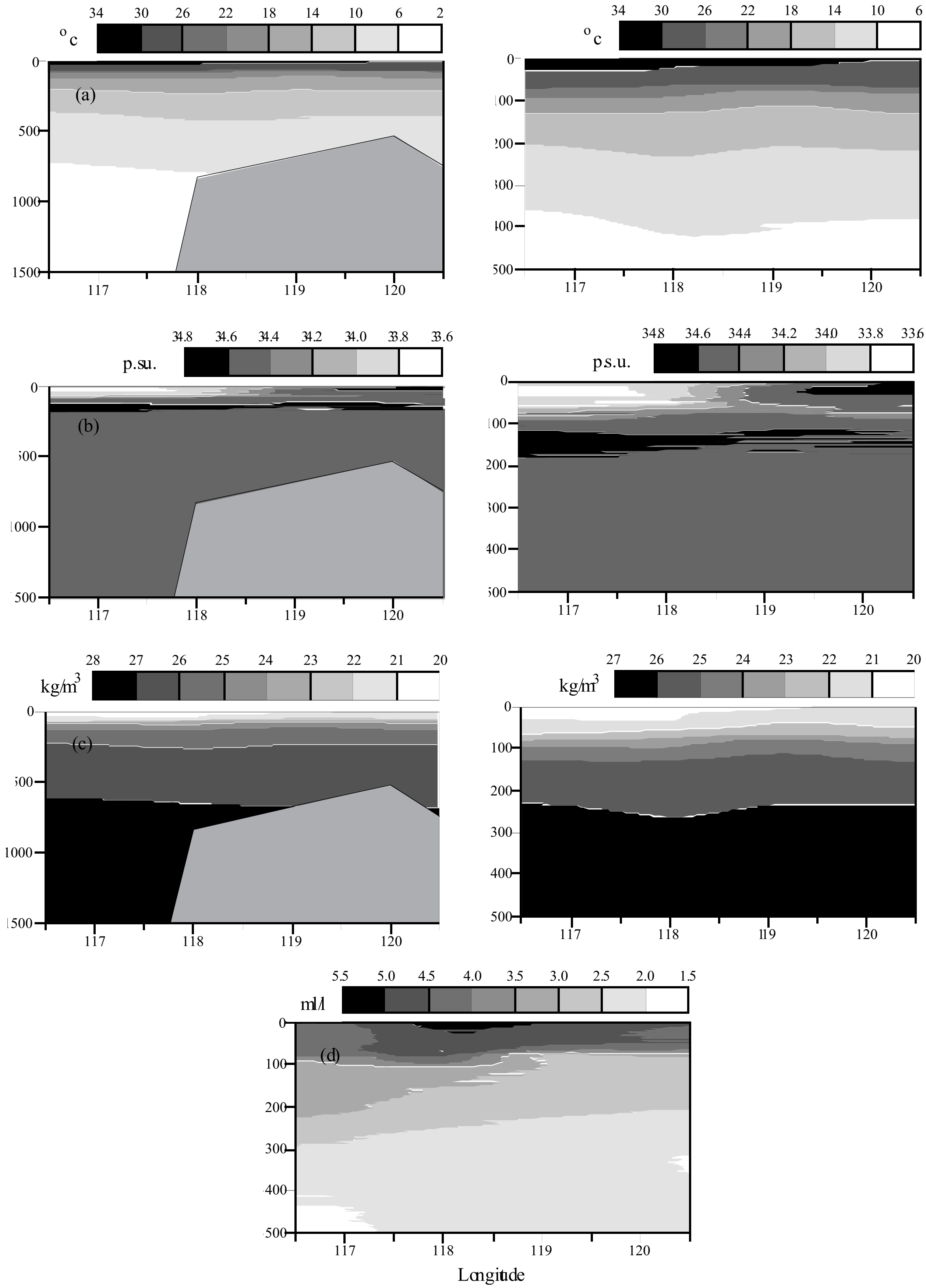

Fig. 11. Distribution of temperature (°c), salinity (p.s.u.), density (kg/m^3) and dissolve oxygen (ml/l) from sea surface to 500 m. and 1500 m. along transect 6.

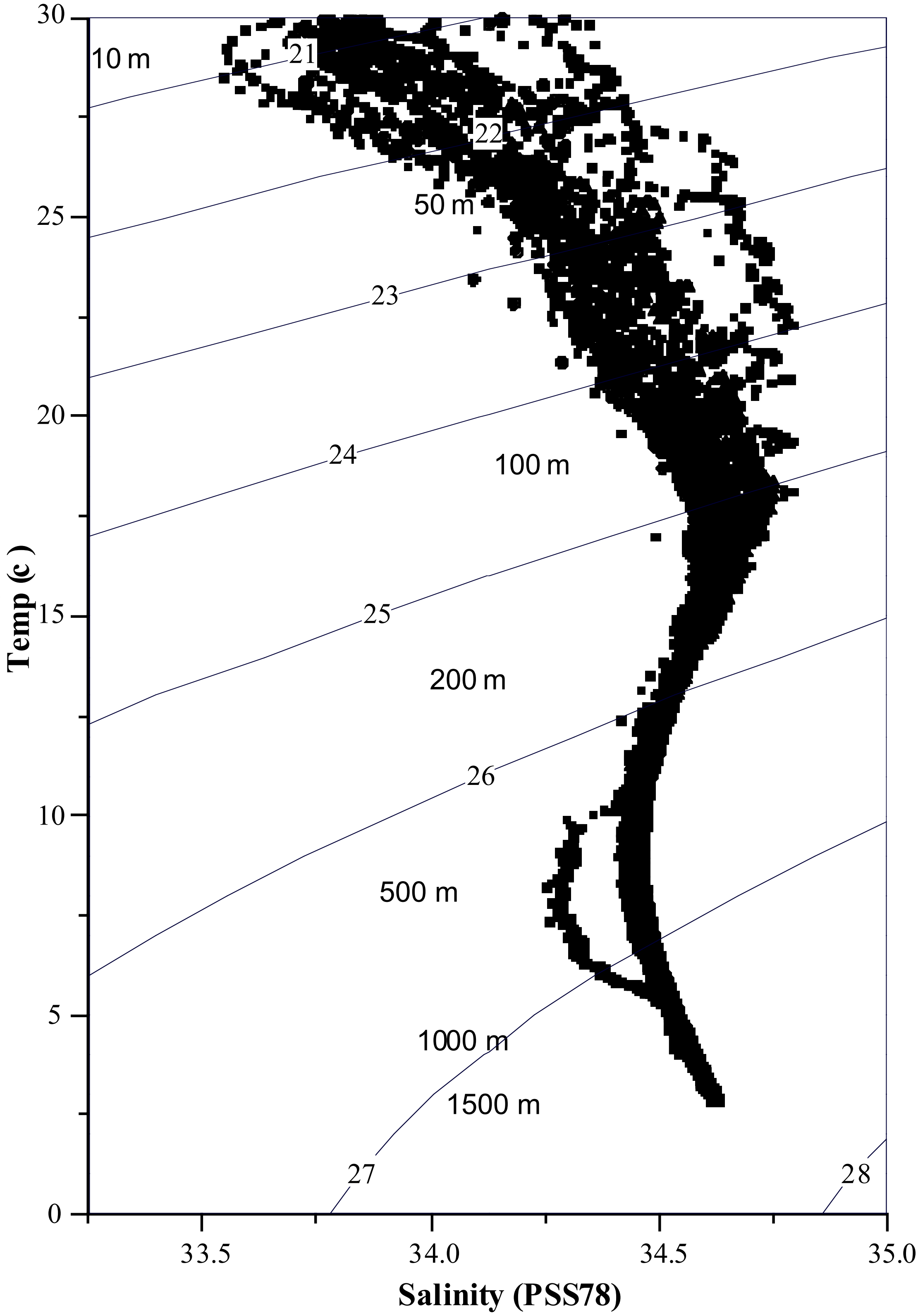

Fig. 12. T-S scatter plot of all the station deeper than 500 m.

