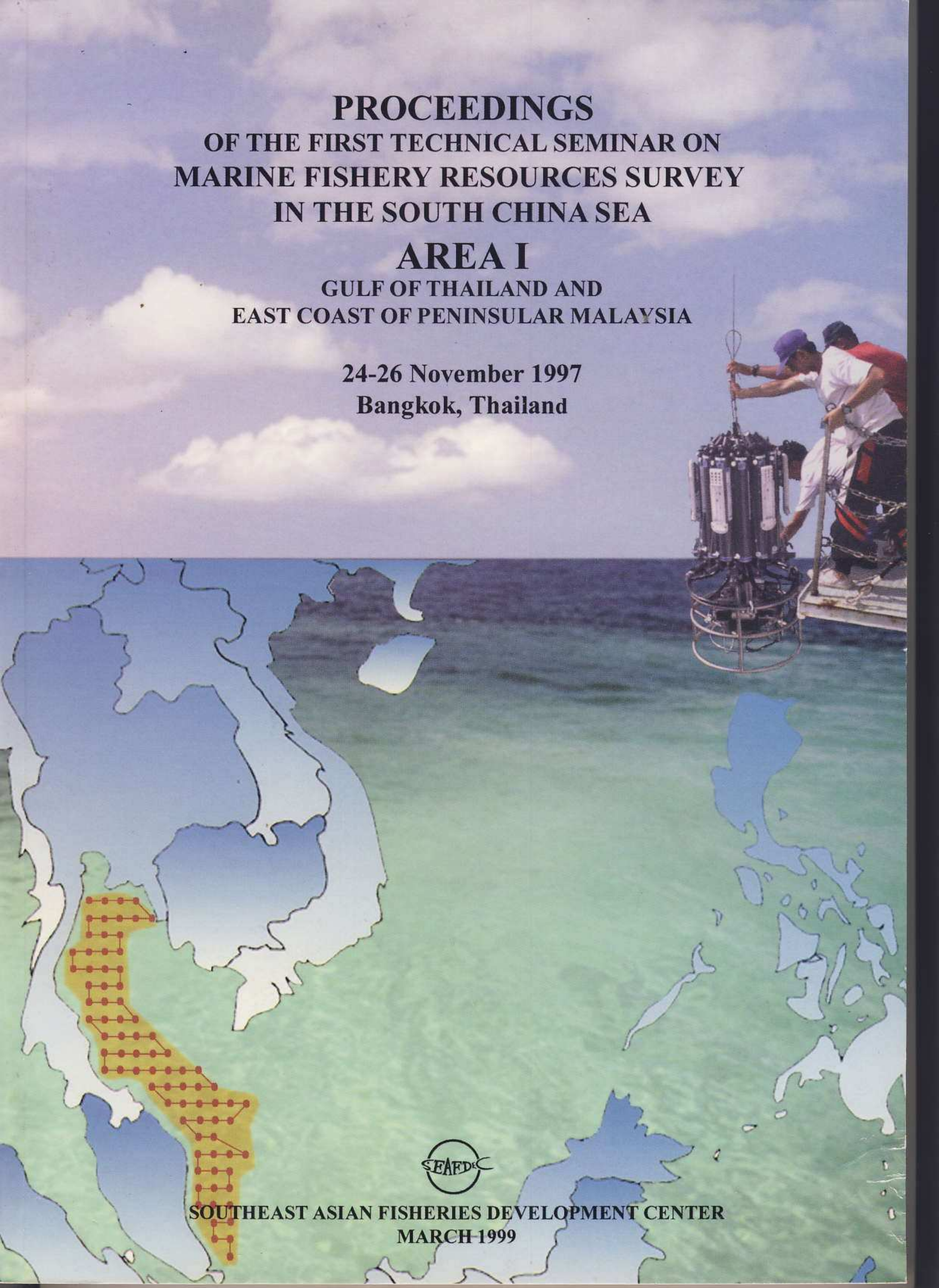


PROCEEDINGS

OF THE FIRST TECHNICAL SEMINAR ON MARINE FISHERY RESOURCES SURVEY IN THE SOUTH CHINA SEA

AREA I

GULF OF THAILAND AND EAST COAST OF PENINSULAR MALAYSIA

24-26 November 1997
Bangkok, Thailand

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
MARCH 1999

PROCEEDINGS OF

THE FIRST TECHNICAL SEMINAR ON MARINE FISHERY RESOURCES SURVEY IN THE SOUTH CHINA SEA, AREA I: GULF OF THAILAND AND PENINSULAR MALAYSIA

24 - 26 NOVEMBER 1997

BANGKOK, THAILAND

TRAINING DEPARTMENT
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

SAMUTPRAKAN, THAILAND
MARCH, 1999

PREFACE

Due to gross over-exploitation and a paucity of adequate information on fishery oceanographic, environmental and biological conditions that sustain the fisheries of the South China Seas region, the fisheries have become greatly impoverished. The deficiency in scientific intelligence has also circumscribed all attempts at substantive and tangible planning or management of fisheries throughout the region. The NAGA Oceanographic Expedition of 1959 – 1961, organized jointly by the United States of America, The Kingdom of Thailand and the erstwhile Republic of Vietnam, achieved pioneering oceanographic work in the Gulf of Thailand and the South China Seas. This invaluable scientific data acquisition was not pursued for a number of reasons, and thus, a holistic and dependable profile of oceanographic conditions and their seasonal variations and patterns failed to develop. Perceiving the vital importance and the deficiency of fundamental information and data for fisheries planning and management, the SEAFDEC Training Department (TD) and the Marine Fishery Resources Development and Management Department (MFRDMD), jointly launched an Inter-Departmental Collaborative Research program in 1995, to evaluate the fisheries resources of the South China Seas as a basal objective in the development of sustainable fisheries.

The first of four defined survey areas, covering the Gulf of Thailand and the East Coast of Peninsular Malaysia was researched during two cruises of the Training & Research Vessel M.V. SEAFDEC, in September-October 1995 and April-May 1996. Five fields of scientific endeavor were researched by 35 scientists from TD and MFRDMD together with invited scientists from other research institutions, departments and universities. The analysis of research findings were presented at a Technical Seminar held in Bangkok, Thailand, on 24-26 November 1997, and are published in these proceedings.

It is fervently hoped that the information compiled in this volume will provide a valuable motivating tool and foundation for fisheries administrators, mangers, Global Information Systems (GIS) programmers and development planners to give shape and substance to feasible fisheries programs in the future and will provide dependable scientific data to realize them.

SEAFDEC wishes to record its appreciation to the Government of Japan for the generous financial assistance provided to facilitate this Research Program, as part of its long-standing support for the operation of the Center, since its inception. Appreciation is also due to all the scientists, the staff of TD and MFRDMD, and the crew of the ship, who spared no efforts to make this scientific expedition a success.

U. Bhatiyasevi

Udom Bhatiyasevi
Secretary-General
SEAFDEC

TABLE OF CONTENTS

SECTION 1: OCEANOGRAPHY PAGE

S1/OG1 Physical Characteristics of Watermass in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Mohd. Nasir Saadon, Penjan Rojana-anawat and Anond Snidvongs) 1-5

S1/OG2 Dissolved Oxygen and Carbonate-Carbon Dioxide in the Sea Water of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Penjan Rojana-anawat and Anond Snidvongs) 6-11

S1/OG3 Some Physical and Chemical Characteristics of Bottom Sediments in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Charumas Chareonpanich and Siriporn Seurungreong) 12-33

S1/OG4 Sedimentological Characteristics of the Sediments of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Mohd-Lokman Husain, M.R. Harith, J. Maurice, Y. Rosnan and K. K. Y. Kassim) 34-53

S1/OG5 Numerical Simulations of The Net Current in the Gulf of Thailand Under Different Monsoon Regimes (Anond Snidvongs and Pramot Sojisuporn) 54-72

SECTION 2: ENVIRONMENTAL STUDIES

S2/ES1 Trace Metals in the Surface Sediments of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Noor A.M. Shazili, Mohamed Kamil Abd Rashid, Mohd Lokman Husain, Asmawi Nordin and Salmah Ali) 73-85

S2/ES2 Biogeochemical Implications of Dissolved Trace Metal Concentration and Distribution in the South China Sea, Area 1: Gulf of Thailand and East Coast of Peninsular Malaysia (Wilaiwan Utoomprurkporn, Manuwadi Hungspreugs, Saravuth Ratanachongkiat and Anond Snidvongs) 86-99

S2/ES3 Polynuclear Aromatic Hydrocarbon(PAH) and Total Aliphatic Hydrocarbon (TAH) in the Bottom Sediment of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Mohamed Kamil Abdul Rashid) 100-104

S2/ES4 Petroleum Hydrocarbon in Seawater and Some Sediments of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Panjarat Wongnapapan, Gullaya Wattayakorn and Anond Snidvongs) 105-110

SECTION 3: PRIMARY PRODUCTION

S3/PP1 Distribution, Abundance and Species Composition of Phytoplankton in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Sopana Boonyapiwat) 111-134

S3/PP2 Primary Production Determination in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Waleerat Musikasung, Mohd Shuki Bin Yusoff and Solahuddin Bin Abdul Razak) 135-146

SECTION 4: FISHERY BIOLOGY

S4/FB1 Distribution, Abundance and Biological Studies of Economically Important Fishes in the South China Sea, Area I: East Coast of Peninsular Malaysia (Mansor Mat Isa, Abd Haris Hilmi Ahmad Arshad and Samsudin Basir) 147-155

S4/FB2 Temporal Changes in the Abundance of Macrobenthos in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Montira Piamthipmanus) 156-171

S4/FB3 Species Composition and Diversity of Fishes in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Chavalit Vidthayanon) 172-240

S4/FB4 Kinds, Abundance and Distribution of the Fish Larvae in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Apichart Termvidchakorn) 241-255

S4/FB5 Distribution, Abundance and Composition of Zooplankton in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Jutamas Jivaluk) 256-284

S4/FB6 Distribution of Macrobenthos in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Abdul Hamid Yasin and Solahuddin A. Razak) 285-293

S4/FB7 Distribution of Dinoflagellate Cysts in the Surface Sediment of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Thaithaworn Lirdwitayaprasit) 294-309

S4/FB8 Microplankton (Including Dinoflagellate And Foraminifera) in the South China Sea, Area I : Gulf of Thailand and Peninsular Malaysia (Lokman Shamsudin, Abdul Hamid Yasin, Solahudin Abdul Razak and Mohd Shukri Yusoff) 310-335

SECTION 5: FISHERY RESOURCES

S5/FR1 Multi-Species Fish Stock Assessment by Acoustic Method in the South China Sea Area I: Gulf of Thailand and East Coast of Peninsular Malaysia (Albert Chuan Gambang, Hadil bin Rajali, Raja Bidin bin Raja Hassan, Rosidi bin Ali, Kunimune Shiomi, Shunji Fujiwara and Shamusudin bin Basir) 336-346

S5/FR2 Biomass Estimation by Hydro-acoustic Methods in the Gulf of Thailand and Peninsular Malaysia (Yuttana Theparoonrat, Suvimon Seakow and Siriporn Seurungreong) 347-266

Physical Characteristics of Watermass in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Mohd. Nasir Saadon[1]
Penjan Rojana-anawat[2]
Anond Snidvongs[3]

[1] Universiti Putra Malaysia Terengganu, Mengabang Telipot, 21030 Kuala Terengganu, Malaysia
[2] Training Department, P.O. Box 97, Phrasamutchedi, Samut Prakan 10290, Thailand
[3] Department of Marine Science, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

ABSTRACT

Our study provides new information on the physical characteristics of watermass in the South China Sea. We analyzed the temperature, salinity and density profiles to determine the effect of the NE monsoon on the variability of the physical properties of watermass, in the Gulf of Thailand and the east coast of Peninsular Malaysia. CTD data were obtained from both the M.V. SEAFDEC cruises conducted before (September 1995) and after (April 1996) the northeast (NE) monsoon season.

We concluded that the NE monsoon caused the variability of the physical properties of watermasses, in the study area, slightly. We observed the movement of the thermocline, halocline and pycnocline layers from deeper depth to shallower depth, before and after the NE monsoon season, respectively. This movement indicates the possible occurrence of downwelling and upwelling processes in the region.

Key words: Thermocline, halocline, pycnocline, downwelling and upwelling processes.

Introduction

The climate of the east of Peninsular Malaysia is controlled by the seasonal monsoon winds. These winds are generated by the difference in atmospheric pressure between the northern (Asian continent) and the southern (Australia) hemispheres [Nasir and Camerlengo (1997), Nasir and Marghany (1996)]. During the northern winter (summer), the northeast (southwest) wind prevails from November to March (May to September) over the South China Sea.

Between these two seasonal monsoon winds, two transitional periods are clearly distinguishable. They last for about four to seven weeks in April and October [Morgan and Valencia (1983)].

The first and second cruises - on board M.V. SEAFDEC - of the SEAFDEC collaborative research program in the South China Sea, between Malaysia and Thailand, were conducted from 5 to 28 September 1995 (before northeast monsoon season) and from 24 April to 17 May 1996 (after the NE monsoon season). The cruises started in the northern coast of the Gulf of Thailand and ended in the sourhern coast of Johore, Peninsular Malaysia. The objective of the cruises was to do a comprehensive survey of the South China Sea in all fields of oceanography.

Since these two cruises were conducted before and after the NE monsoon season, a study on the seasonal variations of the physical characteristics of watermass in the Gulf of Thailand and the east coast of Peninsular Malaysia was conducted. For this purpose, the temperature, the salinity and the density profiles, from both M.V. SEAFDEC cruises, were analyzed and compared.

Our results show that there are slight variations in temperature, salinity and density profiles before and after the NE monsoon season. Furthermore, salinity and density (temperature) values are slightly higher (lower) before than those after the NE monsoon season. These results agree with earlier findings [Nasir and Camerlengo (1997) and Nasir *et al.* (1997)].

Materials and Methods

Temperature and salinity data were collected, using CTD, in the Gulf of Thailand and the east coast of Peninsular Malaysia, before and after the NE monsoon season. The data were gathered from 81 sampling stations (Fig. 1), during the M.V. SEAFDEC first cruise (5 to 28 September 1995) and second cruise (24 April to 17 May 1996). For this investigation, only data from selected sampling stations, were analyzed.

Density data was derived from salinity and temperature data using sigma-t computation tables [Knauss (1987)]. The temperature, the salinity and the density profiles, before and after the NE monsoon season, were plotted, compared and analyzed.

Results

Profiles of temperature, salinity and density are shown in the Appendix, respectively, for both before (thin lines) and after (thick lines) the NE monsoon season. Each figure is divided into two groups; A and B. Group A and B represent data collected from the Gulf of Thailand and the east coast of Peninsular Malaysia, respectively. The sampling station numbers are shown in the bottom right corner of each graphs.

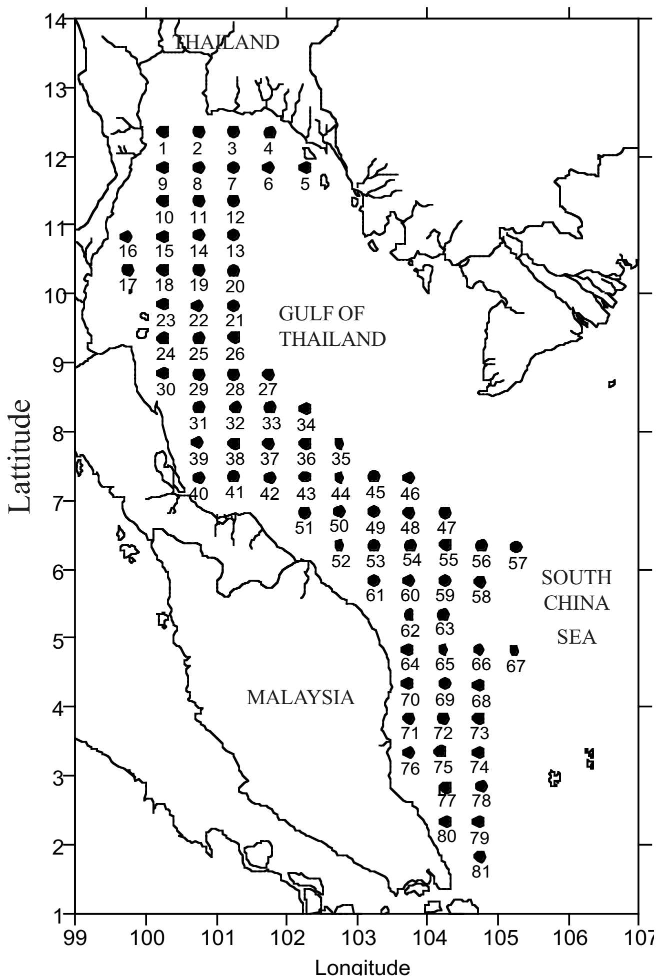


Fig. 1. Location of 81 sampling station during both of the M.V. SEAFDEC cruises.

Temberature profiles

Surface water temperatures, at all stations, are slightly higher (about 1°C) after as compared to before the NE monsoon season, except for stations in the southern tips of Peninsular Malaysia. The difference between surface water temperatures, after and before the NE monsoon season, decreases from the north to the south of the study area.

However, bottom water temperatures, in the Gulf of Thailand and northern region of the east coast of Peninsular Malaysia, are slightly lower after (about 0.5°C)as compared to before the NE monsoon season. In other parts of the east coast of Peninsular Malaysia, bottom water temperatures are mostly higher after than before the NE monsoon season.

In the Gulf of Thailand, the thermocline layers are more distinct after the NE monsoon season. Some stations (Stations 32, 34 and 39) have two thermocline layers. Before the NE monssoon season, many stations, in the Gulf of Thailand, have no thermocline layer which indicates a very well-mixed situation.

In the east coast of Peninsular Malaysia, thermocline layers are present both before and after the NE monsoon season. However, before the NE monsoon season, thermocline layers are mainly found at deeper depth as compared to after the NE monsoon season.

Salinity profiles

In the Gulf of Thailand, surface salinity are higher (about 1 psu) before as compare to after the NE monsoon. Stations in the northern half of the Gulf have high salinity, in the water column, before the NE monsoon. Halocline layers are present at some stations both before and after the NE monsoon. Halocline layers, before (after) the NE monsoon season, are generally found in deeper (shallower) depth.

In the east coast of Peninsular Malaysia, halocline layers are present both before and after the NE monsoon season. These layers are observed at deeper depth before the NE monsoon season.

Density profiles

Surface water densities are generally higher before as compared to after the NE monsoon season, except for areas in the southern part of the east coast of Peninsular Malaysia. Pcynocline layers are present in most sampling stations, both before and after the NE monsoon season. These layers are found at deeper depth before as compare to after the NE monsoon season.

In the northern region of the Gulf of Thailand (stations 6-20), water densities in the water column are higher before as compared to after the NE monsoon season. However, in the sourhern part of the east coast of Peninsular Malaysia (stations 77-81), water densities in the water column are lower before as compared to after the NE monsoon season.

Discussions

Air mass descends over the cold Asian continent during winter enhancing the formation of a high atmospheric pressure system. At the same time, air mass rises over the warm Australian continent. A low atmospheric pressure system is formed. These differences in atmospheric pressure system in unison with Coriolis effect, generate a NE wind in the Gulf of Thailand and along the east coast of Peninsular Malaysia (from November to March). This period is generally known as the NE monsoon season.

In the northern summer, in the Asian continent, the reciprocal is true. A high and low atmospheric pressure system over Australia and the Asian continents, respectively, are enhanced. As a consequence of this a SW wind prevails over the Gulf of Thailand and Peninsular Malaysia (from

May to September). This period is known as the SW monsoon season.

Two transitional periods between the two monsoon seasons are distinguishable. These periods happen in April and October. They tend to last for about four to seven weeks [Nasir and Marghany (1996)].

The NE monsoon season brings heavy rain at the east coast of Peninsular Malaysia. Maximum precipitation, with values ranging from 600 to 800 mm of rainfall, is recorded in November and December [Camerlengo *et al.* (1996a), Camerlengo *et al.* (1997)]. Minimum precipitation is observed during the SW monsoon, especially in July and August [Camerlengo *et al.* (1996b)].

The NE monsoon season (especially in November and December) causes a major decrease of both evaporation and insolation values along the east coast of Peninsular Malaysia [Camerlengo *et al.* (1996c)]. Overcast skies prevent solar radiation into the lower atmosphere. However, highest insolation value is registered in Febreuary and March at the east coast of Peninsular Malaysia.

The NE monsoon wind is stronger than the SW monsoon wind [Taira *et al.* (1996)]. This is due to the fact that the NE monsoon wind is in the same direction as the prevailing NE trade wind of the northern hemisphere. During the NE and SW monsoon seasons, average wind speed of 9 m/s and 6 m/s, respectively, have been recorded [Wang *et al.* (1994)].

Wave heights along the east coast of Peninsular Malaysia are hihger during the NE monsoon season as compared to the SW monsoon season. Wave heights of over 3.5 m during November to January, have been recorded [Malaysian Meteorological Service (1991)]. Larger wave heights, during the NE monsoon season, are due to the stronger wind speed and larger wind fetch as compared to the wind during the SW monsoon season.

Overcast skies, during the NE monsoon season, block the incoming solar radiation. This reduces the sea surface temperature (SST). However, the SST increases, as the sky clears up, after the NE monsoon season is over.

Heavy rainfalls, during the NE monsoon season, increase freshwater runoff in the Gulf of Thailand and along the east coast of Peninsular Malaysia [Nasir *et al*. (1997)], thus, reducing surface water salinity and density values at all sampling station. In the northern part of the Gulf of Thailand, freshwater runoff even makes the water column less saline and less dense. In most deep offshore stations - again due to freshwater runoff - higher salinity and density values in the bottom water have been recorded, after the NE monsoon season.

The halocline and the pycnocline layers are present, at most stations, both before and after the NE monsoon season. However, these layers are at deeper depth before as compared to after the NE monsoon season. This is due to the fact that wave heights are higher, just before the NE monsoon season. This enhances mixing throughout the vertical column.

The movement of the thermocline, halocline and pcynocline layers from deeper depth to shallower depth, before and after the NE monsoon season, respectively, could possibly be due to upwelling and downwelling processes. Usually, during downwelling, these layers move to a deeper depth. However, they will move to a shallower depth during upwelling [Kennish (1994)].

The southern tip of the east coast of Peninsular Malaysia (Stations 77-81), shows a different variation of physical properties as to the northern part of the study area. We don't know what causes this variation. Perhaps a further investigation is needed in this particular part of the study area.

Conclusions

The vertical profiles of temperature, salinity and density in the Gulf of Thailand and along the east coast of Peninsular Malaysia, before and after the NE monsoon season, were analyzed. Our results generally agree with early observations [Nasir and Camerlengo (1997)].

Our results show that the variability of the physical properties, in the Gulf of Thailand and along the east coast of Peninsular Malaysia, is due to the monsoon season. Profiles of temperature, salinity and density show slight different in these physical values, before and after the NE monsoon season, are recorded. In some stations (especially in the northern Gulf of Thailand), temperature, salinity and density values are the same throughout the water column, indicating a well-mixed condition, before the onset of the NE monsoon.

Thermocline, halocline and pycnocline layers are present, both before and after the NE monsoon season. However, these layers are at deeper depth before the onset of the NE monsoon and move to a shallower depth after the NE monsoon. This movement of physical layers, from deeper to shallower depth, can be linked to the downwelling and upwelling processes in the region.

In southern part of the east coast of Peninsular Malaysia (particularly the southern tip), the variability of the physical properties of the watermass is difference as compared to the rest of the study area. We do not have enough data to explain this difference.

We feel that more physical oceanographic cruises, to study the variability of the physical properties during both SW and NE monsoon seasons, are needed. The physical oceanographic data in the South China Sea (especially in the east coast of Peninsular Malaysia), are too scarce to make a good comparison of the variability of physical properties during both monsoon seasons.

Acknowledgment

The authors would like to extend their thanks to Universiti Putra Malaysia Terengganu for cooperating in this research.

References

Camerlengo, A.L., M.O. Rosni and M.S. Nasir (1996a). Monthly distribution of precipitation in Peninsular Malaysia. Submitted for publication to the *Pertanika J. of Sci. & Tech.*

Camerlengo, A.L., M.R. Hisham and M.S. Nasir (1996b). On the passage of the intertropical convergence zone in Peninsular Malaysia. *Malaysian Journal of Physics*, 17(4).

Camerlengo, A.L., M.S. Nasir, M.O. Rosni and M.R. Hisham (1996c). On evaporation and insolation in Peninsular Malaysia. *J. of Phys. Sci*., Vol. 8.

Camerlengo, A.L., M.S. Nasir and B.M. Ismail (1997). Precipitation-evaporation difference in Peninsular Malaysia. Accepted for publication to *ASEAN J. of Sci. & Tech. for Development*.

Kennish, M.J. (1994). *Practical Handbook of Marine Science*. CRC Press, London, p. 566.

Knauss J.A. (1987). *Introduction to Physical Oceanography.* Prentice-Hall, New Jersey, p. 338.

Malaysian Meteorological Services (1991). *Monthly summary of marine meteorological observation - Year 1991*. Issued under the authority of the Director General, Malaysian Meteorological Service, P. Jaya, Malaysia.

Morgan, J.R. and M.J. Valencia (1983). The natural environmental setting. In: *Atlas for marine policy in Southeast Asian Seas*. J.R. Morgan and M.J. Valencia (eds.). Univ. of California Press. pp. 4-17.

Nasir, M.S., A.L. Camerlengo and A. Supirman (1997). Salt intrusion in the Terengganu. *J. of Phys. Sci.,* Vol. 8.

Nasir, M.S. and A.L. Camerlengo (1997). Response of the ocean mixed layer, off the east coast of Peninsular Malaysia, during the northeast and southwest monsoons. *Geoacta*, 22, 134-143.

Nasir, M.S., A.L. Camerlengo and F.A.A. Hasan (1997). Seasonal variations of physical properties in the east coast of Peninsular Malaysia. *J. of Science,* Vol. 6, 1.

Nasir, M.S. and M.M. Marghany (1996). Surface circulation off Kuala Terengganu in the transitional period between the northeast and southwest monsoons. *Pertanika J. Sci. & Technol*. 4(1), 141-148.

Taira, K., M.S. Nasir, S. Kitagawa and T. Yanagi (1996). *J. of Oceanography.* Vol. 52, 251-257.

Wang, W., Q. Huang, Y.S. Li and Z.W. Li (1994). Three-dimensional numerical modelling of the water circulation in South China Sea. In: *Oceanology of China Sea, Vol. 1*. D. Zhou, Y.B. Lian and C.K. Zeng (eds.). Kluwer Academic Publishers, p. 344.

Dissolved Oxygen and Carbonate-Carbon Dioxide in the Sea Water of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Penjan Rojana-anawat[1] and Anond Snidvongs[2]

[1] SEAFDEC/TD, PO. BOX 97, Phrasamutchedee, Samutprakarn, 10290 Thailand
[2] Marine Science Department, Chulalongkorn University, Bangkok, 10330 Thailand

ABSTRACT

Dissolved oxygen and carbonate system in seawater in the Gulf of Thailand and the east coast of Peninsular Malaysiain September 1995 and April-May 1996 were determined. It was found that surface water was well in equilibrium with the atmosphere. The sub-pycnocline water in the Gulf had the chemistry that was distinctly different from the mixed layer as well as from sub-pycnocline water in the South China Sea near the mouth of the Gulf, even with the same depth. There were some evidences that intermediate water in the South China Sea might flow into the Gulf along the central axis and the coast of Vietnam and Cambodia, and exited the Gulf along the Thai-Malay Peninsular coast. The chemistry of deep water in the South China Sea off the coast of Western Malaysia varied its chemistry by a great deal among seasons which might be due to the prevailing monsoon. Seawater in the Gulf of Thailand and South China Sea was supersaturated with respected to the mineral calcite.

Key words: dissolved oxygen, carbonate system, mineral calcite, Gulf of Thailand, Peninsular Malaysia, South China Sea

Introduction

Oxygen and carbon dioxide play very important roles in the metabolism of the ecosystem. The concentrations of these two gases in the water are the net results of all processes, namely biological activities, the air-sea exchange, the lateral transport to and from the area under interest, and reactions with solid phases such as calcium carbonate.

Measurement of dissolved oxygen in seawater in the Gulf of Thailand has been done for a long time as one of the routine activities. However, the measurement of dissolved carbon dioxide and carbonate system in the water has been rarely performed since the work by Rao (1964) who pointed out that the total CO_2 in the Gulf of Thailand water was clearly lower than oceanic water with the same temperature and salinity. This could had been due to high primary production. Subsequent work by Snidvongs (1993) in the Upper Gulf of Thailand further confirmed that the total dissolved inorganic carbon (that is mainly bicarbonate plus carbonate) in the water is low (usually about 2.0 mmol/l) but the partial pressure of CO_2 in surface water is usually higher than the partial pressure of CO_2 in the atmosphere of about 360 matm, especially in the area with high terrestrial input of organic material. This was an evidence that led Snidvongs (1993) to conclude that the nearshore water, less than 15 kilometer from shore, of the Gulf of Thailand was heterotrophic, i.e. total respiration exceeded primary production of the ecosystem.

For further understanding of the Gulf of Thailand as a source or sink of atmospheric carbon dioxide, an important anthropogenic greenhouse gas, the carbonate system and its interaction with biological activities, indicated by oxygen production or consumption, have been determined during the SEAFDEC Collaborative Research Cruises.

Methods

The continuous oxygen profile at each station was obtained using the Beckman Polarographic Oxygen electrode connected to the Falmouth Integrated CTD unit on board the M.V. SEAFDEC. The raw data was averaged at every 1 dbar pressure interval. During the first cruise in September 1995, the obtained profiles were calibrated by assuming surface water was at saturation with atmospheric oxygen. However, during the second cruise in April-May 1996, actual calibration was performed at every station by analyzing 4-8 samples of water collected by the rosette at different depths by Winkler Titration. The profile were adjusted to the calibrated value by using regression.

The dissolved carbonate system in seawater was calculated from pH and total alkalinity. Due to the malfunction of *in situ* pH sensor attached to the CTD in both cruises, pH of seawater collected by rosette sampler was measured in the laboratory on board the vessel soon after it was collected. Water samples for total alkalinity determination were filtered to remove suspended carbonate minerals, mainly calcium carbonate skeletons of some plankton and resuspended sediments. Known amount of hydrochloric acid was added to each sample and the final pH was measured. The concentration of excess proton was calculated from the final pH using the activity coefficients given by Parsons *et al.* (1987). The total alkalinity, which is the capacity of the water to neutralize strong acid, was calculated from the total proton added minus those remain the final solution.

The carbonate alkalinity is calculated by subtracting borate alkalinity from total alkalinity assuming total boron concentration of 0.4 mmol/l. The concentration of each species in the carbonate system, which are carbon dioxide, carbonic acid, bicarbonate and carbonate, can be simply obtained by solving the equilibrium equations of these 3 chemical reactions.

$$CO_2(aq) + H_2O \Longleftrightarrow H_2CO_3$$

$$H_2CO_3 \Longleftrightarrow H^+ + HCO_3^-$$

$$HCO_3^- \Longleftrightarrow H^+ + CO_3^{2-}$$

The saturation state of seawater with respect to the mineral calcite (which is a major mineral in the skeleton of many marine organisms) was calculated from the ratio between the actual carbonate concentration in the water and the concentration at equilibrium which is approximately 53 mmol/l. The ratio that is higher than 100% indicates calcite will be precipitated in that water.

Results

Surface concentration of oxygen obtained during the April-May 1996 cruise when actual calibration against Winkler Titration was performed verified the assumptions used during the September 1995 cruise that dissolved oxygen in surface water was at equilibrium with the atmosphere and the slope (or sensitivity) of the sensor was near 100%. This finding reinforce our confidence to accept the results from both cruises.

Mid depth concentration of oxygen above the pycnocline which is usually situated at about 40m are very close to the saturation of about 4.3 ml/l except two locations off Songkhla and Kota Bahru where slightly low concentration of oxygen was found in both cruises (Fig. 1b and 2b).

Oxygen concentrations in sub-pycnocline deep water of the Gulf (more than 40 m, Fig. 1 and 2) were clearly lower than surface water as well as lower than bottom water in the South China Sea near the mouth of the Gulf. This is a very important finding because it indicate the total respiration that exceed primary production in the Gulf bottom water, but the opposite might occur in the South China Sea. Organic materials net respiration in the bottom water of the Gulf could have been imported from the South China Sea as well as from the nearby land mass. Deep water along the east coast appeared to have higher concentration than the west coast for both seasons indicating new water from the South China Sea might have entered he Gulf along the northeast shore. This deep water could have left the Gulf along the Thai-Malay Peninsular in September when low oxygen deep water was found. The low oxygen water off the coast of Peninsular Malaysia occurred only in September, the month after the period when the area was protected from the Southwest monsoon but not in April-

May when the Northeast monsoon could accelerate the general circulation of the area.

Considering the precision of the determination of the carbonate system of about ±5 % we would conclude that the partial pressure of carbon dioxide gas in surface water during both cruises was not significantly different from the atmospheric partial pressure of about 360 μatm (Fig. 3 and 4). However, in September along the lower Peninsular coast, from Surat Thani to Singapore, the partial pressure of carbon dioxide in the surface water was greater than 400 matm indicating a possibility of a net evasion of carbon dioxide gas from the water to the atmosphere.

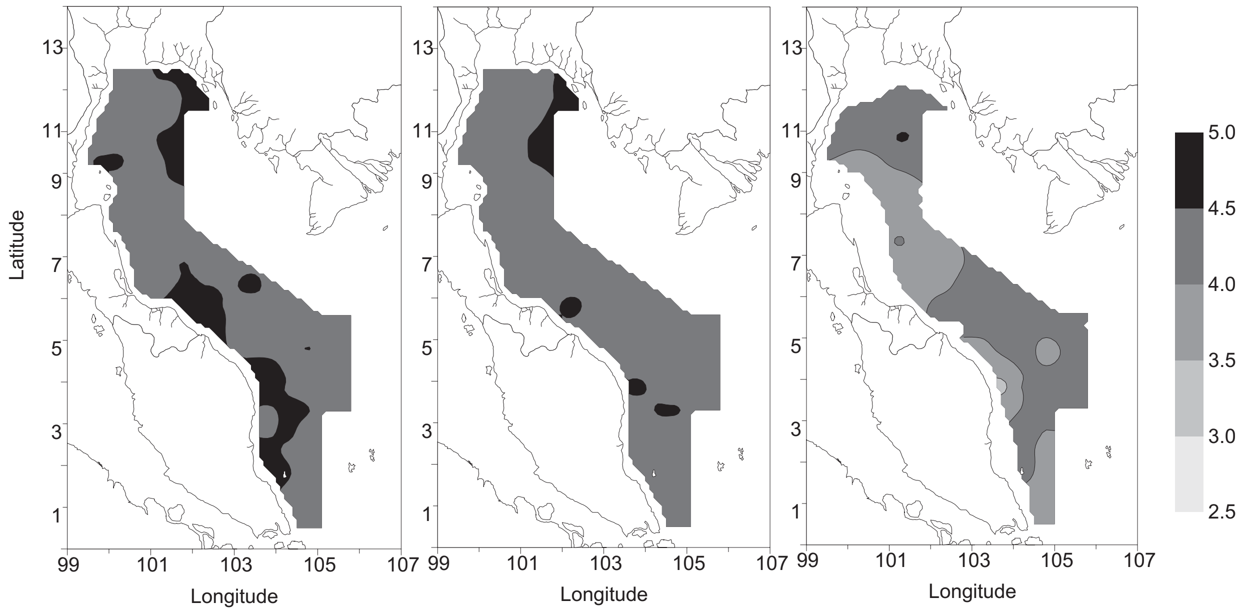


Fig. 1. Dissolved oxygen (ml/l) in the western Gulf of Thailand and eastern Peninsular Malaysia in September 1995; a) Surface level (0-10m), b) Mid-depth level (10-40m), c) Sub pycnocline level (>40m)

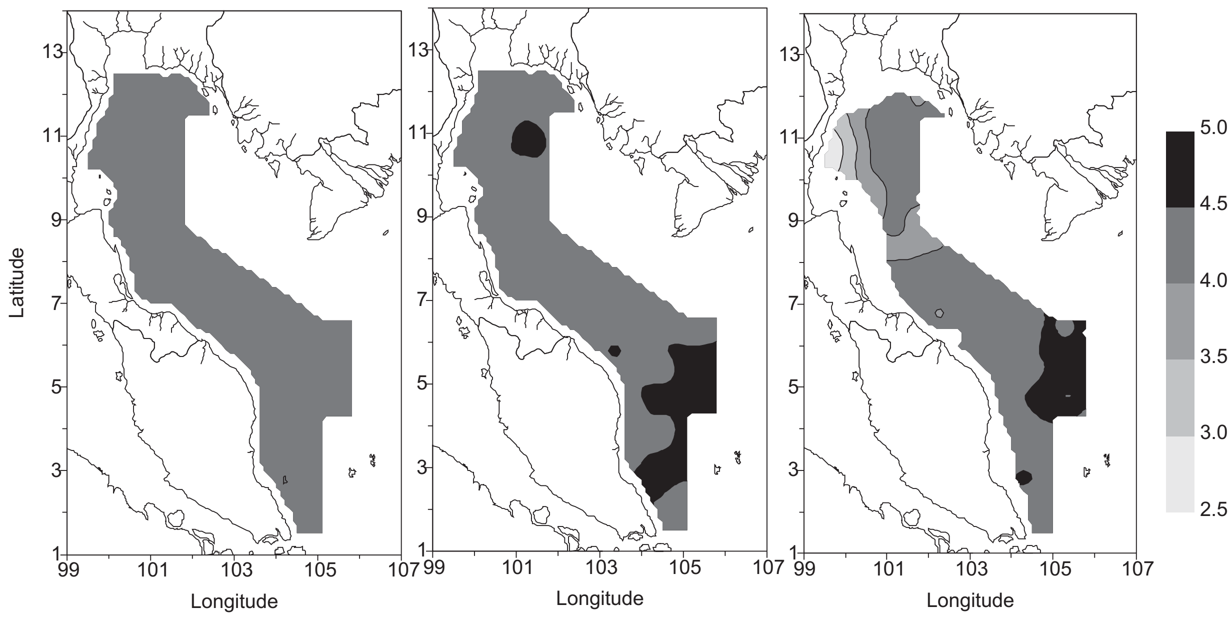


Fig. 2. Dissolved oxygen (ml/l) in the western Gulf of Thailand and eastern Peninsular Malaysia in April-May 1996; a) Surface level (0-10m), b) Mid-depth level (10-40m), c) Sub-pycnocline level (>40m)

The partial pressure of dissolved carbon dioxide in deep sub-pycnocline water showed a very similar pattern to that of dissolved oxygen. Thus confirming our previous conclusion that deep water in the Gulf derived its chemistry as it was aging inside the Gulf.

The water in this study area was supersaturated with respect to calcite throughout the year and at all depths (Fig. 5 and 6). However surface water was more supersaturate (up to 500%) than mid-depth and deep water. Calcite dissolution will not take place in the water column of the Gulf of Thailand.