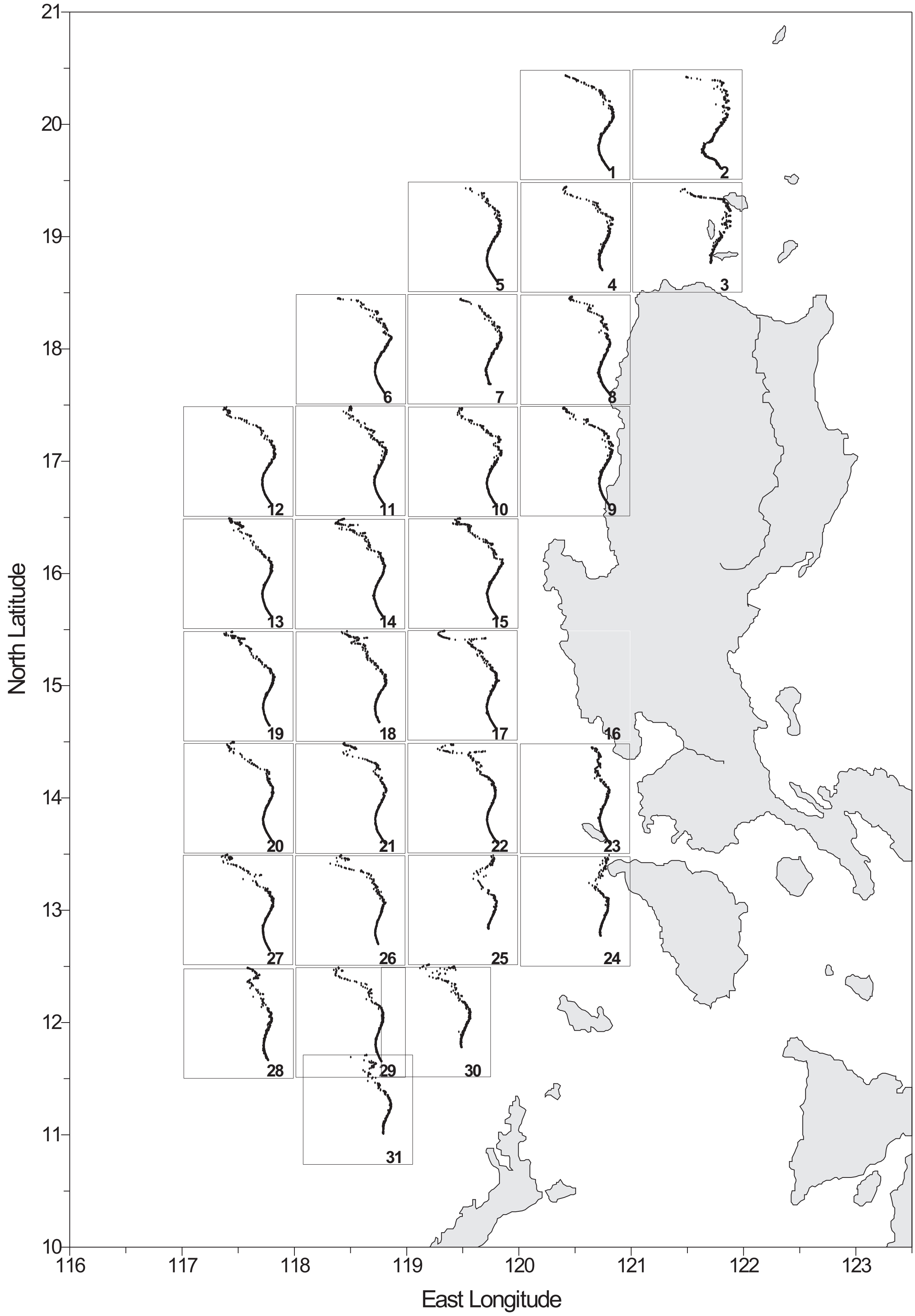

Fig. 13. T-S diagram for the station deeper than 500 m.

Geostrophic and Tidal Currents in the South China Sea, Area III: West Philippines

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Introduction

Physical oceanography is an important environmental factor controlling fishery productivity and fishing potential of a fishing ground. Thus, in this SEAFDEC Collaborative Research Program, physical oceanography has always been included.

Study Area

The study area II of the Collaborative Research was along the western coast of Luzon and Palawan Islands, in the Exclusive Economic Zone of the Philippines. The bathymetry of the area indicated the bottom depth up to more than 4000 m (Fig 1). The area is part of the South China Sea connected to the Pacific Ocean through the Bashi Strait to the north, and the lesser extent through the Visayas Sea. In addition, the area is also connected to the Sulu Sea to the south.

Water circulation in the surface mixed layer of the South China is strongly influenced by prevailing wind (Asian Monsoon and Pacific Trades). Generally the surface water flows northward during the Southwest Monsoon and opposite during the Northeast Monsoon. It is not clear, however, about the orographic effect from the near-by landmass on the Ekman circulation in the study area.

SEAFDEC Cruise No. 50 took place from mid April to mid May 1998, the intermediate period between Northeast and Southwest Monsoons. During the first half of the survey which was in the northern part, the wind was generally from the north and east through the Bashi Strait while during the last half of the survey in the southern part, the wind was generally from the east through the Visayas Area (Fig 2).

Data Collection and Calculations

CTD cast was carried out at all 31 stations using the onboard Falmouth CTD system. Calibrations were not performed due to limitation of funding and lack of suitable high precision calibration instrument. Raw data was averaged at every 1 dbar. Salinity and dynamic height were calculated based on standard equation of state of seawater using the EG&G Post Acquisition Data Analysis Software. Missing values and noises, if occurred, were substituted by binomial interpolation.

For the calculation of relative geostrophic current at each station, where the level of no-motion was assumed at 1000 dbar, data from Stations 3, 23, 24, 25, 30A and 31A were excluded. At each station, the east-west velocity component (u) and north-south velocity component (v) were calculated from dynamic slope to the east and to the north of the station, respectively. Steady state was assumed for the dynamic topography and therefore pressure gradient equal Coriolis force according to

$$g \tan(\theta) = fv \qquad \text{———— (1)}$$

where: g = gravitational acceleration (9.8 m s^{-2})
θ = dynamic topographic slope = dynamic height difference between stations divided by distance
f = Coriolis parameter, $1.455 \times 10^{-4} \sin(\text{latitude})$ s^{-1}
v = velocity, m s^{-1}

Cartesian coordinate system was used, i.e. the vector was positive eastward and northward. A total of 14 stations (1, 5, 6, 7, 10, 11, 12, 13, 14, 18, 19, 20, 21, and 27) had sufficient data to satisfy the calculation.

In addition to geostrophic balance calculation, the actual half-hourly currents at 3 levels (10m, 50m and 100m) over diurnal cycle were observed at Stations 1, 5, 12, and 27. Because the water depth was too large for the bottom tracking mode, the Furuno Doppler Current Indicator was operated in the relative mode, i.e. the recorded currents were relative to surface current at that time.

The observed relative current data was decomposed into u and v vectors. These vectors were smoothened by 3-points running average. Harmonic analysis of these relative vectors for absolute tidal current parameter (diurnal and semidiurnal amplitudes and phases) was done on these relative vectors from all 3 layers according to:

$$v'_{10} + v'_{50} + v'_{100}$$
$$= \text{absolute } v \text{ at } 10\text{ m} - \text{absolute } v \text{ at } 0\text{ m} + \text{absolute } v \text{ at } 50\text{ m} - \text{absolute } v \text{ at } 0\text{ m} + \text{absolute } v \text{ at } 100\text{ m} - \text{absolute } v \text{ at } 0\text{ m}$$

$$\begin{aligned} &= \langle v' \rangle_{10} + A_{1,10}\cos(2\pi t/T_{1,10} + \phi_{1,10}) + A_{2,10}\cos(2\pi t/T_{2,10} + \phi_{2,10}) \\ &+ \langle v' \rangle_{50} + A_{1,50}\cos(2\pi t/T_{1,50} + \phi_{1,50}) + A_{2,50}\cos(2\pi t/T_{2,50} + \phi_{2,50}) \\ &+ \langle v' \rangle_{100} + A_{1,100}\cos(2\pi t/T_{1,100} + \phi_{1,100}) + A_{2,100}\cos(2\pi t/T_{2,100} + \phi_{2,100}) \\ &- 3(A_{1,0}\cos(2\pi t/T_{1,0} + \phi_{1,0}) - A_{2,0}\cos(2\pi t/T_{2,0} + \phi_{2,0})) \qquad \text{———— (2)} \end{aligned}$$

where v' = relative u or v component recorded by current meter (dependent variable)
t = time (independent variable)
$\langle v' \rangle$ = average v' (known constant)
A_1, A_2 = amplitudes of semidiurnal and diurnal components (unknown)
T_1, T_2 = periods of semidiurnal and diurnal components (unknown)
ϕ_1, ϕ_2 = phases of semidiurnal and diurnal components (unknown)
subscripts 0, 50 and 100 are for depths of 0, 50 and 100 meters

Least square method was used to fit Eq. 2 to the observed data.

Results

Dynamic topography at sea surface clearly shows a strong high dynamic surface between about 15° and 16° N and a strong low dynamic surface between 18° - 19° N latitudes (Fig 3). These low and high surfaces could reflect anticyclonic (clockwise) and cyclonic (counterclockwise) circulation, possibly due to eddies. The average speed of surface geostrophic

Table 1. The geostrophic current speed and direction at or near standard depths

z	St 1		St 5		St 6		St 7		St 10		St 11		St 12	
(m	m/s	dir	m/s	dir	m/s	dir	m/s	dir	m/s	dir	m/s	dir	m/s	dir
0	0.33	215.	0.22	347.	0.27	137.	0.48	049.	0.20	073.	0.31	092.	0.23	101.
10	0.33	215.	0.22	345.	0.26	137.	0.47	049.	0.20	074.	0.31	092.	0.23	101.
20	0.33	216.	0.21	344.	0.25	137.	0.46	049.	0.19	074.	0.31	092.	0.23	100.
30	0.32	217.	0.19	344.	0.24	133.	0.43	049.	0.19	074.	0.30	092.	0.23	100.
50	0.28	218.	0.15	343.	0.19	129.	0.34	047.	0.19	071.	0.29	093.	0.22	099.
70	0.22	215.	0.13	344.	0.15	124.	0.27	043.	0.16	065.	0.25	096.	0.19	095.
10	0.13	205.	0.11	350.	0.12	116.	0.19	036.	0.13	054.	0.18	105.	0.12	092.
13	0.07	182.	0.11	355.	0.10	114.	0.15	026.	0.11	043.	0.14	117.	0.08	096.
15	0.06	164.	0.11	358.	0.09	113.	0.13	021.	0.11	039.	0.13	123.	0.06	098.
20	0.06	117.	0.10	000.	0.07	108.	0.09	012.	0.09	033.	0.11	135.	0.04	099.
25	0.08	104.	0.09	000.	0.06	102.	0.06	005.	0.07	028.	0.09	139.	0.03	102.
30	0.09	099.	0.08	358.	0.04	103.	0.04	005.	0.05	028.	0.07	140.	0.01	110.
40	0.10	102.	0.07	355.	0.02	127.	0.02	023.	0.02	021.	0.04	130.	0.00	182.
50	0.09	100.	0.06	354.	0.02	150.	0.02	056.	0.00	213.	0.03	109.	0.01	204.
60	0.08	095.	0.04	353.	0.01	180.	0.02	073.	0.01	211.	0.02	085.	0.01	203.
70	0.06	090.	0.03	347.	0.02	192.	0.02	079.	0.01	209.	0.01	069.	0.00	214.
80	0.04	079.	0.02	345.	0.01	186.	0.01	077.	0.01	206.	0.01	058.	0.00	276.
90	0.02	074.	0.01	334.	0.00	174.	0.01	064.	0.00	203.	0.00	070.	0.00	278.

z	St 13		St 14		St 18		St 19		St 20		St 21		St 27	
(m	m/s	dir	m/s	dir	m/s	dir	m/s	dir	m/s	dir	m/s	dir	m/s	dir
0	0.04	012.	0.14	174.	0.35	240.	0.38	277.	0.21	051.	0.22	049.	0.16	334.
10	0.04	015.	0.16	205.	0.24	248.	0.38	264.	0.21	051.	0.22	049.	0.16	337.
20	0.04	015.	0.15	205.	0.24	247.	0.38	264.	0.20	050.	0.22	048.	0.15	339.
30	0.04	011.	0.15	204.	0.25	246.	0.38	265.	0.20	050.	0.22	048.	0.15	342.
50	0.03	011.	0.14	201.	0.25	245.	0.36	266.	0.16	047.	0.21	044.	0.15	351.
70	0.04	008.	0.14	197.	0.22	242.	0.28	268.	0.08	028.	0.18	045.	0.17	359.
10	0.05	356.	0.12	192.	0.18	236.	0.15	280.	0.03	324.	0.16	046.	0.18	005.
13	0.04	339.	0.12	187.	0.14	230.	0.09	296.	0.04	296.	0.13	048.	0.18	013.
15	0.04	332.	0.12	185.	0.13	228.	0.08	308.	0.04	293.	0.12	052.	0.18	014.
20	0.03	319.	0.11	182.	0.11	221.	0.06	321.	0.04	294.	0.10	063.	0.16	014.
25	0.03	315.	0.09	179.	0.10	215.	0.05	326.	0.03	299.	0.08	071.	0.14	013.
30	0.02	326.	0.08	177.	0.09	212.	0.05	332.	0.03	310.	0.06	078.	0.12	011.
40	0.03	349.	0.06	176.	0.07	210.	0.04	336.	0.02	335.	0.04	093.	0.08	008.
50	0.02	358.	0.04	174.	0.06	212.	0.03	331.	0.02	345.	0.02	098.	0.05	356.
60	0.02	358.	0.03	171.	0.05	218.	0.03	331.	0.01	351.	0.01	091.	0.04	347.
70	0.01	359.	0.02	158.	0.04	225.	0.03	338.	0.00	348.	0.01	081.	0.02	352.
80	0.01	004.	0.01	169.	0.02	230.	0.01	332.	0.00	070.	0.01	068.	0.01	333.
90	0.00	007.	0.00	178.	0.01	232.	0.00	319.	0.00	056.	0.00	044.	0.00	274.

current around these eddies were in the range of 0.3 - 0.4 m s^{-1}. The remnant of these eddies could be observed as deep as 500 meter, where the geostrophic velocities were between 0 - 0.05 m $^{-1}$ (Table 1).