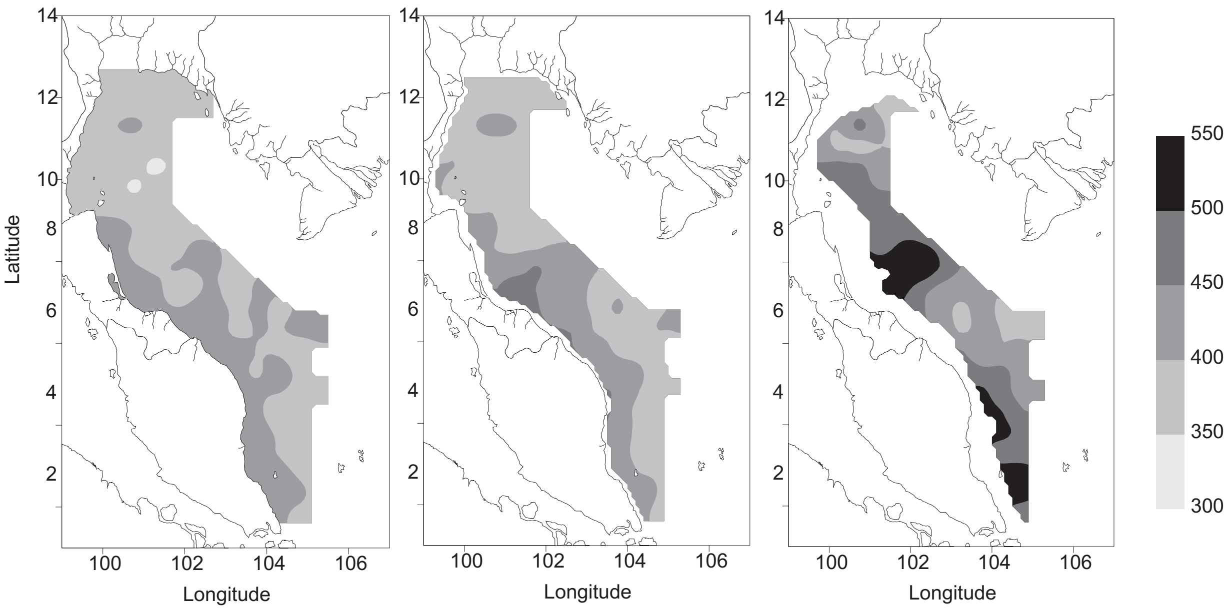


Fig. 3. Partial pressure of dissolved carbon dioxide (μatm) in the western Gulf of Thailand and eastern Peninsular Malaysia in September 1995; a) Surface level (0-10m), b) Mid-depth level (10-40m) and c) Sub-pycnocline level (>40m)

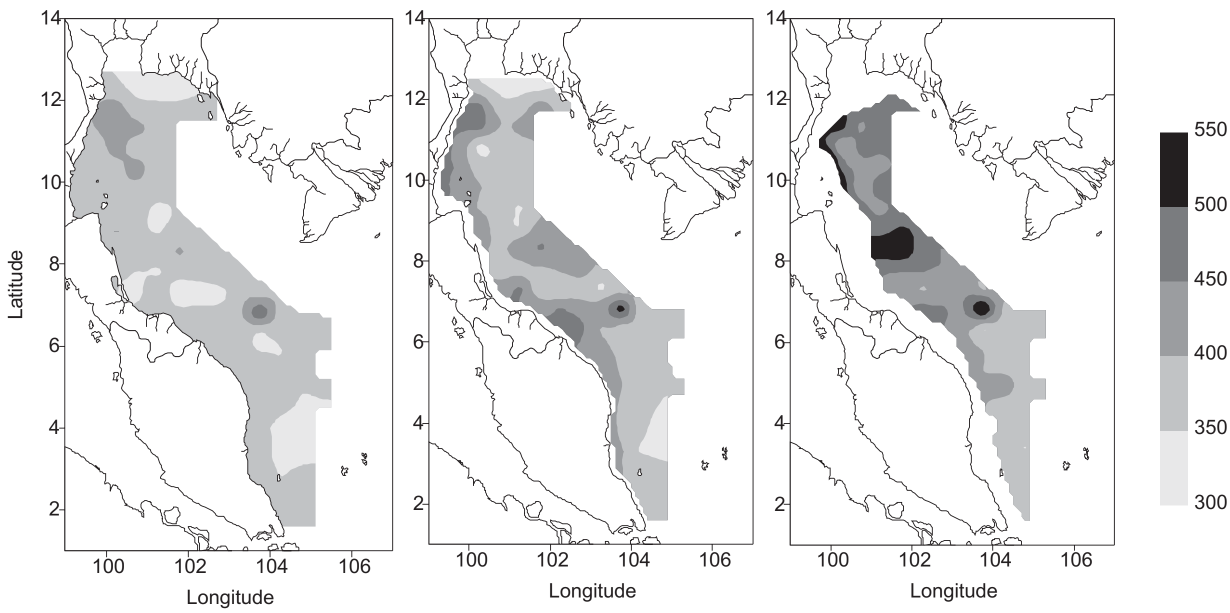


Fig. 4. Partial pressure of dissolved carbon dioxide (μatm) in the western Gulf ofThailand and eastern Peninsular Malaysia in April-May 1996; Surface level (0-10m) Mid-depth level (10-40m) Sub-pycnocline level (>40m)

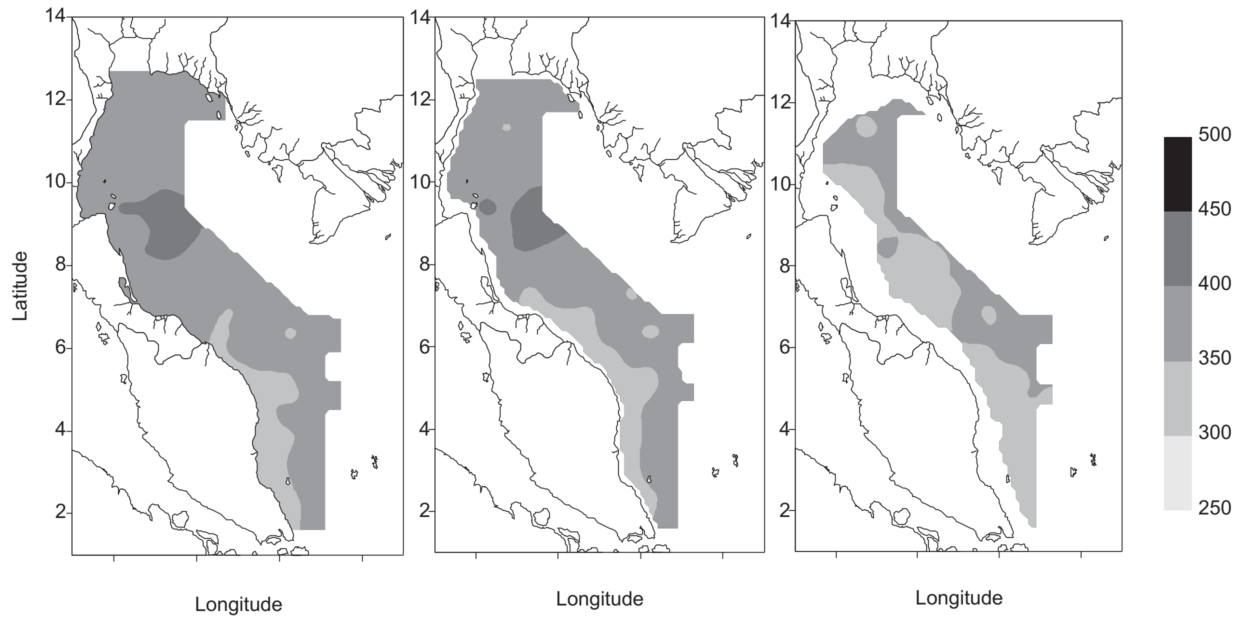


Fig. 5. Saturation state of seawater with respect to calcite in the western Gulf of Thailand and eastern Peninsular Malaysia in September 1995; a) Surface level (0-10m), b) Mid-depth level (10-40m) and c) Sub-pycnocline level (>40m)

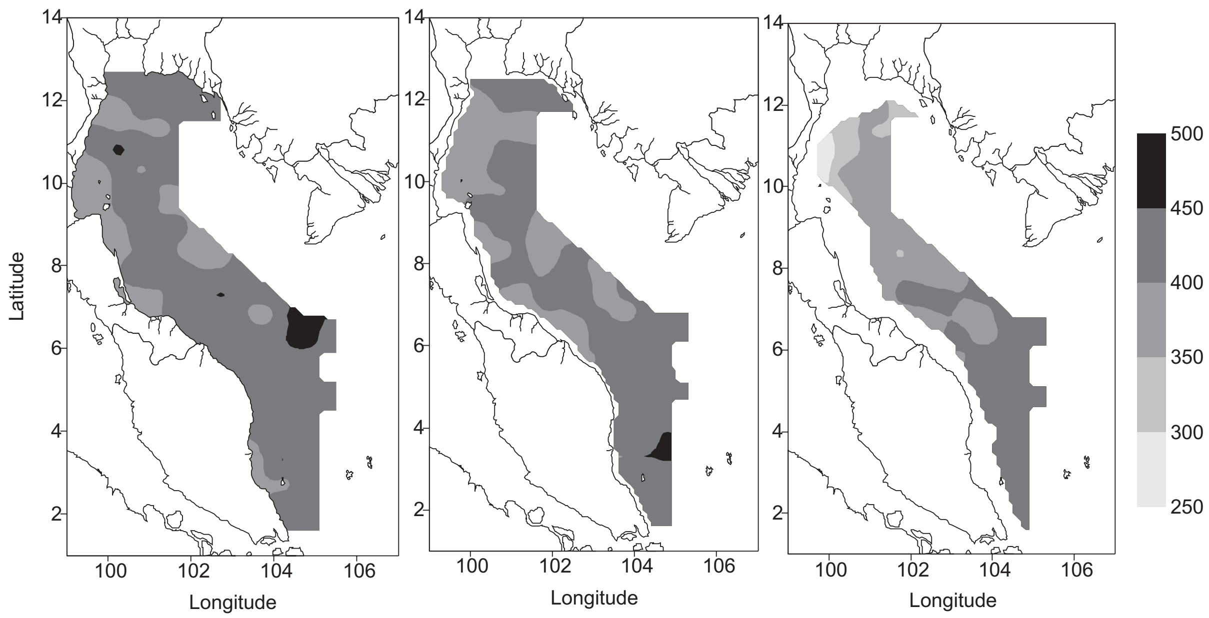


Fig. 6. Saturation state of seawater with respect to calcite in the western Gulf of Thailand and eastern Peninsular Malaysia in April-May 1996; a) Surface level (0-10m), b) Mid-depth level (10-40m) and c) Sub-pycnocline level (>40m).

Conclusions

1) With respect to dissolved oxygen and carbon dioxide gases, surface water in the Gulf of Thailandand the east coast of Peninsular Malaysia was in equilibrium with the atmosphere.
2) Sub-pycnocline water in the Gulf had the chemistry that was modified by the net respiration of organic matters.
3) Apparently deep water exited the Gulf via a near shore along the Thai-Malay Peninsular at least during the Southwest monsoon Period.
4) Sub-pycnocline water in the South China Sea off the east coast of Peninsular Malaysia varied its chemistry by a great deal between seasons which might be due to the prevailing monsoon.
5) Seawater in the study area was supersaturated up to 500% with respect to mineral calcite throughout the year.

References

Parson, T. R., Maita, Y. and Lalli, C. M.: A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford: Pergamon Press, 1984, 173 pp.

Snidvongs, A. : Geochemistry of Organic Particulate in Shallow Water Continental Shelf Environments. Ph.D. Dissertation, University of Hawaii, 1993, 201 pp.

Sedimentological Characteristics of the Sediments of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Mohd-Lokman Husain[1]
Harith, M.R.[1]
Maurice, J.[1]
Rosnan, Y.[1]
and
Kassim K. K. Y.[2]

[1]Faculty of Applied Science and Technology, University Putra Malaysia Terengganu (UPMT)
21030 Kuala Terengganu, Malaysia.
[2] Marine Fishery Resource Development and Management Department
South East Asian Fisheries Development Center, 21080 Kuala Terengganu, Malaysia

ABSTRACT

Two batches of eighty sediment samples were cut from the first centimeter of sediment cores collected during September 1995, representing the pre-monsoon period, and April 1996, representing the post-monsoon period, at the same location. The sample were collected within the waters of the Gulf of Thailand and the eastern board of Peninsular Malaysia. The sediment samples were analyzed for their sedimentological characteristics using the techniques of sieving and laser diffraction. In general the sediments of the Gulf of Thailand is finer, better sorted, more peaked than that of the Malaysian waters. Skewness of sediments from Thailand waters was more positively skewed than the Malaysian sediments for the pre-monsoon period but tended to be more negatively skewed for the post-monsoon period. It is also interesting to note that in general, the sediments collected during the post-monsoon period are finer, better sorted, more positively skewed and less peaked than the sediments collected during the pre-monsoon period. This is true for both the sediments collected from the Gulf of Thailand and the Malaysian waters. Near-shore sediments were also found to be the coarsest, followed by the off-shore sediments.

Introduction

In the study of the oceans, the bottom sedimentological properties not only play a major role in determining the richness of benthic life and productivity i.e. the diversity of benthic organisms but is also an important parameter that closely relates to pollution and mineral resources in the ocean. Studies on ocean sediments have begun since the early 1900s and the geophysical properties of ocean sediments have been used as environmental indicators (Wentworth, 1929; Krumbein 1937, 1938; and Folk, 1966). The bottom sedimentological properties of the South China Sea, nevertheless, are not well documented. This may be partly attributed to the prohibitive cost associated with the need for a research vessel, experienced crews and proper equipment. Some of the more extensive reports concerning the South China Sea sediments are those published by University Pertanian Malaysia and Kagoshima University through their joint expeditions aboard Kagoshima Maru. The expeditions were referred to as Matahari expeditions and were conducted in 1985, 1986, 1987 and 1989. These expeditions, however, cover only small portions at one time and was not expansive in coverage even if the different study areas are all added together.

Beginning 1995 SEAFDEC's Marine Fishery Resource Development and Management Department (MFRDMD) in Malaysia and the Training Department in Thailand in collaboration with the Fishery Departments of Thailand and Malaysia and university researchers from both countries have embarked upon a broad program of information gathering on the South China Sea. The vessel used was a modern vessel-M.V. SEAFDEC. Cruises were done during the pre (September 1995) and post -monsoon period (April, 1996) covering area I, the Gulf of Thailand and the EEZ waters bordering the eastern board of Peninsular Malaysia. One of the objectives of the cruise is to study the sediment grain size distribution and some general characteristics of the seafloor sediments.

This report focuses only on the information gathered and data analyzed from the bottom sediment samples collected during the first and second cruises..

Description of Study Area (Fig. 1)

The study area stretches from the Gulf of Thailand in the north to the Malaysian waters off Johor coast in the south. The waters within the Gulf of Thailand are relatively enclosed and thus protected when compared to the open conditions of the Malaysian waters exposed to the broad and long expanse of the South China Sea.

Typical of the continental shelf, the water depth is rather shallow. The average depth is approximately 52 m. Stations located close to the shore have water depths of approximately 25 meters, while the area furthest from shore are in water depths of approximately 70 m.

The current direction in the South China Sea, particularly, is controlled by seasonal winds of the monsoon. The predominant wind is from the north during the northeast monsoon seasons and from the south during the northwest monsoon (Wrytki, 1961).

Materials and Method

Sediment samples were collected using a gravity corer. Upon retrieval of the core, several parameters were recorded: color, stratification and length of sediment collected. The cores were then capped, freezed and brought back to the laboratory for further analyses. During the pre-monsoon cruise, out of the 81 stations, sampling was successfully done for 80 stations. Station 27 was not sampled due to technical problems. For the second cruise of April 1996, sampling was only done for eighty stations only since there was some technical problems at station 2.

Laboratory Methods

One centimeter of sediment was cut from the surface of each core. The methodology chosen to analyze the sedimentological characteristics depended upon the amount of coarse (>63 microns) or fine sediments (<63microns) available in each sample. Samples consisting mostly fine sediments with less than 10% coarse sediments, were analyzed using a laser diffractometer. However, if the opposite occurs then the sediments were analyzed via sieving.

For sieving approximately 100 grams of split samples were passed through a set of ASTM standard sieves with intervals of approximately 0.25 ø. The sediments were sieved using a sieve shaker for 15 minutes. The sediments trapped on each sieve were then weighed, recorded and used in the determination of the sedimentological parameters: mean, median and skewness and kurtosis.

The sediments are reported in terms of phi unit following standard convention in the study of sediments. The formula for phi is as given below:

$$\text{Phi } (\text{ø}) = -\log_2 D$$

ø = Particle diameter in phi
D = Particle diameter in mm

For laser diffraction analyses, the sediments are first removed off carbonate shell materials and organic matter using hydrochloric acid and hydrogen peroxide solutions respectively. Then a dispersing agent (sodium hexametaphosphate) was added to the sediments solution prior to passing it through the laser diffractometer. The particle size analyzer used in this study was the Malvern-E.

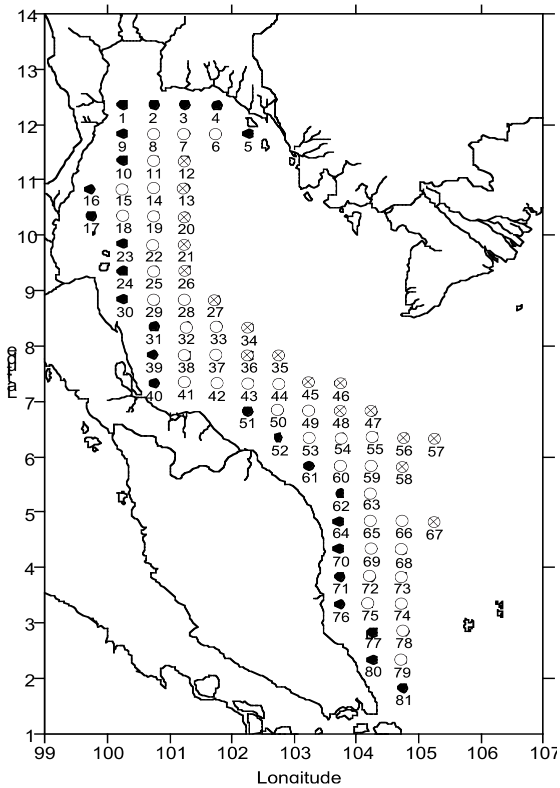


Fig. 1. Sampling locations within the Gulf of Thailand and West coast of peninsular Malaysia
(● Nearshore, ○ Midshore, ⊗ Offshore stations)

Data obtained from both methodologies were calculated using the method of moments as suggested by Griffiths (1967), McBride (1971) and Folk (1980) among others. Formulas used for the calculation of the sedimentological parameters are as given below:

$$Mean(X\phi) = \frac{\sum fm}{n}$$

$$S\tan dard\text{–}\ Deviation(S\phi) = \sqrt{\frac{\sum f(m - X\phi)^2}{100}}$$

$$Skewness(Sk) = \frac{\sum f(m - X\phi)^3}{100\sigma^3}$$

$$Kurtosis\,(K\phi) = \frac{\sum f(m - X\phi)^4}{100\sigma^4}$$

f = weight percent (frequency) in each grain size grade present
m = midpoint of each grain size grade in phi values
n = total number in sample, which is 100 when "f" is in percent.

Color and texture of sediments were determined using the classification system and standard color proposed in the Japanese Standards for soil survey (Oyama, 1996).

Results and discussions

The result of this sedimentological investigation are divided into three sections: Sedimentological characteristics, texture classifications and color.

Sedimentological Characteristics (Tabs. 1A to 1G; Figs. 2 to 5)

Generally, the post-monsoon sediments are finer than the pre-monsoon sediments. The mean size of pre-monsoon sediments was 4.74ø (coarse silt) while the mean size of post-monsoon sediments was 5.50ø (medium silt). The distribution of medium silt is more widespread for post-monsoon compared to the pre-monsoon sediments (fig. 2). The range of mean size for post and pre-monsoon sediments were 6.60ø (fine silt) to 0.46ø (coarse sand) and 6.40ø (fine silt) to -1.10ø (granules). For both batches of sediments the coarsest and the finest sediments are found in the waters of Malaysia and Thailand respectively. Both sediment batches are poorly sorted but the values and also the sorting distribution as shown in figure 3 indicate that the post-monsoon sediments are better sorted compared to the pre-monsoon sediments. The mean sorting value for post-monsoon sediments is 1.57 compared to the mean sorting value of September sediment is 1.57 compared to the mean sorting value of 1.80 for the pre-monsoon period. The range between maximum and minimum values is however larger for the post-monsoon sediments (2.48) compared to the pre-monsoon sediments (1.34).

Comparatively, the post-monsoon sediments tend to be more positively skewed (average value 0.15) compared to the pre-monsoon sediments (average value 0.05). This trend is true for the Malaysian sediments but for the sediments collected from the Gulf of Thailand the post-monsoon sediments (0.09) tend to be slightly more negative compared to the pre-monsoon sediments (0.10) (fig. 4).

Additionally, the post-monsoon sediments also tended to be more peaked than the pre-monsoon sediments. This is clear from the larger average kurtosis values of 2.86 compared to 2.41 for the pre-monsoon sediments. The extent of extremely leptokurtic sediments is more widespread for the post-monsoon sediments as compared to the pre-monsoon sediments (fig. 5). For both sediment batches, the Thai sediments have higher kurtosis values than the Malaysian sediments, indicating a more stable depositional environment.

For the sediment samples collected during the pre-monsoon and post-monsoon cruises the differences in characteristics between the Malaysian and Thai sediments are quite different statistically (tabs. 2A to 2E). For the pre-monsoon sediments only the mean size was statistically significant in its difference between the Malaysian and Thai sediments. However, for the post-monsoon, the differences between the Malaysian and Thai sediments are statistically significant for all the parameters of mean size, sorting, skewness and kurtosis.

On a cross-shore basis the general fining trend from pre to post-monsoon sediments remains. The mean size of near-shore, mid-shore and off-shore sediments are finer for post-monsoon sediments compared to the pre-monsoon sediments. For both batches of sediment the near-shore sediments are the coarsest followed by off-shore sediments, while the mid-shore remains the finest. The mid-shore sediments for both batches are the most poorly sorted, while the near-shore sediments are the best sorted.

The differences between the Malaysian and Thai sediments can probably be attributed to the Thai sediments being sampled from the Gulf of Thailand which is comparatively enclosed and protected as opposed to the conditions of the Malaysian sediment sampling stations which are located in the exposed area of the South China Sea. On the other hand, the differences between the pre and post-monsoon sediments can most probably be attributed to the weather conditions prevailing during both seasons. The conditions during and before the sampling period are vastly different. The difference in cross-shore basis may be attributed to the near-shore region being most affected by wave, which tend to act as a siever to remove finer materials thus allowing only coarser materials to settle. Thus a smaller range of size and better sorting values.

Table 1a. Statistical parameters of bottom sedimentological characteristics.

	ALL STATIONS											
		Mn			S.D			Skew			Kurt	
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	4.74	5.50	0.76	1.80	1.57	-0.23	0.05	0.15	0.10	2.41	2.86	0.45
Min	6.40	6.60	0.20	1.02	0.51	-0.51	-0.84	-0.57	0.27	1.68	1.57	-0.11
Max	-1.10	0.46	1.56	2.36	2.99	0.63	0.90	0.90	0.00	3.91	4.62	0.71
Range	7.50	6.14	-1.36	1.34	2.48	1.14	1.74	1.47	-0.27	2.23	3.05	0.82
	MALAYSIAN WATERS											
		Mn			S.D			Skew			Kurt	
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	4.35	5.19	0.84	1.80	1.67	-0.13	0.01	0.21	0.20	2.38	2.69	0.31
Min	5.90	6.60	0.70	1.02	0.51	-0.51	-0.84	-0.57	0.27	1.68	1.57	-0.11
Max	-1.10	0.46	1.56	2.36	2.99	0.63	0.90	0.90	0.00	3.91	3.69	-0.22
Range	7.00	6.14	-0.86	1.34	2.48	1.14	1.74	1.47	-0.27	2.23	2.12	-0.11
	THAILAND WATERS											
		Mn			S.D			Skew			Kurt	
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.12	5.77	0.65	1.80	1.49	-0.31	0.10	0.09	-0.01	2.43	3.00	0.57
Min	6.40	6.49	0.09	1.42	1.03	-0.39	-0.73	-0.52	0.21	1.88	2.26	0.38
Max	3.40	4.43	1.03	2.29	1.88	-0.41	0.71	0.68	-0.03	3.55	4.62	1.07

Table 1b. Statistical parameters of bottom sediment with respect to shoreline.

	ALL NEARSHORE STATIONS											
		Mn			S.D			Skew			Kurt	
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	3.95	5.20	1.25	1.77	1.52	-0.25	0.16	0.18	0.02	2.37	2.97	0.60
Min	6.40	6.49	0.09	1.02	0.51	-0.51	-0.84	-0.52	0.32	1.76	1.94	0.18
Max	-1.10	0.46	1.56	2.36	2.80	0.44	0.90	0.73	-0.17	3.91	4.62	0.71
Range	7.50	6.03	-1.47	1.34	2.29	0.95	1.74	1.25	-0.49	2.15	2.68	0.53
	ALL MIDSHORE STATIONS											
		Mn			S.D			Skew			Kurt	
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	4.98	5.61	0.63	1.88	1.61	-0.27	0.06	0.16	0.10	2.33	2.84	0.51
Min	6.30	6.41	0.11	2.34	1.03	-1.31	-0.51	-0.57	-0.06	1.68	1.57	-0.11
Max	3.60	4.08	0.48	1.43	2.99	1.56	0.70	0.90	0.20	3.35	4.26	0.91
Range	2.70	2.33	-0.37	0.91	1.96	1.05	1.21	1.47	0.26	1.67	2.69	1.02
	ALL OFFSHORE STATIONS											
		Mn			S.D			Skew			Kurt	
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.43	5.71	0.28	1.72	1.58	-0.14	-0.08	0.07	0.15	2.56	2.74	0.18
Min	6.20	6.60	0.40	1.33	1.21	-0.12	-0.73	-0.56	0.15	1.91	1.90	-0.01
Max	4.50	4.43	-0.07	2.09	2.07	-0.02	0.47	0.49	0.02	3.55	3.76	0.21
Range	1.70	2.17	0.47	0.76	0.86	0.10	1.20	1.05	-0.15	1.64	1.86	0.22

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 1c. Statistical parameters of bottom sediment with respect to shoreline.

	ALL NEARSHORE STATIONS											
	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	3.95	5.20	1.25	1.77	1.52	-0.25	0.16	0.18	0.02	2.37	2.97	0.60
Min	6.40	6.49	0.09	1.02	0.51	-0.51	-0.84	-0.52	0.32	1.76	1.94	0.18
Max	-1.10	0.46	1.56	2.36	2.80	0.44	0.90	0.73	-0.17	3.91	4.62	0.71
Range	7.50	6.03	-1.47	1.34	2.29	0.95	1.74	1.25	-0.49	2.15	2.68	0.53
	NEARSHORE STATIONS (MALAYSIAN WATERS)											
	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	2.82	5.74	2.92	1.72	1.45	-0.27	0.07	0.14	0.07	2.36	3.10	0.74
Min	5.40	6.49	1.09	1.02	1.10	0.08	-0.84	-0.52	0.32	1.76	2.27	0.51
Max	-1.10	4.59	5.69	2.36	1.97	-0.39	0.90	0.73	-0.17	3.91	4.62	0.71
Range	6.50	1.90	-4.60	1.34	0.87	-0.47	1.74	1.25	-0.49	2.15	2.35	0.20
	NEARSHORE STATIONS (THAILAND WATERS)											
	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	4.81	4.43	-0.38	1.81	1.63	-0.18	0.22	0.24	0.02	2.38	2.71	0.33
Min	6.40	5.79	-0.61	1.42	0.51	-0.91	-0.35	-0.41	-0.06	1.88	1.94	0.06
Max	3.40	0.46	-2.94	2.29	2.80	0.51	0.71	0.61	-0.10	2.98	3.53	0.55
Range	3.00	5.33	2.33	0.87	2.29	1.42	1.06	1.02	-0.04	1.10	1.59	0.49

Table 1d. Statistical parameters of bottom sediment with respect to shoreline.

	ALL MIDSHORE STATIONS											
	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	4.98	5.61	0.63	1.88	1.61	-0.27	0.06	0.16	0.10	2.33	2.84	0.51
Min	6.30	6.41	0.11	2.34	1.03	-1.31	-0.51	-0.57	-0.06	1.68	1.57	-0.11
Max	3.60	4.08	0.48	1.43	2.99	1.56	0.70	0.90	0.20	3.35	4.26	0.91
Range	2.70	2.33	-0.37	0.91	1.96	1.05	1.21	1.47	0.26	1.67	2.69	1.02
	MIDSHORE STATIONS (MALAYSIAN WATERS)											
	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.38	5.82	0.44	1.68	1.58	-0.10	-0.05	-0.03	0.02	2.57	2.77	0.20
Min	5.90	6.39	0.49	1.33	1.21	-0.12	-0.53	-0.48	0.05	1.91	2.41	0.50
Max	4.70	4.43	-0.27	2.09	1.88	-0.21	0.47	0.24	-0.23	2.96	3.76	0.80
Range	1.20	1.96	0.76	0.76	0.67	-0.09	1.00	0.72	-0.28	1.05	1.35	0.30
	MIDSHORE STATIONS (THAILAND WATERS)											
	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.53	5.64	0.11	1.80	1.58	-0.22	-0.13	0.15	0.28	2.54	2.72	0.18
Min	6.20	6.60	0.40	1.54	1.30	-0.24	-0.73	-0.56	0.17	2.05	1.90	-0.15
Max	4.52	4.52	0.02	2.07	2.07	0.00	0.15	0.49	0.34	3.55	3.51	-0.04
Range	2.08	2.08	0.38	0.53	0.77	0.24	0.88	1.05	0.17	1.50	1.61	0.11

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 1e. Statistical parameters of bottom sediment with respect to shoreline.

ALL OFFSHORE STATIONS

	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.43	5.71	0.28	1.72	1.58	-0.14	-0.08	0.07	0.15	2.56	2.74	0.18
Min	6.20	6.60	0.40	1.33	1.21	-0.12	-0.73	-0.56	0.17	1.91	1.90	-0.01
Max	4.50	4.43	-0.07	2.09	2.07	-0.02	0.47	0.49	0.02	3.55	3.76	0.21
Range	1.70	2.17	0.47	0.76	0.86	0.10	1.20	1.05	-0.15	1.64	1.86	0.22

OFFSHORE STATIONS (MALAYSIAN WATERS)

	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.38	5.82	0.44	1.68	1.58	-0.10	-0.05	-0.03	0.02	2.57	2.77	0.20
Min	5.90	6.39	0.49	1.33	1.21	-0.12	-0.53	-0.48	0.05	1.91	2.41	0.50
Max	4.70	4.43	-0.27	2.09	1.88	-0.21	0.47	0.24	-0.23	2.96	3.76	0.80
Range	1.20	1.96	0.76	0.76	0.67	-0.09	1.00	0.72	-0.28	1.05	1.35	0.30

OFFSHORE STATIONS (THAILAND WATERS)

	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.53	5.64	0.11	1.80	1.58	-0.22	-0.13	0.15	0.28	2.54	2.72	0.18
Min	6.20	6.60	0.40	1.54	1.30	-0.24	-0.73	-0.56	0.17	2.05	1.90	-0.15
Max	4.50	4.52	0.02	2.07	2.07	0.00	0.15	0.49	0.34	3.55	3.51	-0.04
Range	1.70	2.08	0.38	0.53	0.77	0.24	0.88	1.05	0.17	1.50	1.61	0.11

Table 1f. Statistical parameters of bottom sediment with respect to shoreline.

NEARSHORE STATIONS

	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	2.82	5.74	2.92	1.72	1.45	-0.27	0.07	0.14	0.07	2.36	3.10	0.74
Min	5.40	6.49	1.09	1.02	1.10	0.08	-0.84	-0.52	0.32	1.76	2.27	0.51
Max	-1.10	4.59	5.69	2.36	1.97	-0.39	0.90	0.73	-0.17	3.91	4.62	0.71
Range	6.50	1.90	-4.60	1.34	0.87	-0.47	1.74	1.25	-0.49	2.15	2.35	0.20

MIDSHORE STATIONS

	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	4.70	5.77	1.07	1.97	1.48	-0.49	0.02	0.09	0.07	2.23	3.03	0.80
Min	5.30	6.41	1.11	1.64	1.03	-0.61	-0.51	-0.37	0.14	1.68	2.26	0.58
Max	3.70	4.88	1.18	2.34	1.76	-0.58	0.70	0.68	-0.02	3.20	3.58	0.38
Range	1.60	1.53	-0.07	0.70	0.73	0.03	1.21	1.05	-0.16	1.52	1.32	-0.20

OFFSHORE STATIONS

	Mn			S.D			Skew			Kurt		
	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif	Sept	April	Dif
Average	5.38	5.82	0.44	1.68	1.58	-0.10	-0.05	-0.03	0.02	2.57	2.77	0.20
Min	5.90	6.39	0.49	1.33	1.21	-0.12	-0.53	-0.48	0.05	1.91	2.41	0.50
Max	4.70	4.43	-0.27	2.09	1.88	-0.21	0.47	0.24	-0.23	2.96	3.76	0.80
Range	1.20	1.96	0.76	0.76	0.67	-0.09	1.00	0.72	-0.28	1.05	1.35	0.30

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 1g. Statistical parameters of bottom sediment with respect to shoreline. (Thai waters)

1G	Mn			S.D			Skew			Kurt		
NEARSHORE STATIONS												
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	3.95	5.74	1.79	1.77	1.45	-0.32	0.16	0.14	-0.02	2.37	3.1	0.73
Min	6.4	6.49	0.09	1.02	1.1	0.08	-0.84	-0.52	0.32	1.76	2.27	0.51
Max	-1.1	4.59	5.69	2.36	1.97	-0.39	0.9	0.73	-0.17	3.91	4.62	0.71
Range	7.5	1.9	-5.6	1.34	0.87	-0.47	1.74	1.25	-0.49	2.15	2.35	0.2
MIDSHORE STATIONS												
	Mn			S.D			Skew			Kurt		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	5.24	5.77	0.53	1.79	1.48	-0.31	0.09	0.09	0	2.43	3.03	0.6
Min	6.3	6.41	0.11	1.43	1.03	-0.4	-0.4	-0.37	0.03	2.09	2.26	0.17
Max	3.6	4.88	1.28	2.07	1.76	-0.31	0.69	0.68	-0.01	3.35	3.58	0.23
Range	2.7	1.53	-1.17	0.64	0.73	0.09	1.09	1.05	-0.04	1.26	1.32	0.06
OFFSHORE STATIONS												
	Mn			S.D			Skew			Kurt		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	5.53	5.82	0.29	1.8	1.58	-0.22	-0.13	-0.03	0.1	2.54	2.77	0.23
Min	6.2	6.39	0.19	1.54	1.21	-0.33	-0.73	-0.48	0.25	2.05	2.41	0.36
Max	4.5	4.43	-0.07	2.07	1.88	-0.19	0.15	0.24	0.09	3.55	3.76	0.21
Range	1.7	1.96	0.26	0.53	0.67	0.14	0.88	0.72	-0.16	1.5	1.35	

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 2a. T-test results for malaysian water vs. Thailand water

PARAMETER	Mean		Sorting		Skewness		Kurtosis	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	< 5%	< 5%	> 10%	< 5%	> 10%	< 10%	> 10%	< 5%
CONCLUSION	Significant	Significant	Not Significant	Significant	Not Significant	Significant	Not Significant	Significant
AVERAGE	4.35 > 5.12	5.19 > 5.77		1.67 > 1.49		0.21 > 0.09		2.69 > 2.46

Table 2b. T-test results for malaysian water vs Thailand water

PARAMETER	%Sand		%Silt		%Clay	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	< 5%	< 5%	> 10%	< 5%	> 10%	> 10%
CONCLUSION	Significant	Significant	Not Significant	Significant	Not Significant	Significant
AVERAGE	43.98 > 33.85	24.15 > 11.96		66.76 > 79.17		

Table 2c. Anova results for distance from shore (near, mid,offshore)

PARAMETER	Mean		Sorting		Skewness		Kurtosis	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	< 5%	< 10%	> 10%	> 10%	< 10%	> 10%	> 10%	> 10%
CONCLUSION	Significant	Significant	Not Significant	Not Significant	Significant	Not Significant	Not Significant	Not Significant
AVERAGE								

Table 2d. Anova results for distance from shore (near : mid : off - shore)

PARAMETER	%Sand		%Silt		%Clay	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	< 5%	> 10%	< 10%	> 10%	< 10%	< 5%
CONCLUSION	Significant	Not Significant	Significant	Not Significant	Significant	Significant
AVERAGE	50.43>36.35>27.36		44.52>46.26>53.53			

Table 2e. Anova results for distance from shore (near : mid : off shore) - Thailand waters

PARAMETER	Mean		Sorting		Skewness		Kurtosis	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	>10%	>10%	>10%	>10%	<5%	>10%	>10%	>10%
CONCLUSION	Not Significant	Not Significant	Not Significant	Not Significant	Significant	Not Significant	Not Significant	Not Significant
AVERAGE								

Table 2f. Anova results for distance from shore (near : mid : off - shore) - Thailand waters

PARAMETER	%Sand		%Silt		%Clay	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	> 10%	> 10%	> 10%	> 10%	> 0%	> 10%
CONCLUSION	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
AVERAGE						

Table 2g. Anova results for distance from shore (near : mid : off-shore) - Malaysian waters

PARAMETER	Mean		Sorting		Skewness		Kurtosis	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	< 5%	< 5%	< 5%	> 10%	> 10%	> 10%	> 10%	> 10%
CONCLUSION	Significant	Significant	Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
AVERAGE	2.82 > 4.7 >5.38	4.43 > 5.4 > 5.64	1.72 < 1.97 < 1.68					

Table 2h. Anova results for distance from shore (near : mid : off-shore) - Malaysian waters

PARAMETER	%Sand		%Silt		%Clay	
	Sep-95	Apr-96	Sep-95	Apr-96	Sep-95	Apr-96
PROBABILITY	< 5 %	< 5%	> 10%	> 10%	< 5%	< 5%
CONCLUSION	Significant	Significant	Not Significant	Significant	Significant	Significant
AVERAGE	64.66 > 41.19 > 28.12	38.12 > 23.56 > 12.91		56.13 < 66.05 < 76.46	11.18 < 14.31 < 20.08	5.75 < 10.36 < 10.64

Texture (Tabs. 3A to 3D)

The seafloor of the study area during the post-monsoon sampling seems to be more similar in texture compared to the pre-monsoon sampling. This is clear when texture classification is examined in the overall area of sampling and on smaller scales of the Gulf and the Malaysian waters. Overall, eight classifications of sediment texture, ranging from light clay to silt loam, are identified for the pre-monsoon sediments but only five are identified for the post-monsoon sediments. On a smaller scale, the variety of texture classification was also reduced from seven to five and from six to three in the Malaysian and Thai sediments respectively.

In the Malaysian waters, the dominant texture of clay loam, which makes up approximately 25% of the sediment classification for the pre-monsoon was changed to silt loam, for the post-monsoon sediments. Silt loam makes up approximately 62% of the texture classification. In the waters of the Gulf, the dominant texture of silty clay loam, which makes up approximately 50% of the bottom sediments for the pre-monsoon sediment was changed to silt loam (76%) for the post-monsoon sediments.

The near-shore region has more variability of sediment texture followed by the mid-shore region and the off-shore region for the pre-monsoon sediments. For the post-monsoon sediments, the near-shore region remains the most varied but with the mid-shore and the off-shore region having the same texture classification of three. The three different texture classifications for the mid-shore region of post-monsoon sediments is however, less than the mid-shore region of pre-monsoon sediments, which has five texture classifications.