The cyclonic eddy found near the head of Luzon Island was due to wind turbulence as the low altitude airmass was forced by Northeast Trade Wind in the Pacific into the South China Sea through the Bashi Channel between Taiwan and Luzon Islands. This turbulence driven cyclonic eddy in this part of the South China Sea was likely to be a regular annual feature that will effect ecology and fisheries production in the area.

The dynamic high off the west coast of central Luzon could be the result of the westerly wind from Pacific Ocean through the Visayas Area. On entering the South China Sea, the northern portion of this wind stream bent toward the Northwest and causing the net surface Ekman transport toward the west coast of Luzon. The generally southward transport due to wind turbulence near the head of the Island could further strengthen the convergence and thus high dynamic surface was observed.

While dynamic topography and geostrophic balance calculation represented more to a longer term of water circulation, as resulted from dynamic equilibrium between the atmosphere

Table 2. Harmonic constants for u and v components of tidal current

St	z (m)	vector	T_1 (h)	A_1 (m/s)	ϕ_1 (deg)	T_2 (h)	A_2 (m/s)	ϕ_2 (deg)
1	0	u	24.26	0.384	2.6	11.81	0.507	1.4
		v	23.23	0.048	103.0	11.63	0.028	34.4
	10	u	24.17	0.393	0.8	11.82	0.519	4.3
		v	23.92	0.077	121.1	12.00	-0.037	227.9
	50	u	24.28	0.378	2.6	11.80	0.523	-1.8
		v	25.52	0.132	-70.7	8.55	-0.072	-58.4
	100	u	24.52	0.421	-9.0	11.79	0.489	-3.3
		v	2061	-0.202	86.6	8.48	0.111	-272.2
5	0	u	24.26	0.384	2.6	11.81	0.507	1.4
		v	23.68	-0.125	-43.1	13.13	-0.129	93.5
	10	u	24.17	0.393	0.8	11.82	0.519	4.3
		v	23.89	-0.112	-30.4	13.20	-0.124	86.0
	50	u	24.28	0.378	2.6	11.80	0.523	-1.8
		v	21.85	0.080	57.1	13.92	0.107	-31.2
	100	u	24.52	0.421	-9.0	11.79	0.489	-3.3
		v	16.49	0.308	-99.1	15.67	0.360	48.9
12	0	u	25.00	-0.798	2.2	12.40	-0.298	-2.8
		v	26.10	0.724	-172.5	12.37	0.019	-26.8
	10	u	25.08	-0.798	-0.5	12.47	-0.250	1.7
		v	26.10	0.178	-114.9	26.14	-0.609	-2.4
	50	u	25.01	-0.805	1.1	12.42	-0.293	-3.8
		v	26.02	-0.771	1.1	14.68	-0.008	18.2
	100	u	25.00	-0.777	-2.6	12.39	-0.309	4.6
		v	25.99	-0.783	0.8	12.24	0.014	19.2
27	0	u	25.95	0.031	135.1	12.61	0.051	-104.9
		v	27.94	0.032	152.4	11.98	0.035	-6.8
	10	u	12.67	0.032	-116.4	8.34	-0.014	-106.5
		v	58.32	0.009	13.6	8.27	-0.031	-64.0
	50	u	24.72	-0.089	21.4	11.76	0.026	100.1
		v	24.88	-0.113	62.8	11.86	-0.051	-105.2
	100	u	24.37	-0.130	49.7	12.06	-0.043	24.4
		v	24.48	0.089	-57.5	13.47	0.010	-99.3

and the water, instantaneous current as observed at a moment in time would reflect more to the tidal and local winds which exerted a shorter time and space scale, and thus was less likely to reach the equilibrium. The characteristics of the tidal current are summarized in Table 2.

Tidal current at the sea surface was dominated by east-west diurnal component at St 1 with the maximum magnitude of about 0.5 ms^{-1} (Fig 4). The diurnal component became more dominant as the latitude decreased. At St 12, the northeast-southwest vectors were very prominent, over 1 m s^{-1}. Surface tidal current was negligible at St 27.

At 50-meter depth, tidal current pattern and magnitude were more or less similar to those at the surface (Fig 5). At St 1 the north-south component became slightly significant. Also at St 27, tidal current especially northeast-southwest diurnal was more observable than at the surface.

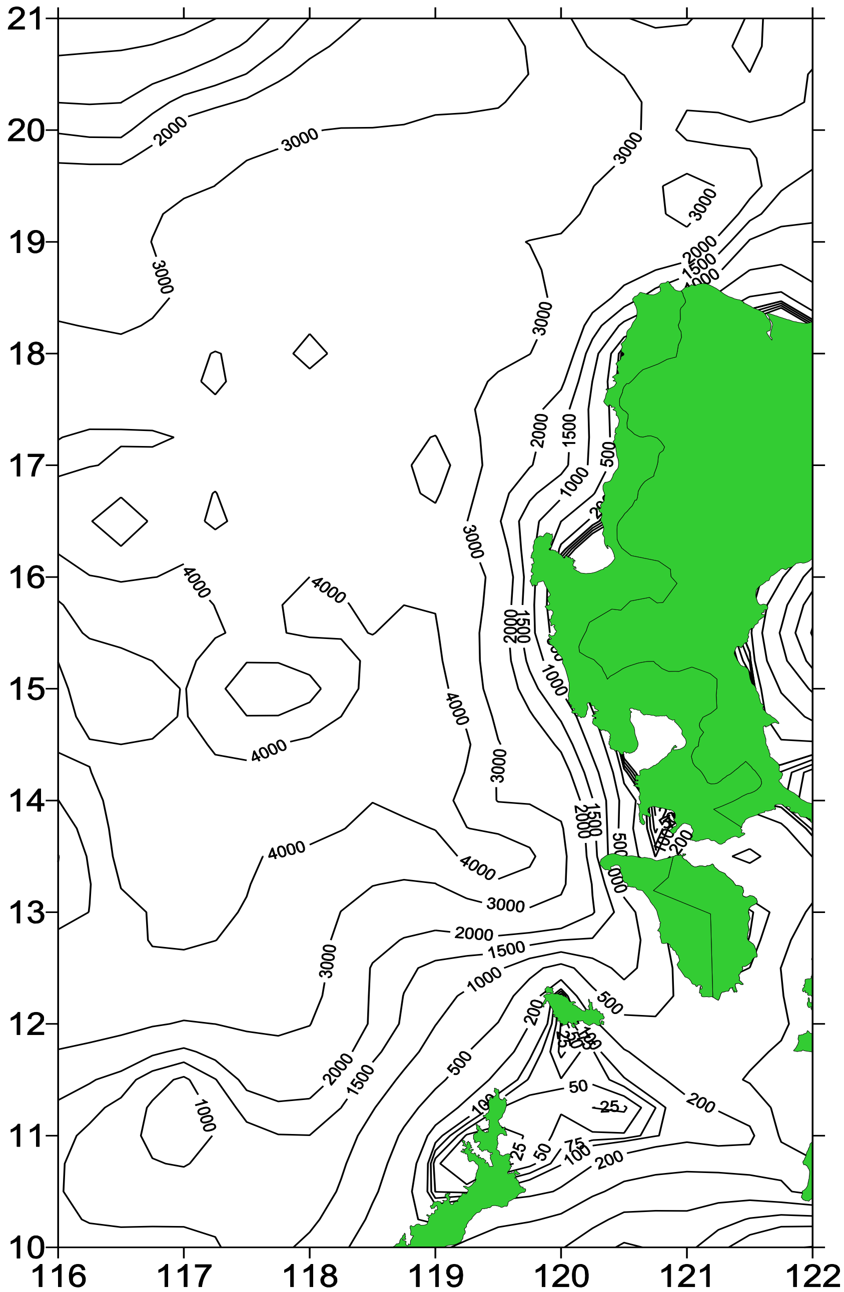

Fig. 1. Bathymetry of the study area.