Compared to Thailand the Malaysian seafloor have more sand (fig. 6). This is true for both periods of sampling and the difference is statistically significant. The silt and clay content did not differ statistically for the pre-monsoon sediments but is statistically significant in difference for silt for the post-monsoon sediments (tabs. 2A and 2B). The post-monsoon near-shore sediments have

Table 3a. Texture distribution of bottom sediments

	ALL			Malaysian Water			Thailand Water		
	Sept	April	Diff	Sept	April	Diff	Sept	April	Diff
Light Clay	3 (3.75%)	0	-3	2 (5%)	0	-2	1 (2.5%)	0	-1
Silty Clay	2 (2.5 %)	0	-2	0	0	0	2(5%)	0	-2
Clay Loam	13 (16.25%)	0	-13	10(25%)	0	-10	3 (7.5%)	0	-3
Silty Clay Loam	29 (36.25%)	15 (18.75%)	-14	9 (22.5%)	8 (21.62%)	-1	20 (50%)	7(16.28%)	-13
Sand	4 (5.0%)	1 (1.25%)	-3	4 (10%)	1 (2.70%)	-3	0	0	0
Sandy Loam	2 (2.5%)	1 (1.25%)	-1	2 (5%)	1 (2.70%)	-1	0	0	0
Loam	15 (18.7%)	7 (8.75%)	-8	5 (12.5%)	4 (10.81%)	-1	3 (6.98%)	3 (6.98%)	-7
Silt Loam	12 (15%)	56 (70%)	44	8 (20%)	23 (62016%)	15	33 (76.74%)	33 (76.74%)	29

Table 3b. Texture distribution of bottom sediments

	Nearshore			Midshore			Offshore		
	Sept	April	Diff	Sept	April	Diff	Sept	April	Diff
Light Clay	0	0	0	1 (3.23%)	0	-1	2 (9.25%)	0	-2
Silty Clay	1 (3.57%)	0	-1	1 (3.23%)	0	-1	0	0	0
Clay Loam	4 (14.29%)	0	-4	7 (22.58%)	0	-7	2 (9.25%)	0	-2
Silty Clay Loam	5 (17.86%)	2 (2.50%)	-3	12 (38.71%)	8 (25.81%)	-4	12 (57.14%)	5 (22.73%)	-7
Sand	4 (14.29%)	1 (1.25%)	-3	0	0	0	0	0	0
Sandy Loam	2 (7.14%)	1 (1.25%)	-1	0	0	0	0	0	0
Loam	9(32.14%)	4 (5.00%)	-5	5(16.13%)	2 (6.54%)	-3	1 (4.76%)	1 (4.55%)	0
Silt Loam	3 (10.71%)	19(23.75%)	17	5 (16.13 %)	21 (67.74%)	16	4 (19.05%)	16 (72.73%)	12

Table 3c. Texture distribution of bottom sediments Malaysian water

	Nearshore			Midshore			Offshore		
	Sept	April	Diff	Sept	April	Diff	Sept	April	Diff
Light Clay	0	0	0	0	0	0	2 (15.38%)	0	-2
Silty Clay	0	0	0	0	0	0	0	0	0
Clay Loam	1 (8.33 %)	0	-1	7 (46.67%)	0	-7	2 (15.38%)	0	-2
Silty Clay Loam	1 (8.33 %)	0	-1	2 (13.33%)	4 (30.8%)	2	6 (46.15%)	4 (30.8%)	-2
Sand	4 (33.33%)	1 (9.1%)	-3	0	0	0	0	0	0
Sandy Loam	2 (16.167%)	1 (9.1%)	-1	0	0	0	0	0	0
Loam	2 (16.67%)	2 (18.2%)	0	3 (20%)	2 (15.4%)	-1	0	0	0
Silt Loam	2 (16.67)	7 (63.6%)	5	3 (20%)	7 (53.8%)	4	3 (23.08%)	9 (69.2%)	7

Table 3d. Texture distribution of bottom sediments Thailand water

	Nearshore			Midshore			Offshore		
	Sept	April	Diff	Sept	April	Diff	Sept	April	Diff
Light Clay	0	0	0	1 (6.25%)	0	-1	0	0	0
Silty Clay	1 (6.25%)	0	-1	1 (6.25%)	0	-1	0	0	0
Clay Loam	3 (18.75%)	0	-3	0	0	0	0	0	0
Silty Clay Loam	4 (5%)	2 (12.5%)	-2	10 (62.5%)	4 (22.2 %)	-6	6 (75%)	1 (11/1%)	-5
Sand	0	0	0	0	0	0	0	0	0
Sandy Loam	0	0	0	0	0	0	0	0	0
Loam	7 (43.75%)	2 (12.5%)	-5	2 (12.5%)	0	-2	1 (12.5%)	1(11.1%)	0
Silt Loam	1 (6.25%)	12 (75.0%)	11	12 (75.0%)	14 (77.8%)	12	1 (12.5%)	7 (77.8%)	6

Sept denote - September 1995 sediment, April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

more occurrences of sand compared to the pre-monsoon near-shore sediments. The difference in sand content (fig. 6) can probably be attributed to sea conditions. The roughness associated with the open sea would have caused the Malaysian waters to have less silt and clay since the water turbulence aids in dispersing the finer sediment further off-shore, while the semi enclosed condition of the gulf helps to reduce turbulence thus at the same contain the river discharges within the gulf.

The sand content of the near-shore sediments is highest followed by mid-shore and off-shore areas. This trend is true for both the Malaysian and Thailand waters during both sampling periods (tabs. 4A to 4G; figures 7 and 8). An interesting trend is that the amount of sand is significantly less in the post-monsoon sediments compared to that of the pre-monsoon sediments.

The trend for silt and clay is opposite to that of sand; they show a decreasing trend shoreward. The differences in their amount is statistically significant for the pre but not so for the post-monsoon sediments (tabs. 1 and 2). Sand being denser than silt and clay would settle earlier along their transport path. Thus accounting for more sand in the near-shore areas compared to mid or off-shore.

Color (Tabs. 5A to 5D)

Although colors is less important now in the study of sediments due to the advancement in the field of organic substances in soil, composition of primary and secondary minerals in the soil, it remains a useful tool in the field to describe soil characteristics since some color change may occur as a result of oxidation and exposure prior to further laboratory analyses.

Overall there are 4 classifications of sediment colors determined for the pre-monsoon sediments: dull yellow orange, light yellow, grayish olive and olive yellow. It is interesting to note, however, that only the dull yellow orange color was identified for the sediments in the Gulf of Thailand. However, caution must be exercised since the first 8 stations in the gulf of Thailand was not included in this description due to some technical error. But the dominance of the color is remarkable, especially when contrasting it with the myriad of other colors found in the Malaysian sediments.

The sediment color for the post-monsoon sediments did not seem to differ too much from the pre-monsoon sediments. Except for the dull yellow orange color, which were found in the pre-monsoon sediments all the three other color remains. The dull yellow orange color, which were identified for the pre-monsoon sediments, is substituted by dull yellow colored sediments. This color dominates the mid-shore and off-shore areas of both the Malaysian and Thailand sediments.

Besides the sediment source, pollution levels and oxidation process may be the contributing factors to this differences in sediment color. Further analysis and correlation with other chemical and biological parameters are needed before further any definitive conclusion can be made.

Conclusion

Three general trends can be discerned from the results. Firstly, the April ‘96 sediments are finer, better sorted, more positively skewed and more peaked than the September ‘95 sediments. Secondly, the Malaysian sediments in general are coarser, more poorly sorted and less peaked than the sediments collected from the Thai waters. Thirdly, the coarsest and best sorted sediments are found near-shore while the mid-shore region has the finest and most poorly sorted sediments.

Additionally, it can also be concluded that although there are some similarities between the waters of Thailand and Malaysia, nevertheless, the differences in the amount of sand changes the texture of the sediments and would thus influencing the structure and diversity of the benthic communities. The marked difference in the sediment colors also indicate the differences in the component of primary and secondary minerals within the soil of the gulf and the open ocean of the Malaysian waters. The geological structures of the respective country may be another factor that may have contributed to the differences in the sediment color and grain size distribution patterns. Additionally, it seems that the inorganic sediment within the gulf and the continental shelf of the Malaysian waters are mainly terrestrially derived.

Table 4a. Percentages of sand, silt and clay

	% SAND			% SILT			% CLAY		
NEARSHORE STATIONS	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	38.92	17.59	-21.30	47.72	73.43	25.71	15.95	9.00	-6.95
Minimum	7.80	0.00	-7.80	4.10	0.00	-4.10	4.10	0.00	-4.10
Maximum	100.00	100.00	0.00	76.30	95.01	18.71	32.60	18.15	-14.50
Range	92.20	100.00	7.80	72.20	95.01	22.81	28.50	18.15	-10.40
MALAYSIAN STATIONS	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	43.98	24.15	-19.80	45.16	66.76	21.60	15.84	0.09	-15.80
Minimum	13.90	1.94	-12.00	4.10	0.00	-4.10	8.10	0.00	-8.10
Maximum	100.00	100.00	0.00	70.70	86.83	16.13	29.90	18.15	-11.80
Range	86.10	98.06	11.96	66.60	86.83	20.23	21.80	18.15	-3.65
THAILAND STATIONS	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	33.85	11.96	-21.90	50.03	79.17	29.14	16.04	8.92	-7.12
Minimum	7.80	0.00	-7.80	26.90	39.27	12.37	4.10	2.28	-1.82
Maximum	64.70	52.72	-12.00	76.30	95.01	18.71	32.60	15.45	-17.20
Range	56.90	52.72	-4.18	49.60	55.74	6.34	28.50	13.17	-15.30

Table 4b. Percentages of sand, silt and clay

	% SAND			% SILT			% CLAY		
ALL NEARSHORE STATIONS	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	50.43	23.24	-27.20	44.52	69.68	25.16	13.15	7.07	-6.08
Minimum	7.80	0.00	-7.80	21.50	0.00	-21.50	4.10	0.00	-4.10
Maximum	100.00	100.00	0.00	67.00	90.47	23.47	28.50	14.47	-14.00
Range	92.20	100.00	7.80	45.50	90.47	44.97	24.40	14.47	-9.93
ALL MIDSHORE STATIONS	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	36.35	16.03	-20.30	46.26	74.50	28.24	15.97	9.46	-6.51
Minimum	11.80	1.49	-10.30	4.10	36.61	32.51	8.10	3.50	-4.60
Maximum	67.00	54.01	-13.00	67.30	74.50	7.20	32.60	9.46	-23.10
Range	55.20	52.52	-2.68	63.20	37.89	-25.30	24.50	5.96	-18.50
ALL OFFSHORE STATIONS	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	27.36	12.87	-14.50	53.53	76.53	23.00	19.10	10.71	-8.39
Minimum	13.90	1.49	-12.40	30.10	52.34	22.24	8.90	4.72	-4.18
Maximum	45.50	40.44	-5.06	76.30	90.02	13.72	29.90	18.15	-11.80
Range	31.60	38.95	7.35	46.20	37.68	-8.52	21.00	13.43	-7.57

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 4c. Percentages of sand, silt and clay

	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
	ALL NEARSHORE STATIONS								
	% SAND			% SILT			% CLAY		
Average	50.43	23.24	-27.20	44.52	69.68	25.16	13.15	7.07	-6.08
Minimum	7.80	0.00	-7.80	21.50	0.00	-21.50	4.10	0.00	-4.10
Maximum	100.00	100.00	0.00	67.00	90.47	23.47	28.50	14.47	-14.00
Range	92.20	100.00	7.80	45.50	90.47	44.97	24.40	14.47	-9.93
	ALL NEARHORE STATIONS (MALAYSIAN WATERS)								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	64.66	38.12	-26.50	41.10	56.13	15.03	11.80	5.75	-6.05
Minimum	22.50	8.12	-14.40	21.50	0.00	-21.50	8.10	0.00	-8.10
Maximum	100.00	100.00	0.00	67.00	85.52	18.52	16.50	10.20	-6.30
Range	77.50	91.88	14.38	45.50	85.52	40.02	8.40	10.20	1.80
	ALL NEARSHORE STATIONS (THAILAND WATERS)								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	39.76	13.02	-26.70	46.23	78.99	32.76	13.82	7.67	-5.85
Minimum	7.80	0.00	-7.80	26.6-9	39.27	12.37	4.10	2.28	-1.82
Maximum	64.60	52.72	-11.90	64.30	90.47	26.17	28.50	14.47	-14.00
Range	56.80	52.72	-4.08	37.40	51.20	13.80	24.40	12.19	-12.20

Table 4d. Percentages of sand, silt and clay

	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
	ALL NEARSHORE STATIONS								
	% SAND			% SILT			% CLAY		
Average	36.35	16.03	-20.32	46.26	74.50	28.24	15.97	9.46	-6.51
Minimum	11.80	1.49	-10.31	4.10	36.61	32.51	8.10	3.50	-4.60
Maximum	67.00	54.01	-12.99	67.30	74.50	7.20	32.60	9.46	-23.14
Range	55.20	52.52	-2.68	63.20	37.89	-25.31	24.50	5.96	-18.54
	ALL MIDSHORE STATIONS (MALAYSIAN WATERS)								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	41.19	23.56	-17.63	41.57	66.05	24.48	14.31	10.36	-3.95
Minimum	22.20	6.85	-15.35	4.10	36.61	32.51	11.00	4.83	-6.17
Maximum	67.00	54.01	-12.99	65.50	85.32	19.82	21.50	17.12	-4.38
Range	44.80	47.16	2.36	61.40	48.71	-12.69	10.50	12.29	1.79
	ALL MIDSHORE STATIONS (THAILAND WATERS)								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	31.81	10.58	-21.23	50.67	80.61	29.94	17.52	8.81	-8.71
Minimum	11.80	1.49	-10.31	27.20	59.79	32.59	8.10	3.50	-4.60
Maximum	64.70	35.89	-28.81	67.30	95.01	27.71	32.60	14.48	-18.12
Range	52.90	34.40	-18.50	40.10	35.22	-4.88	24.50	10.98	-13.52

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 4e. Percentages of sand, silt and clay

	ALL OFFSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	27.36	12.87	-14.50	53.53	76.53	23.00	19.10	10.71	-8.39
Minimum	13.90	1.49	-12.40	30.10	52.34	22.24	8.90	4.72	-4.18
Maximum	45.50	40.44	-5.06	76.30	90.02	13.72	29.90	18.15	-11.80
Range	31.60	38.95	7.35	46.20	37.68	-8.52	21.00	13.43	-7.57
	ALL OFFSHORE STATIONS (MALAYSIAN WATERS)								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	28.12	12.91	-15.20	51.80	76.46	24.66	20.08	10.64	-9.44
Minimum	13.90	1.94	-12.00	30.10	52.34	22.24	12.80	6.19	-6.61
Maximum	45.50	37.10	-8.40	70.70	86.83	16.13	29.90	18.15	-11.80
Range	31.60	35.16	3.56	40.60	34.49	-6.11	17.70	11.96	-5.74
	ALL OFFSHORE STATIONS (THAILAND WATERS)								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	26.14	12.82	-13.30	56.35	76.63	20.28	17.51	10.82	-6.69
Minimum	14.80	1.49	-13.30	44.90	55.75	10.85	8.90	1.49	-7.41
Maximum	44.30	40.44	-3.86	76.30	90.02	13.72	22.80	15.45	-7.35
Range	29.50	38.95	9.45	31.40	34.27	2.87	13.90	13.96	0.06

Table 4f. Percentages of sand, silt and clay - Malaysian waters

	NEARSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	64.66	38.12	-26.50	41.10	56.13	15.03	11.80	5.75	-6.05
Minimum	22.50	8.12	-14.40	21.50	0.00	-21.50	8.10	0.00	-8.10
Maximum	100.00	100.00	0.00	67.00	85.52	18.52	16.50	10.20	-6.30
Range	77.50	91.88	14.38	45.50	85.52	40.02	8.40	10.20	1.80
	MIDSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	41.19	23.56	-17.60	41.57	66.05	24.48	14.31	10.36	-3.95
Minimum	22.20	6.85	-15.40	4.10	36.61	32.51	11.00	4.83	-6.17
Maximum	67.00	54.01	-13.00	65.50	85.32	19.82	21.50	17.12	-4.38
Range	44.80	47.16	2.36	61.40	48.71	-12.70	10.50	12.29	1.79
	OFFSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	28.12	12.91	-15.20	51.80	76.46	24.66	20.08	10.64	-9.44
Minimum	13.90	1.94	-12.00	30.10	52.34	22.24	12.80	6.19	-6.61
Maximum	45.50	37.10	-8.40	70.70	86.83	16.13	29.90	18.15	-11.80
Range	31.60	35.16	3.56	40.60	34.49	-6.11	17.10	11.96	-5.14

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 4g. Percentages of sand, silt and clay - Thailand waters

	NEARSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	39.76	13.02	-26.70	46.23	78.99	32.76	13.82	7.97	-5.85
Minimum	7.80	0.00	-7.80	26.90	39.27	12.37	4.10	2.28	-1.82
Maximum	64.60	52.72	-11.90	64.30	90.47	26.17	28.50	14.47	-14.00
Range	56.80	52.72	-4.08	37.40	51.20	13.80	24.40	12.19	-12.20
	MIDSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	31.81	10.58	-21.20	50.67	80.61	29.94	17.52	8.81	-8.71
Minimum	11.80	1.49	-10.30	27.20	59.79	32.59	8.10	3.50	-4.60
Maximum	64.70	35.89	-28.80	67.30	95.01	27.71	32.60	14.48	-18.10
Range	52.90	34.40	-18.50	40.10	35.22	-4.88	24.50	10.98	-13.50
	OFFSHORE STATIONS								
	% SAND			% SILT			% CLAY		
	Sept.	April	Diff.	Sept.	April	Diff.	Sept.	April	Diff.
Average	26.14	12.82	-13.30	56.35	76.63	20.28	17.51	10.82	-6.69
Minimum	14.80	1.49	-13.30	44.90	55.75	10.85	8.90	1.49	-7.41
Maximum	44.30	40.44	-3.86	76.30	90.02	13.72	22.80	15.45	-7.35
Range	29.50	38.95	9.45	31.40	34.27	2.87	13.90	13.96	0.06

Sept denote - September 1995 sediment
April denote - April 1996 sediment
Dif denote - Difference between September 1995 and April 1996

Table 5a. Colour distribution of bottom sediments

	ALL	Malaysian Water	Thailand Water
Dull Yellow	34 (51.51%)	20 (64.52%)	14 (40.00%)
Dull Yellow Orange	4 (6.06%)	2 (6.45%)	2 (5.71%)
Grayish Olive	11 (16.66%)	1 (3.24%)	10 (28.57%)
Olive Yellow	17 (25.76%)	8 (25.81%)	9 (25.71 %)

Table 5b. Colour distribution of bottom sediments

	Nearshore	Midshore	Offshore
Dull Yellow	3 (18.75%)	15 (55.56%)	15 (71.43%)
Dull Yellow Orange	0 (0%)	0 (0%)	4 (19.05%)
Grayish Olive	4 (25.00%)	5 (18.52%)	2 (9.25%)
Olive Yellow	9 (56.25%)	7 (25.93%)	0 (0%)

Table 5c. Colour distribution of bottom sediments Thailand water

	Nearshore	Midshore	Offshore
Dull Yellow	1 (10.00%)	6 (42.86%)	6 (60.00%)
Dull Yellow Orange	0 (0%)	0 (0%)	2 (20.00%)
Grayish Olive	4 (40.00%)	4 (28.57%)	2 (20.00%)
Olive Yellow	5 (50.00%)	4 (28.57%)	0 (0%)

Table 5d. Colour distribution of bottom sediments Malaysian water

	Nearshore	Midshore	Offshore
Dull Yellow	2 (33.33%)	9 (69.23%)	9 (81.81%)
Dull Yellow Orange	0 (0%)	0 (0%)	2 (18.18%)
Grayish Olive	0 (0%)	1 (7.69%)	0 (0%)
Olive Yellow	4 (66.66%)	3 (23.08%)	0 (0%)

Table 5e. Colour distribution of bottom sediments for April 1996 sediments

	All	Malaysian water	Thailand Water
Dull Yellow	34 (51.51%)	20 (64.52%)	14 (40.00%)
Dull Yellow Orange	4 (6.06%)	2 (6.45%)	2 (5.71%)
Grayish Olive	11 (16.66%)	1 (3.24%)	10 (28.57%)
Olive Yellow	17 (25.76%)	8 (25.81%)	9 (25.71%)

Table 5f. Colour distribution of bottom sediments for April 1996 sediments

	Nearshore	Midshore	Offshore
Dull Yellow	3 (18.75%)	15 (55.56%)	15 (71.43%)
Dull Yellow Orange	0 (0%)	0 (0%)	4 (19.05%)
Grayish Olive	4 (25.00%)	5 (18.52%)	2 (9.25%)
Olive Yellow	9 (56.25%)	7 (25.93%)	0 (0%)

Table 5g. Colour distribution of bottom sediments for April 1996 sediments Thai water

	Nearshore	Midshore	Offshore
Dull Yellow	1 (10.0%)	6 (42.86%)	6 (60.00%)
Dull Yellow Orange	0 (0%)	0 (0%)	2 (20.00%)
Grayish Olive	4 (40.00%)	4 (28.57%)	2 (20.00%)
Olive Yellow	5 (50.00%)	4 (28.57%)	0 (0%)

Table 5h. Colour distribution of bottom sediments for April 1996 sediments Malaysian water

	Nearshore	Midshore	Offshore
Dull Yellow	2 (33.33%)	9 (69.23%)	9 (81.81%)
Dull Yellow Orange	0 (0%)	0 (0%)	2 (18.18%)
Grayish Olive	0 (0%)	1 (7.69%)	0 (0%)
Olive Yellow	4 (66.66%)	3 (23.08%)	0 (0%)

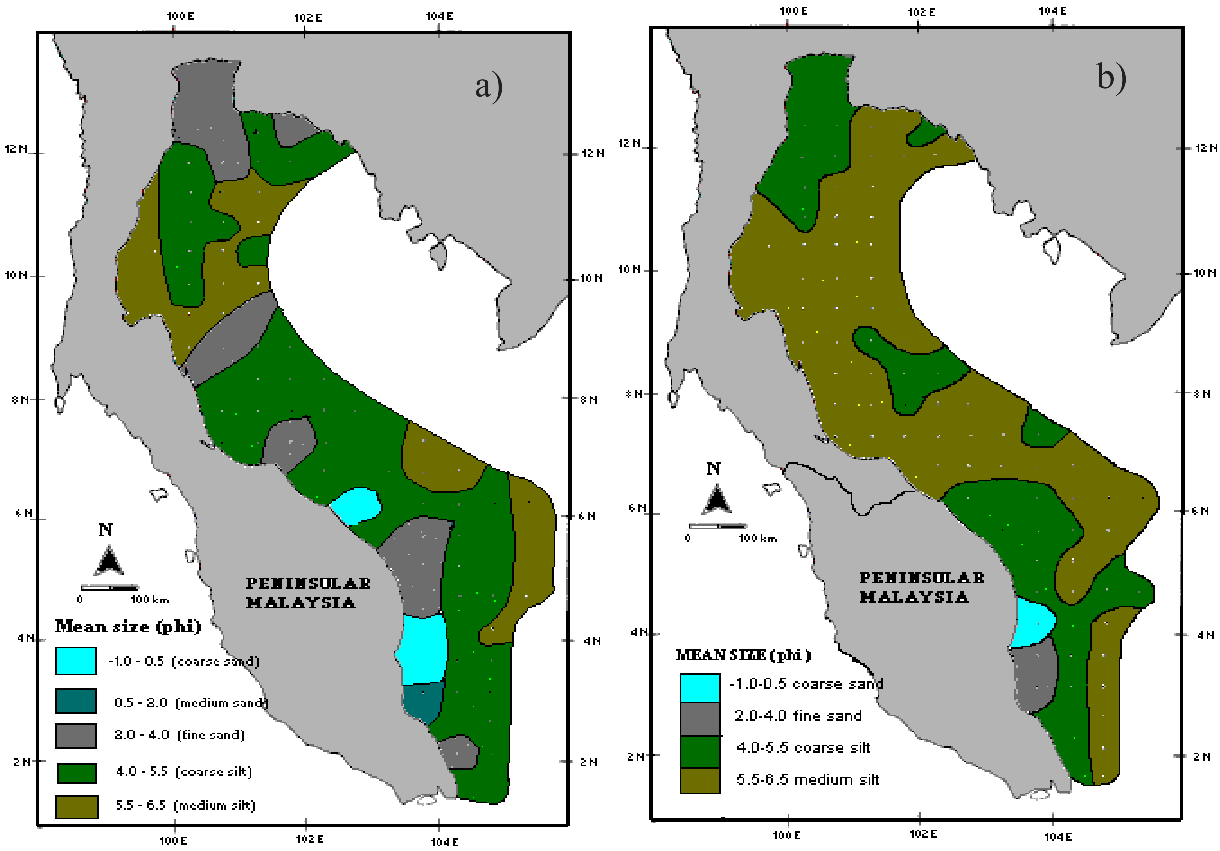


Fig. 2 Patterns of sediment mean size distribution in September of 1995 (a) and April of 1996 (b)

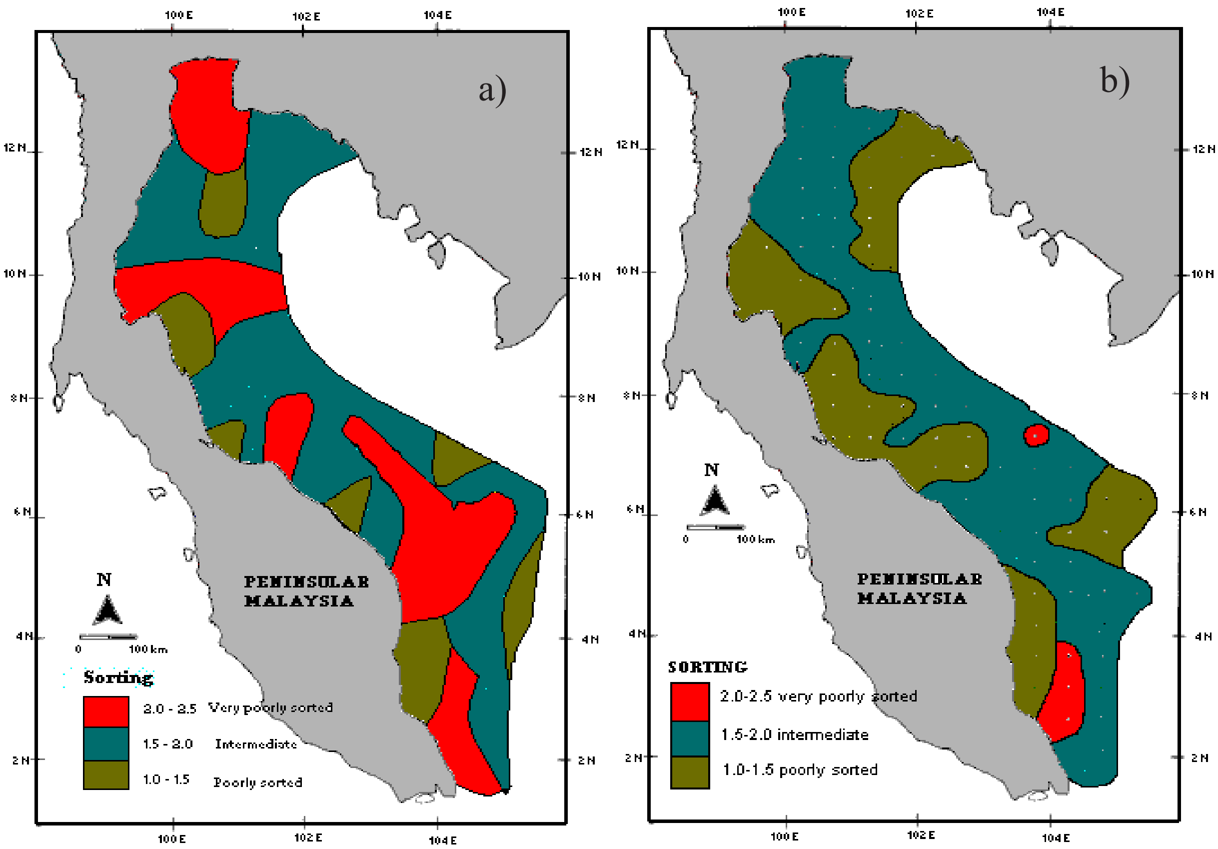


Fig. 3 Patterns of sediment sorting distribution in September of 1995 (a) and April of 1996 (b)

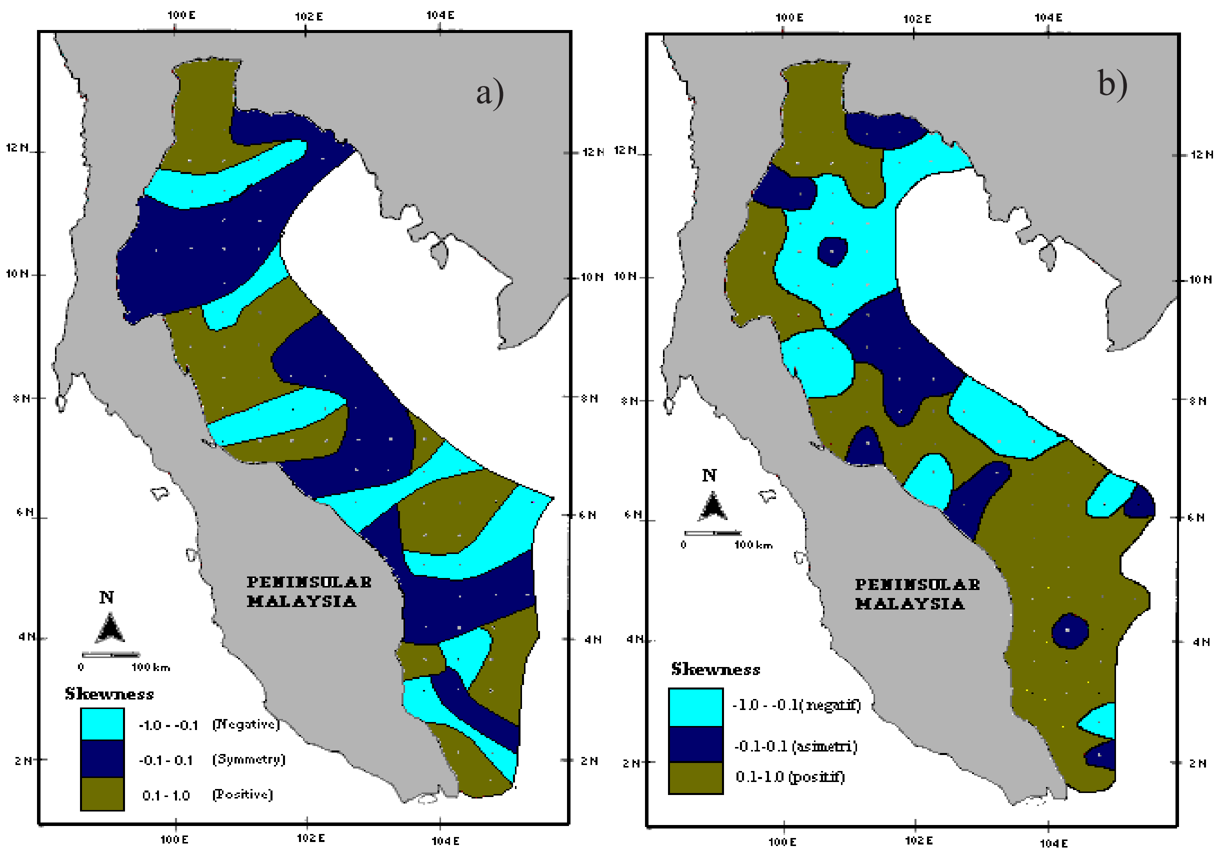


Fig. 4 Patterns of sediment skewness distribution in September of 1995 (a) and April of 1996 (b)

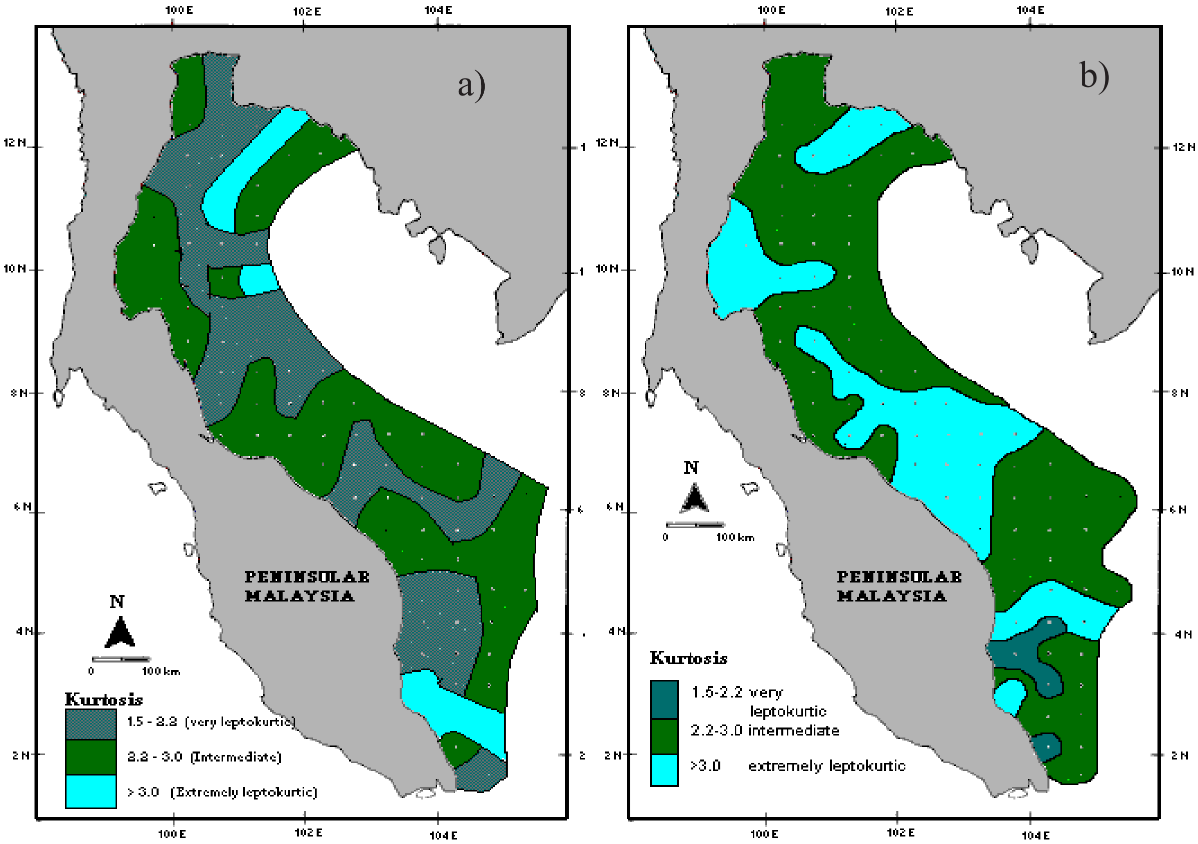


Fig. 5 Patterns of sediment kurtosis distribution in September of 1995 (a) and April of 1996 (b)

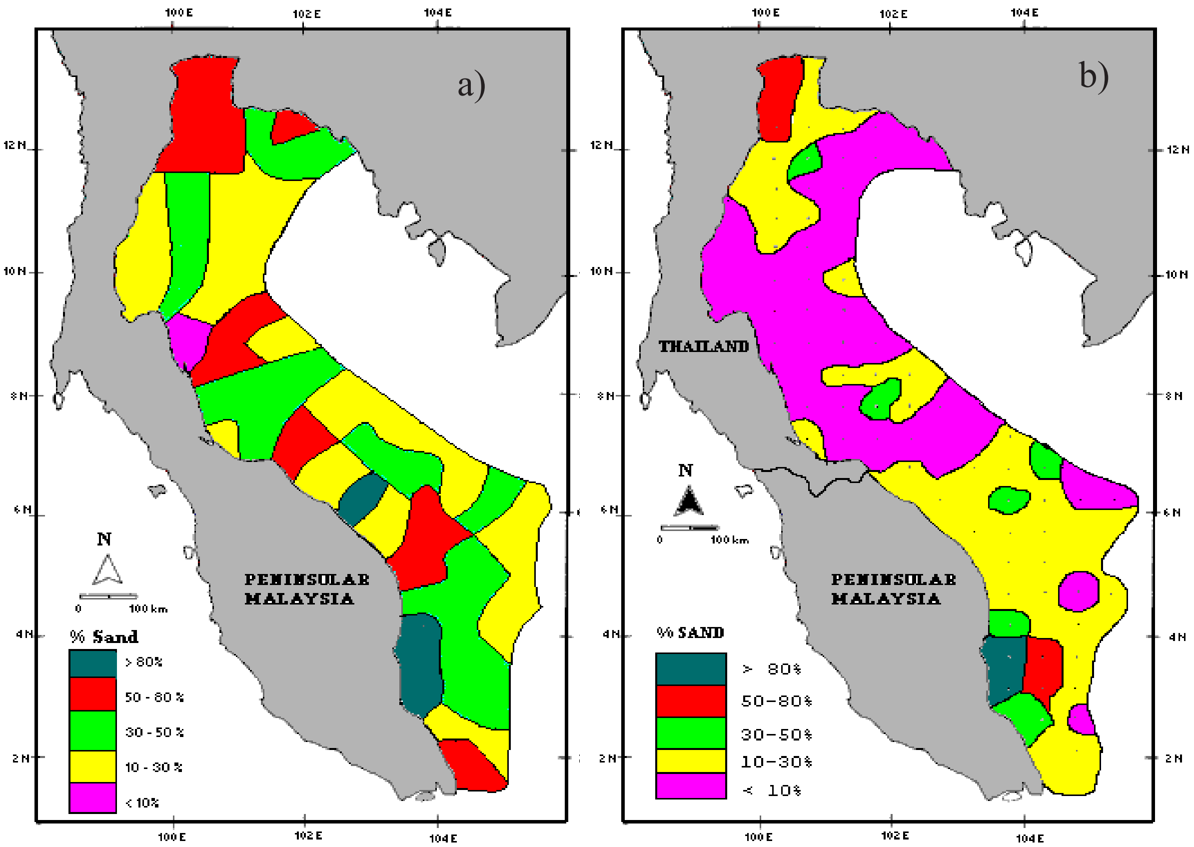


Fig. 6 Sand content distribution in September of 1995 (a) and April of 1996 (b)

Acknowledgement

The support and permission from the authorities of University Putra Malaysia Terengganu (UPMT) in allowing us to actively participate in this project are gratefully acknowledged.

References

Folk, R. L. 1980. Petrology of sedimentary rocks. Austin, Hemphill Publishing Company.

Folk, R.L. 1966. A review of grain size parameters. *Sedimentology*. (6): 73-93

Griffiths, J. C. 1967. Scientific method in analysis of sediments. New York, McGraw Hill Inc.

Japanese Ministry of Agriculture, Forestry and Fisheries. 1996. Revised Standard Soil Color Charts.

Krumbein, W.C. 1937. Sediments and exponential curves. *Jour. Geol*. (45): 577-601

Krumbein, W.C. 1938. Size frequency distributions and the normal phi curves. *Jour. Sed. Petrol*. (8): 49-90

Mc Bride, F. E. 1971. Mathematical Treatment of Size Distribution data. In: T. E. Carver (Ed.). Procedures in sedimentary Petrology. Toronto, Wiley Interscience. 109-128

Mohsin, A. K. M. and M. I. Mohamed. 1987. Ekspedisi Matahari '87: A study on the off-shore waters of the Malaysian EEZ. Occassional Publication. No.8. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia.

Mohsin, A. K. M., M. I. Mohamed and M. A. Ambak. 1985. Ekspedisi Matahari '85: A study on the off-shore waters of the Malaysian EEZ. Occassional Publication. No.3. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia.

Mohsin, A. K. M., R. A. Rahman and M. A. Ambak. 1986. Ekspedisi Matahari '86: A study on the off-shore waters of the Malaysian EEZ. Occassional Publication. No.4. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia.

Mohsin, A. K. M., M. Z. M. Said and M. I. Mohamed. 1989. Ekspedisi Matahari '89: A study on the off-shore waters of the Malaysian EEZ. Occassional Publication. No.9. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia.

Wentworth, C.K. 1929. Method of Computing mechanical composition types in sediments. *Bull. Geol. Soc. Am.* (40): 771-790

Wrytki, K. 1961. Physical oceanography of the Southeast Asian waters. Naga report: Scientific results of marine investigations of the South China Sea and the Gulf of Thailand 1959-1961.

Numerical Simulations of The Net Current in the Gulf of Thailand Under Different Monsoon Regimes

Anond Snidvongs[1]
Pramot Sojisuporn[2]

[1]Marine Science Department, Chulalongkorn University
[2]Harbour Department, Ministry of Communication

ABSTRACT

Net circulation in the three layers in the Gulf of Thailand 0-10 m, 10-40 m and >40 m were simulated by a hydrological model using tri-monthly average of observed temperature, salinity, depth and wind. Prevailing monsoon was an important factor controlling current speed and direction of water above the pycnocline (0-40 m). The water in the upper 10 m flew from the South China Sea during the Northeast Monsoon and opposite during the Southwest Monsoon. The water in the near surface layer in all simulations was replenished mainly by the opposite flow in the mid-depth layer and only slightly from the deep, nutrient enriched, water below 40 m. The true circulation gyre could not be seen in our simulations but different degrees of eddies and meanders were evident in almost all runs. These features could play very important roles in the distribution and dispersion of dissolved, particulate and biological species, including pollution and larvae, and deserved more in depth studies in the future.

Introduction

The net circulation is an important factor that governs the distribution, dispersion and residence time of dissolved and suspended materials, biotic as well as abiotic forms, in the water. It is a basic information frequently required to explain the results of other chemical and biological studies of seawater.

The net circulation pattern of a large area, such as the Gulf of Thailand and Eastern Peninsular Malaysia is difficult and very costly to obtain. Direct observation by mean of deployment of a large number of current meters, each covers the time period at least 1 tidal cycle (i.e. 15 days), is definitely impossible during this SEAFDEC Collaborative Research Program. Existing current observation data available from several data centers worldwide are however few and the stations were too far apart to able to interpolate the result to get a reasonable picture of current field.

The lack of current data and the difficulties in obtaining them for large study areas are not uncommon problems among marine and coastal studies. Hydrologists and oceanographers, therefore, have developed a well established approach of numerical modeling to get around the problems. By using concepts and theories in classical physics, forcing functions for water movement and circulation can be described and interrelated by mathematical equations. The suites of equations are subsequently solved for velocity and other variables using numerical techniques.

In this report, we will attempt to simulate the net circulation, that is free from tidal effects, for the Gulf of Thailand. The coastal shelf off the Peninsular Malaysia, however, is too open to the South China Sea and the condition for the model that the open boundary must be horizontally homogeneous may not be true for this case, thus the area was excluded.

The model used in this study had been successfully implemented for the upper Gulf of Thailand, which is a small (100 km x 100 km) bay situated at the northernmost part of the Gulf (Sojisuporn 1995). The model relates the water movement in three dimension with the oceanographic variables easily and frequently measured, and therefore can cover extensive area within a short sampling period, i.e. temperature, salinity and meteorological data. However the reader must always aware that the simulation done here is only a simplification of the natural system, where there are much more factors involved. Many of those may occur only in small areas and/or in short time periods. These small scale temporal and spatial variations are usually missed by the sampling programs especially when spatial data is not collected simultaneously. For the purpose of obtaining the general picture of the current field of a large area, there are usually irrelevant in term of time and space scales.

Numerical Model

The governing equations are the momentum equations, the continuity equation, and the conservation of heat and salt. The momentum equations are used to calculate horizontal velocity components. The equations retain temporal changes, field accelerations, the Coriolis effects, pressure gradient terms, and horizontal and vertical eddy viscosities. Using conventional notations in the left-hand Cartesian coordinate, the momentum equations for horizontal velocities are written as

$$\frac{fu}{ft}+u\frac{fu}{fx}+v\frac{fu}{fy}+w\frac{fu}{fz}-fv=-\frac{1}{\rho_0}\frac{fP}{fx}+A_h\frac{f^2u}{fx^2}+A_h\frac{f^2u}{fy^2}+A_v\frac{f^2u}{fz^2} \qquad (1)$$

$$\frac{fv}{ft}+u\frac{fv}{fx}+v\frac{fv}{fy}+w\frac{fv}{fz}+fu=-\frac{1}{\rho_0}\frac{fP}{fy}+A_h\frac{f^2v}{fy^2}+A_h\frac{f^2v}{fy^2}+A_v\frac{f^2v}{fz^2} \qquad (2)$$

where: *x* and *y* are horizontal axes
z is vertical axis
t is time
u and *v* are horizontal velocity components corresponding to *x* and *y* axis, respec tively
f is the Coriolis parameter (2Wsinf, where f is latitude)
ρ_0 is density
A_h and A_v are horizontal and vertical eddy viscosity coefficients, respectively.

The pressure terms are represented by both hydrostatic and buoyancy terms, and are expressed as

$$P = \rho_0 g\xi - \rho_0\int_0^z Bdz \qquad (3)$$

$$B=\frac{\rho_0-\rho}{\rho_0}g \qquad (4)$$

where: *g* is gravitational acceleration (980 cm s^{-2})
B is buoyancy force
ρ is referenced density

The continuity equation is used for the calculation of water surface elevation and vertical velocity component. The equation can be expressed as

$$\frac{fu}{fx}+\frac{fv}{fy}+\frac{fw}{fz}=0 \qquad (5)$$

The water surface elevation is calculated from vertical velocity at the surface:

$$\frac{f\eta}{ft}=-W_s \qquad (6)$$

where: h is water surface elevation
W_S is vertical velocity at the surface.

The conservation of heat and salt are used to calculate the changes of these two parameters due to advection and diffusion processes (Sarmiento and Bryan, 1982). The equations also include the terms that draw the calculated values to the observed ones. The equations are written as

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = K_h\frac{\partial^2 T}{\partial x^2} + K_h\frac{\partial^2 T}{\partial y^2} + K_v\frac{\partial^2 T}{\partial z^2} + \gamma(T^* - T) \qquad (7)$$

$$\frac{fS}{ft} + u\frac{fS}{fx} + v\frac{fS}{fy} + w\frac{fS}{fz} = K_h\frac{f^2 S}{fx^2} + K_h\frac{f^2 S}{fy^2} + K_v\frac{f^2 S}{fz^2} + \gamma(S^* - S) \qquad (8)$$

where: T and S are modeled temperature and salinity, respectively
K_h and K_v are horizontal and vertical diffusivity coefficients, respectively
T^* and S^* are observed temperature and salinity, respectively.

The g terms in (7) and (8) are introduced by Sarmiento and Bryan (1982) to prevent the deviations of calculated T and S values from the observed ones. The value of g indicates the degree of modification of the observed values by the local advective-diffusive balance (Fujio and Imasato, 1991). For a small or zero g, the model is nearly independent or independent of the observed values, approaching the prognostic model (Yanagi and Takahashi, 1993). For a large g, the model is restricted by the observed values, approaching diagnostic model (Fujio and Imasato 1991).

Full-slip condition is employed at the lateral walls. The bottom stress is given as

$$A_v\frac{\partial u}{\partial z} = \gamma_b|u|u \qquad (9)$$

where: g_b is bottom drag coefficient
u is horizontal velocity in the bottom layer.

The surface momentum flux from the wind is given as

$$\rho_0 A_v\frac{\partial u}{\partial z} = \rho_a C_d|W|W \qquad (10)$$

where: ρ_a is air density (0.0012 g cm^{-3})
C_d is surface drag coefficient
W is wind velocity.

There is no flux of temperature and salinity at the lateral walls, the water surface, and the bottom. Cramped open boundary condition and sponge layers are used at the open boundary (for definition see Roed and Cooper, 1986) . Tidal forcing is neglected because we want to obtain velocity field at steady state. The leap-frog scheme is used with centered difference in space and forward in time. Backward computation was inserted every 10 time steps. And semi-implicit scheme is employed for the calculation of water elevation (Backhaus, 1983).

Model Implementation

The model was applied to the Gulf of Thailand (about 400 km x 800 km). Grid size of 0.2 degree by 0.2 degree was chosen in order to optimize both accuracy and memory usage. The water column was divided into three layers, surface (0-10 m), mid-depth (10-40), and bottom (>40 m). The bottom layer was generally represented deep-water below the pycnocline which was well developed in the Gulf of Thailand.

Because the data from the collaborative research alone did not cover the entire Gulf, we decided to supplement SEAFDEC data with long-term data available from WDC-A (Oceanography) and JODC for the same months. One these data were available, they enable us to perform additional simulations for other months so that the intra-annual trends among seasons can be seen.

Since the data for some months did not evenly cover the whole Gulf, we combined data into 4 groups according to the monsoon regimes, December-February (Northeast Monsoon), March-May (First Inter-Monsoon), June-August (Southwest Monsoon) and September-November (Second Inter-Monsoon). By this way the whole area of the Gulf was well blanketed by data points. The numbers of stations used in these four simulations are 1779, 858, 1145 and 1314, respectively.

The observed temperature and salinity data (both CTD and serial station data) within each of the three depth intervals were averaged. The spatial data of temperature, salinity and bottom depth were subsequently gridded using Krigging Method (Kegler, 1994). The gridded data was formatted according to the requirement of the model which was written in FORTRAN.

The condition and parameter used in each simulation are given in Tables 1 and 2.

Results and Discussion

Northeast Monsoon Season (December-February)

Surface temperature during the Northeast Monsoon (Fig. 1a) shows that the water from the Chao Phraya River systems had temperature that was 1-2 ^{o}C lower than surface temperature in the Gulf. Sea surface temperature was lower along the west than the east coast. There was also a plume of low salinity from Tapi River system that extended as far as 100 km from shore (Fig. 1b). Apparently there has been no explanation for this plume since the runoff from this river system in this season should not be more than 50 m^3/s which was much less than that in the Upper Gulf of Thailand. Mid-depth temperature and salinity distribution were in general agreement to those at the surface (Figs. 2a and 2b).

A strong meander was formed in surface layer and the general direction of flow along the meander was toward the head of the Gulf (Fig. 1c). There was also a small counter clockwise eddy near the center of the Gulf.

Along the western half of the Gulf, surface current was westward toward the coast of the peninsular (Fig. 1c). However the mid-depth water flowed in an opposite direction (Fig. 2c). The water balance indicated a net gain of water in the Gulf and that was well supported by observations by the others that sea level in the Gulf was higher during the Northeast Monsoon.

Deep water temperature and salinity below the pycnocline (Figs. 3a and 3b) clearly suggested an intrusion of intermediate water from the South China Sea along the shore of Vietnam and Cambodia. Deep water circulated anticlockwisely and exited the Gulf along the west coast. The speed of the deep water current was less than 5 cm/s (Fig. 3c).

First Inter-Monsoon Season (March-May)

According to the temperature and salinity, surface and mid-depth waters in the Gulf in this season was well distinguished from the South China Sea water (Figs. 4a, 4b, 5a and 5b). A weak counterclockwise eddy was formed near the mouth of the Gulf and a clockwise eddy was formed in Cambodian EEZ (Figs. 4c and 5c). In general the direction of surface flow in the lower part of the Gulf, Songkhla and below, was outward. However, to the north of Songkhla, surface water along the west coast flew northward. Surface current speed was apparently slow (mostly less that 10 cm/s) relative to surface velocity in other seasons.

There was a prominent tongue of low temperature high salinity water extended from the South

China Sea into the central deep basin of the Gulf (Figs. 6a and 6b). The velocity of this inward flow of deep water was quite strong (up to 10 cm/s, Fig. 6c) compare to the deep water velocity during the Northeast Monsoon.

Southwest Monsoon Season (June-August)

Sea surface and mid-depth temperature of the Gulf were higher near the center of the Gulf and spread along the southwest coast, toward the Thai-Malaysian border (Figs. 7a and 8a). Surface and mid-depth salinity indicated that the head of the Upper Gulf and all the east coast of the Gulf from Thailand through Cambodia to Vietnam were major sources of freshwater input (Figs. 7b and 8b). These near surface plumes of low salinity water along the east coast however were unlikely to cross the southeastward meander which was well developed roughly along the central axis of the Gulf. The velocity along this meander was up to 40 cm/s but there was no eddy formed in the surface layer in this simulation (Fig. 7c). Nevertheless the low salinity water from the eastern side of the gulf could cross the central axis of the Gulf at the mid-depth layer where the meander was much weaker. A mid-depth clockwise eddy was also evident in the northern part of the Gulf confirming the difference in the circulation characteristics between surface and mid-depth layers. The general flow pattern in the mid-depth layer near the mouth was southwestward, i.e. from the Cambodia-Vietnam EEZ to the Thai-Malay Peninsular (Fig. 8c).

Inflow of intermediate water from the South China Sea into the sub-pycnocline layer of the Gulf was extended as far north as 10^{o}N (Figs. 9a and 9b). The velocity was also quite strong (up to 10 m/s, Fig. 9c) but considerably less than the velocity found in the First Inter-Monsoon Period.

Second Inter-Monsoon Season (September-November)

Plume of Upper Gulf water characterized by its relatively higher temperature was well observed in the surface and mid-depth layers as far south as the center of the Gulf. This southward plume might had been merging with another high temperature water from Nakorn Sri Thamarat (Figs. 10a and 11a). The water originated from Cambodia easily distinguished by its low salinity was confined only to the southeastern portion of the Gulf near the mouth and did not cross the central axis toward the Thai-Malay Peninsular (Figs. 10b and 11b). The surface current vectors were southeastward into the South China Sea (Fig. 10c) while the mid-depth current vectors were mostly eastward with a small counterclockwise eddy near the center of the Gulf (Fig. 11c) indicating replenishment of surface water by mid-depth water.

Deep water in this season in the Gulf in terms of temperature and salinity was indistinguishable from intermediate water of the South China Sea (Figs. 12a and 12b). The northwestward inflow of South China Sea water, although could be seen (Fig. 12c), the magnitude was less than that in the previous season which might indicate an intermediate stage of changing of the monsoonal effect. No clear eddies or meanders were seen in this simulation.

Table 1. Assumptions and constants used for all runs

Constants	Value
Grid size	0.2 x 0.2 degree (2.22 x 10^6 cm^2)
Surface layer	0-10 m
Mid-depth layer	10-40 m
Bottom layer	>40 m
Lateral boundary drag	Full slip
Gravity wave	None
Bottom drag coefficient	0.0026
Median latitude	9^o N
Tidal forcing at boundaries	None
(Open) Boundary values	
. Surface temperature	30 ^oC
· Mid-depth temperature	28 ^oC
· Bottom temperature	28 ^oC
· Surface salinity	33 psu
· Mid-depth salinity	33 psu
· Bottom salinity	33 psu
Surface wind drag coefficient	0.0013
Solar heating	
· Mean	5.72 x 10^{-3} cal cm^{-2} s^{-1}
· Amplitude variation	5.73 x 10^{-4} cal cm^{-2} s^{-1}
· Phase	0
· Frequency	2.02 x 10^{-7} s^{-1}
River discharge None	
Run time	10 days
Time step	240 s
Eddy viscosity	
· Horizontal	1.0 x 10^7 cm s^{-1}
· Vertical	3.0 x 10^7 cm s^{-1}
Eddy diffusivity	
· Horizontal	5.0 x 10^7 cm s^{-1}
· Vertical	5.0 cm s^{-1}

Table 2. Variables for each run

	Dec.-Feb.	Mar.-May	Jun.-Aug.	Sep.-Nov.
Wind (m/s)	5 (NE)	2 (SE)	5 (SW)	5 (SW)
Temperature	Tri-monthly averaged of SEAFDEC, NODC and JODC data			
Salinity	Tri-monthly averaged of SEAFDEC, NODC and JODC data			

S1/OG5<ANOND>

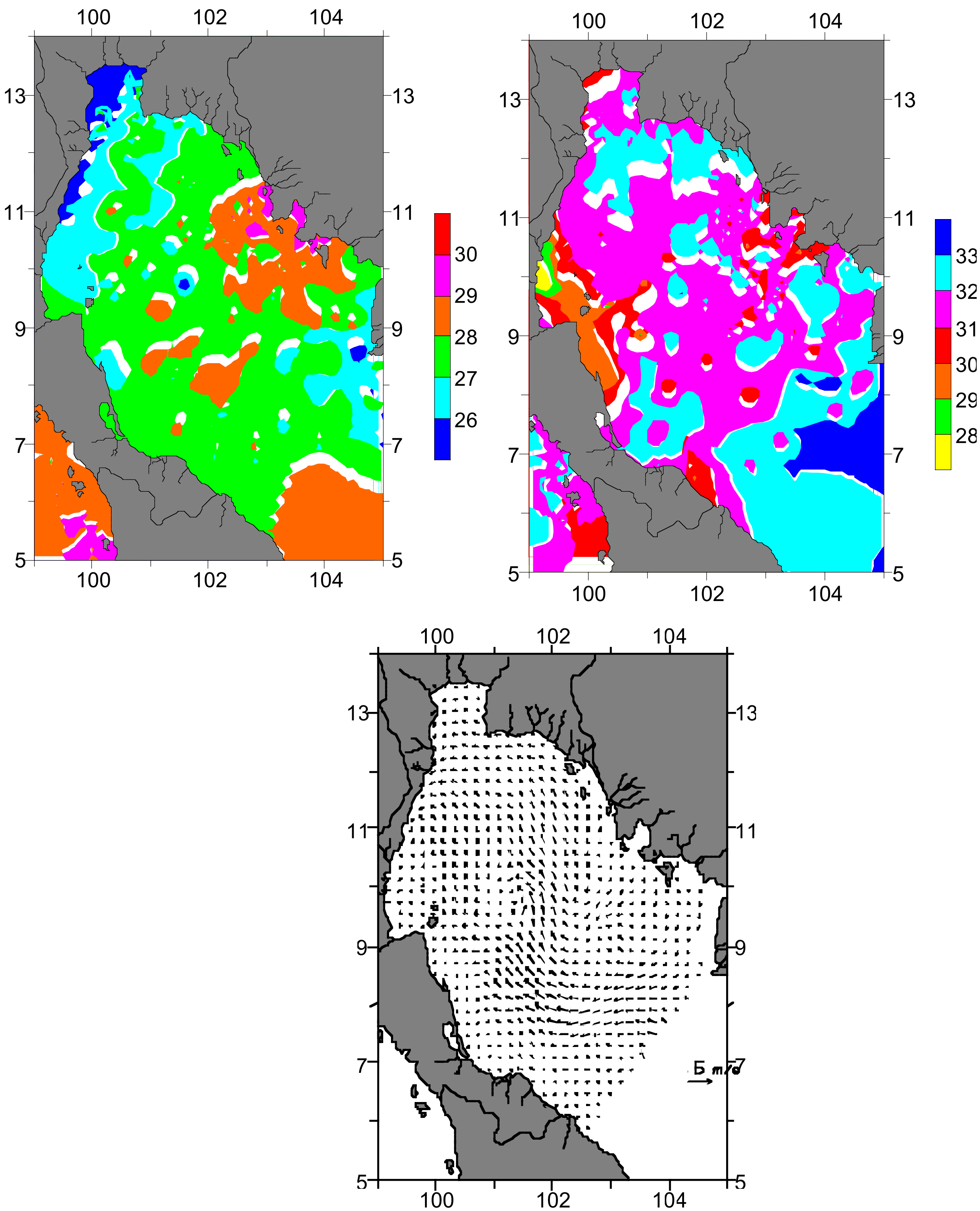


Fig. 1. December-February surface (0-10 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

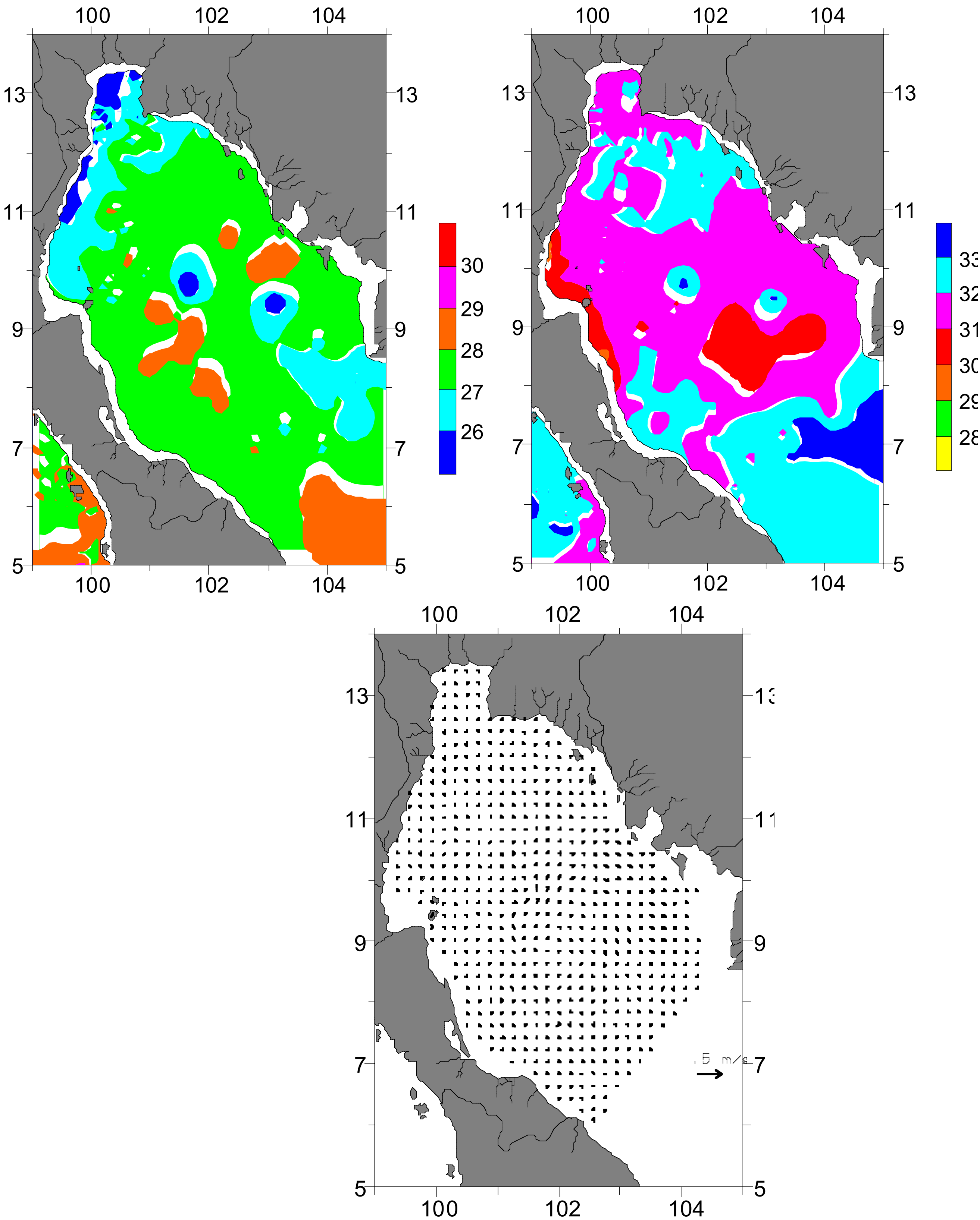


Fig. 2. December-February mid-depth (10-40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

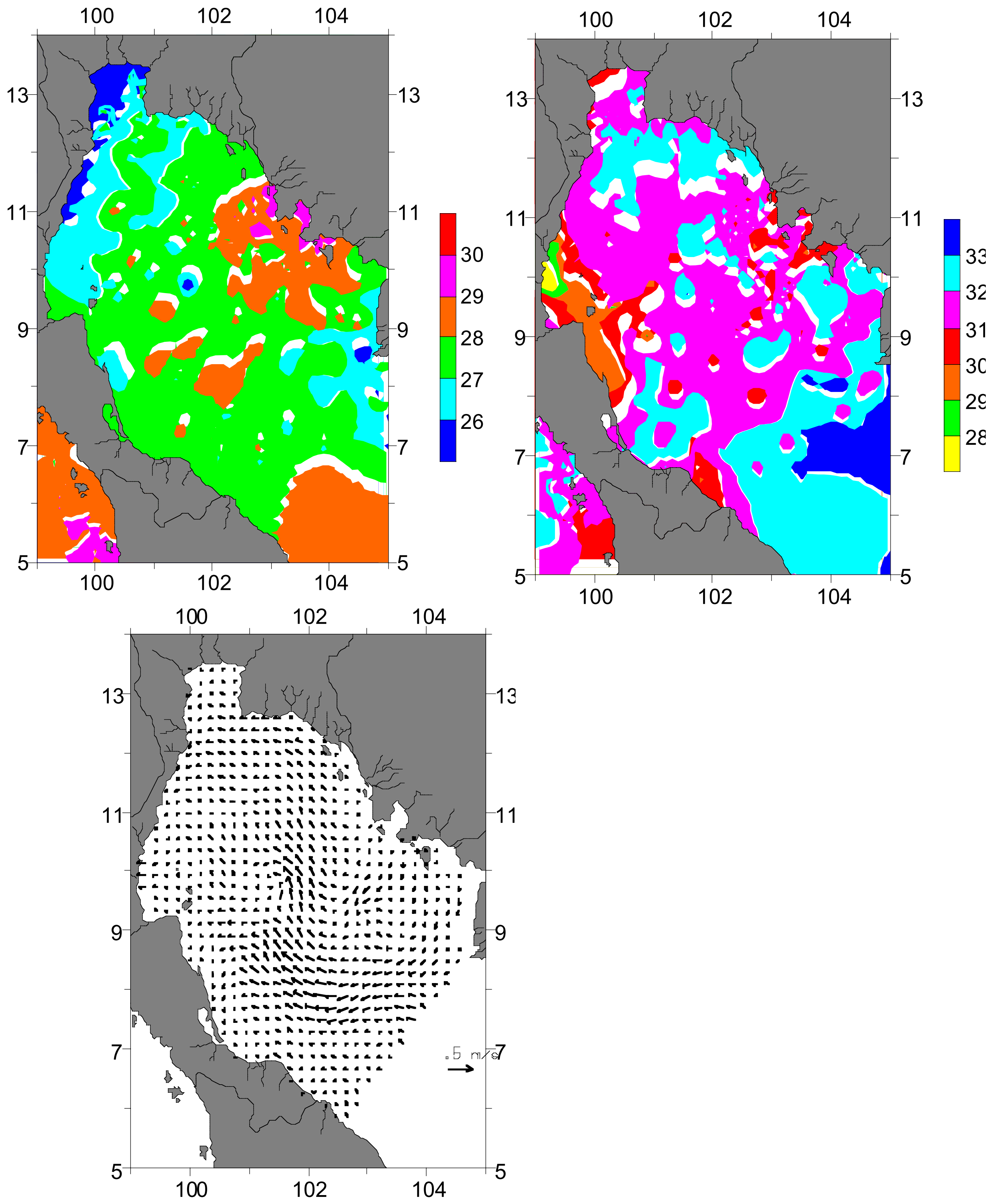


Fig. 3. December-February deep-water (>40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

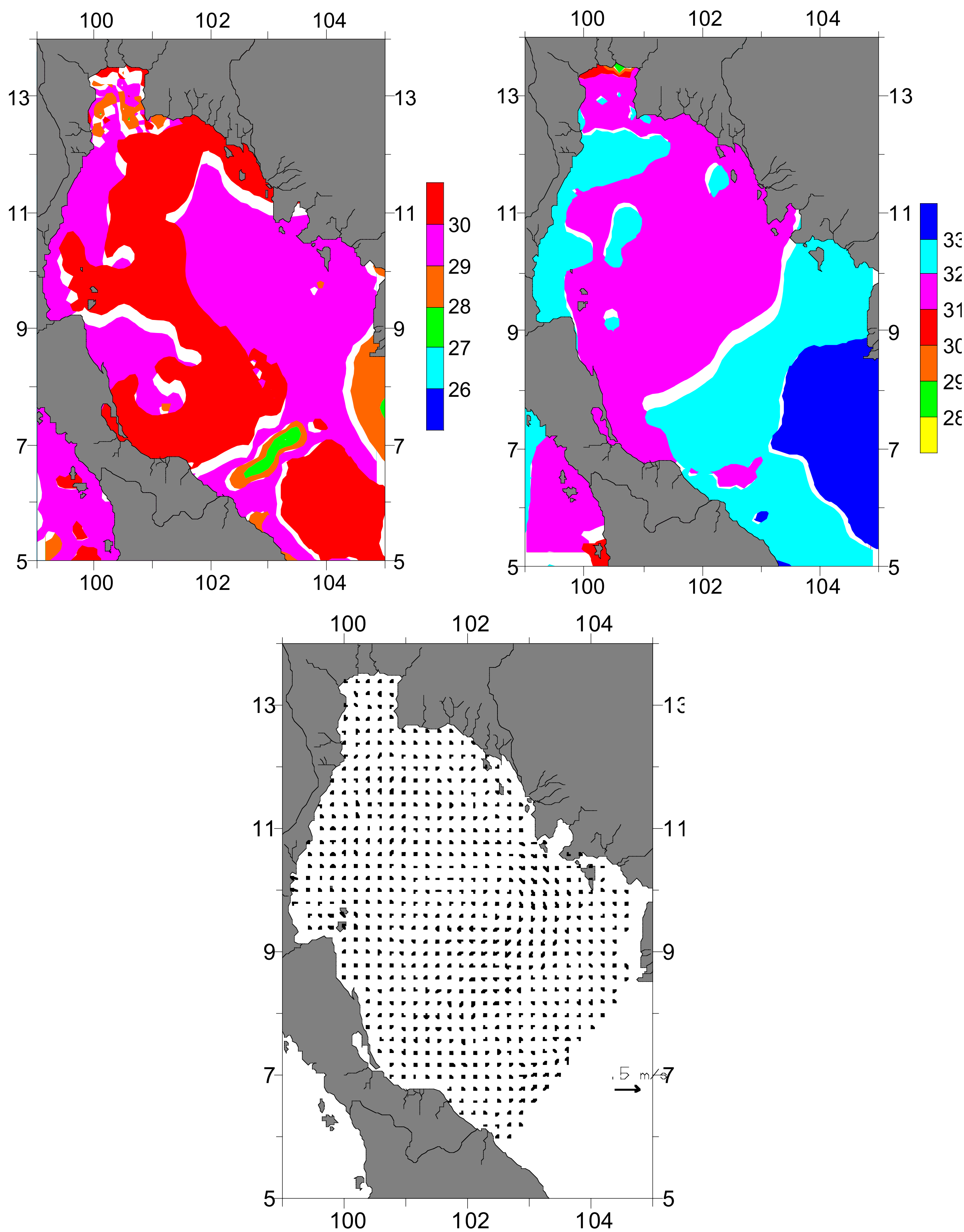


Fig. 4. March-May surface (0-10 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

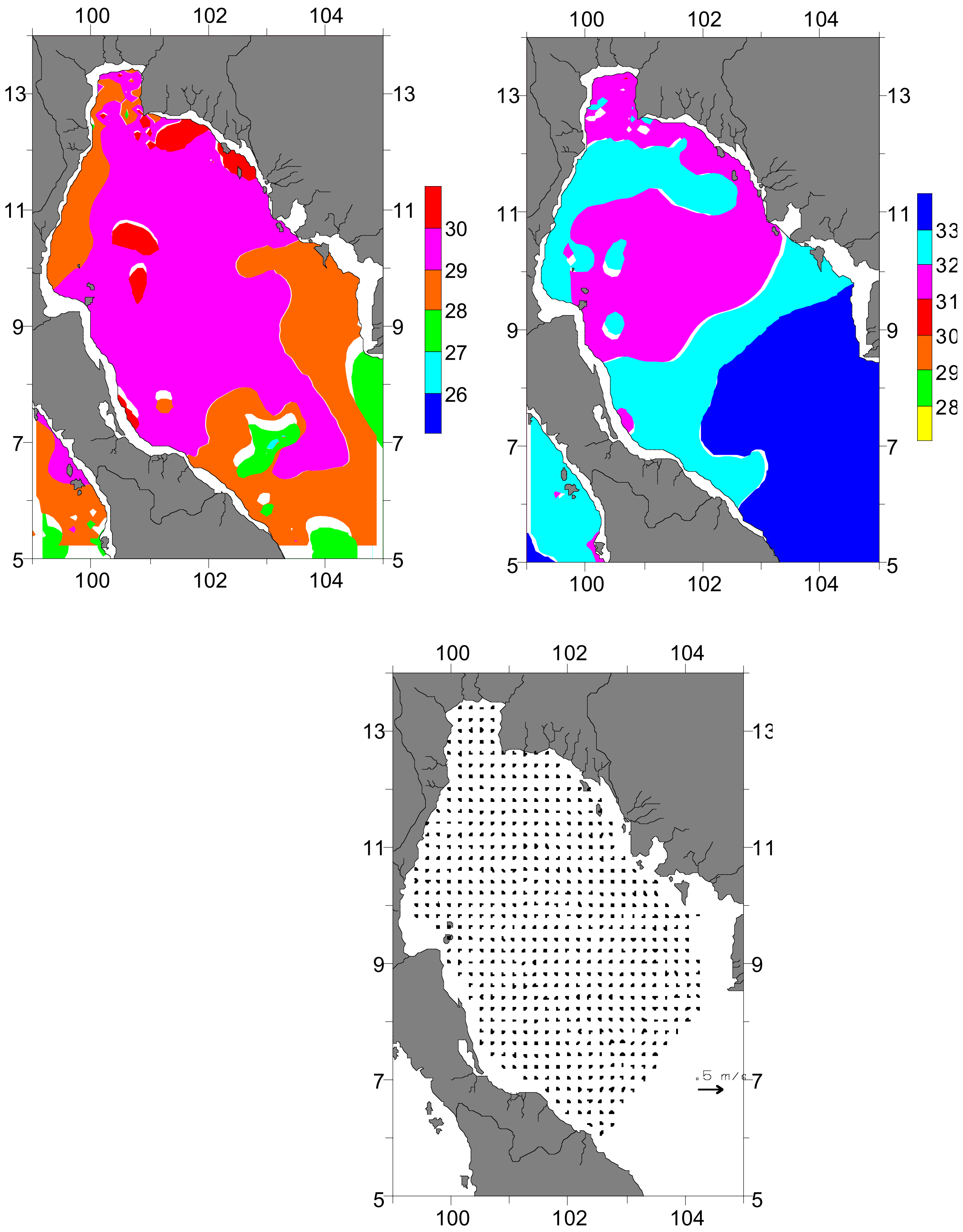


Fig. 5. March-May mid-depth (10-40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

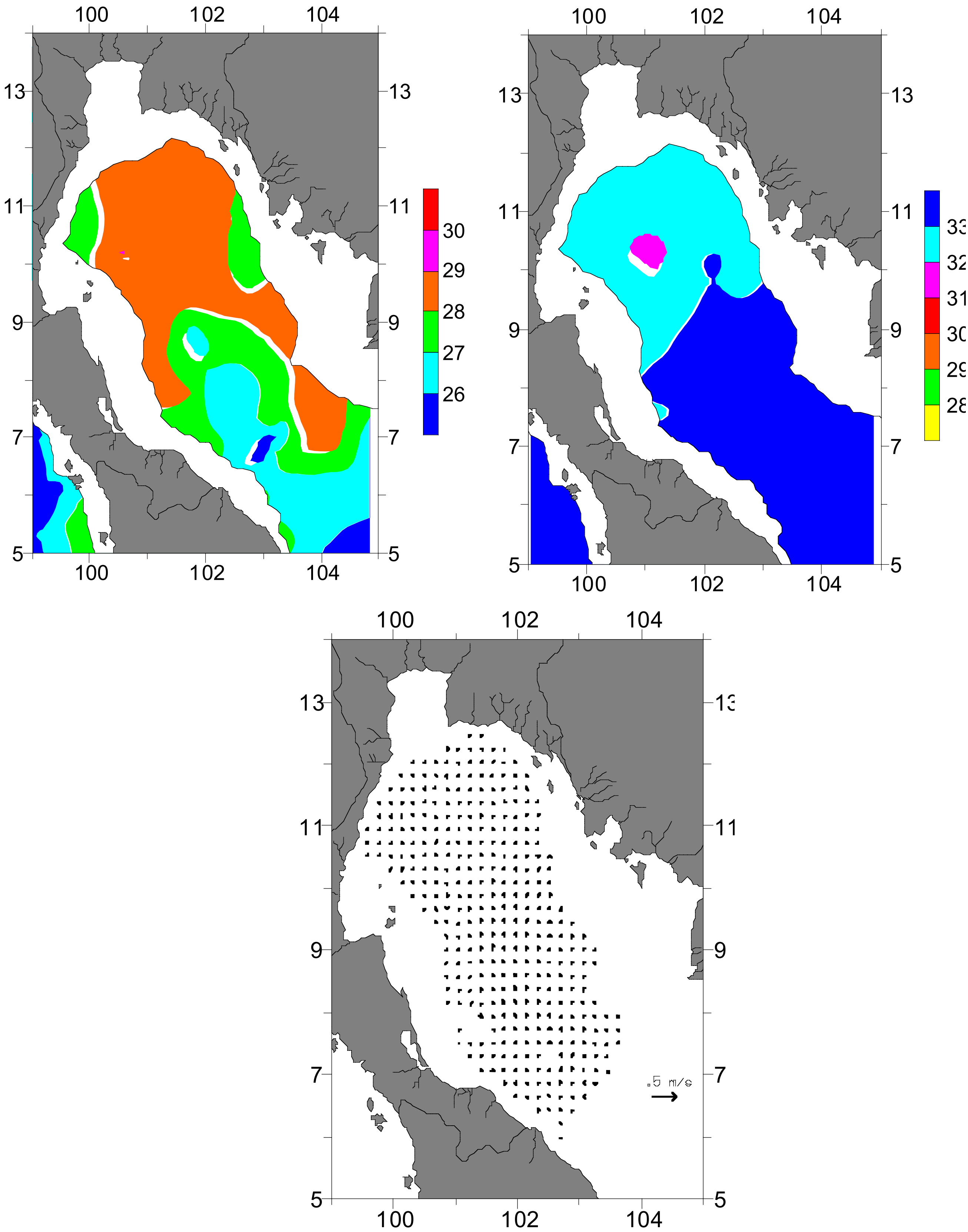


Fig. 6. March-May deep-water (>40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