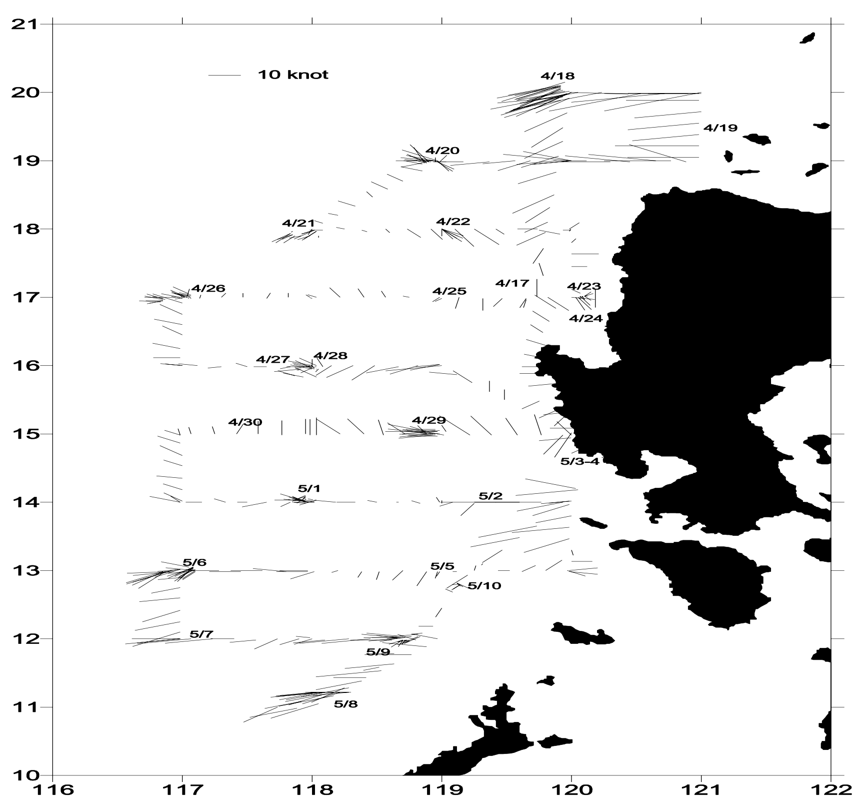

Fig. 2. Hourly wind vector along the cruise track

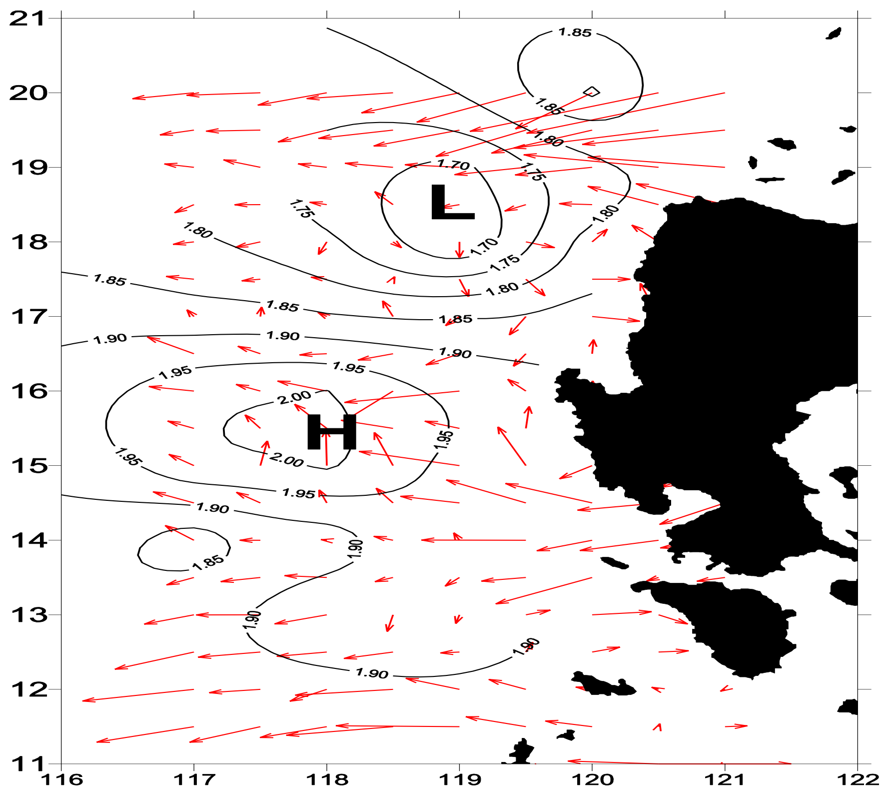

Fig. 3. Dynamic topography (dyn.m) at sea surface relative to 1000 dBar.