S1/OG5<ANOND>

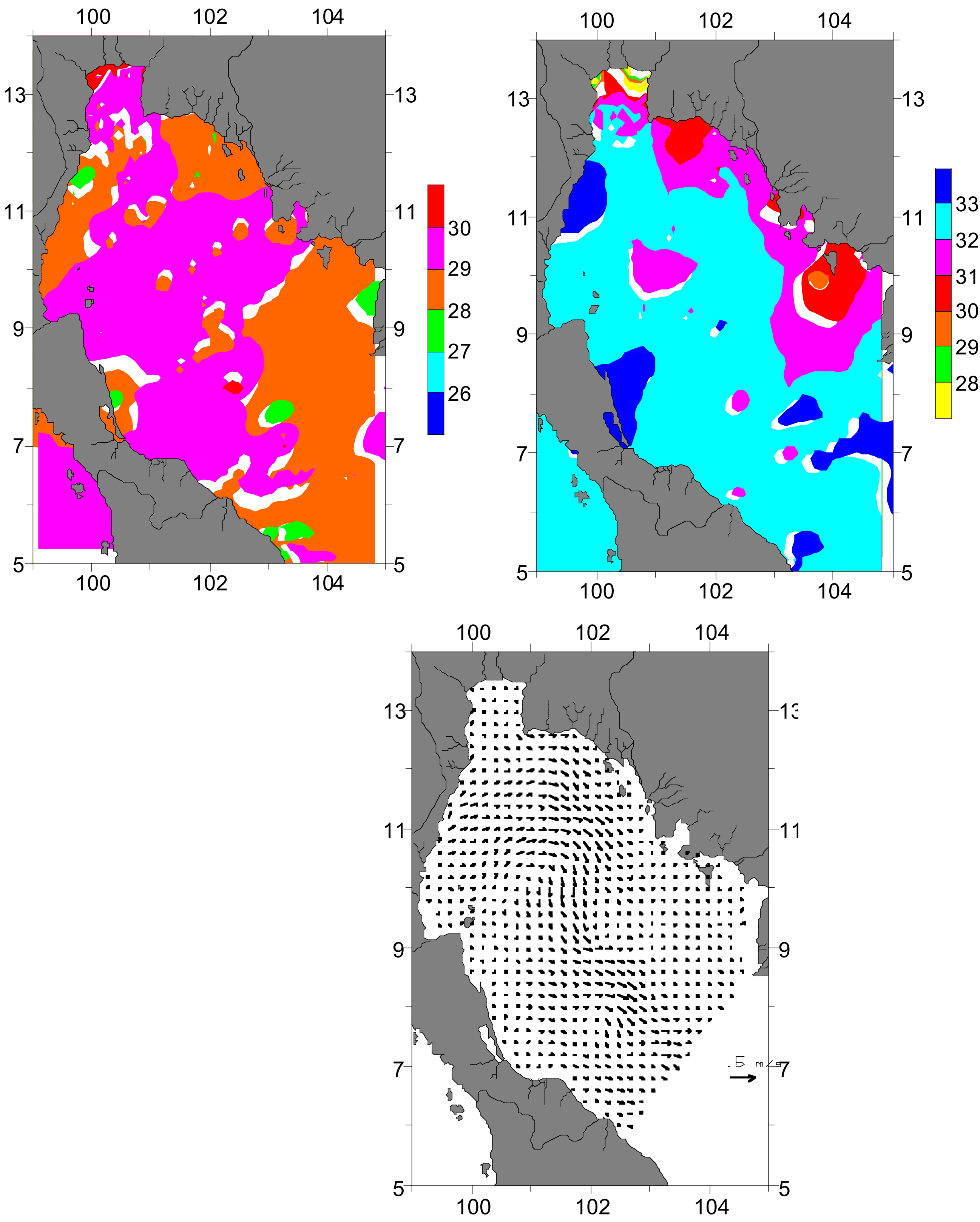


Fig. 7. June-August surface (0-10 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

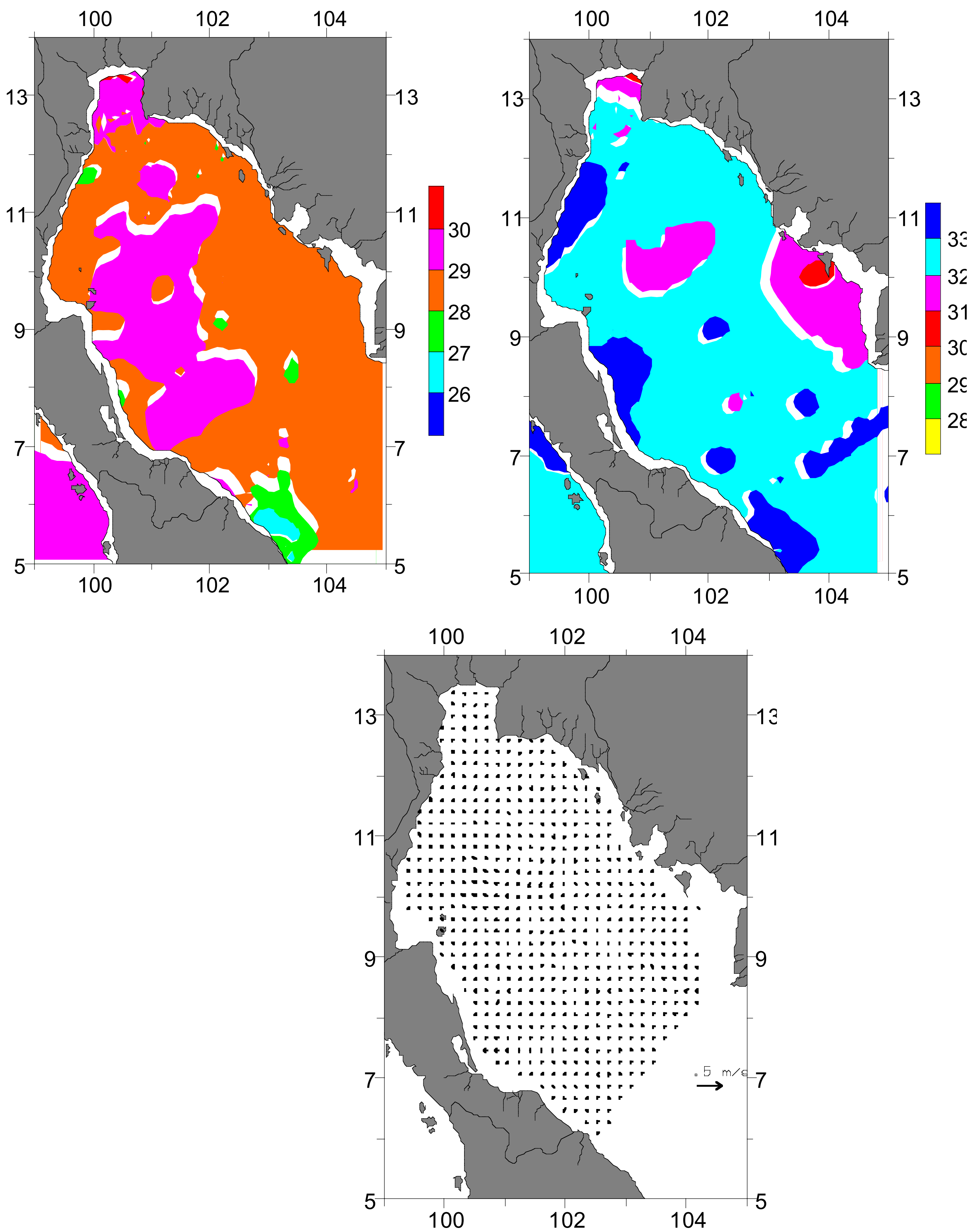


Fig. 8. June-August mid-depth (10-40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

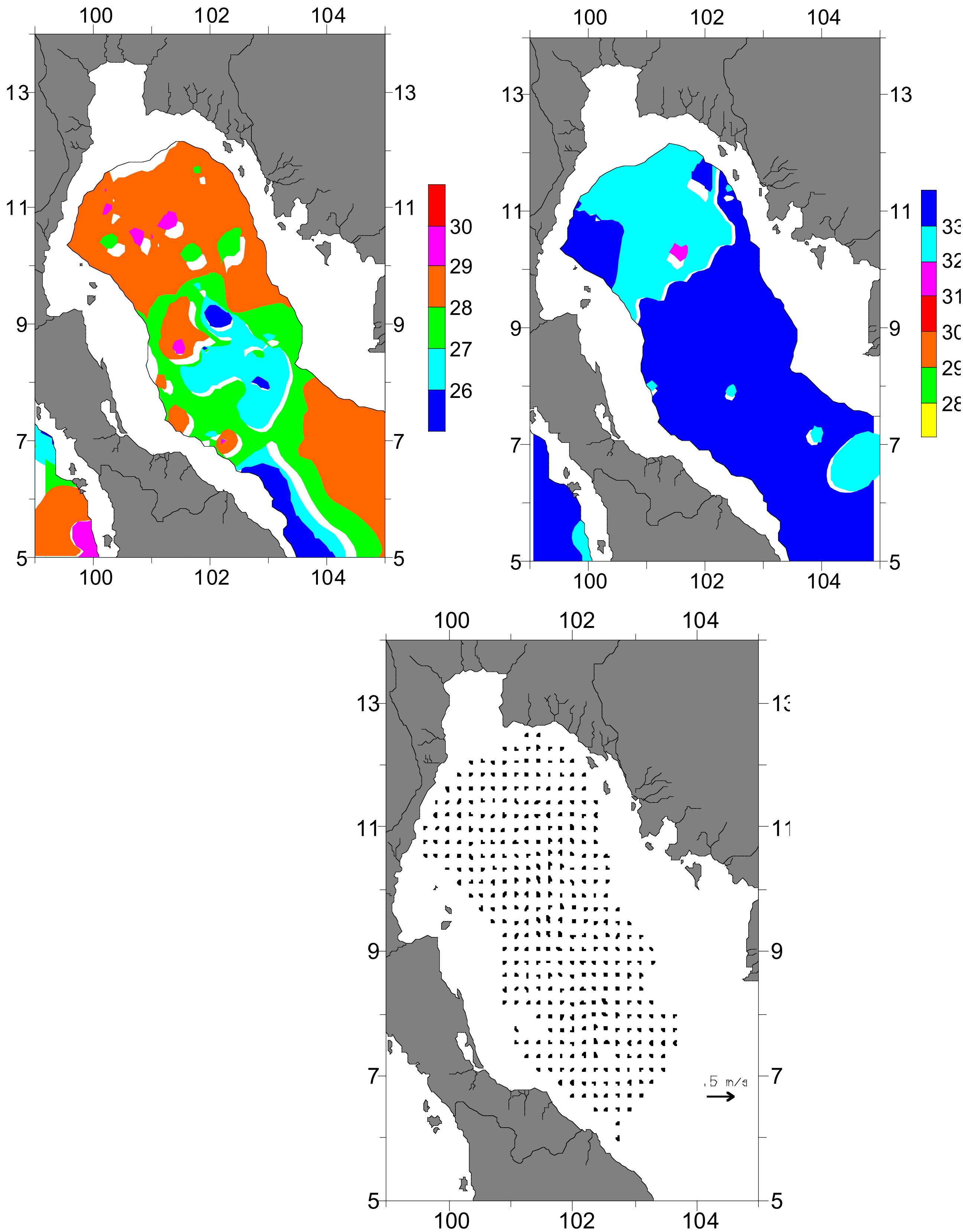


Fig. 9. June-August deep-water (>40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

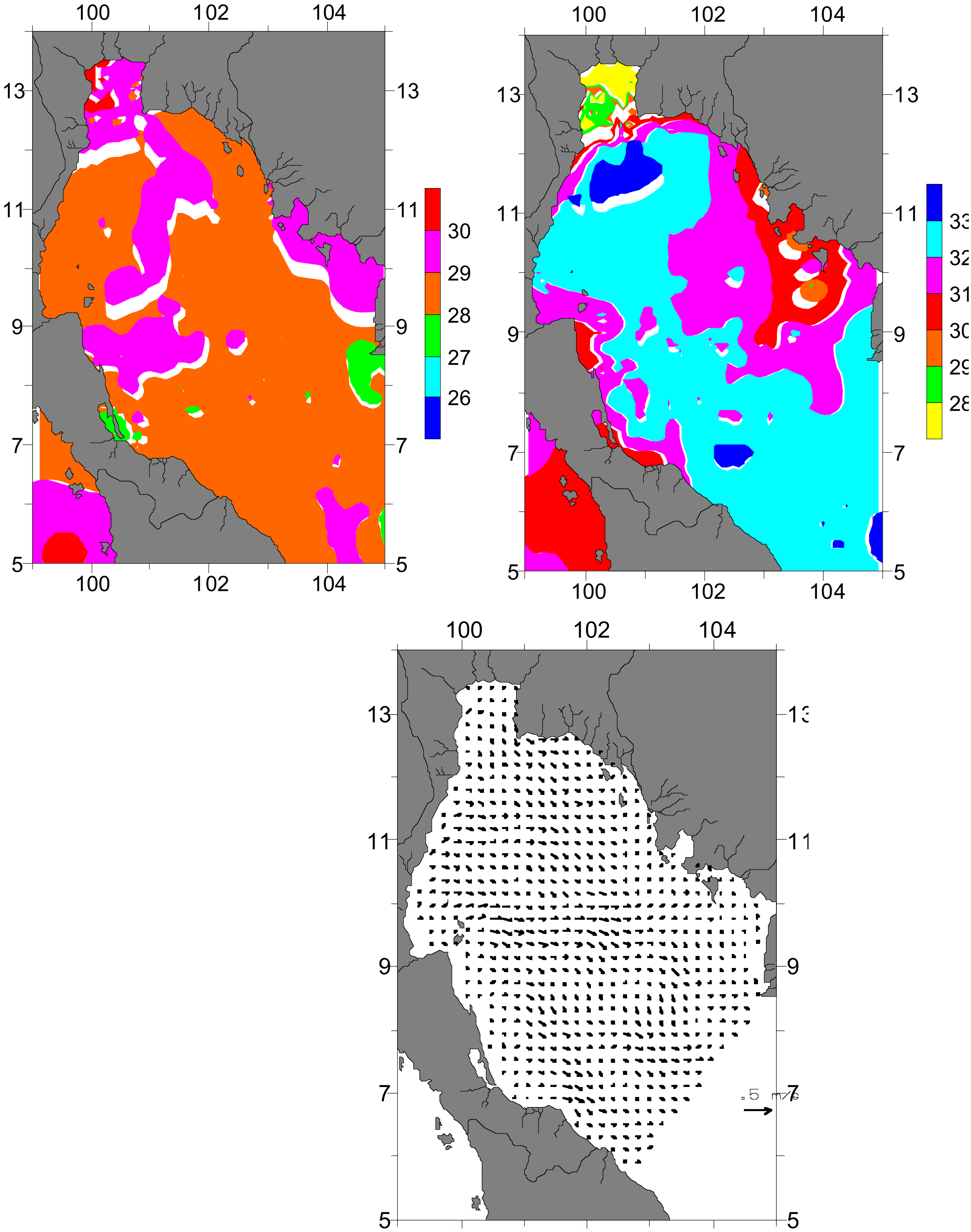


Fig. 10. September-November surface (0-10 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

S1/OG5<ANOND>

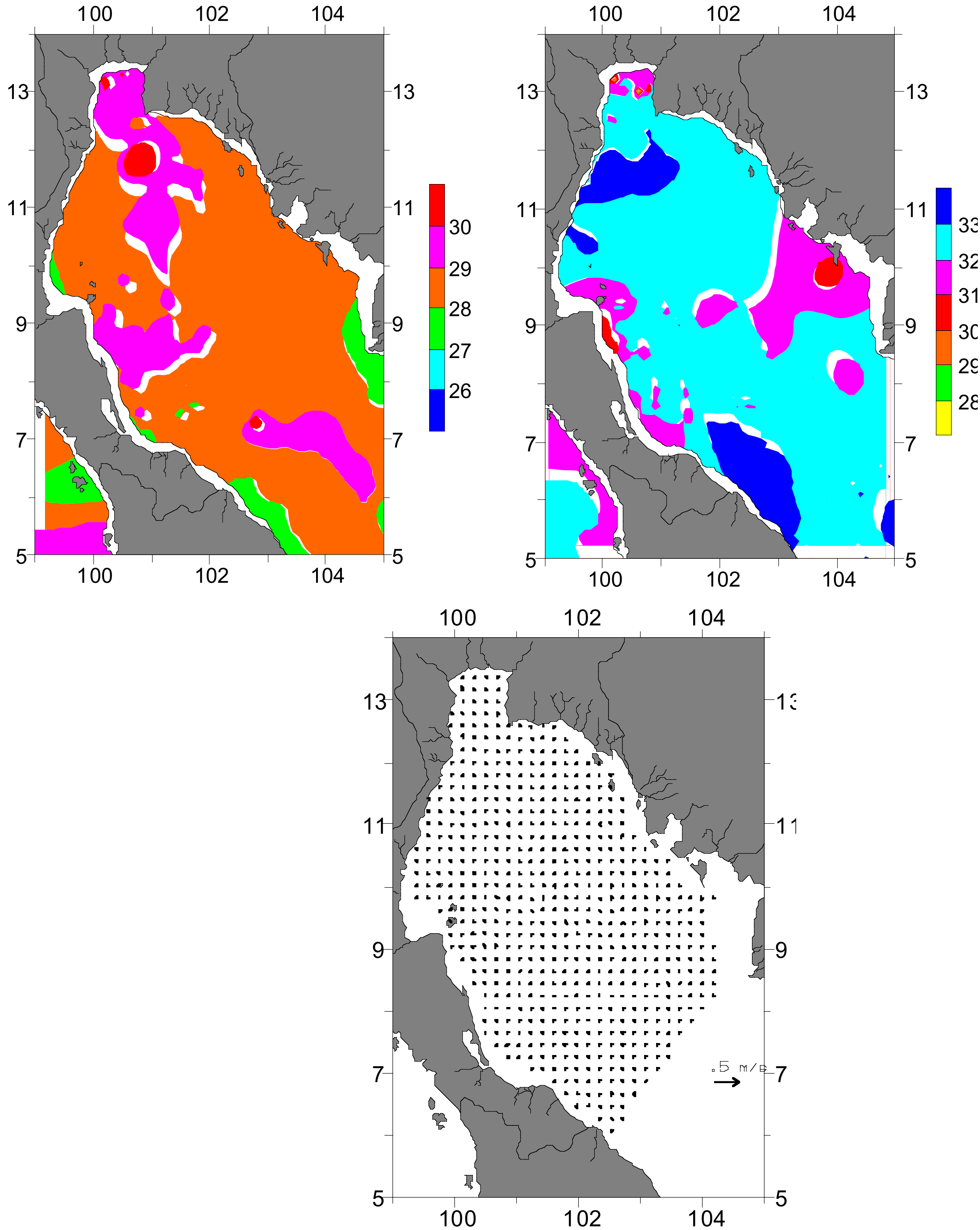


Fig. 11. September-November mid-depth (10-40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

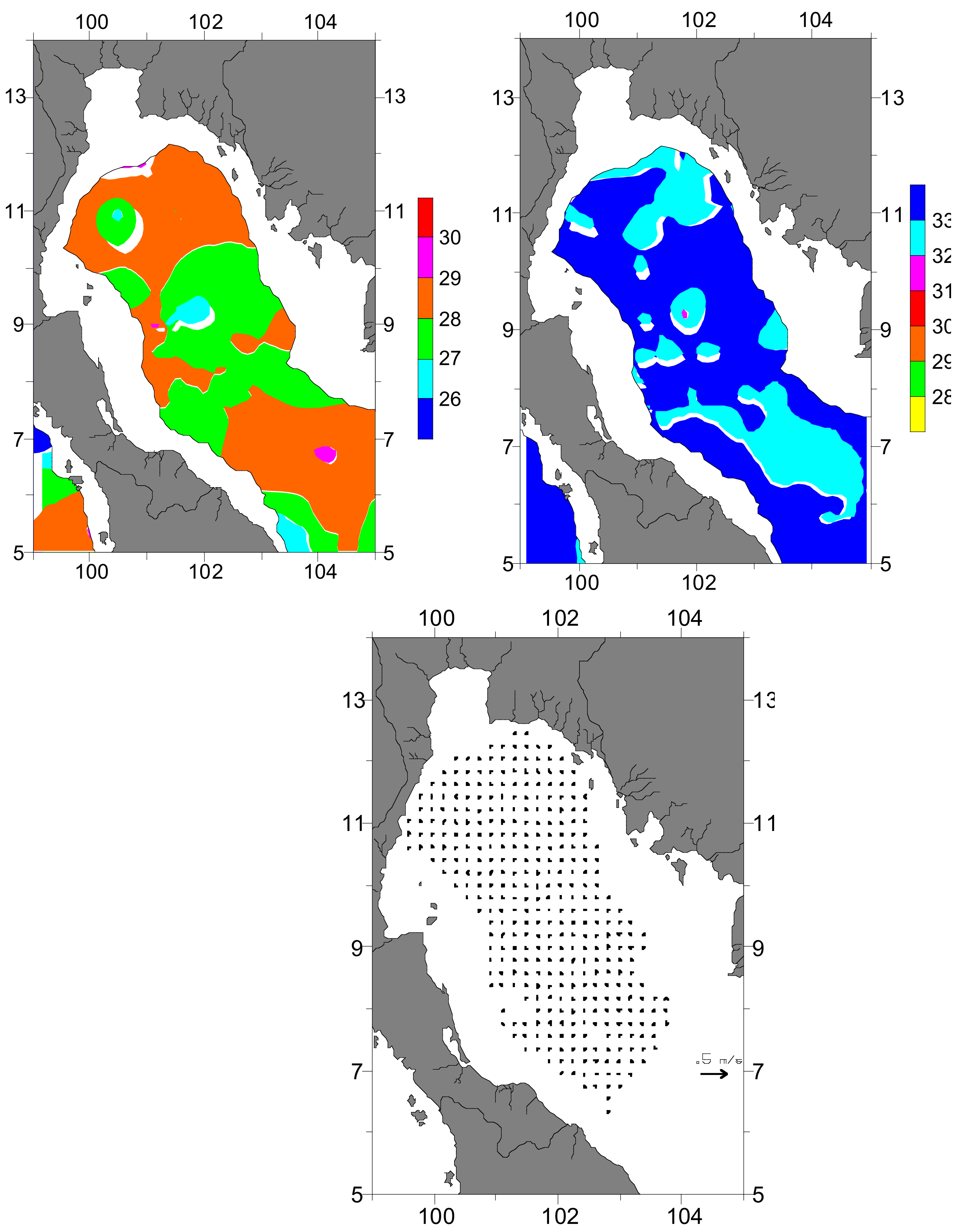


Fig. 12. September-November deep-water (>40 m) contours of (a) temperature and (b) salinity, and (c) current vector field. Observation points are given as +.

Conclusion and Recommendations

1) Surface current (0-10 m) in the Gulf of Thailand was strongly influenced by prevailing Monsoon. The surface vector field was northeastward in to the Gulf from the South China Sea during the Northeast Monsoon and opposite during the Southwest Monsoon.
2) Mid-depth (10-40 m) flow was more or less in opposite to the surface current in every season which suggested that the major replenishment of water in the surface layer was by the mid-depth layer. Because the water from these two layer had generally the same chemistry, this vertical replenishment of surface water would not supplement surface water by nutrient enrichment.
3) Water flow in the central deep basin (>40 m) also changed direction among seasons. This might be due to density gradient rather than wind. It was not clear from the simulations that whether this nutrient enriched deep water was actually "upwelled" to the surface.
4) Contrary to some previous believes, the simulations in this study did not reveal any true circulation gyres in the Gulf. However, eddies and meanders of different degrees could be developed. These physical features could play very important role in the distribution and dispersion of chemicals, particles and biological species.
5) More detailed simulations must be done in order to get a more realistic picture of circulation in the Gulf, including fine scale characteristics.

References

Backhaus, J. O. 1983. A semi-implicit scheme for the shallow water equation for application to shelf water sea modeling. Continental Shelf Res. 2: 243-254.

Fujio, S. and Imasato, N. 1991. Diagnostic calculation and water mass movement in the deep Pacific. J. Geophys. Res. 96: 759-774.

Kegler, 1994

Roed, L. P. and Cooper, C. K. 1986. Open boundary conditions in numerical ocean models. In: Advance Physical Oceanographic Numerical Modeling. J. J. O'Brien (ed.). Kluwer Academic Publishers, Massachusetts, pp. 411-433.

Sarmiento, J. L. and Bryan, K. 1982. An ocean transport model for the North Atlantic. J. Geophys. Res. 87: 394-408.

Sojisuporn, P. 1995. Density-driven and Wind-driven Current in The Upper Gulf of Thailand. Research report submitted to the National Research Council of Thailand, 23 pp.

Yanagi, T. and Takahashi, S. 1993. Seasonal variation of circulations in the East China Sea and the Yellow Sea. J. Oceanogr. 49: 503-520.

Trace Metals in the Surface Sediments of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Noor A.M. Shazili
Mohamed Kamil Abd Rashid
Mohd Lokman Husain
Asmawi Nordin and Salmah Ali

Marine Science Department, Faculty of Applied Science and Technology, Universiti Kolej Universiti Putra Malaysia, Mengabang Telipot, 21030 Kuala Terengganu, Malaysia.

ABSTRACT

The trace metal distribution in the surface sediments of the Gulf of Thailand and the South China Sea were studied. Samples were obtained from two cruises of the MV SEAFDEC Total metal content were measured in the 63mm fraction of dried sediment. For the first cruise (Pre-Northeast monsoon) results, metal concentration ranges were between 0.41- 0.19mgg^{-1}Cd, 10-36mgg^{-1}Cu, 7.02-27.8mgg^{-1}Pb, 15.3-352mgg^{-1}Zn, 20.5-122mgg^{-1} Cr, 209-720mgg^{-1}Mn, 0.79-5.96%Al and 0.71-2.82%Fe. Similar results were obtained for the second cruise (Post-Northeast monsoon) results, with metal concentrations in the range of 0.10-0.94 mgg^{-1}Cd, 10.3-61.4 mgg^{-1}Cu, 5.24-78.2 mgg^{-1}Pb, 18.1-98 mgg^{-1}Zn, 21.1-101 mgg^{-1}Cr, 117-797 mgg^{-1}Mn, 1.89-7.22 %Al and 0.70-2.38 %Fe.

The concentrations of Al, Cr, Cu and Mn were significantly higher in the Gulf of Thailand in the pre-monsoon while concentrations of Fe, Cd and Zn were similar for both areas. For the post-monsoon Al, Cu and Mn concentrations were higher in Gulf sediments. Differences in metal concentrations were noted between the pre- and the post monsoon samples. Fe, Cr and Mn concentrations were generally higher in the pre-monsoon period for both areas but the distribution of Pb was higher in the post-monsoon while Zn and Cu distribution differed between the Gulf and the South China Sea areas.

However normalisation of the metal data to aluminium content of the sediment showed generally uniform concentration of the metals studied over most of the area studied. Some enrichment by Cu in sediments from two sampling stations in the upper Gulf of Thailand is indicated by Cu:Al ratios exceeding normal crustal abundances of these metals. However low Cu:Al ratios in sediments from some areas of the South China Sea may indicate depletion of Cu in the sediments.

Key words: Metals, Gulf of Thailand, South China Sea, normalisation

Introduction

The trace metal concentrations in sediments from the Gulf of Thailand and the South China Sea have only been sporadically studied in the past. Hungspreugs and Yuangthong (1983) found high Cd and Pb concentrations in surface collected from the Chao Phraya estuary. Studies in the Upper Gulf of Thailand found sedimentation rate of sediments of about 4 to 11 mm yr^{-1} and mean total metal levels of 0.015 mg g^{-1} Cd, 6.5 mg g^{-1} Pb and 9.8 mg g^{-1}Co (Windom et al., 1984).

Shazili et al. (1989) reported strong acid leachable trace metal levels in surface sediments for some areas of the South China Sea off Terengganu and Pahang. Mean levels were 1.8-8.8 mg g^{-1} for Cu, 1.6 - 26 mg g^{-1} Pb, 12-47 mg g^{-1} Zn and 2.5 - 25 mg g^{-1} Ni.

For purposes of comparisons, total dissolution of sediments would provide measurements of metal concentrations that can be compared with other studies as well as allowing quality control of the measurements to be assessed against standard reference materials.

In this study, total metal levels in surface sediments from the Gulf of Thailand and the South China Sea were examined with the aim of characterising the geochemistry of the sediments. The effect of the monsoon seasons on sediment geochemistry has not been studied in any detail for the Gulf of Thailand and the South China Sea and this study provides an opportunity to compare the effects of the monsoon on metal distribution.

Methods

Sample collection and preparation

Sediment was collected with a Smith McIntyre grab in two cruises of the MV SEAFDEC in a joint oceanographic study between the Training Department of SEAFDEC Thailand and MFRMD in Malaysia. The first cruise was in September 1995 and the second in April 1996. A total of 81 stations were sampled in the Gulf of Thailand and the South China Sea off East Coast Malaysia (Fig. 1).

A portion of sediment from the top 3 cm was removed with a clean polyethylene spatula, avoiding sediment in contact with the grab surface. The samples were then stored in clean glass bottles at -20ΥC until ready for analysis. Large shell fragments were removed and the samples dried at 105ΥC, after which the samples were lightly ground in a mortar and pestle to break up the particles. The samples were then sieved through a stainless steel mesh of size 63 µm. Aliquots of about 1g of the 63 µm fraction sediment were then totally digested in open PTFE beakers with a mixture of nitric, perchloric and hydrofluoric acids at about 120ΥC (Katz and Jenniss, 1983). The final residue was redissolved in 10% nitric acid and made up to 50 ml with Milli-Q water.

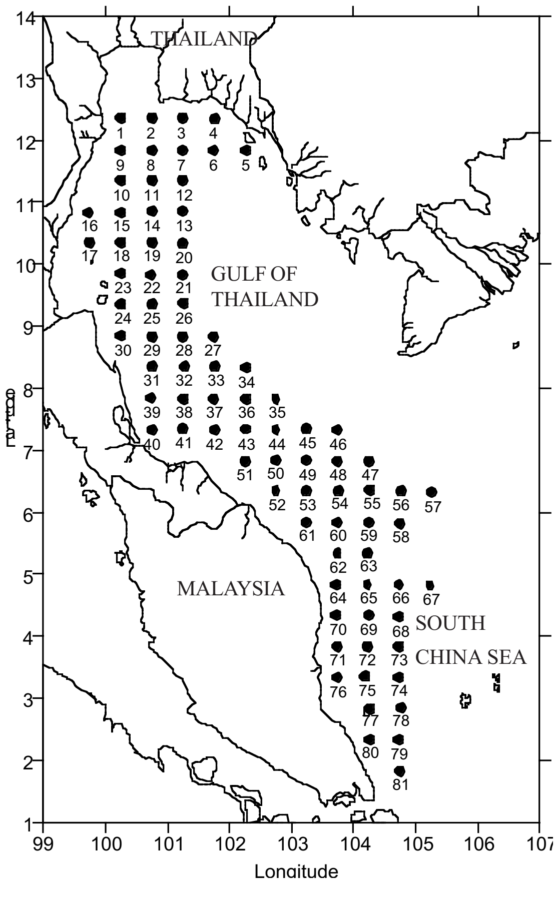


Fig. 1. Sediment sampling locations in the Gulf of Thailand and the East Coast of Peninsular Malaysia

Metal analyses

Metal concentrations were determined with a flame AAS with Deuterium background correction (Perkin-Elmer 3100) except Cd and Pb which were measured with a graphite furnace (Hitachi Z-8270) equipped with Zeeman background correction.

Quality Assurance

Certified sediment reference material (NBS 1646a) from the National Bureau of Standards were similarly prepared and analysis of the metals showed acceptable recoveries for most of the metals (Table 1) but low recoveries were obtained for Mn and Pb while some contamination was found for Cd.

Results and Discussion

The total metal concentrations for the first and second cruises are shown in Tables 2 and 3 respectively. For the pre-monsoon results, metal concentration ranges were between 0.41-0.19μg g^{-1}Cd, 10-36μg g^{-1}Cu, 7.02-27.8μg g^{-1}Pb, 15.3-352μg g^{-1}Zn, 20.5-122μg g^{-1}Cr, 209-720μg g^{-1}Mn, 0.79-5.96%Al and 0.71-2.82%Fe. For the post-monsoon results, Cd ranged between 0.10-0.94μg g^{-1}, 10.3-61.4μg g^{-1}Cu, 18.1-98μg g^{-1}Zn, 21.1-101μg g^{-1}Cr, 117-797μg g^{-1}Mn, 1.89-7.22%Al and 0.70-2.38%Fe. The distribution of these metals are shown in isopleth maps (Figure 2) for the results of the post-monsoon period only due to the incomplete Al data for the pre-monsoon. Slightly higher concentrations of Cu and Mn were measured at stations 1 and 3 at the northernmost part of the upper Gulf of Thailand but relatively little variation was seen in the distribution of the other metals measured.

ANOVA comparisons of metal concentrations between the Gulf of Thailand and the East Coast of Peninsular Malaysia indicate no significant differences (at the 95% level) in Fe, Cd and Zn for the pre-monsoon results. However Al, Cr, Cu, Mn and Pb were significantly higher in Gulf sediments. For the post-monsoon results (Table 2), Al, Cu and Mn were significantly higher in Gulf sediments while Fe, Cr and Zn levels were similar for both areas. The Cd data for the second cruise was not compared due to incomplete data. The Zn data showed a large standard deviation value for the East Coast Peninsular Malaysia due to four stations having Zn values exceeding 300μg g^{-1}.

Comparison of data for the Gulf of Thailand area between the pre-monsoon and the post-

Table 1. Analysis of certified reference material (NBS 1646a)

Metal	**Certified value** (ug/g)	**Measured value** (ug/g)	**Recovery** (%)
Aluminium (%)	2.297	2.13	92.7
Iron (%)	2.008	1.92	95.6
Cadmium	0.148	0.20	135.1
Chromium	40.9	39.15	95.7
Manganese	234.5	167.79	71.6
Lead	11.7	9.79	83.7
Zinc	48.90	48.94	100.01

monsoon periods indicated that concentrations of Fe, Zn, Cr and Mn were significantly higher in the pre-monsoon period while Cu and Pb were significantly higher in the post-monsoon period. For the East Coast Peninsular area, concentrations of Fe, Cr and Mn were higher in the pre-monsoon period and Pb higher in the post-monsoon period. Cu and Zn levels however were similar between the two periods.

In order to differentiate more objectively any real differences in metal distribution between the Gulf of Thailand and the East Coast Peninsular Malaysia sediments, the metal levels for the post-monsoon period were normalised against Al (Windom et al., 1989). The distribution of these normalised values is as shown in isopleth maps (Fig. 3). With reference to Pb, over 50% of the sampling locations had values exceeding 20 $\mu g\ g^{-1}$ which is the average concentration in world average shale. If these values were to be compared to average crustal material, most of the stations would then exceed these natural values. A total of eight stations in the study area had concentrations had concentrations of Pb/Al ratios of 10 x 10^{-4} and greater compared to natural levels of only 2.91 x 10^{-4} in average continental shelf sediments (Hanson et al., 1986) indicating elevated values. The Upper Gulf sediments have Pb/Al ratios of 6-17 x 10^{-4} and the higher ratio values, exceeding 10 x 10^{-4} here are found at stations nearest shore. The sediment here are composed mainly of silt and clay and is thus expected to bind higher amounts of metals. Anthropogenic input contributing to these elevated levels may be a factor that should not be ruled out. The higher Pb/Al ratios in the south of the study area, off Pahang and Johor however are associated with relatively low Al content in the sediment.

Over the other areas studied the observed metals concentration (except Pb) were generally uniform and reflect average or lower than average values compared with reported crustal abundances (Hanson et al., 1986). However a small number of locations showed variations from the general distribution pattern. It can be seen that Cu:Al ratios (x10^{-4}) are comparatively higher in sediments in the upper Gulf of Thailand with ratios of 7.5 - 12 x10^{-4} and in sediments off the coast of Pahang, Malaysia with a ratio of about 6 x10^{-4}. As such the higher Cu:Al ratios especially that measured for

Table 2. Mean concentrations of metals in sediment for the Gulf of Thailand and East Coast Peninsular Malaysia sampled in the pre-monsoon period and the post-monsoon period.

	Mean concentration (ug g^{-1} dry wt.)	
	Gulf of Thailand	**East Coast Peninsular Malaysia**
Pre-monsoon		
Al	4.38 1.18%	3.04 1.4%
Fe	2.13 0.39%	2.03 0.45%
Cd	0.42 0.19	0.38 0.20
Cr	85.0 15.3	74.0 16.9
Cu	19.7 6.4	16.0 7.2
Pb	16.2 4.6	13.4 5.4
Zn	61.0 26.7	76.3 83
Post-monsoon		
Al	5.34 1.03%	4.57 1.34%
Fe	1.22 0.35%	1.36 0.38%
Cd	0.35 0.04	0.34 0.04
Cr	62.7 13.1	58.9 13.9
Cu	25.7 12.7	15.1 2.7
Pb	29.9 15.0	19.3 15.6
Zn	51.6 12.1	56.1 17.1
Mn	368 104	269 80

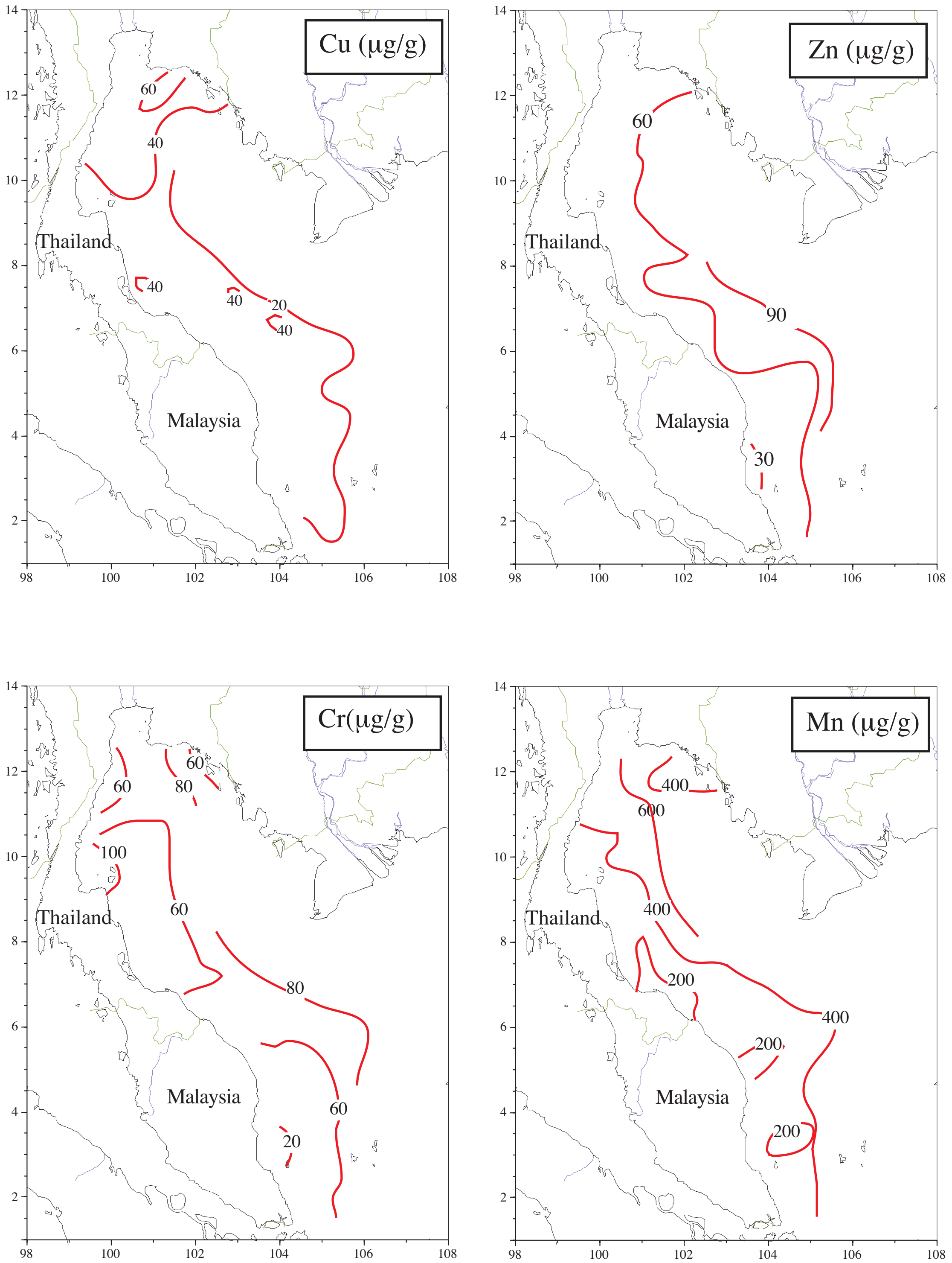


Fig. 2. Isopleths of metal concentrations in surface sediments of the Gulf of Thailand and East Coast Peninsular Malaysia.

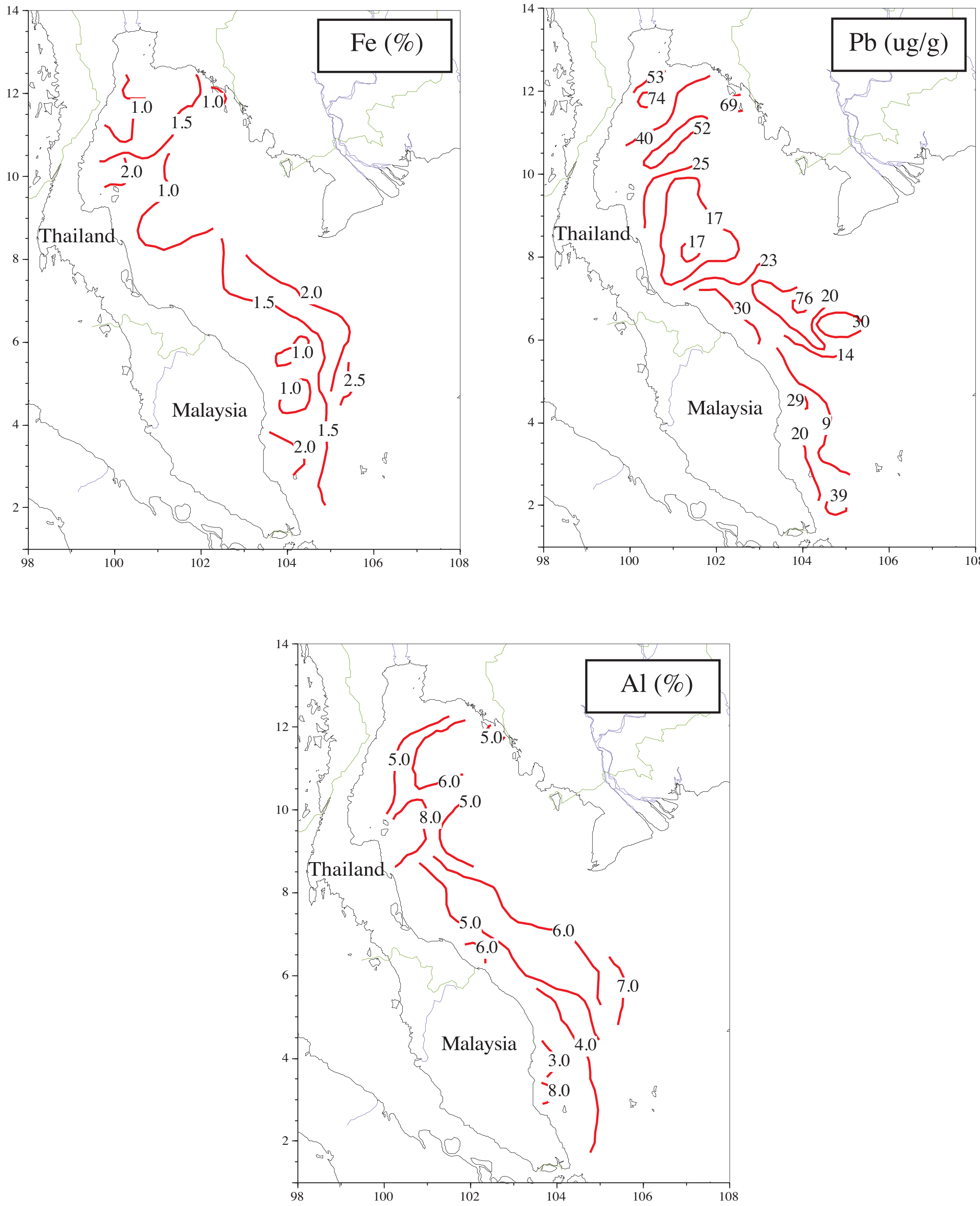


Fig. 2 (continue) Isopleths of metal concentrations in surface sediments of the Gulf of Thailand and East Coast Peninsular Malaysia.

Table 3. First cruise: Total metal concentrations in sediments from the Gulf of Thailand and the South China Sea for all sampling stations.

Stn	Cd	Cr	Cu	Mn	Pb	Zn	Al	Fe
	(ug/g)						%	%
1	0.42	54	29.1	552	51.49	45	3.97	1
2	-	-	-	-	-	-	-	-
3	0.1	67	56	798	34.9	54	4.39	1.7
4	0.14	59	40	394	38.76	38	5.25	1.51
5	0.26	58	37	249	55.44	42	4.04	0.91
6	0.24	71	40	424	51.04	44	5.35	1.28
7	0.24	86	41	340	56.46	48	5.36	1.54
8	0.19	68	61	592	34.7	46	6.33	0.99
9	0.15	52	19.7	411	78.2	38	4.41	1.4
10	0.17	61	33	450	36.71	43	5.09	0.92
11	0.57	66	27	475	47.47	49	5.56	1.21
12	0.35	74	48	501	50.85	64	5.88	1.26
13	0.55	57	44	455	36.7	46	5.23	1.17
14	0.26	60	37	345	40.88	43	5.19	1.14
15	0.33	61	23	386	38.05	46	4.3	0.89
16	0.27	69	28	377	27.96	50	5.48	1.07
17	0.33	101	31	282	33.06	69	6.84	1.85
18	0.94	72	39	322	51.22	58	4.82	1.77
19	0.32	64	26	442	27.3	80	6.16	1.11
20	0.21	46	15	304	16.84	34	3.74	0.89
21	0.25	45	17	414	10.53	40	4.32	1.03
22	0.15	71	23	309	8.83	61	6.38	1.1
23	0.15	97	25	636	35.62	78	8.47	1.61
24	0.06	71	17	262	15.72	48	6.39	0.67
25	0.16	66	17.8	351	22.58	56	6.63	1.38
26	0.13	47	19.1	387	7.15	50	4.98	1.05
27	0.13	57	17.9	447	9.55	57	4.82	0.96
28	0.19	56	17.6	213	11.3	51	5.95	1.03
29	0.06	57	13.8	375	12.5	41	5.11	0.95
30	0.1	76	13.1	336	18.99	56	7.07	1.34
31	0.14	49	12.8	266	11.26	34	3.87	0.95
32	0.08	52	16.3	191	5.99	41	4.79	0.78
33	0.08	56	18	360	24	55	5.21	1
34	0.1	66	17.9	493	19.11	59	5.18	1.34
35	-	88	21	370	19.33	81	7.22	2.38
36	-	74	22	315	11.32	72	6.24	1.68
37	-	60	17.9	405	13.23	65	5.88	1.43
38	-	50	15.1	190	6.16	40	4.44	1.54
39	-	51	24.3	221	9.62	41	4.66	1.13
40	-	43	10.5	237	21.05	33	5.26	1.4
41	-	58	14.2	167	19.77	62	5.56	1.48

Table 3. (continue)

Stn	Cd	Cr	Cu	Mn	Pb	Zn	Al	Fe
	(ug/g)						%	%
42	0.23	53	17.4	191	28.65	53	3.21	0.63
43	0.53	52	12.9	167	19.97	50	4.99	1.32
44	0.2	57	26.8	402	11.83	62	5.62	0.72
45	0.37	75	19.7	342	28.86	76	6.68	2
46	0.22	77	17.4	292	29.98	77	5.59	1.38
47	0.12	63	17	231	8.48	61	5.36	1.52
48	0.29	84	21	316	75.87	84	6.29	1.65
49	0.14	71	15.9	306	11.79	74	5.4	1.67
50	0.1	58	13.3	225	15.78	59	4.98	1.28
51	-	67	15.9	182	11.39	56	5.95	1.24
52	-	71	18.8	271	41.44	58	5.42	1.32
53	0.32	77	16	312	21.63	80	6.19	1.43
54	0.24	64	15.6	381	25.76	90	6.09	1.22
55	0.35	55	18.7	296	34.33	51	5.21	1.46
56	-	70	18	338	37.41	98	6.19	2.16
57	-	78	19	308	22.72	73	7.21	1.64
58	-	69	14.4	276	26.91	58	5.64	1.38
59	-	52	11.9	145	6.22	39	4.09	1.01
60	-	56	11.8	190	17.05	52	4.09	1.18
61	-	61	14.5	214	14.52	55	4.21	1.43
62	-	50	12.7	199	8.27	40	3.95	1.04
63	-	55	12.6	286	17.46	49	4.64	1.14
64	-	55	16	287	6.38	45	4.05	1.48
65	-	51	12	195	5.24	44	4.01	0.92
66	-	63	13.6	432	20.03	56	4.97	2.03
67	-	81	18.6	473	12.67	82	6.69	2.26
68	-	61	13.6	340	11.76	61	3.96	1.25
69	-	51	12.9	297	12.95	42	3.88	0.88
70	-	45	16.7	412	13.16	38	3.02	0.77
71	-	21	16.9	312	21.11	30	2.16	1.06
72	-	47	12.4	147	13.94	38	3.35	1.2
73	-	43	10.3	117	12.42	41	2.46	1.14
74	-	54	11.5	220	17.32	47	3.55	1.01
75	-	45	12.9	227	15.89	40	3.6	0.7
76		23	11	162	20.07	18	1.89	1.71
77	-	61	15.1	286	6.79	58	4.19	1.8
78	-	61	13.5	243	12.82	58	3.86	1.14
79	-	62	16.9	244	23.69	62	3.95	1.6
80	-	47	13.4	234	9.34	47	3.08	0.99
81	-	54	16.6	215	42.92	37	3.16	1.17

Table 4. Second cruise: Total metal concentrations in sediments from the Gulf of Thailand and the South China Sea for all sampling stations.

Stn	Cd	Cr	Cu	Mn	Pb	Zn	Al	Fe
	(ug/g)						%	%
1	0.24	86	110	424	17.5	90	3.66	2.82
2	0.51	96	210.9	428	16.4	38.1	5.63	2.29
3	0.24	104	18.9	428	21.7	40.5	-	3.1
4	0.26	60	17.5	410	16.7	125	1.72	2.17
5	0.48	92	25.5	367	27.8	82	3.59	2.55
6	0.53	100	19.4	4.31	20.2	46	-	2.31
7	0.47	118	28.9	477	17.7	63	-	1.91
8	0.52	92	29.5	549	17.6	91	4.38	2.49
9	0.34	78	13	509	17.9	16.4	3.31	1.97
10	0.45	84	23.4	460	15	57	3.96	1.79
11	0.3	91	23.7	452	14.5	54	-	1.73
12	0.34	87	17	563	16.3	28	2.76	1.75
13	0.29	78	19	597	13.9	47	-	1.86
14	0.53	75	18.3	531	18.1	53	-	1.86
15	0.71	89	19.4	476	15.2	39	5.21	2.01
16	1.03	101	39	416	23.3	56	5.14	2.58
17	0.6	101	32.3	450	23.1	102	5.96	2.56
18	0.39	97	23.2	646	24	63	-	2.47
19	0.3	76	16.8	571	15.4	56	-	2.01
20	0.35	65	19.3	504	14.4	42.5	-	1.6
21	0.36	65	16.5	396	11.8	41.9	-	1.56
22	0.65	81	31.6	422	14.9	86	4.76	2.3
23	0.8	121	31.9	617	14.5	136	6.32	2.57
24	0.27	92	10.8	349	12.6	118	4.42	2.21
25	0.3	92	11.7	383	22.9	104	5.94	2.54
26	0.32	83	15.9	409	9.01	60	-	2.09
27	-	-	-	-	-	-	-	-
28	0.3	76	15.6	324	7.02	53	-	1.86
29	0.83	79	15.7	362	8.26	49	-	2.04
30	0.4	101	11.4	318	19.3	43	5.94	2.49
31	0.42	66	7.77	307	14.3	44	3.52	1.71
32	0.58	67	15.2	301	19.2	47	-	1.7
33	0.39	72	19.5	463	9.1	49	-	1.55
34	0.29	89	23.6	720	17	67	-	2.22
35	0.81	122	25.9	447	18.4	89	-	3.09
36	0.42	92	21.4	485	16.6	68	-	2.17
37	0.26	85	19.6	503	18.6	58	-	2.48
38	0.27	69	12.8	236	10.6	15	3.81	1.63
39	0.38	63	17.9	293	18.1	67	4.41	1,95
40	0.39	58	16.4	262	20.4	53	3.77	2.18
41	0.24	79	15.4	264	9.88	51	-	2

Table 4. (continue.)

Stn	Cd	Cr	Cu	Mn	Pb	Zn	Al	Fe
			(ug/g)				%	%
42	0.86	80	19.8	375	10.1	61	-	2.24
43	0.26	68	14.4	259	10.7	47	-	1.65
44	0.44	80	19	338	13	61	-	1.9
45	0.3	97	20.1	520	19.6	67	-	3.04
46	0.32	102	19.5	379	18.1	67	-	2.57
47	0.29	80	16	307	12.8	62	-	2.14
48	0.33	97	17.2	374	9.24	74	-	2.77
49	0.3	87	18.6	395	11	71	-	2.54
50	0.36	82	15.9	278	18.2	57	-	1.81
51	0.4	85	15.6	297	18.6	34	3.77	2.08
52	0.39	74	45.8	319	10.1	15.5	4.93	1.81
53	0.48	94	36.6	394	2.49	131	4.57	2.27
54	0.24	84	15.2	342	19.1	66	-	2.17
55	0.3	79	15	289	7.3	61	-	2.02
56	0.31	79	28.8	308	14.6	65	-	2.18
57	0.27	82	16.3	329	14.4	67	-	2.27
58	0.36	67	13.8	299	16.1	55	-	1.7
59	0.26	55	13.5	209	14.3	44	-	1.42
60	0.39	69	12.8	256	17.2	45	3.05	1.89
61	0.64	74	11.5	307	6.84	339	2.73	1.96
62	0.22	67	9.7	258	12.4	15.3	2.48	1.9
63	0.31	72	10.8	279	8.17	21.2	3.54	2.04
64	0.27	84	13.1	335	16.5	21.6	3.91	2.03
65	0.23	64	14.1	308	6.78	49	-	1.9
66	0.54	81	18.1	405	9.05	76	-	2.45
67	0.24	95	13.9	440	4.17	40	5.95	2.57
68	0.25	70	10.8	355	7.43	23	2.44	2.16
69	0.17	68	13.8	288	11	63	-	2.23
70	0.69	59	14.1	516	17.9	26.1	1.15	1.89
71	1.02	27	13.1	298	21.8	29.7	0.79	0.71
72	0.54	67	13.8	249	21.6	50	-	2.11
73	0.32	54	13.1	261	12.3	13	1.35	1.33
74	1.1	73	15.3	292	10.4	29.6	3.77	1.87
75	0.35	73	16.1	288	12.8	65	-	2.31
76	0.43	20	10	246	13.3	25.1	0.76	1.03
77	0.28	74	12.3	301	17.8	28.6	2.88	1.95
78	0.36	74	12	293	13.2	308	2.71	1.96
79	0.31	84	11.3	308	17.4	352	3.45	2.44
80	0.37	64	12.1	273	27.2	137	2.97	1.56
81	0.23	78	11.3	317	8.9	86	4.3	2.14

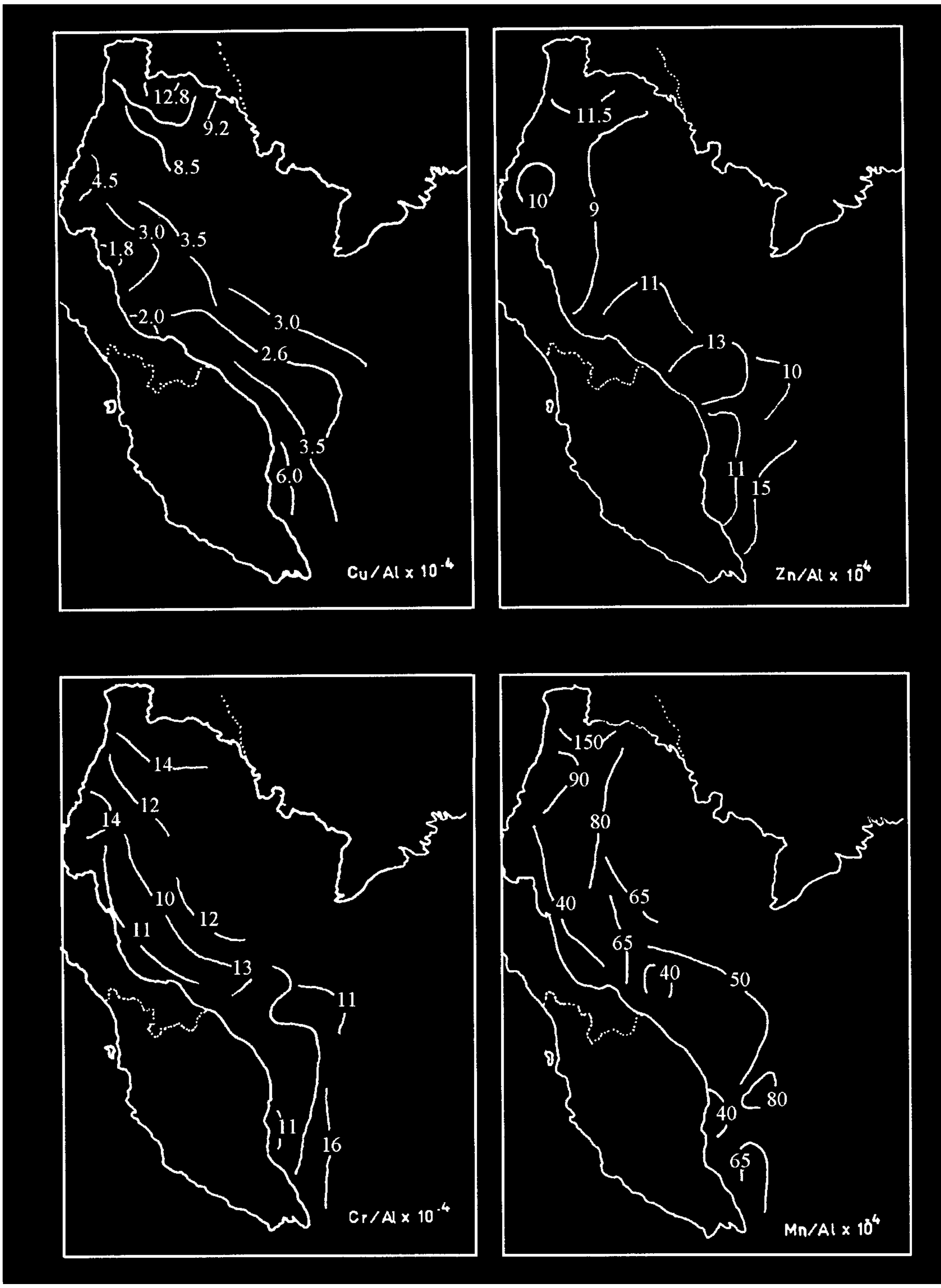


Fig. 3. Isopleths of metal to aluminium concentration ratios for surface sediments in the Gulf of Thailand and East Coast Peninsular Malaysia.

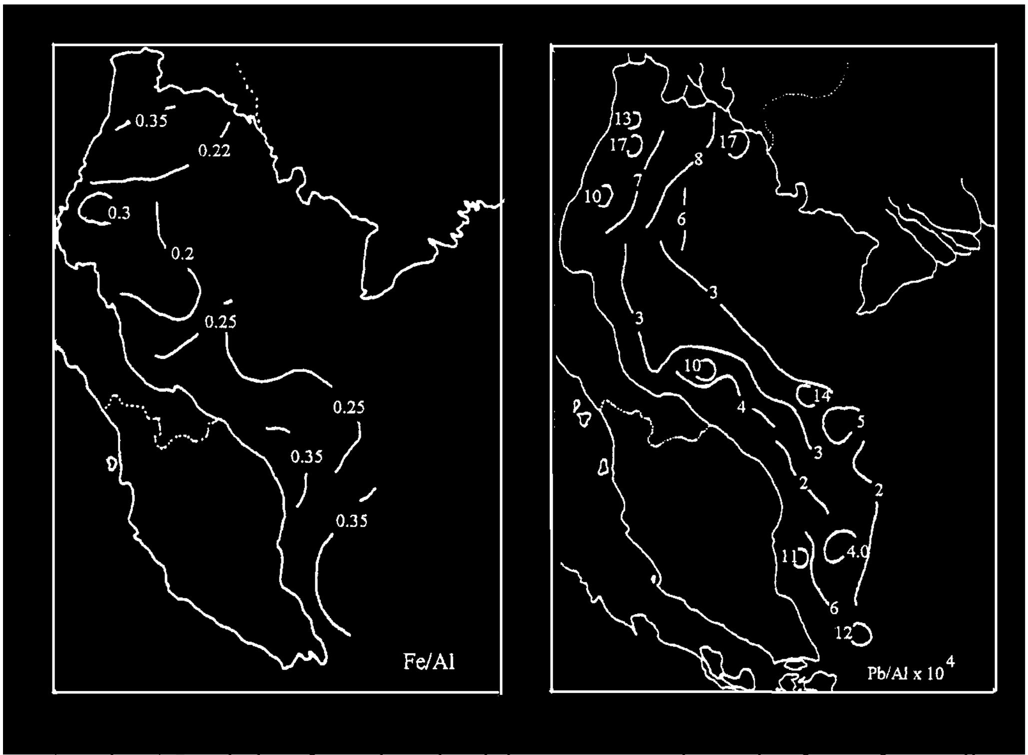


Fig. 3. (continue) Isopleths of metal to aluminium concentration ratios for surface sediments in the Gulf of Thailand and East Coast Peninsular Malaysia.

stations 1 and 3 in the upper Gulf area, may indicate enrichment by Cu in the upper Gulf region closest to shore. The high ratio of Cu/Al off Pahang is associated with low Al content in the sediment. The ratios for the lower Gulf region and the South China Sea of between 2.6-3.5 x10^{-4} over most of the area studied indicate concentrations lower than the natural value for continental shelf sediments of 8.14 x10^{-4} (Hanson et al., 1986). The concentrations of Cr and Mn are similarly lower than "global average" earth crust and shale. Such a finding, of lower than average crustal material of Cu, Cr and Mn was also noted in a recent study of elements in the coastal environment off Penang and in the Johor Strait (Wood et al., 1997). They suggested that this might be due to increased solubility of these elements in the tropical environment.

The Mn:Al ratios for the Gulf of Thailand differed somewhat to the values for the East Coast Peninsular Malaysia, with values of 80-90 x10^{-4} for the upper Gulf region, 50-95 x10^{-4} for the lower Gulf region and 40-65 x10^{-4} for the East Coast Peninsular Malaysia region. The Zn:Al ratios were similar for all sampling locations, ranging between 9 x10^{-4} and 11 x10^{-4} for the Gulf area and 10-15 x10^{-4} for East Coast Peninsular Malaysia. Iron:Al ratios for all areas were in the range of 0.20-0.35 thus indicating uniform Fe concentration over the whole study area.

Pb:Al ratios varied between 2 x10^{-4} and 18x10^{-4} . The higher ratios were found at four locations in the Upper Gulf of Thailand with values of between 10 x10^{-4} and 18 x10^{-4} and two locations in the South China Sea off Peninsular Malaysia. With values of 10 x10^{-4} and 14 x10^{-4} . These ratios are much higher than world average continental crust values but generally are within the Pb:Al ratios for near-shore detrital sands and muddy sands (Hanson *et al*., 1986).

Conclusions

The normalised elemental concentration data for the Gulf of Thailand and East Coast Peninsular Malaysia sediments from this study showed generally uniform distribution of metals over most of the area studied. Elevated Cu and Pb levels in a number of isolated sites in the Upper Gulf of Thailand and in the South China Sea off Peninsular Malaysia can be attributed to higher content of fine sized sediment (Calvert *et al*., 1993) and low Al content. The levels of Cr, Mn and Cu are lower than in average earth material and are probably due ti increased solubilities of these elements.

References

Calvert, S.E., Pedersen, T.F. and Thunell, R.C. (1993). Geochemistry of the surface sediments of the Sulu and South China Seas. Marine Geology, 114, 207-231.

Hanson, P.J., Wells, J.A. and Newman, M.W. (1986). Preliminary results of the 1984-85 National Benthic Surveillance Project:Southeast Atlantic and Gulf of Mexico coasts. IEEE Oceans '86 Conference Proceedings, Washington, D.C.,572-577.

Hungspreugs, M. and Yuangthong, C. (1983). A history of metal pollution in the upper Gulf of Thailand. Mar. Pollut. Bull.,14(12),465-469.

Katz, S.A. and Jenniss, S.W. (1983). Regulatory compliance monitoring by atomic absorption spectroscopy. Verlag Chemie International, 278pp.

Shazili,N.A.M., Mohamed,C.A.R. and Yaakob,R. (1989). Heavy metals in sediments of the South China Sea. Proc. 12th. Annual Seminar of the Malaysian Society ofMarine Sciences, 99-106.

Windom, H.L., Silpipat,S., Chanpongsang,A., Smith,R.G. and Hungspreugs, M. (1984). Trace metal composition of and accumulation rates of sediMarine Sciences, 99-106.

Windom, H.L., Silpipat,S., Chanpongsang,A., Smith,R.G. and Hungspreugs, M. (1984). Trace metal composition of and accumulation rates of sediments in the upper Gulf of Thailand. Estuarine, Coastal and Shelf Science,19,133-142.

Windom, H.L., Schropp, S.J., Calder, F.D., Ryan, J.D., Smith, R.G., Burney, L.C., Lewis, F.G. and Rawlinson, C.H. (1989). Natural trace metal concentrations in estuarine and coastal marine sediments of the Southeastern United States. Environmental Science & Technology, 23,314-318.

Wood, A.K., Ahmad, Z., Shazili, N.A.M., Yaakob, R. and Carpenter, R. (1997). Geochemistry of sediments in Johor Strait between Malaysia and Singapore. Continental Shelf Research, 17(10), 1207-1228.

Biogeochemical Implications of Dissolved Trace Metal Concentration and Distribution in the South China Sea, Area 1: Gulf of Thailand and East Coast of Peninsular Malaysia

Wilaiwan Utoomprurkporn
Manuwadi Hungspreugs
Saravuth Ratanachongkiat
Anond Snidvongs

Department of Marine Science, Chulalongkorn University, Bangkok 10330, Thailand.

ABSTRACT

Dissolved cadmium, copper, iron, lead and nickel in seawater at different depths were analyzed using the cobalt-APDC coprecipitation technique. The concentrations found were low and within the range found in natural seawater elsewhere. Terrestrial sources, especially near the head of the Gulf of Thailand and the Nakorn Sri Thammarat-Songkhla area on the Thai-Malay Peninsular, were clearly observed especially during the high runoff season. External input and horizontal dispersion dominated over internal recycling and removal in controlling concentration and distribution of iron and copper but it was the opposite for cadmium, nickle and lead where biological removal near surface and bottom regeneration might explain the “nutrient type” vertical profiles of these elements.

Introduction

Trace metals are the natural components in seawater. Prior to the period of human disturbance of the environment, trace metals in the water were derived from continental rocks by weathering and partly from sediment due to leaching, desorption, dissolution, cation exchange, and other processes. For some elements, such as lead, anthropogenic atmospheric input may also be important. As the natural system is at equilibrium, the input must be equal to the output where these dissolved trace metals in the water are removed back to solid phase, i.e. sediments, by a suite of geochemical reactions such as adsorption, precipitation and cation exchange. Some metals, mercury for example, can be volatile and removed via the atmosphere. These physical and chemical processes involving trace metals are strongly controlled by environmental factors, for instances, temperature, salinity (ionic strength), pH and redox potential (e.g. Drever, 1989).

It was suspected that trace metals at some locations in the Gulf of Thailand and Eastern Peninsular Malaysia may be originated from anthropogenic sources. However, due to difficulties in analyzing very low concentration of trace elements in seawater which has a very high ionic strength, most of previous measurement before 1980 were probably unreliable. Utoomprurkporn et al. (1987) had shown that trace metal concentrations reported for several estuarine and coastal water in the Gulf of Thailand were gradually decreasing by as much as 500 times from 1979 to 1985. It is highly unlikely that this was due to a drastic reduction in metal loading. Actually anthropogenic loading is known to increase. Improvement in sampling and analytical techniques are more reasonable explanations.

Concentration and distribution of trace metal in large coastal area, such as the Gulf of Thailand and Eastern Peninsular Malaysia, can provide some details on sources, cycling and removal processes. It is also a good indicator for human impact and imprint on the environment and quality of its living resources.

Methods

Sampling

Seawater from at least two depths (surface and bottom) were collected from pre-selected stations using 2.5 liter Teflon coated General Oceanic GoFlo samplers attached to a rosette. There were a total of 19 and 80 stations for September 1995 and April-May 1996 cruises, respectively. At some stations, water at intermediate depths were also collected to get a resolution for the vertical profiles of trace metals.

Once water samples were on board they were immediately transferred into 1 liter Nalgene polyethylene bottles. Within an hour after sampling, seawater was filtered on board using filtered compressed air and an in-line filtration apparatus. Nuclepore 0.4 mm membranes were used. Filtered water was acidified to pH ∪ 3 with Suprapure HNO_3 acid

Sample preparation and analysis

Dissolved trace metals in water samples were coprecipitated with cobalt-APDC (Boyle and Edmond, 1977, modified by Huizenga, 1981). Precipitates were collected by hand vacuum filtration on Nuclepore 0.45 mm membranes. The precipitates were further taken up in HNO_3 and diluted with Milli-Q water. The final solutions were measured for cadmium, copper, iron, lead and nickel using a Perkin Elmer Zeeman Graphite Furnace 4100ZL atomic absorption spectrophotometer. Merck standard solutions diluted by Milli-Q water was used as standards. Certified Reference Seawaters NASS-1 and CASS-2 of the Institute for Environmental Chemistry, Canada, were included in every batch of sample preparation and analysis as quality control samples to ensure the accuracy of the results (Table 1).

All bottles, filter membranes and labwares that would be in contact with samples were carefully pre-washed by 10% Suprapure HNO_3 acid and Milli-Q water.

Table 1. Analytical performance based on two Reference Seawater (Mean ± SD, μg/l)

	Cd	Cu	Fe	Pb	Ni
NASS-1	0.029±0.004	0.099±0.010		0.039±0.006	0.257±0.027
Our results	0.031±0.002	0.102±0.018		0.034±0.007	0.265±0.016
CASS-2	0.019±0.004	0.675±0.039	1.20±0.12	0.019±0.006	0.298±0.036
Our results	0.024±0.004	0.638±0.036	1.26±.13	0.021±0.002	0.283±0.039

Results and Discussion

The results clearly show that concentration of the five dissolved trace metals in every samples were very low and well within the range found in normal nearshore seawater elsewhere. These metals may be divided into two categories according to their vertical distribution, (a) those without bottom enrichment, and (b) those with strong bottom enrichment (Table 2, 3).

Trace metals without bottom enrichment

Iron and copper fell into this category. Terrestrial runoff via the Upper Gulf and from Nakorn Sri Thammarat-Songkhla area clearly cause extensive surface plumes during the periods of both cruises (Figs. 1 and 2). Concentration of the two metals in the surface plumes, especially at stations near to the discharge locations during the high runoff (September 1995), were generally higher than the concentrations in bottom water. Dissolved metals found in the plume could be both in truly ionized forms and those chelated with dissolved organic matters. The latter form could be especially

Table 2 Concentrations of trace metals in the Gulf of Thailand and East Coast of Peninsular Malaysia

Metal		Sept. 95	April-May 96
Cd (ng/l)	surf	1.0-4.8	0.1-11.1
	bot.	2.1-7.8	3.3-18.5
Pb (µg/l)	surf.	0.01-0.15	0.01-0.18
	bot.	0.01-0.44	0.01-0.19
Ni (µg/l)	surf.	0.1-0.5	0.1-0.5
	bot.	0.1-1.0	0.1-0.7
Cu (µg/l)	surf.	0.1-0.9	0.1-0.6
	bot.	0.1-1.3	0.1-0.5
Fe (µg/l)	surf.	0.5-4.9	0.4-3.0
	bot.	0.6-4.5	0.3-3.0

Table 3. Generalization of vertical distribution pattern of 5 metals at coastal plumes and offshore water of the Gulf during the high and low river discharge seasons.

Element	Sept. 95 (High Runoff)		April-May 96 (Low Runoff)	
	Plumes	Offshore	Plumes	Offshore
Ni	BE	VH, BE	SE	VH
Cd	BE	VH, BE	VH	BE
Pb	BE	BE	VH	VH
Cu	VH, SE	VH, SE	SE	VH, SE
Fe	VH, SE	VH	VH, SE	VH

BE: Bottom enrichment
SE: Surface enrichment
VH: Vertically homogeneous

important for copper.

Concentration and vertical distribution of trace metals in this category could be chiefly determined by river input and horizontal dispersion. Biological uptake by phytoplankton, regeneration by organic decay in deep water layer and those released from sediments were apparently insignificant relative to the horizontal input since there was not a clear vertical gradient observed.

Trace metals with strong bottom enrichment

This category includes cadmium and lead. River input, which even though was the largest external source, left only small recognizable impact and only very near to river mouths in the high runoff season (Figs. 3 and 4). This indicated internal processes that were fast and efficient relative to runoff in controlling the metal concentration. The “nutrient type” behavior of these metals, i.e. low