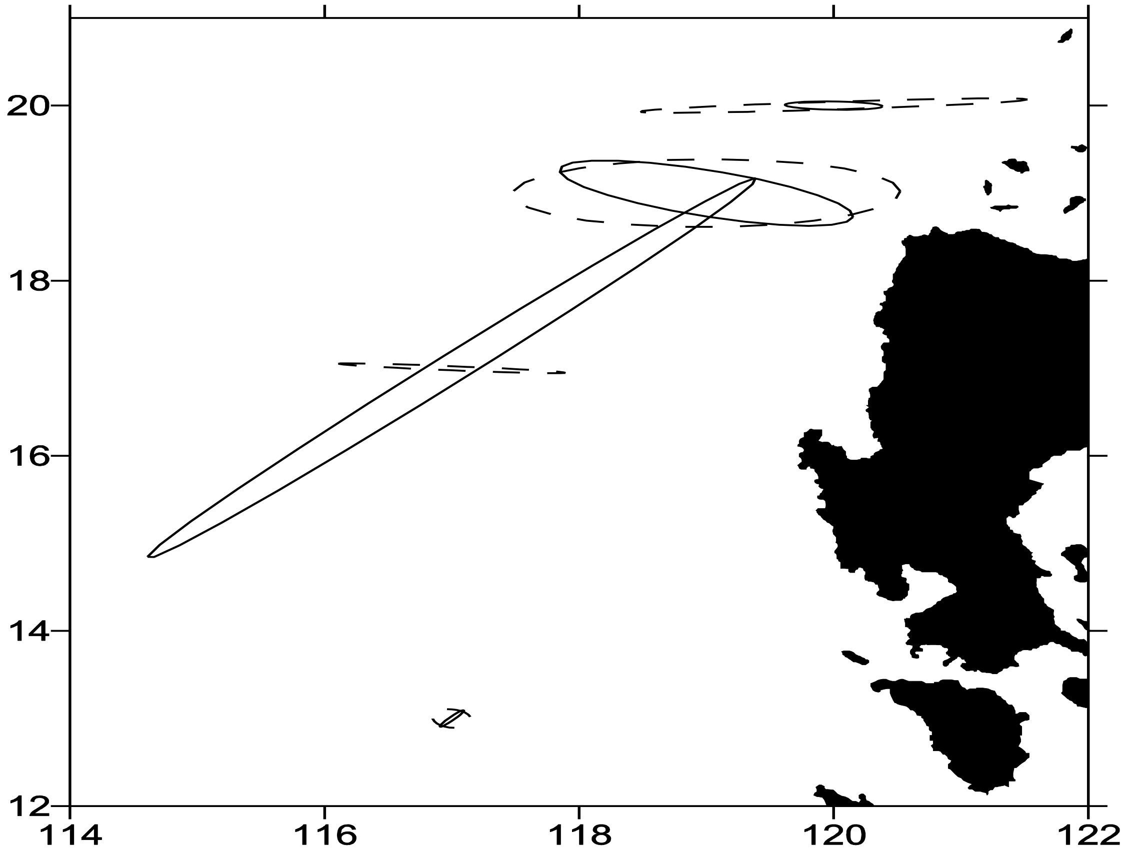

Fig. 4. Diurnal (solid lines) and semidiurnal (dashed lines) components of tidal current at sea surface

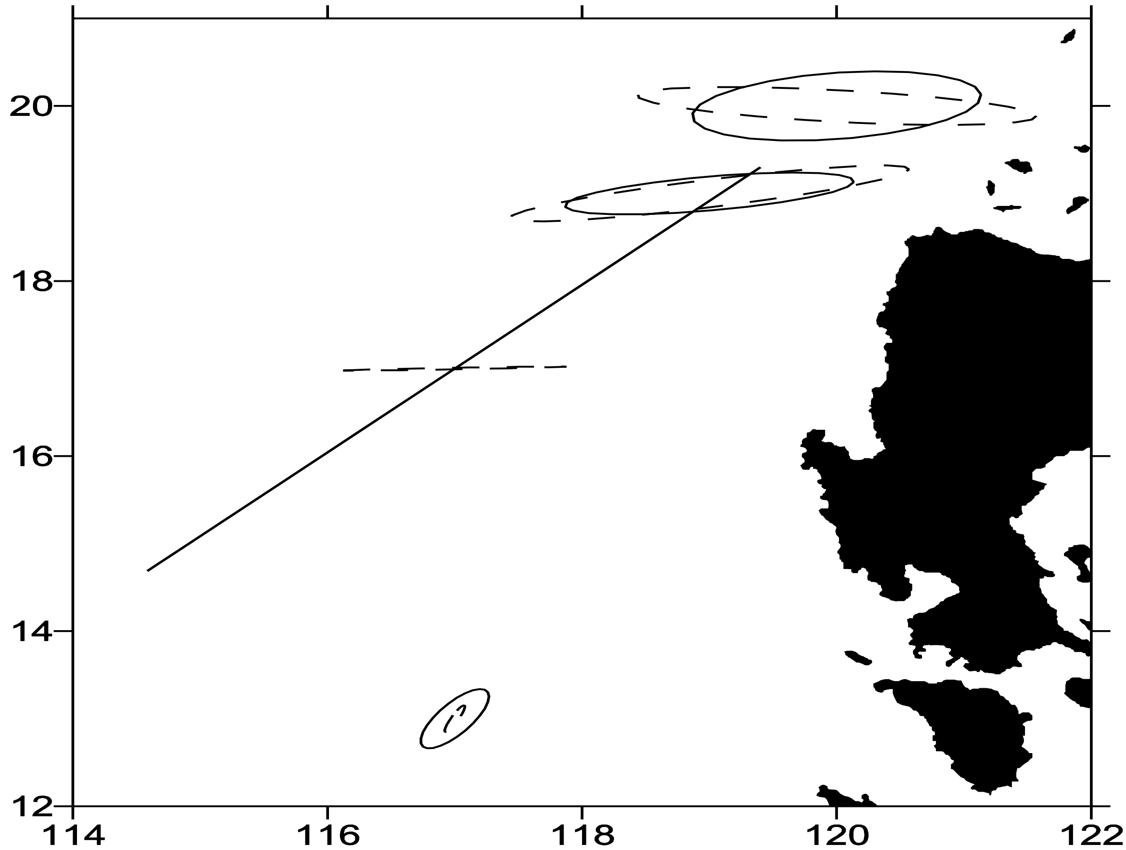

Fig. 5. Diurnal (solid lines) and semidiurnal (dashed lines) components of tidal current at 50m

Discussion

The dynamic high and low in this study area were owed to the relative vertical movement of water. The high area reflected a downward movement or downwelling in which as far as fisheries is concerned, less potential for fisheries. The low dynamic surface due to cyclonic eddy caused by wind turbulence near the head of Luzon Island indicated a potential fishing ground for this season.

Wind-dominated circulation with some orographic effects suggested that potential fishing ground might be located for each season from wind data from coastal as well as ship (GTS) stations. Topex/Poseidon data was attempted in this study, however it was soon found out that the global tidal model used by NASA could not resolve the temporal tidal effect (Fig 6). The lack of reliable tidal data for the area prohibited the usefulness of remote sensing data.