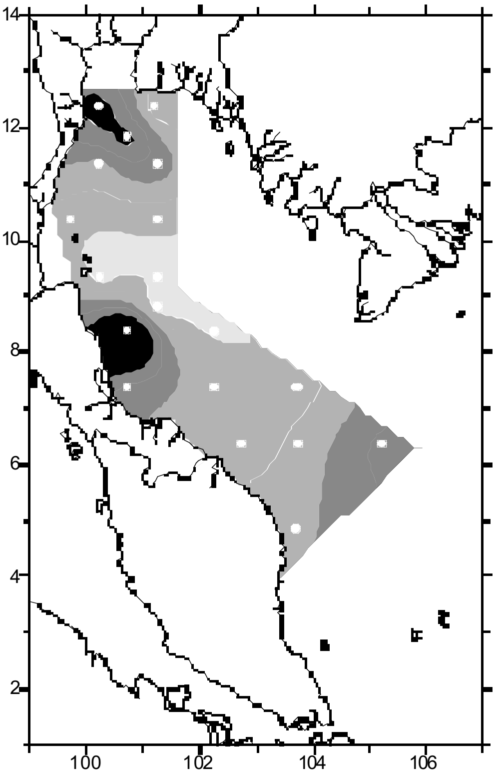


Fig. 1a. Concentration of iron (μg/l) in surface water in September 1995

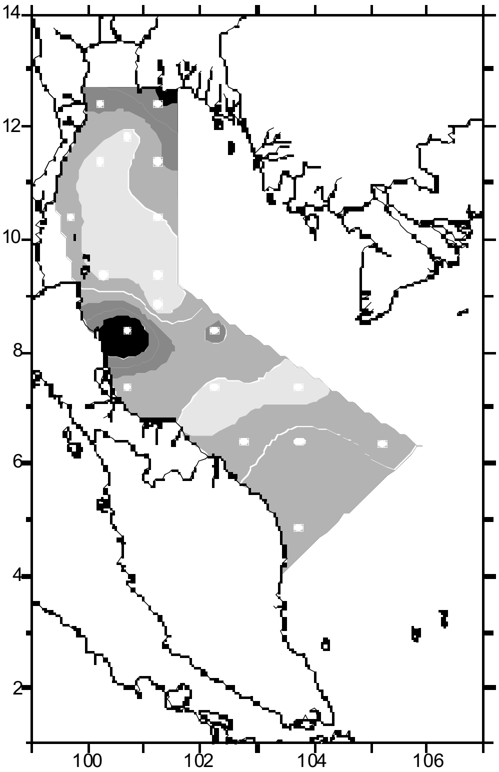


Fig. 1b. Concentration of iron (μg/l) in bottom water in September 1995

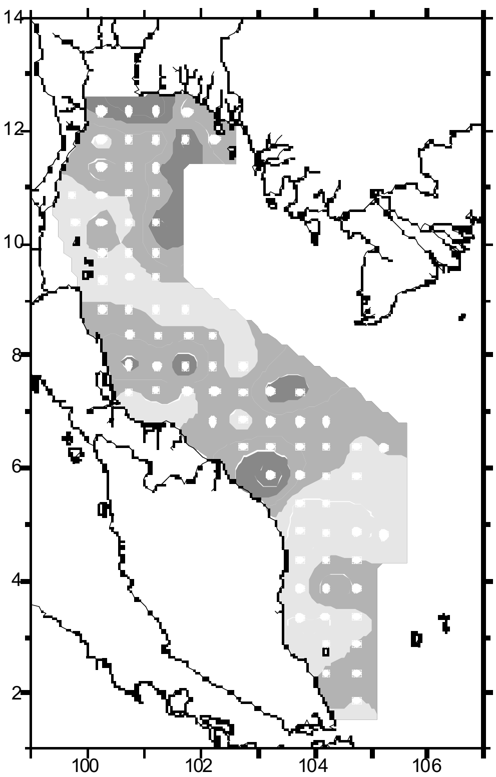


Fig. 1c. Concentration of iron (μg/l) in surface water in April-May 1996

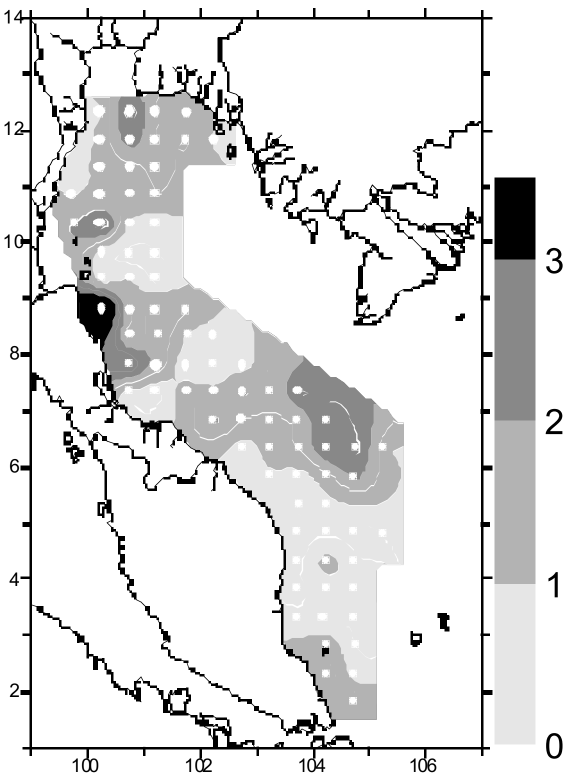


Fig. 1d. Concentration of iron (μg/l) in bottom water in April-May 1996

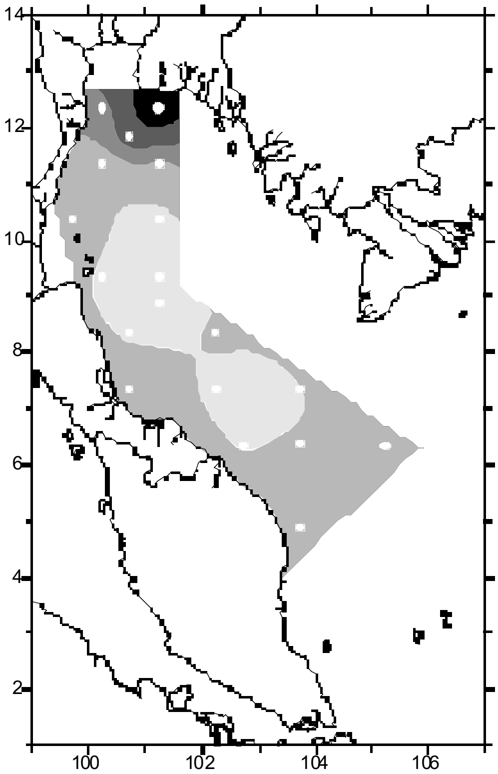


Fig. 2a. Concentration of copper (µg/l) in surface water in September 1995

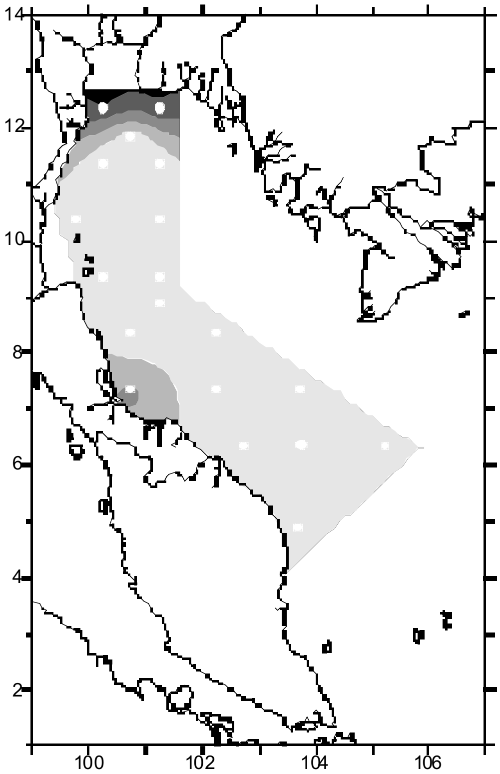


Fig. 2b. Concentration of copper (µg/l) in bottom water in September 1995

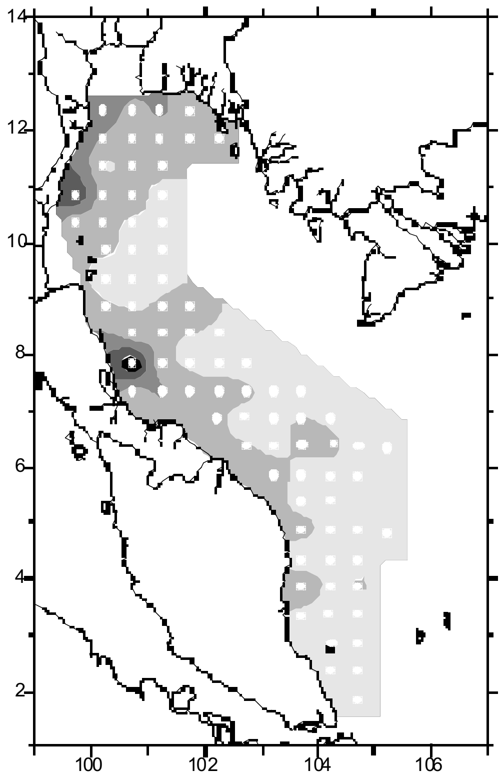


Fig. 2c. Concentration of copper (µg/l) in surface water in April-May 1996

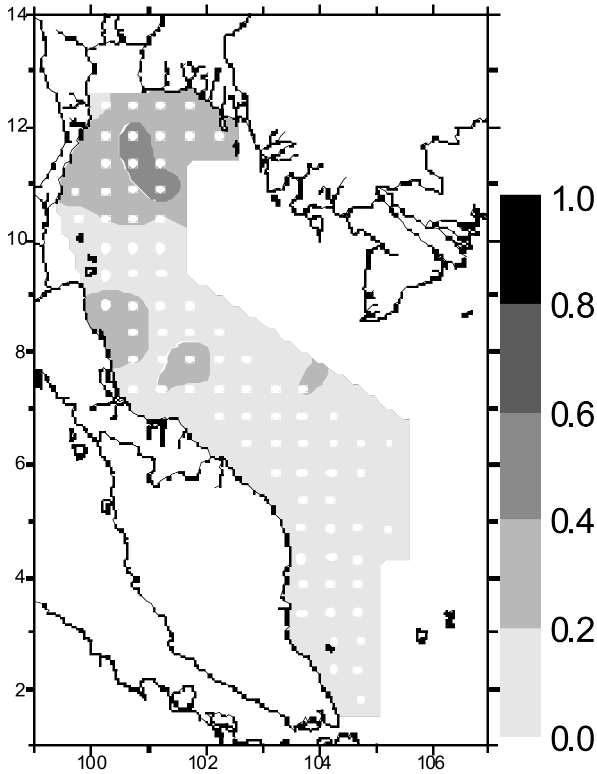


Fig. 2d. Concentration of copper (µg/l) in bottom water in April-May 1996

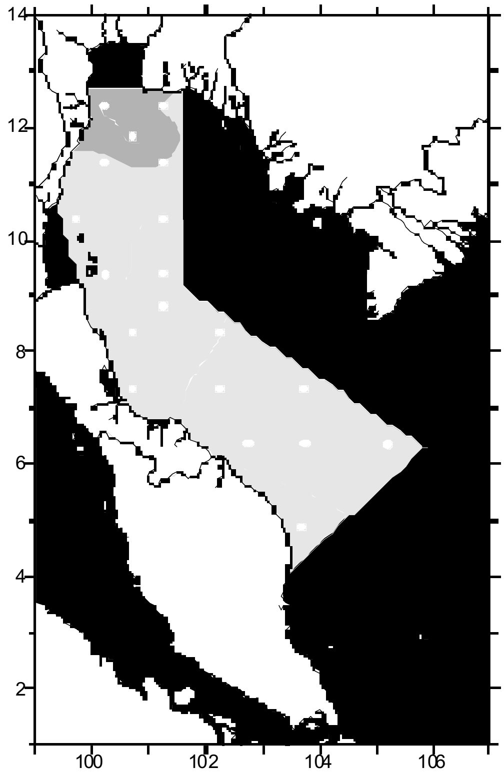


Fig. 3a. Concentration of cadmium (ng/l) in surface water in September 1995

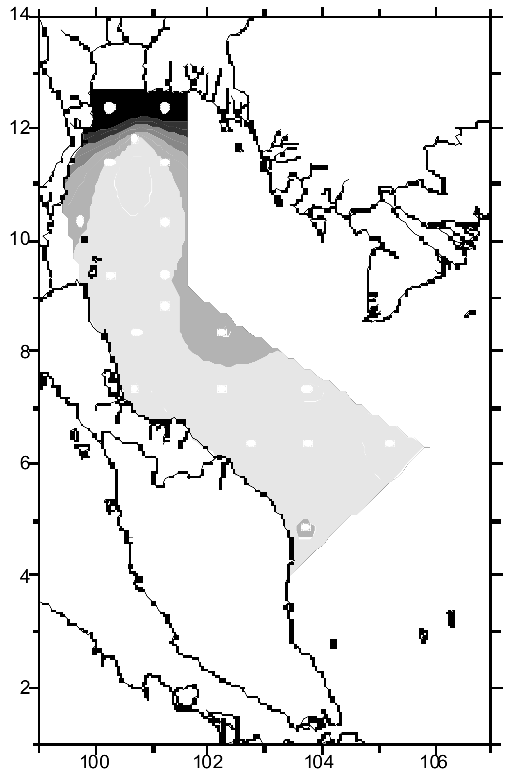


Fig. 3b. Concentration of cadmium (ng/l) in bottom water in September 1995

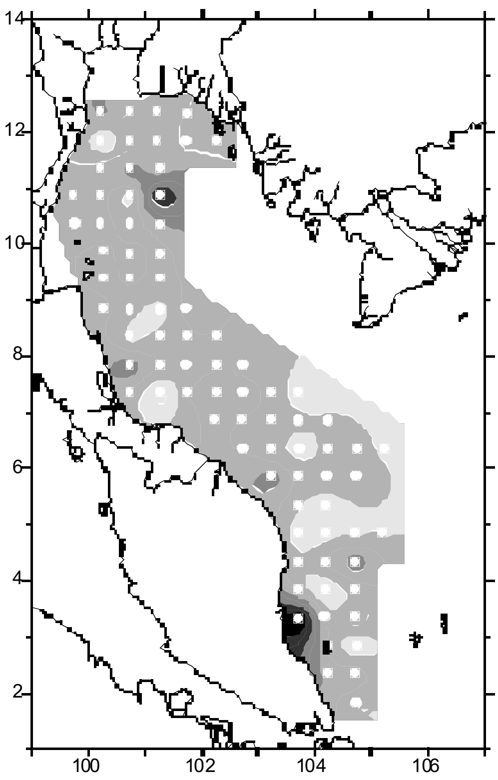


Fig. 3c. Concentration of cadmium (ng/l) in surface water in April-May 1996

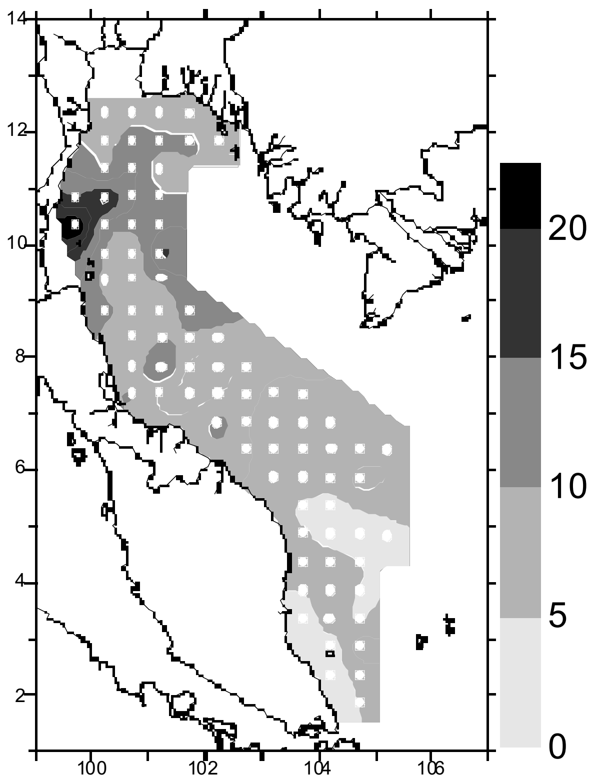


Fig. 3d. Concentration of cadmium (ng/l) in bottom water in April-May 1996

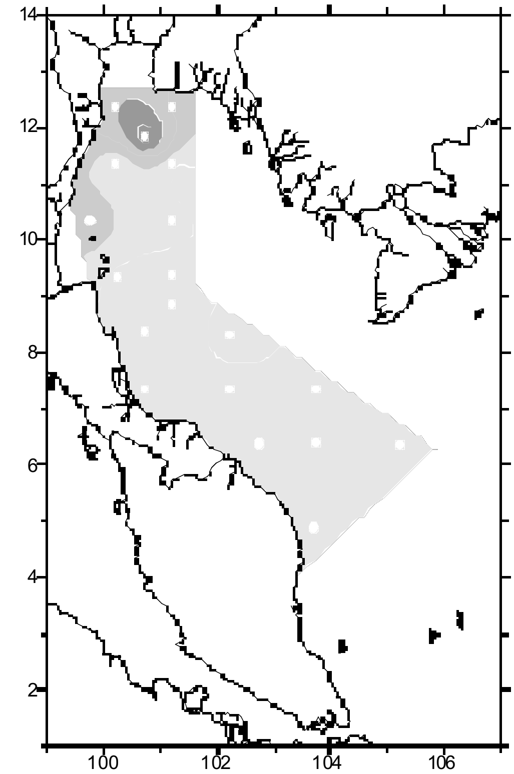


Fig. 4a. Concentration of lead (μg/l) in surface water in September 1995

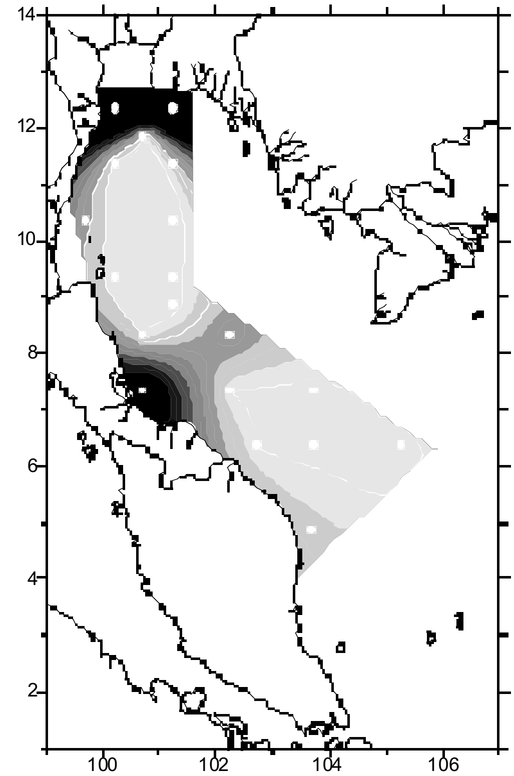


Fig. 4b. Concentration of lead (μg/l) in bottom water in September 1995

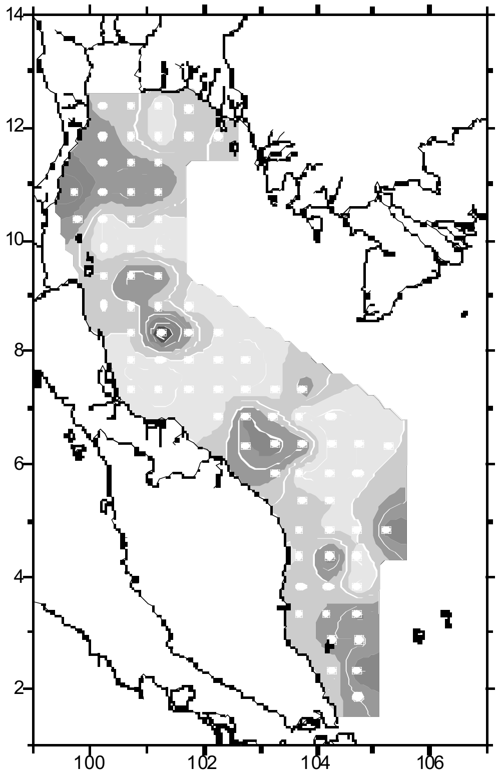


Fig. 4c. Concentration of lead (μg/l) in surface water in April-May 1996

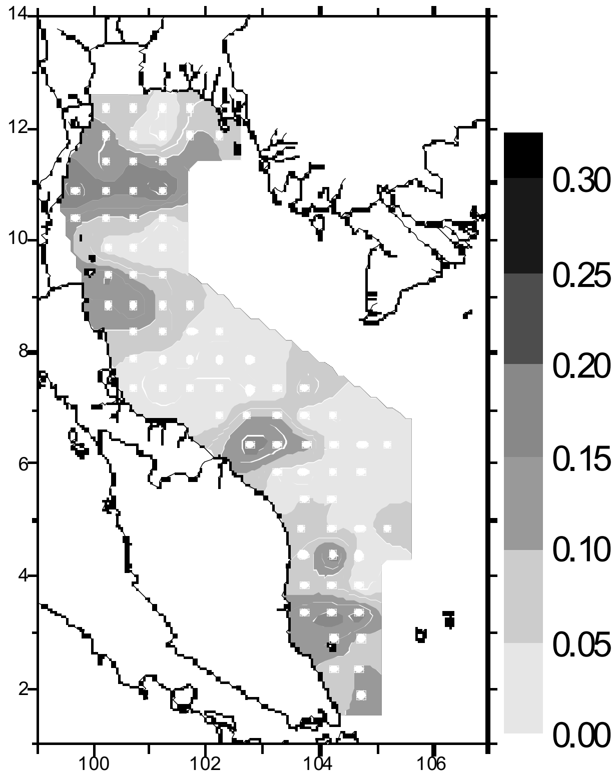


Fig. 4d. Concentration of lead (μg/l) in bottom water in April-May 1996

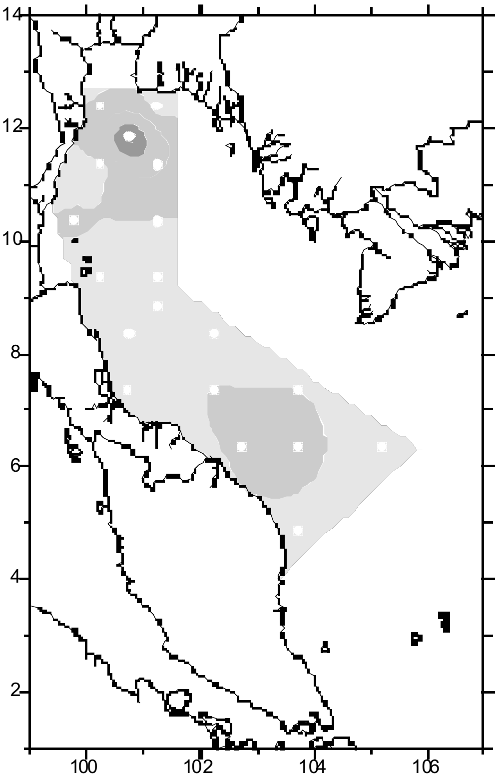


Fig. 5a. Concentration of nickel (μg/l) in surface water in September 1995

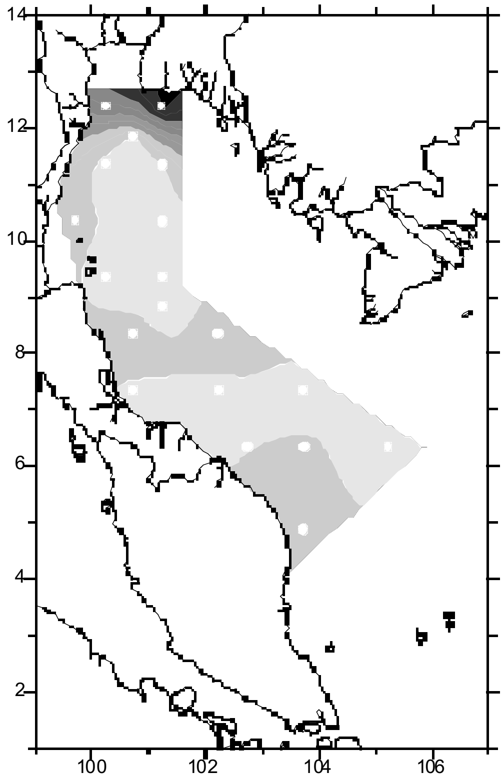


Fig. 5b. Concentration of nickel (μg/l) in bottom water in September 1995

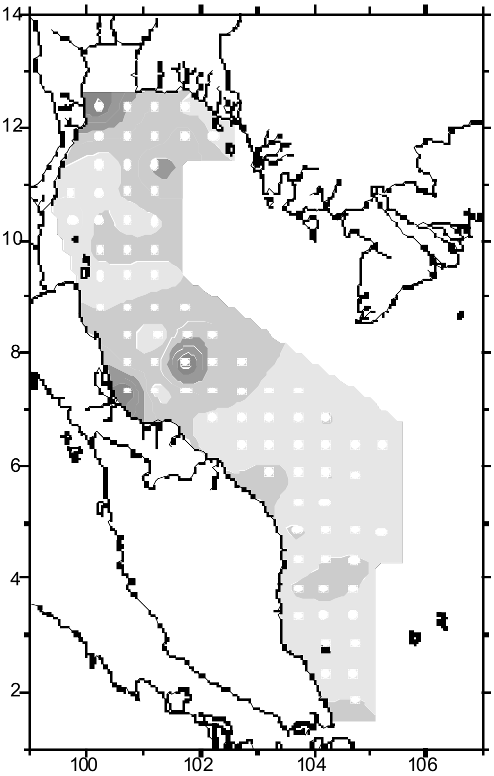


Fig. 5c. Concentration of nickel (μg/l) in surface water in April-May 1996

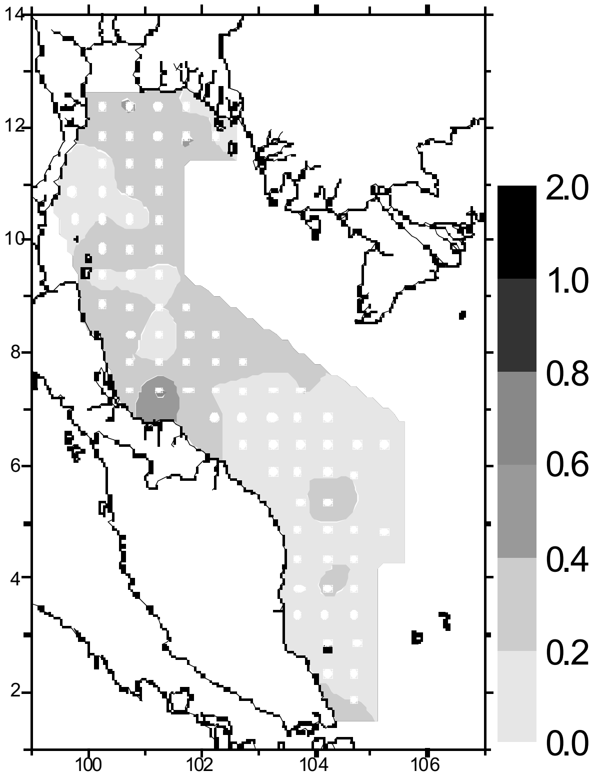


Fig. 5d. Concentration of nickel (μg/l) in bottom water in April-May 1996

concentration at sea surface and enriched near bottom, obviously pointed out that biological processes played some roles in their internal cyclings. Biological uptake especially by phytoplankton in the surface layer could deplete the concentration quite fast, relative to the lateral transport. Settling of organic particles and subsequent decays in bottom layer enriched bottom water by regenerated metals. In addition, sediments could be another significant source of these metals for bottom water of this study area.

Nickel might have been included in this category (b), even though it had a mixed behaviors between the two groups. During the high runoff, it behaved like cadmium and lead while behaved like iron and copper during the dry season. The Upper Gulf and Songkhla lagoon were external source for nickel, especially in April-May 1996 (Fig. 5).

Summary

1) The concentrations of all five trace metals found in this study were not unusually high.
2) The plume from the Upper Gulf was the largest source of all five trace metals for the Gulf of Thailand. The second source appeared to be the land area of Nakorn Sri Thammarat and Songkhla Provinces.
3) These five metals could be subdivided into two groups based on their vertical distribution. Iron and copper, which had no significant bottom enrichment, could be controlled by external sources and horizontal dispersion while cadmium, nickle and lead showed some degree of bottom enrichment, indicating roles of biological processes and sediment fluxes.

References

Boyle, E.A. and Edmond, J.M. 1977. Determination of Cu, Ni and Cd in seawater by APDC chelate coprecipitation and flameless atomic absorption spectrophotometry. *Anal. Chim. Acta.*, 91 :189-197.

Drever, J. I. 1989. *The Geochemistry of Natural Waters.* Prentice-Hall.

Huizenga, D. L. 1981. The cobalt-APDC coprecipitation technique for the preconcentration of trace metal samples. Graduate School of Oceanography, University of Rhode Island, Technical Report 81-3, 93 pp.

Utoomprurkporn, W., Hungspreugs, M., Dharmvanij, S. and Yuangthong, C. 1987. Improvement of the processes for the determination of trace elements in sea water and river water. Proceeding of the Fourth Seminar on the Water Quality and the Quality of Living Resources in Thai Waters, Surat Thani, 7-9 July 1987, National Research Council of Thailand, p. 388-393.

Appendix A. Dissolved trace metals in seawater in September 1995. Concentrations in parentheses are excluded from discussion

Stations	Depth (m)	Pb (μg/l)	Cd (ng/l)	Cu (μg/l)	Ni (μg/l)	Fe (μg/l)
1	0	0.099	7.75	0.53	0.22	3.26
	24	(0.792)	(31.58)	(8.69)	0.68	2.20
3	0	0.066	4.79	0.95	0.17	0.98
	28	(0.758)	(25.68)	(6.72)	1.01	2.99
8	0	0.148	8.19	0.73	0.55	3.23
	5	0.061	5.78	0.40	0.22	0.94
	10	0.147	5.67	0.32	0.29	1.81
	20	0.395	6.05	2.24	0.46	2.80
	30	0.020	2.46	0.40	0.18	0.85
	35	0.020	3.25	0.97	0.17	0.54
10	0	0.021	3.75	0.23	0.17	1.79
	45	0.017	3.39	0.13	0.15	0.78
12	0	0.023	4.83	0.34	0.32	2.40
	55	0.076	4.89	0.27	0.20	2.01
17	0	0.076	2.93	0.29	0.22	1.17
	40	0.106	5.63	0.43	0.27	1.10
20	0	0.029	2.13	0.16	0.19	1.13
	60	0.008	3.90	0.09	0.14	0.92
24	0	0.016	3.13	0.18	0.15	0.75
	26	0.017	2.71	0.12	0.14	0.86
26	0	0.020	2.00	0.16	0.15	0.97
	60	0.020	4.89	0.12	0.13	0.78
28	0	0.012	0.98	0.12	0.13	0.50
	55	0.012	4.13	0.07	0.11	0.38
31	0	0.015	1.28	0.17	0.16	4.90
	26	0.034	4.22	1.32	0.28	4.54
34	0	0.035	2.50	0.22	0.15	0.91
	10	0.045	1.61	0.31	0.20	1.34
	20	0.02	2.09	0.23	0.14	1.25
	30	0.029	4.40	0.36	0.17	1.20
	40	0.020	4.61	0.27	0.19	0.87
	50	0.020	6.39	0.20	0.19	1.04
	60	0.086	13.27	0.62	0.30	2.97
	70	0.02	3.73	0.25	0.19	1.66
	74	0.149	7.77	1.05	0.28	2.27
40	0	0.017	2.09	0.38	0.16	2.23
	19	0.437	2.21	0.47	0.18	1.16
43	0	0.017	3.25	0.16	0.21	1.64
	48	0.022	3.09	0.11	0.17	0.72
46	0	0.017	4.71	0.20	0.20	1.29
	48	0.012	2.14	0.15	0.15	0.64
52	0	0.017	2.73	0.19	0.20	1.22
	36	0.024	3.01	0.13	0.20	1.26
54	0	0.021	3.13	0.22	0.22	1.69
	57	0.018	4.72	0.20	0.22	1.96
57	0	0.016	28.13	0.23	0.15	2.72
	58	0.013	1.32	0.22	0.14	1.36
64	0	0.025	2.02	0.39	0.19	1.87
	56	0.065	5.20	0.58	0.25	1.92

Appendix B. Dissolved trace metals in seawater in April-May 1996. Concentrations in parentheses are excluded from discussion.

Stations	Depth (m)	Pb (μg/l)	Cd (ng/l)	Cu (μg/l)	Ni (μg/l)	Fe (μg/l)
1	0	0.089	10.58	0.558	0.737	2.30
	27	0.075	8.02	0.188	0.359	0.90
2	0	0.095	7.16	0.318	0.394	2.66
	5	0.105	12.59	0.437	0.511	2.81
	10	0.184	8.65	0.406	0.355	4.79
	15	0.105	8.03	0.393	0.419	6.42
	20	0.076	6.39	0.161	0.285	1.10
	27	0.083	9.67	0.344	0.429	2.88
3	0	0.025	8.65	0.469	0.289	2.95
	5	0.029	7.82	0.330	0.273	1.98
	10	0.017	9.19	0.233	0.187	0.95
	15	0.032	13.53	0.564	0.455	1.70
	20	0.016	8.06	0.225	0.170	0.78
	31	0.019	7.89	0.203	0.246	1.31
4	0	0.089	7.41	0.215	0.177	1.09
	15	0.083	9.94	0.197	0.146	0.78
	18	0.094	8.51	0.240	0.196	1.24
	20	0.073	6.94	0.215	0.160	0.88
	24	0.076	6.89	0.172	0.149	0.64
	26	0.078	7.38	0.222	0.181	1.15
5	0	0.070	6.64	0.238	0.162	1.06
	10	0.109	8.52	1.057	0.180	1.20
	20	0.100	9.32	0.348	0.209	0.80
	26	0.108	6.87	0.188	0.168	0.77
	29	0.090	6.94	0.217	0.165	0.90
6	0	0.081	6.79	0.326	0.390	2.88
	10	0.083	7.28	0.212	0.368	1.60
	20	0.079	7.15	0.189	0.338	3.01
	25	0.099	9.23	0.157	0.328	2.85
	30	0.091	5.99	0.154	0.306	2.25
	40	0.090	6.76	0.167	0.482	1.17
	50	0.112	11.36	0.202	0.434	1.57
7	0	0.027	8.89	0.180	0.213	0.71
	45	0.015	10.85	0.264	0.270	1.33
8	37	0.028	10.97	0.544	0.249	2.33
9	0	0.117	1.57	0.356	0.304	0.59
	20	0.397		1.357	0.307	1.83
	35	0.127		0.258	0.265	1.13
10	0	0.116	9.96	0.166	0.115	2.10
	47	0.109	9.58	(7.597)	0.132	1.17
11	0	0.118	11.13	0.258	0.237	1.16
	53	0.173	12.95	0.428	0.322	1.30
12	0	0.106	8.72	0.259	0.460	2.09
	25	0.158	7.48	0.243	0.374	1.55
	57	0.134	7.45	0.389	0.407	1.61
13	0	0.125	19.34	0.116	0.326	1.66
	40	0.155	11.70	0.390	0.332	1.39
	65	0.192		0.516	0.286	1.52
14	0	0.140	3.18	0.292	0.229	1.01
	45	0.153	9.91	0.374	0.285	1.47
15	0	0.136	8.14	0.296	0.183	0.89
	53	0.157	18.54	0.284	0.177	1.16
16	0	0.194	8.77	0.834	0.104	0.61
	48	0.191	15.07	0.288	0.109	0.95

Appendix B. continue

Stations	Depth (m)	Pb (µg/l)	Cd (ng/l)	Cu (µg/l)	Ni (µg/l)	Fe (µg/l)
17	0	0.135	8.00	0.212	0.031	0.85
	10	0.163	9.39	0.232	0.141	1.01
	20	0.114	8.57	0.198	0.157	0.79
	30	0.088	7.20	0.150	0.116	0.81
	38	0.076	7.10	0.114	0.121	0.49
	45	0.105	23.15	0.106	0.108	2.06
18	0	0.013	9.75	0.233	0.247	1.27
	60	0.081	10.74	0.202	0.223	3.01
19	0	0.071	5.87	0.172	0.108	0.79
	62	0.099	10.41	0.227	0.109	0.85
20	0	0.034	8.34	0.201	0.183	2.65
	64	0.013	12.33	0.150	0.228	0.70
21	0	0.020	6.66	0.156	0.257	1.90
	68	0.004	15.83	0.157	0.242	0.53
22	0	0.039	8.94	0.193	0.273	0.97
	56	0.016	7.59	0.134	0.379	0.37
23	0	0.022	6.49	0.220	0.262	1.07
	35	0.027	9.22	0.116	0.349	0.64
24	0	0.082	6.86	0.137	0.128	0.51
	10	0.102	6.67	0.120	0.104	0.54
	20	0.083	8.17	0.135	0.029	0.62
	28	0.162	9.15	0.134	0.129	0.70
25	0	0.150	7.72	0.131	0.122	0.48
	40	0.091	9.46	0.150	0.153	1.06
26	0	0.133	7.18	0.149	0.123	1.04
	10	0.148	5.91	0.158	0.161	0.67
	20	0.068	2.85	0.131	0.151	0.49
	30	0.130	5.35	0.122	0.138	0.60
	40	0.074	3.20	0.142	0.152	0.30
	50	0.123	3.90	0.106	0.138	0.56
	63	0.077	9.92	0.126	0.146	0.32
27	0	0.034	8.31	0.277	0.238	0.44
	55	0.041	11.46	0.147	0.189	0.51
	77	0.061	12.26	0.144	0.257	1.58
28	0	0.069	3.76	0.240	0.316	0.83
	58	0.078	7.10	0.173	0.202	1.86
29	0	0.095	5.86	0.199	0.231	1.10
	30	0.153	9.39	0.231	0.275	1.34
30	0	0.088	8.24	0.228	0.192	1.21
	24	0.115	10.48	0.271	0.340	4.94
31	0	0.054	3.91	0.257	0.231	1.45
	27	0.094	7.70	0.289	0.253	1.00
32	0	0.276	5.99	0.229	0.106	1.18
	40	0.100	4.89	0.112	0.082	0.40
	52	0.083	10.01	0.119	0.105	1.84
33	0	0.107	7.12	0.196	0.372	1.38
	45	0.022	6.41	0.173	0.244	2.42
	71	0.034	9.18	0.144	0.268	0.89
35	0	0.012	6.81	0.159	0.264	0.58
	50	0.024	7.08	0.154	0.268	0.70
	70	0.031	9.26	0.168	0.261	0.77
36	0	0.029	7.33	0.165	0.255	1.17
	65	0.036	7.09	0.108	0.225	0.97
	72	0.012	5.50	0.122	0.265	0.56
37	0	0.029	6.37	0.184	0.845	2.71
	40	0.024	7.21	0.161	0.360	0.96
	58	0.026	6.61	0.384	0.230	0.57

Appendix B. continue

Stations	Depth (m)	Pb (μg/l)	Cd (ng/l)	Cu (μg/l)	Ni (μg/l)	Fe (μg/l)
38	0	0.021	7.49	0.227	0.245	1.63
	48	0.026	13.59	0.186	0.211	1.78
39	0	0.025	12.16	1.025	0.252	2.27
	27	0.033	8.24	0.203	0.195	3.16
40	0	0.030	6.92	0.263	0.723	0.83
	10	0.028	8.85	0.183	0.457	0.35
	20	0.029	10.30	0.147	0.295	0.55
41	0		0.61	0.441	0.106	
	40	0.017	6.76	0.210	0.686	0.35
42	0	0.036	7.75	0.243	0.281	0.87
	30	0.042	8.65	0.283	0.473	4.15
	49	0.029	6.09	0.132	0.233	1.41
43	0	0.041	8.82	0.242	0.291	1.20
	35	0.030	8.26	0.173	0.261	2.92
	49	0.036	7.70	0.183	0.188	1.17
44	0	0.027	8.90	0.222	0.221	1.38
	20	0.025	7.18	0.126	0.163	1.20
	52	0.024	8.71	0.113	0.151	2.10
45	0	0.030	6.75	0.154	0.169	2.37
	15	0.037	4.57	0.102	1.006	3.53
	55	0.028	5.97	0.113	0.153	1.63
46	0	0.127	3.57	0.143	0.158	2.15
	10	0.080	3.00	0.025	0.143	0.96
	30	0.074	2.91	0.112	0.130	0.60
	40	0.309	6.31	0.179	0.204	1.19
	46	0.098	7.22	0.219	0.204	2.56
47	0	0.011	5.45	0.181	0.206	1.16
	58	0.023	6.71	0.142	0.169	2.60
48	0	0.006	5.75	0.207	0.189	0.92
	57	0.017	6.69	0.110	0.178	1.55
49	0	0.090	6.49	0.191	0.144	1.28
	30	0.132	3.83	0.106	0.188	2.12
	53	0.106	5.57	0.122	0.159	1.31
50	0	0.164	7.12	0.151	0.164	0.66
	50	0.103	7.67	0.145	0.119	1.44
51	0	0.027	7.98	0.215	0.159	1.21
	10	0.016	7.24	0.147	0.193	1.11
	46	0.031	11.10	0.157	0.233	2.14
52	0	0.146	7.26	0.211	0.147	1.85
	38	0.178	7.74	0.112	0.137	0.63
53	0	0.171	5.56	0.177	0.134	1.94
	10	0.118	5.76	0.145	0.129	0.92
	51	0.144	6.26	0.123	0.136	1.34
54	0	0.135	3.59	0.218	0.135	1.43
	60	0.119	6.13	0.146	0.184	1.57
55	0	0.013	5.98	0.236	0.194	1.34
	59	0.031	6.75	0.134	0.187	2.76
56	0	0.030	5.88	0.116	0.154	0.86
	60	0.040	6.14	0.138	0.199	2.64
57	0	0.038	4.43	0.103	0.178	1.04
	30	0.041	6.56	0.152	0.212	2.78
	59	0.028	7.48	0.152	0.170	1.01
58	0	0.032	7.23	0.189	0.183	0.84
	60	0.035	8.76	0.119	0.182	2.14
59	0	0.008	6.01	0.141	0.204	0.94
	63	0.026	5.35	0.094	0.181	1.26

Appendix B. continue

Stations	Depth (m)	Pb (µg/l)	Cd (ng/l)	Cu (µg/l)	Ni (µg/l)	Fe (µg/l)
60	0	0.017	6.88	0.165	0.187	1.50
	57	0.014	7.02	0.089	0.183	0.70
61	0	0.106	11.38	0.244	0.254	3.03
	20	0.043	5.22	0.174	0.306	3.34
	48	0.022	6.79	0.094	0.161	0.93
62	0	0.076	4.85	0.163	0.134	0.11
	20	0.061	3.50	0.079	0.114	0.20
	58	0.061	4.35	0.115	0.152	0.63
63	0	0.052	3.86	0.187	0.186	0.46
	64	0.050	4.12	0.086	0.356	0.83
64	0	0.048	3.87	0.242	0.223	0.33
	57	0.051	5.53	0.084	0.154	0.24
65	0	0.044	4.08	0.168	0.150	0.22
	64	0.047	3.43	0.090	0.144	0.45
66	0	0.042	4.55	0.145	0.136	0.22
	70	0.044	3.29	0.078	0.104	0.23
67	0	0.176	4.96	0.156	0.182	0.70
	30	0.117	3.23	0.156	0.154	0.90
	76	0.066	4.05	0.076	0.127	0.53
68	0	0.016	12.33	0.182	0.215	1.11
	40	0.008	3.79	0.104	0.142	1.05
	71	0.012	5.06	0.082	0.201	0.58
69	0	0.181	8.50	0.170	0.206	1.22
	20	0.275	4.93	0.144	0.231	0.98
	25	0.149	4.35	0.125	0.198	0.93
	40	0.193	5.47	0.123	0.156	0.83
	45	0.174	4.09	0.126	0.174	1.69
	64	0.176	7.15	0.105	0.188	1.33
70	0	0.053	5.19	0.095	0.105	0.37
	15	0.050	9.13	0.079	0.106	0.41
	38	0.084	6.13	0.066	0.100	0.40
71	0	0.062	6.05	0.349	0.228	0.76
	15	0.086	8.40	0.236	0.198	0.29
	30	0.080	5.04	0.080	0.137	0.43
72	0	0.092	1.60	0.160	0.269	1.93
	20	0.092	10.20	0.101	0.194	1.57
	54	0.074		0.093	0.249	0.67
73	0	0.015	5.23	0.215	0.202	1.47
	30	0.024	3.48	0.074	0.187	1.41
	72	0.012	4.74	0.086	0.155	0.89
74	0	0.160	9.24	0.120	0.111	0.82
	25	0.124	5.33	0.051	0.094	1.02
	66	0.167	4.62	0.040	0.108	0.30
75	0	0.109	6.04	0.097	0.101	0.39
	10	0.145	3.56	0.051	0.094	0.59
	54	0.160	6.40	0.051	0.097	0.70
76	0	0.083	24.14	0.135	0.112	0.47
	10	0.115	8.52	0.115	0.123	0.59
	26	0.148	3.61	0.088	0.117	0.57
77	0	0.123	6.25	0.152	0.147	0.75
	10	0.186	3.62	0.092	0.124	1.11
	48	0.125	3.59	0.105	0.116	1.36
78	0	0.114	2.69	0.166	0.119	1.09
	28	0.164	2.83	0.291	0.129	1.82
	63	0.077	9.49	0.071	0.117	0.44
79	0	0.181	9.82	0.170	0.143	1.07
	10	0.132	8.26	0.145	0.133	0.79
	25	0.058	8.15	0.119	0.125	0.95
	30	0.067	6.63	0.113	0.115	0.66
	50	0.089	5.05	0.085	0.145	1.41
	59	0.110	5.58	0.124	0.108	0.66
80	0	0.055		0.201	0.176	1.13
	15	0.074	8.45	0.135	0.182	0.74
	31	0.079	3.63	0.170	0.198	1.72
81	0	0.123	4.86	0.178	0.209	0.98
	10	0.129	6.75	0.124	0.178	2.31
	53	0.105	5.13	0.117	0.209	1.90

Polynuclear Aromatic Hydrocarbon(PAH) and Total Aliphatic Hydrocarbon (TAH) in the Bottom Sediment of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Mohamed Kamil Abdul Rashid

Faculty of Applied Science and Technology, University Putra Malaysia Terengganu
Kuala Terengganu, Malaysia

ABSTRACT

Surface sediment (0-2cm) from 23 station in the Gulf of Thailand and the South China Sea were analysed for Polynuclear Aromatic Hydrocarbon (PAH), and Total Aliphatic Hydrocarbon (TAH). PAH was found to be in the range between 0.7047 mmg/g dry wt. (Stn 70) to 26.6066 mmg/g dry wt. (Stn 52) to 25.5314 mmg/g dry wt. (Stn 41). Long chain aliphatic hydrocarbon (n>20) were found to be dominant species in the most of the sample.