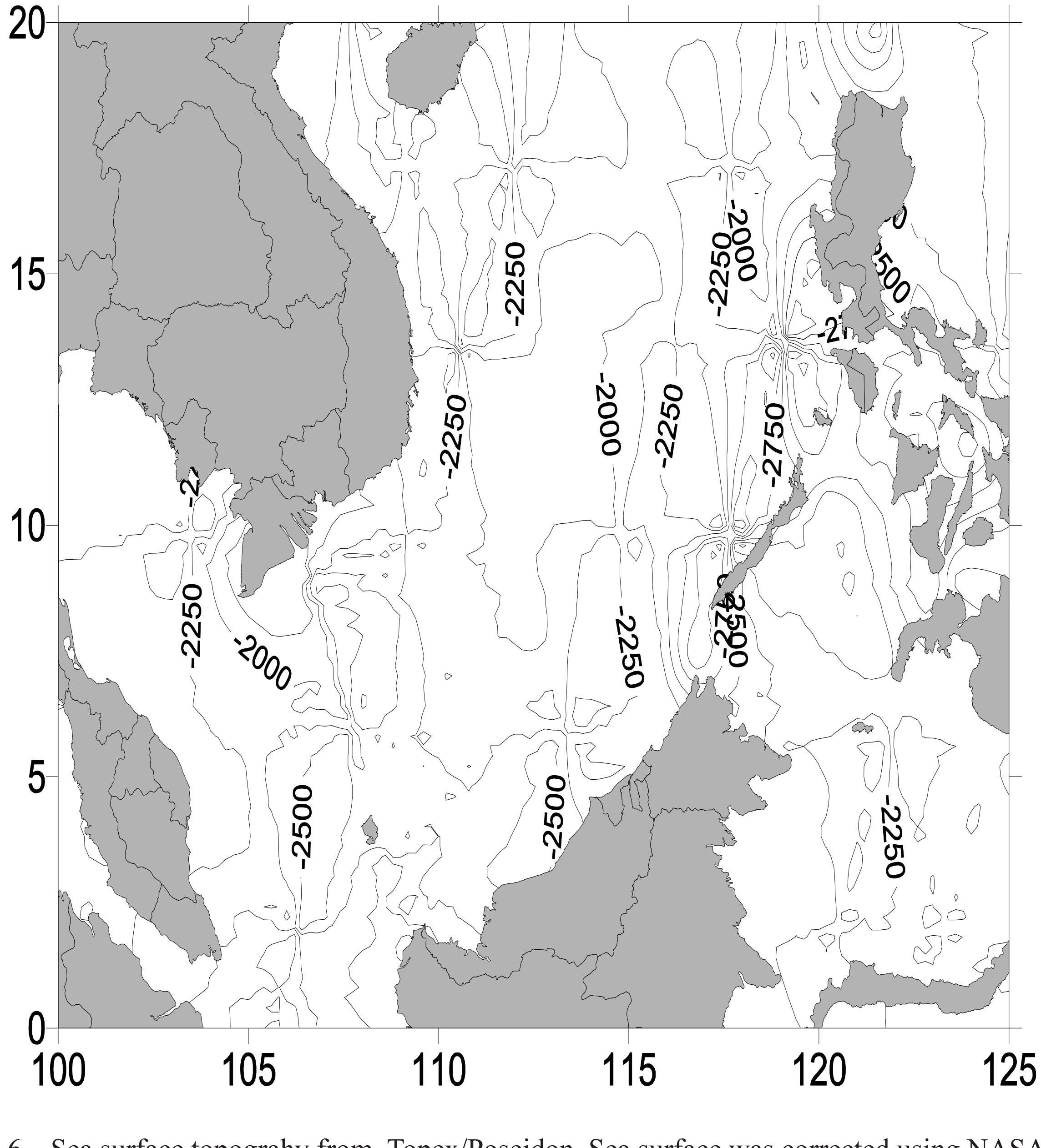

Fig. 6. Sea surface topograhy from Topex/Poseidon. Sea surface was corrected using NASA global tidal model. Yet Troughs ridges were still prominaent

Petroleum Hydrocarbon Contamination in Seawater along the Western Coast of the Philippines

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ABSTRACT

A study on petroleum hydrocarbon concentrations in seawater from the South China Sea off the western coast of the Philippines was conducted during April to May 1998. The concentrations of dissolved/dispersed petroleum hydrocarbons (DDPH) in seawater samples were measured at 31 stations, using Ultraviolet Fluorescence (UVF) Spectroscopy technique. The DDPH concentrations were found to be in the range of 0.02 – 1.47 µg/l as chrysene equivalent, with an average of 0.25 µg/l.

An attempt was made to compare between petroleum hydrocarbons in seawater samples from the near-shore area (8 stations) and the offshore area (23 stations). It was found that the DDPH concentrations of the near-shore stations were in the range of 0.03 – 0.47 µg/l, with an average of 0.12 µg/l, whereas the DDPH concentrations of the offshore stations were in the range of 0.02- 1.47 µg/l, with an average of 0.29 µg/l. However, the student's t-test of the two data groups indicated that the two means were not significantly different at $\alpha = 0.05$.

Introduction

The waters of Southeast Asia occupy a crossroad position between the Indian and Pacific oceans on the trade routes of Europe, Africa, the Middle East, Japan and other Far Eastern nations. The major transportation route for oil imported into the region is from the Middle East and Africa through the Straits of Malacca and the South China Sea, most of it in transit to Japan, with offshoots to Thailand, Taiwan and the Philippines. Hence, the water along this route is constantly at a risk of being contaminated by oil, either from accidental spills or routine ship operations such as loading, discharging and bunkering.

The various sources from land and marine-based oil pollution of the ASEAN marine environment have been studied (WHO/PEPAS, 1981). Hydrocarbon concentrations were measured in both the open seas and coastal waters. Concentrations vary widely in the region, but coastal areas are generally more than 1000 times higher than the open sea baseline measurement (Bilal and Kuhnhold,1980).

This study deals mainly with part of the South China Sea off the western coast of the Philippines to provide an information on the levels of petroleum hydrocarbons generally present in this region. The study is a joint cooperation between the Bureau of Fisheries and Aquatic Resources (BFAR) of the Philippines, the Marine Fishery Resources Development and Management Department (MFRDMD) of Malaysia, Southeast Asian Fisheries Development Center, Training Department (SEAFDEC TD) and Chulalongkorn University, Thailand.

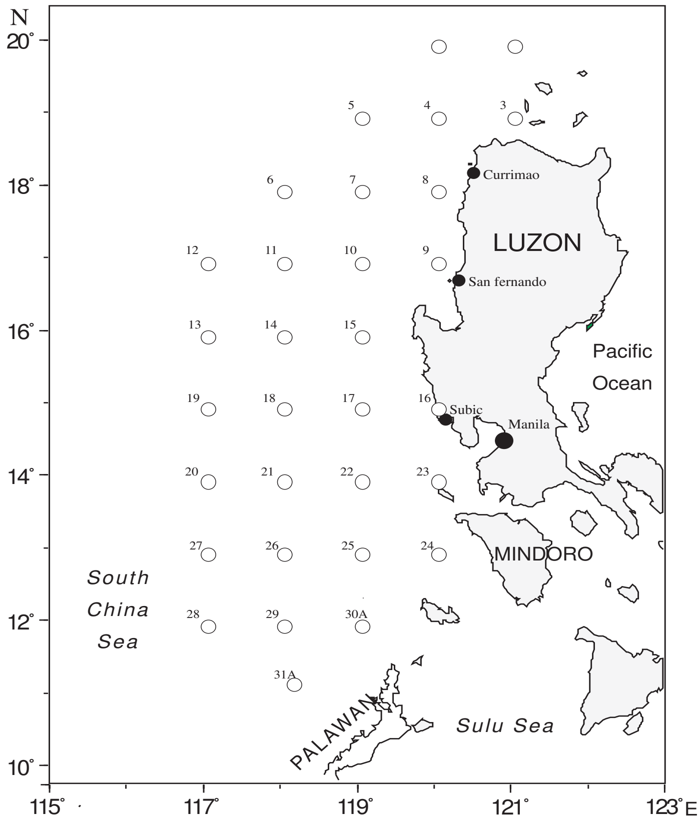

Fig. 1. Map of the sampling stations off the western coast of the Philippines.

Materials and methods

Sampling sites

Water samples were taken from 31 stations along the western coast of the Philippines. Sample collection took place on board the M.V.SEAFDEC between the months of April to May 1998. The study area is located between 117^o and 121^o E longitude and 11^o and 20^o N latitude. These included 8 stations from the near-shore area and 23 stations from offshore area (Figure 1).

Analytical procedures

Seawater samples were collected at 1 meter depth below sea surface, using 4 -liters amber coloured glass bottles mounted on a weighted frame, the design of which is in accordance with IOC standard procedure (IOC/UNESCO,1984). There after 100 ml of each sample was discarded and immediately replaced with 50ml nano-grade hexane. The samples were thoroughly shaken before storage in a dark, cool place. Analysis for dissolved/dispersed petroleum hydrocarbon (DDPH) concentration was conducted in the laboratory upon returning to shore.

Each water sample was extracted three times with nano-grade hexane in a separatory funnel. The combined hexane volume was dried by an addition of anhydrous Na_2SO_4 and concentrated to 5 ml using a rotary evaporator. Ultraviolet fluorescence (UVF) intensity of the reduced samples was measured at an emission wavelength of 360 nm and excitation wavelength of 310 nm, using a Perkin Elmer Model 3000 Spectrofluorometer.

The measurement of UVF intensity obtained from the samples was calibrated against standard chrysene. Statistical analysis for this study was a simple student's t-test.

Table 1 Dissolved/dispersed petroleum hydrocarbon (DDPH) concentrations in seawater from sampling stations in the South China Sea (µg/l as chrysene equivalents).

Station	DDPH	Station	DDPH
1	0.38	17	0.03
2	0.45	18	0.03
3	0.03	19	0.02
4	0.04	20	0.02
5	0.13	21	0.05
6	0.35	22	0.51
7	0.05	23	0.04
8	0.03	24	0.03
9	0.04	25	0.32
10	0.86	26	0.64
11	0.02	27	0.2
12	0.02	28	0.32
13	0.03	29	0.27
14	0.02	30	0.56
15	0.47	31	1.47
16	0.26	Average	0.25

Table 2 Dissolved/dispersed petroleum hydrocarbon (DDPH) concentrations categorized according to geographical location into near-shore and offshore areas (µg/l as chrysene equivalent).

Near-shore		**Offshore**			
Station	**DDPH**	**Station**	**DDPH**	**Station**	**DDPH**
3	0.03	1	0.38	18	0.03
4	0.04	2	0.45	19	0.02
8	0.03	5	0.13	20	0.02
9	0.04	6	0.35	21	0.05
15	0.47	7	0.05	22	0.51
16	0.26	10	0.86	25	0.32
23	0.04	11	0.02	26	0.64
24	0.03	12	0.02	27	0.2
Average	**0.12**	13	0.03	28	0.32
		14	0.02	29	0.27
		17	0.03	30	0.56
		Average	**0.29**	31	1.47

Table 3 Summary of statistical values (mean, range, S.D., variance, t-value) of DDPH concentrations in the South China Sea (µg/l as chrysene equivalents).

Area	**n**	**Range**	**Mean**	**S.D.**	**Variance**
Near-shore	8	0.03 - 0.47	0.11	0.16	0.03
Offshore	23	0.02 – 1.47	0.29	0.35	0.12

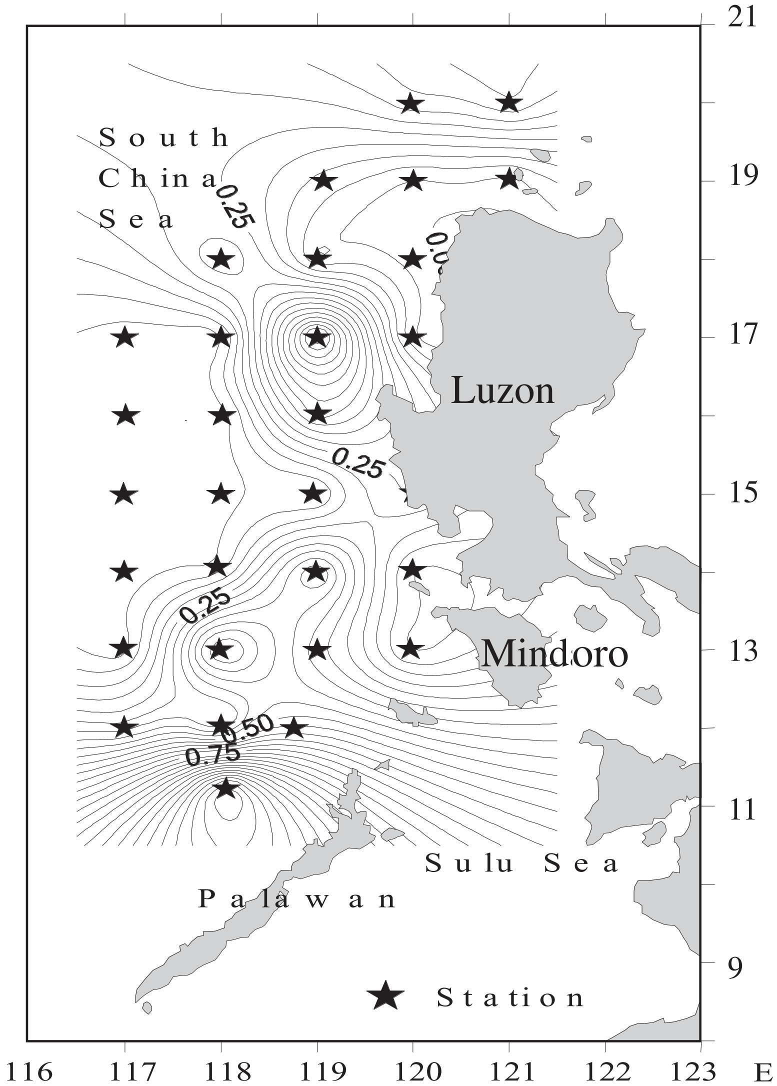

Fig. 2. Contour lines of DDHP concentration in the South China Sea.

Results and discussion

Analysis of the seawater samples taken from 31 stations in the South China Sea yields the total of DDPH concentration values as shown in Figure 2 and Table 1. The obtained DDPH concentrations are within the range of 0.02-1.47 µg/l as chrysene equivalent, with a mean value of 0.25 µg/l.

DDPH concentrations in seawater can be grouped into two general areas, namely the near-shore and the offshore stations (Table 2). The DDPH concentrations of the near-shore stations were in the range between 0.03-0.47 µg/l, with the mean value of 0.11 µg/l. Meanwhile, the offshore concentrations were found in the range of 0.02-1.47 µg/l, with an average value of 0.29 µg/l. However, student's t-test of the data indicated no significant difference between the mean of the near-shore area as compared to that of the offshore area, within the 95% confidence interval (Table 3).

Figure 2 shows elevated concentrations of DDPH in water samples off the Palawan Island, particularly at Station 31 which has the highest DDPH concentration of 1.47 µg/l as chrysene equivalent. This high concentration may be due to the fact that Station 31 is located near an offshore oil exploration and production site. However, the high DDPH concentrations at Station 10, 15, 22, 25, and 26 would be probably due to contamination from shipping operation since these stations are located along a major shipping route for crude oil transport in Southeast Asia (Finn et al., 1979).

Generally the concentrations of DDPH in this part of the South China Sea are lower than that in the Gulf of Thailand and the east coast of Peninsular Malaysia (Wattayakorn et al., 1998; Wongnapapan et al., 1997). This finding indicates that coastal areas and semi-enclosed marine embayment, like the Gulf of Thailand, have higher levels of petroleum contamination in water as compared to the open sea areas since the biggest contributions of oil come from terrestrial sources (National Research Council, 1985) .

Conclusions

1. The analysis shows that contamination of DDPH in this area is likely to be the result of maritime and shipping activities as well as offshore oil exploration and production.
2. The mean value of DDPH concentrations from near-shore and offshore areas is not significantly different from each other within the range of the 95% confidence interval.

Acknowledgments

The authors would like to express their sincere gratitude to SEAFDEC Training Department and Faculty of Science, Chulalongkorn University for funding this research. We would also like to thank Dr. Anond Snidvongs for his advice during sample collection. Lastly, our thanks also go to Mr. Valeriano M. Borja for his valuable assistance.

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