Introduction

Oil introduced into the estuaries, coastal waters and the open sea originates from a diversity of source. Of all the oil reaching the sea, approximately 45% is derived from river runoff, urban runoff, minicipal wastes, and the effluent from nonpetroleum industries. Activities related to oil transportation account for another 33% of the polluting oil (Kennish, 1994). According to Clark (1992), oil input originating from the users of petroleum product far exceeds that from extraction and transport industries which are reponsible for little more than 25% of the total input of oil in the sea.

Among the most widespread chemical contaminant in estuarine and nearshore environments are PAH, a group of ubiquitous compounds commonly occuring in bottom sediments, overlying waters, and biota, especially those in proximity to urban industrialized areas. PAH enter estuarine and nearshore marine environments via several routes, most notably sewage and industrial effluents,oil spills, creosote oil, combustion od fossil fuels, and forest and bush fires (Neff, 1979). Owing to their relative insolubility in waterand strong adsorption to particulated matter, PAH tend to concentrate in bottom sediments.

Law and Zulkifli (1987) have made a study on the distribution of petroleum hydrocarbon in the bottom sediments of the southern paert of the South China Sea and found that the mean concentration in the surface sedimen (0-8cm) was 42.92mg/kg dry wt. This result shows that the hydrocarbon pollution still at its early stage. However, Law and Saili (1988) found that the mean concentration of petroleum hydrocarbon in the surface bottom sediments (0-10cm) in the Sarawak water was 54.04 mg/kg dry wt. Which indicates that the pollution problem is taking place.

Material and Methods

Sampling

Sediment were collected with a Smith McIntyre grab on board the M.V. SEAFDEC in a joint oceanography study between SEAFDEC Thailand and MFRMD Malaysia. The sample were taken during the second cruise in April 1996. Aportion of the surface sediment (0-2cm) was removed with a precleaned stainless steel spatula. The sample were then store in aclean glass bottles wraped in clean plastic bag at -20^{0}C prior to analysis in the laboratory at UPM Terengganu.

Soxhlet Etraction

Wet sediment (10-20 g) was placed in a tared preclean cellulose thimble with 50 g of sodium sulfateas drying agent. The mixture was then spiked with 50 µl recovery standart and extracted with 200 ml CH_2Cl_2 for about 16 -24 hours.

TEL (Total Extractable Lipid)

After the extraction processes, the CH_2Cl_2 was then dried using rotary evaporator. About 1.0 ml of the remaining solvent was then transferred into the preweight teflon caplined vial. The flask was rinsed a few times . The solvent was then dried using nitrogen gas flow. The dried component was then weight to get the TEL.

Separation between TAH and PAH

Before separation , any sulphur presence in the sample was first eliminated using the copper column. Separation of TAH and PAH was done using a silica gel and alumina column. Basically tah was extracted using 30 ml hexane through the column while PAH was extracted using40 ml 50% hexane in CH_2C1_2. Both of the extracts were then dry using rotary evaporator and nitrogen gas flow about 1.0 ml . The sample were then ready for analysis using HP 6890 Series Gas Chromathography equipped with flame ionized detector (FID).

Result and Discussion

Due to equipment problem and the time constraint, only portion of the samples colleted during the second cruise were able to be analysed yet. The samples selected were those along the coastal zone of the Gulf of Thailand and the East coast of peninsular Malaysia. The concentration of TAH and PAH are shown in Table 1 and 2, respectively. TAH was found to be in the range between 2.1819 µg/g dry wt. (Stn.52) to 25.5314 µg/g dry wt. (Stn. 41). As a whole higher concentration of TAH was found in samples from the Gulf of Thailand if compare to those in the South China Sea. Station 39 shows the highest concentration of TAH followed by Station 41, Station 31 and Station 1 respectively. All of these stations were situated in the Gulf of Thailand. Long chain aliphatic hydrocarbon (n>20) were found to be the dominant species in most of the samples analysed which was dominanted by C28 compound, C24 and C30 respectively.

PAH was found to be in the range between 0.07047 µmg/g dry wt. (Stn. 70) to 26.6066 µg/g dry wt.(Stn. 1). As a whole the concentration of PAH shows the same trend as TAH where higher concentration was found in samples from the Gulf of Thailand especially in Station 1 (26.6066 µg/g dry wt) followed by Station 10 (21.7853 µg/g dry wt.) and Station 31 (14.1442 µg/g dry wt.) respectively. Compound containing the benzene rings were found to be dominant in most of the samples. These compounds such as Benzo(a)anthracene, Benzo(b)flouranthene, Benzo(k)flouranthene, Benzo(a)pyrene and Benzo(ghi)perylene were found to be high in concentration especially in samples from the Gulf of Thailand.

Conclusion

From these prelimenary result, there was a contrast different between the distributions of TAH and PAH in the coastal surface sediment of the Gulf of Thailand and the South China Sea. Higher concentrations of both these compounds were seen in samples from Gulf of Thailand. These result could be attributed to the higher concentration of population and higher human activities around the Gulf of Thailand. The physical conditions of the Gulf area such as its closed system with lack of mixing may also be considered.

Table 1. Concentration of TAH in the surface bottom sediment of the Gulf of Thailand and East Coast of Peninsular Malaysia

Concentration of TAH μg/g dry wt. with station

No.	Species	1	9	10	16	17	18	23	24	30	31	39	40	41	52	61	62	64	70	71	76	77	80	81	Total
1	C12																								
2	C14															0.046			0.022					0.029	**0.097**
3	C16	0.817	0.304	0.560	0.487	0.385	0.487								0.232	0.039	0.285	0.420				0.338			**4.351**
4	C17	0.295	0.097	0.169	0.109		0.209	0.093				0.134	1.140		0.050	0.056	0.046	0.064	0.058	0.081	0.065	0.100	0.074	0.089	**2.926**
5	C18	0.426	0.102	0.221	0.230	0.115	0.158	0.100	0.180	0.155	0.171	0.151	0.142	0.229	0.055	0.057	0.112	0.107	0.069	0.028	0.022	0.102	0.012	0.067	**3.009**
6	C20	0.633	0.279	0.313	0.354	0.156	0.450	0.138		0.198	0.283	0.248	1.250	0.323	0.099	0.086	0.109	0.243	0.126	0.209	0.298	0.116	0.037	0.116	**6.063**
7	C21	1.269	0.562	1.077	0.904	0.700	1.501	0.606	0.132	1.468	1.996	1.682	1.075	1.500	0.101	0.276	1.198	0.637	0.352	0.515	0.506	0.316	0.379	0.387	**19.138**
8	C22	1.968	1.030	2.303	1.949	1.083	2.803	1.297	0.303	2.429	3.099	3.424	2.410	3.216	0.214	0.591	0.427	0.998	0.737	1.075	1.040	0.498	0.802	0.586	**34.279**
9	C24	3.559	1.608	3.952	3.564	1.591	3.773	2.286	0.697	4.104	4.668	6.130	4.482	5.790	0.406	1.074	0.715	1.585	1.177	1.754	1.797	0.963	1.616	0.919	**58.209**
10	C28	4.812	1.769	4.056	4.513	1.523	3.511	2.102	1.083	4.102	4.316	6.838	4.469	6.309	0.539	1.059	0.672	1.399	1.416	1.915	1.913	1.169	2.237	0.824	**62.545**
11	C30	4.174	1.602	3.453	3.845	1.190	2.592	1.605	0.998	3.305	3.326	5.539	3.647	5.598	0.401	0.834	0.471	0.873	1.035	1.696	1.555	0.842	1.933	0.564	**51.074**
12	C32	1.143	0.701	1.624	1.030	0.426	0.901	0.690	0.388	1.454	1.274	1.846	1.629	2.568	0.086	0.302	0.145	0.265	0.232	0.709	0.535	0.177	0.489	0.119	**18.729**
	Total	**19.094**	**8.053**	**17.727**	**16.984**	**7.167**	**16.384**	**8.916**	**3.782**	**17.214**	**19.132**	**25.991**	**20.244**	**25.531**	**2.182**	**4.420**	**4.179**	**6.589**	**5.223**	**7.981**	**7.731**	**4.621**	**7.579**	**3.698**	**260.42**

Table 2. Concentration of PAH in the surface bottom sediment of the Gulf of Thailand and East Coast of Peninsular Malaysia

Concentration of PAH µg/g dry wt. with station

No.	Species	1	9	10	16	17	18	23	24	30	31	39	40	41	52	61	62	64	70	71	76	77	80	81	Total
1	Naphthalene																								**0.000**
2	Acenaphthlene															0.233									**0.233**
3	Acenaphthne																					0.459			**0.459**
4	Flourene																					0.073			**0.073**
5	Phenantherene										0.322					0.100						0.076			**0.498**
6	Anthracene						0.291	0.210	0.257	0.313	0.422	0.324	0.354	0.435	0.140	0.186	0.117	0.259	0.063	0.160	0.147	0.144	0.107	0.106	**4.035**
7	Flouranthene						0.208	0.237	0.420	1.024	0.223	0.328	0.410	0.537	0.083	0.125	0.085	0.210	0.090	0.221	0.718	0.144	0.096	0.165	**5.323**
8	Pyrene	1.227		3.602	1.604		1.057	0.519	0.277	0.846	1.243	0.385	0.756	1.158	0.300	0.483	0.193	0.724	0.028	0.392	0.421	0.246	0.331	0.146	**15.937**
9	Benzo(a)anthracene	7.012	2.268	4.809	1.909	0.236	0.502	0.347	0.113	0.387	0.554	0.821	0.306	0.890	0.033		0.040	0.098		0.139	0.137	0.027			**20.626**
10	Chyrsene		1.386				0.236	0.163		0.242	0.386	0.331	0.295	0.462	0.064	0.115	0.070	0.146		0.101	0.089	0.077	0.086	0.082	**4.293**
11	Benzo(b)Flouranthene					0.315	0.208	4.432		7.844	6.627	4.874	4.332	0.354	1.172	1.390	1.170	0.109		0.084	0.075	0.868	1.133		**34.985**
12	Benzo(k)Flouranthene		2.931				0.280	0.291	1.740	0.426	0.521	0.355	0.235	0.651	0.089	0.105	0.102	0.192	0.392	0.134	0.120	0.086	0.084	0.648	**9.379**
13	Benzo(a)pyrene	11.363		7.903	3.554	0.314	0.384	0.342	0.209	0.657	0.535	0.542	0.429	0.541	0.119	0.142	0.159	0.269		0.151	0.165	0.152	0.083	0.110	**28.123**
14	Indeno[1.2.3-cd]pyrene	4.332	1.197	3.126	1.508	1.161	1.838	0.073	0.533	0.151	2.023	1.681	1.563	0.325	0.026	0.468	0.574	0.127	0.087	0.056	0.050	0.364	0.383	0.156	**21.802**
15	Dibenz[a,h]anthracene					0.238								0.476	0.119					0.115	0.150				**1.097**
16	Benzo[ghi]perylene	2.672		2.345			1.277	1.120	0.336		1.287	1.099	1.048	2.751	0.439	0.290	0.406	0.680	0.045	0.695	0.487	0.257	0.245	0.099	**17.579**
	Total	**26.607**	**7.782**	**21.785**	**8.575**	**2.265**	**6.280**	**7.733**	**3.886**	**11.888**	**14.144**	**10.741**	**9.728**	**8.543**	**2.582**	**3.635**	**2.915**	**2.812**	**0.705**	**2.247**	**2.557**	**2.970**	**2.549**	**1.511**	**164.440**

References

Clark, R. B. (1992). Marine Pollution, 3rd. ed. Clarendon Press, Oxford.

Kennish, J.M. Ed. (1994). Practical Handbook of Marine Science (2nd. ed). CRC Press, Boca Raton, Florida.

Law, A.T. and Zulkifli, M. (1987). Distribution of petroleum hydrocarbon in the south-western portion of the South China Sea . In: Mohsin, A. K. M., Ridwan, A.R. and Azmi, A. (eds). Matahari Expedition '86. A study of the offshore water of the Malaysian EEZ. Faculty of Fisheries and Marine Science, UPM. Occasional Publication No. 4, pp147.

Law, A.T. and Saili, H.L. (1988). Distribution of petroleum hydrocarbon in the coastal water of Sarawak. In: Mohsin, A. K. M., Ridwan, A.R. and Azmi, A. (eds). Matahari Expedition '87. A study of the offshore water of the Malaysian EEZ. Faculty of Fisheries and Marine Science, UPM. Occasional Publication No. 5, pp 61-67.

Neff, J. M. (1979). Polycyclic Aromatic Hydrocarbon in the Aquatic Environment : Sources, Fates, and Biological Effects. Applied Science Publisher, London.

Petroleum Hydrocarbon in Seawater and Some Sediments of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Panjarat Wongnapapan[1]
Gullaya Wattayakorn[1]
Anond Snidvongs[1,2]

[1] Department of Marine Science, Faculty of Science, Chulalongkorn University
[2] To whom correspondences should be addressed to

ABSTRACT

Petroleum hydrocarbon in water samples and sediments collected during the Pre-Southwest Monsoon Cruise in the Gulf of Thailand and Eastern Peninsular Malaysia in April-May 1996 point out that land-based and sea-based sources were both important. High concentration (> 0.5 mg/l) found in coastal water of the northern part and western part near Songkhla-Pattani could be derived from land-based sources. Elevated concentration of petroleum hydrocarbons in seawater and residuals in sediments of the central area of the Gulf could be originated from offshore activities. However physical oceanography of the Gulf could also play very important roles in redistribution, dispersion and accumulation of petroleum hydrocarbon in the water.

Introduction

Petroleum hydrocarbon in seawater and sediments are derived from 2 sources, natural seepage and anthroupogenic sources. Because the Gulf of Thailand and offshore water off the eastern Peninsular Malaysia are areas where petroleum is explored and produced, natural seepage is a possibility, even though it is not well documented. Contrary, anthropogenic input of petroleum hydrocarbon into marine environment is more concerned by general puplic due to the potential of large scale catastrophic effects on organisms and ecosystems. However, more realistically, large scale oil spill is rarely occurred. Most petroleum hydrocarbon are released into the sea are from small, widely distributed sources, such as from smalll vessels without proper water treatment systems, discharge of bilge water by tankers coming to the region to load oil and condensates, and petroleum products from coastal sources--domestics, transport and industrial.

Concentration and distribution of petroleum hydrocarbon is a good indicator for the health of the sea. It can indicate the source of the pollutant that deserve special emphasis or needs more control.

Petroleum hydrocarbon in coastal water of the Gulf of Thailand has been measured since early 1970s. Hungspreugs (1979), for example, reported the concentration between 0.37-1.42 μg/l. Subsequent studies revealed the concentration is highly variable, depending on location and season (Intarapanich, 1979; Sompongchaiyakul and Lim, 1983; Watayakorn, 1986, 1987; Petpiroon, 1988; and Suthanarak, 1991). The major components of petroleum hydrocarbon are degraded crude oils, combusted hydrocarbons and normal alkanes (Silpipat and Ehrhardt, 1986).

In the offshore South China Sea, Law and Mahmood (1986) found the concentration in the range of 0-75 ppb crude oil equivalent.

Comparison of hydrocarbon concentration reported by different papers are difficult to compare because of different standard used. In the past, crude oil was used as standard but the problem is there are several types of crude with defferent chemical compositions. The extracting solvents used by different people were also different. It was in 1984 that the Intergovernmental Oceanographic Commision had established a standard method for determination of hydrocarbon in seawater by using hexane as the extractant and chrysene as standard. Concentration reported by this method, however will not be the absolute concentration of total hydrocarbon in seawater. Rather it represent the relative concentration of hydrocarbon that can be compared among locations and times.

Methods

Sampling and sample preparation

Surface seawater were collected from all 81 stations during the Pre-Southwest Monsoon Cruise in the Gulf of Thailand and Eastern Peninsular Malaysia in April - May 1996. Five liters of seawater was collected from each station using the pre-cleaned amber glass bottles (IOC-UNESCO 1984). At stations 7, 60, 62, 64, 74, 79 and 81 duplicates were collected as a quality assurance. About 75 ml of nanograde hexane was added immediacy after sampling. Samples were stored in a dark cool place until analysis.

Surface sediment samples were collected from stations 1, 3, 12, 20, 24, 40, 44 and 46 using a grab sampler.

Laboratory analysis of samples

Fifty one water samples from the Gulf of Thailand were extracted by nanograde hexane. Residual water in hexane was removed by Na_2SO_4. The final volume of extractant was reduced to 5 ml using a rotary evaporator. The extracted petroleum hydrocarbon was quantified using a spectrofluorometer and using chrysene as the standard.

Sediment samples were extracted by dichloromethane. Internal standards were added to sample prior extraction. Aliphatic and aromatic hydrocarbon fractions were separated using silica gel. Both fractions were analyzed by a Varian 3700 gas chromatograph. Seven species of polycyclic aromatic hydrocarbons (PAHs) were measured: naphthalene, biphenyl, phenanthrene, pyrene, chrysene, perylene and benzo (ghi) perylene.

Total organic content in sediments was analyzed by $K_2Cr^2O_7$ wet oxidation method.

Details of sample preparation and quantitative analysis can be found in Wongnapapan(1996).

Results

Seawater

The concentration of petroleum hydrocarbon in surface seawater at each station is shown in Table 1. Duplicate samples indicated that the precision of these results was better than 18%. The arithmetic mean concentration was 0.564 μg/l and the geometric mean was 0.252 μg/l. The highest concentration of 4.128 μg/l was found at station 46, which is an offshore station.

Sediments

Porosity (percent water content) and total organic carbon in sediments are given in Table 2.

Aliphatic hydrocarbons

Concentration of n-alkane in sediments is ranged from non-detectable to 232.5 ng/g dry weight. The total identified aliphatic hydrocarbons were between 0.04-1.36 μg/g (average 0.27 μg/g dry weight). The result is shown in Table 3.

Aromatic hydrocarbons

Seven polycyclic aromatic hydrocarbons (PAHs)-- naphthalene, biphenyl, phenanthrene, chrysene, pyrene, perylene and benzo (ghi) perylene--existent and concentration in sediments are given in Table 4.

Discussion

Table 1. Concentration of petroleum hydrocarbon at each station (in mg/l chrysene equivalent)

Station	Concentration
1	1.74
2	0.38
3	1.14
4	0.66
5	0.13
6	0.15
7	0.42
8	2.08
9	0.16
10	0.08
11	0.14
12	0.49
13	0.26
14	3.64
15	0.14
16	NA
17	0.69
18	0.47
19	1.09
20	0.20
21	0.07
22	0.14
23	0.25
24	0.09
25	0.39
26	0.11
27	1.48
28	NA
29	0.18
30	0.11
31	0.82
32	0.09
33	0.12
34	0.27
35	0.29
36	0.11
37	0.19
38	0.19
39	0.18
40	2.31
41	0.14

Station	Concentration
42	2.75
43	0.11
44	0.08
45	0.44
46	3.61
47	4.13
48	0.31
49	0.63
50	0.08
51	0.05
52	0.214
53	0.124
54	0.107
55	0.086
56	0.108
57	0.149
58	0.084
59	NA
60	0.125
61	0.162
62	0.130
63	0.144
64	0.159
65	0.092
66	0.101
67	0.133
68	0.359
69	0.305
70	0.786
71	0.191
72	0.135
73	NA
74	0.116
75	0.097
76	0.176
77	0.130
78	0.161
79	3.928
80	0.089
81	0.157

NA = Data not available

Generally the order of magnitude of petroleum hydrocarbon concentration in seawater found in this study is not different from that reported by Hungspreugs (1979) for the same general locations. This can be interpreted either as the sources were not increased much during the last 15 years or the natural processes (physical and chemical) in the Gulf that control and remove petroleum hydrocarbon in seawater were still fast relative to the input.

Elevated concentration of petroleum hydrocarbon in seawater (>0.5 μg/l) were found at four distinct areas (Fig. 1). Firstly, the area near the mouth of the upper Gulf and extended eastward to Rayong Province. This is quite understandable because the Upper Gulf of Thailand and Rayong are considered the most busiest sea routes in the Gulf, for large cargo vessels and tankers as well as small crafts. There are also several large cities and industrial eatates in this area. The second area is the coastal water off the city of Songkhla and Pattani Provinces. This area also consists of deep-sea ports and several fish-landing piers which can be the significant distribution sources of petroleum hydrocarbons. Cities, towns and industries along the coast culd contribute additional land-based source of hydrocarbons to the coastal waters.

Two offshore areas where high concentrations of petroleum hydrocarbon were found were the area near the mouth of the Gulf that opens to the South China Sea and extends inward to the center of the Gulf, and the offshore area off the coast of the State of Johor. This result was quite controver-

Table 2. Water content (%) and total organic carbon (%) in sediments

Station	% water	% organic carbon
1	26.56	0.2
3	38.66	0.55
12	51.75	0.24
20	34.13	0.67
24	45.19	1.13
40	31.94	0.69
44	36.93	0.27
46	47.48	0.57

Table 3. Petroleum hydrocarbons in sediments (ug/g dry weigth)

Station	Total identified n-alkanes	Total identidied PAHs	Total HC
1	0.12	0.06	0.18
3	0.05	0.28	0.33
12	0.04	0.02	0.06
20	1.36	0.04	1.40
24	0.10	0.04	0.14
40	0.12	0.01	0.13
44	0.05	0.10	0.15
46	0.34	0.08	0.42
range	0.04-1.36	0.01-0.28	0.06-1.40
mean	0.27	0.08	0.35
S.D.	0.45	0.09	0.44

Table 4. Polycyclic aromatic hydrocarbons (PAHs) in the Gulf of Thailand sediments (ng/g dry weight).

Chemical	Station							
	1	3	12	20	24	40	44	46
Naphthalene	16.40	49.26	2.32	4.07	22.93	12.68	39.07	20.06
Biphenyl	12.15	41.54	ND	11.25	4.98	ND	10.92	10.65
Phenanthrene	ND	40.47	5.63	12.97	9.90	ND	10.31	11.08
Chrysene	ND	19.95	ND	12.73	ND	ND	ND	30.15
Pyrene	ND	ND	ND	ND	ND	ND	ND	7.33
Perylene	ND	88.02	ND	ND	ND	ND	37.71	ND
Benzo(ghi)perylene	30.18	43.29	13.26	ND	ND	ND	ND	ND
Total	58.73	282.5	21.21	41.02	37.81	12.68	98.01	79.27

ND = not detectable

sial at the bigining since we expected the offshore area to be less "polluted" than the coastal area. However, this finding supports a previous study by Wattayakorn (1986) that concentration of petroleum hydrocarbons in offshore water in the Gulf was higher than in coastal waters.

In addition to those in seawater, petroleum hydrocarbon in offshore sediments (Stations 12, 20, 44, and 46) were also higher than that at coastal staions (Stations 1, 3, 24 and 40). From the results of seawater and sediments of this study, we suspect that offshore activities, such as navigation in the South China Sea sea-routes and offshore oil exploration and production, might leave some measurable impacts on water and sediments. However, we can not rule out the highly probable hypothesis that the circulation pattern of the Gulf could cause petroleum hydrocarbon to be redistributed accumulated in the central region surface water. As chemical degradation proceeds, petroleum hydrocarbons in the water could be assimilated into the particulate phases and eventually deposited in sediments.

Conclusions

1) Concentration of petroleum hydrocarbons in seawater found in this study was not sinificantly different than that reported for 15 years ago for the same general locations.
2) Land and harbor based sources could be important for coastal areas near the Upper Gulf of Thailand, and Rayong, Songkhla and Pattani Provinces.
3) Concentration of petroleum hydrocarbons in water and sediments at some offshore stations in the Gulf of Thailand and the South China Sea appeared to be higher than at most coastal stations. Offshore sources as well as physical oceanography of the area might be attributed to this observation.

References

Hungspreugs, M. 1979. Petroleum hydrocarbons in seawater at 1 meter depth in the Gulf of Thailand using spectrofluorescense. Project Report, Department of Marine Science, Chulalongkorn University, Bangkok.

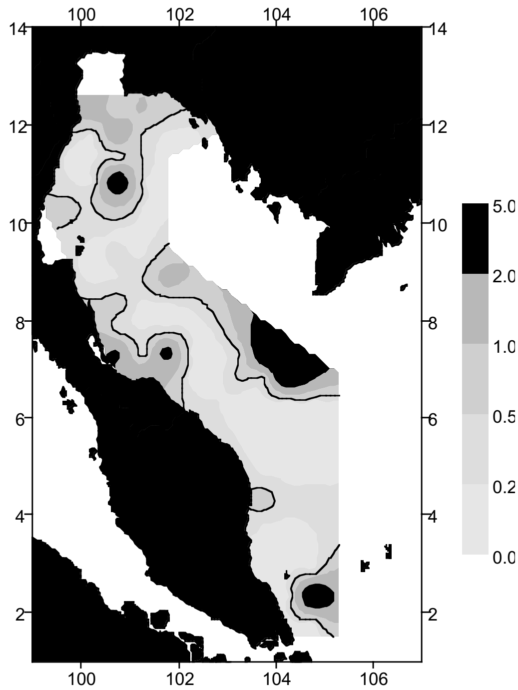


Fig. 1. Distribution of petroleum hydrocarbon in seawater in the Gulf of Thailand (contoured by Krigging). The 0.5 mg/l in chrysene equivalent contour lines are shown.

Intarapanich, O. 1979. Beach tar and petroleum hydrocarbon in water and sediment. Special Problem Report, Department of Marien Science, Chulalongkorn University, Bangkok.

IOC-UNESCO, 1984. Manual for monitoring oil and dissolved/disperse petroleum hydrocarbon in marine water an don beaches IOC Manual and Guides Number 3. Paris: IOC-UNESCO.

Law, A. T. and Mahmood, Z. B. 1986. Distribution of petroleum hydrocarbon in the south-western portion of the South China Sea. Ekspedisi Matahari '86, pp. 53-60

Petpiroon, S. 1988. Petroleum hydrocarbon in seawater of the east coast (Pattaya-Trad). Eastern Marine Fisheries Development Center s\Scientific Report Number 5/2531.

Silpipat, S. and Ehrhardt, M. 1986. Petroleum hydrocarbon pollutant in the Gulf of Thailand. Paper presented at the Third National Marine Science Seminar, 6-8August 1986, National Research Council of Thailand.

Sompongchaiyakul, P. and Lim, S. 1983. Petroleum hydrocarbon in the Upper Gulf of Thailand. Special Problem Report, Department of Marine Science, Chulalongkorn University, Bangkok.

Suthanarak, P. 1991. Petroleum hydrocarbon in the marine environment around ship-breaking industry area, Map Ta Phud, Rayong Province. Master's Thesis, Chulalongkorn University.

Wattayakorn, G. 1986. Petroleum hydrocarbon in seawater and sediments in the Gulf of Thailand. Paper presented at the Third National Marine Science Seminar, 6-8 August 1986, National Research Council of Thailand.

Watayakorn, G. 1987. Distribution of petroleum residues in surficial sediments from the Gulf of Thailand. Paper presented at the Specialised Conference on Coastal and Estuarine Pollution, Kyushu University/IAWPRC/JSWPR, October 19-21, 1987.

Wongnapapan, P. 1996. Petroleum hydrocarbons in water and sediments from the lower Gulf of Thailand. Special Problem Report, Department of Marine Science, Chulalongkorn University, Bangkok.

Distribution, Abundance and Species Composition of Phytoplankton in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Sopana Boonyapiwat

Reprinted from

Proceedings of the First Technical Seminar on

Marine Fishery Resources Survey in

the South China Sea, Area I:

Gulf of Thailand and East Coast of Peninsular Malaysia.

24-26 November 1997, Bangkok, Thailand.

Distribution, Abundance and Species Composition of Phytoplankton in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Sopana Boonyapiwat

Oceanic Fisheries Division, Department of Fisheries,
Paknam, Samut Prakan 10270, Thailand.

ABSTRACT

Phytoplankton samples were collected from 81 stations in the Gulf of Thailand and the east coast of Peninsular Malaysia during pre-northeast monsoon season (4 Sept. - 4 Oct. 1995) and the post-northeast monsoon season (23 Apr. - 23 May 1996). Two hundred and sixty taxa, composed of 2 species of blue green alga, 133 species of diatoms and 107 species of dinoflagellates, were identified. One species of blue green algae and 17 species of diatoms dominated the population in the study area. The dominant species most frequently found were *Oscillatoria erythraea, Thalassionema frauenfeldii, Chaetoceros lorenzianus* and *C. compressus*. The greatest phytoplankton bloom occurred by the highest cell density of *Skeletonema costatum* in the post-monsoon season near the end of Peninsular Malaysia. The toxic dinoflagellates were found with low cell densities. Species diversity indices (richness indices, diversity indices and evenness indices) were high in the coastal areas in the post-monsoon season.

Key words : Phytoplankton, South China Sea, Gulf of Thailand, Peninsular Malaysia.

Introduction

Phytoplankton is a vital and important organism as a producer of the primary food supply of the sea. Data of abundance, distribution and species composition of phytoplankton are very necessary for the study of marine ecosystems. Phytoplankton in the Gulf of Thailand have been studied for a long time. The earliest observations of dioflagellates and diatoms in this area were reported by Schmidt (1901) and Ostenfeld (1902), respectively. The investigations of phytoplankton ecology and taxonomy were carried out mostly in estuarine waters, coastal areas and the upper part of the Gulf of Thailand (Rose, 1926; Boonyapiwat, 1978, 1982 b, 1983, 1984; Suvapepun, 1979; Bhovichitra and Manowejbhan, 1981, 1984; Suvapepun *et al*., 1980; Wongrat, 1982; Piromnim, 1984; Piyakarnchana *et al*., 1991). Phytoplankton species and distribution in some deep areas of the Gulf were studied by Silathornvisut (1961), Boonyapiwat (1982a, 1986) Boonyapiwat *et al.*(1984), Piromnim (1985). In addition, Pholpunthin (1987) identified species of some dinoflagellate families and Boonyapiwat (1987) studied the distribution of the large diatom species, *Thalassiosira thailandica*, in almost the whole area of the Gulf.

Species diversity indices are used to characterize species abundance relationships in communities. Diversity is composed of two components. The first being the number of species in the community; ecologists refer to this as species richness and the second component is species evenness which refers to how the species abundances are distributed among the species . The indices for characterizing species richness and evenness are richness indices and evenness indices (Ludwig and Reynolds, 1988). Boonyapiwat (1978, 1982 a,b) examined the diversity indices of phytoplankton in the Chao Phraya Estuary and the middle Gulf and found that these were very low during phytoplankton blooms. The richness and evenness index in the Gulf have never been reported.

This present study is the first investigation of abundance, species composition and distribution of phytoplankton, including species diversity indices in the Gulf of Thailand down to the east coast of Peninsular Malaysia. The wide distribution of species some of which may be important for the red tide phenomenon and will be of benefit for studies of the marine fisheries of Thailand and Malaysia.

The objectives of this study were :

1) to identify phytoplankton species and their distribution.
2) to study species abundance.
3) to describe the species diversity indices.

Materials and Methods

Phytoplankton Sampling Survey, Cell Count and Identification

Phytoplankton sampling surveys were carried out on board M.V. SEAFDEC at 80 stations during the pre-northeast monsoon season (4 Sept. - 4 Oct. 1995) and at 81stations during the post-northeast monsoon season (23 Apr. - 23 May 1996)(Fig. 1). The samples were collected by a Van Dorn water sampler at 2-4 m below the sea surface. Twenty to fifty litres of the water samples were filtered through a phytoplankton net (20 µm mesh size) and preserved in a 2%formalin/sea water mixture. The samples were concentrated by precipitation. Cell count and identification were made by using a small counting slide, compound microscope fitted with a phase contrast device and an electron microscope. A filament count was done for only blue green algae.

Species Diversity Indices

The species diversity indices composed of the richness index (R), diversity index (H′) and evenness index (E) are described following the methods in Ludwig and Reynolds (1988). The

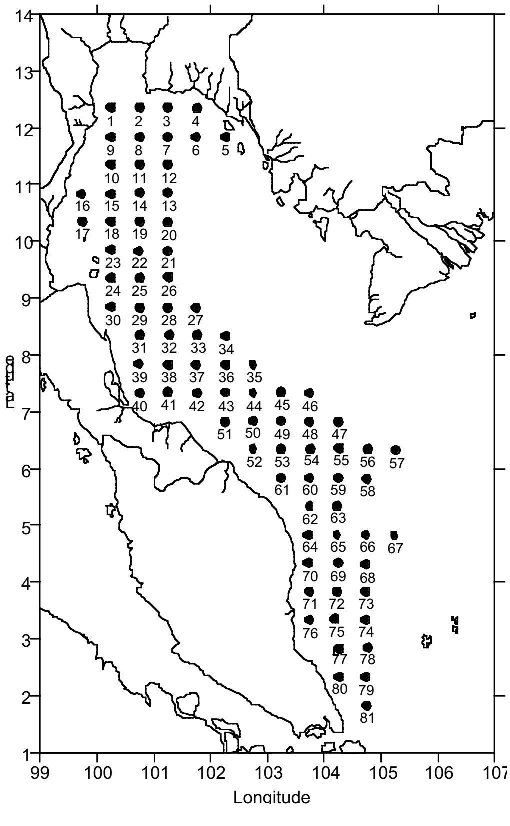


Fig. 1. Area and station of collaborative research survey in the Gulf of Thailand and east coast of Peninsular Malaysia.

Menhinick index, Shannon index and the modified Hill's ratio were used to calculate the richness index, diversity index and evenness index, respectively. The equations are as follows :

$$R = \frac{N}{\sqrt{n}}$$

$$H' = -\sum_{i=1}^{s}[(n_i / n) \ln(n_i / n)]$$

$$E = \frac{(1/\lambda) - 1}{e^{H'} - 1}$$

$$\lambda = \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{n(n-1)}$$

S, the total number of species
n, the total number of individuals
n_i, the number of individuals of the i th species

Results

Identification

A total of 260 taxa, composed of 2 genera, 2 species of blue green alga, 55 genera, 133 species of diatoms and 30 genera, 107 species of dinoflagellates, were identified. The taxonomic list is given in Table 1.

Abundance and distribution

Pre-monsoon season

Phytoplankton in the upper part of the Gulf of Thailand was abundant, and the highest cell count was found near the west coast (Fig. 2). Cell densities at the coastal area of the lower part of the Gulf were rather low, but were higher from the station near Pattani Bay to the coast of Peninsular Malaysia. The ranges of cell density in the Gulf of Thailand and East Coast of Peninsular Malaysia were 214-33,520 and 135-8,180 cells/l, respectively.

Blue green algae was abundant near the east coast of the Gulf of Thailand, off-shore areas of the lower Gulf and the east coast of Peninsular Malaysia (Fig. 3).

Diatoms were the main group of phytoplankton. Fig. 4 shows diatom distribution which is very similar to Fig. 2. Thus, total phytoplankton and diatom cell densities seemed to have the same pattern of distribution.

The upper Gulf of Thailand was rich in dinoflagellate cell density near the coastal areas and the highest abundance was distinct at the west coast as shown in Fig. 5. Low cell densities were found in the lower Gulf through to Malaysian waters and were higher at the lower part of Peninsular Malaysia.

Post-monsoon season

Phytoplankton densities in the coastal zones of the whole study area were higher than those in the off-shore stations, as shown in Fig. 6. Greater abundance was found in Malaysian waters where

Table 1. The taxonomic list of phytoplankton identified :

Phylum Cyanophyceae (Blue green algae)

Calothrix crustacea Schousboe & Thuret
Oscillatoria (Trichodesmium) erythraea (Ehrenberg) Kutzing

Phylum Bacillariophyceae (Diatom)

Actinocyclus spp.
Actinoptychus senarius (Ehrenberg) Ehrenberg
A. splendens (Shadbolt) Ralfs
Asterionellopsis glacialis (Castracane) F.E. Round
Asterolampra marylandica Ehrenberg
Asteromphalus elegans Greville
A. heptactis (Bre´bisson) Greville
A. flabellatus (Bre´bisson) Greville
Azpeitia nodulifera (A. Schmidt) G. Fryxell & P.A. Sims
Bacillaria paxillifera (O.F. Muller) Hendey
Bacteriastrum comosum Pavillard
B. delicatulum Cleve
B. elongatum Cleve
B. furcatum Shadbolt
B. hyalinum Lauder
B. minus Karsten
Campylodiscus sp.
Campylosira sp.
Cerataulina bicornis (Ehrenberg) Hasle
C. pelagica (Cleve) Hendey
Chaetoceros aequatorialis Cleve
C. affinis Lauder
C. anastomosans Grunow
C. atlanticus Cleve
C. brevis Schütt
C. coarctatus Lauder
C. compressus Lauder
C. constrictus Gran
C. costatus Pavillard
C. curvisetus Cleve
C. dadayi Pavillard
C. debilis Cleve
C. decipiens Cleve
C. densus (Cleve) Cleve
C. denticulatus Lauder
C. dichaeta Ehrenberg
C. didymus Ehrenberg
C. distans Ehrenberg
C. diversus Cleve
C. laciniosus Schütt
C. laevis Leuduger - Fortmorel
C. lorenzianus Grunow
C. messanensis Castracane
C. nipponicus Ikari
C. paradoxus Cleve
C. peruvianus Brightwell
C. pseudocurvisetus Mangin
Chaetoceros pseudodichaeta Ikari
C. rostratus Lauder
C. setoensis Ikari
C. simplex Ostenfeld
C. socialis Lauder
C. subtilis Cleve
C. sumatranus Karsten
C. tetrastichon Cleve
C. tortissimus Gran
C. wighamii Brighwell
C. weissflogii Schutt
C. vanheurecki Gran
Climacodium biconcavum Cleve
C. frauenfeldianum Grunow
Corethron hystrix Hensen
Coscinodiscus centralis Ehrenberg
C. concinnus W. Smith
C. gigas Ehrenberg
C. granii Gough
C. jonesianus (Greville) Ostenfeld
C. perforatus Ehrenberg
C. radiatus Ehrenberg
C. weilesii Gran & Angst
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin
Dactyliosolen blavyanus (H. Peragallo) Hasle
D. fragilissimus (Bergon) Hasle
D. phuketensis (Sundstrom) Hasle
Detonula pumila (Castracane) gran
Ditylum brightwelii (West) Grunow
D. sol Grunow
Entomoneis sp.
Eucampia cornuta (Cleve) Grunow
E. zodiacus Ehrenberg
Fragilaria sp.
Fragilariopsis doliolus (Wallich) Medlin & Sims
Guinardia cylindrus (Cleve) Hasle
G. flaccida (Castracane) H. Peragallo
G. striata (Stolterfoth) Hasle
Gossleriella tropica Schütt
Gyrosigma sp.
Halicotheca thamensis (Shrubsole) Ricard
Haslea gigantea (Hustedt) Simonsen
H. wawrikae (Hustedt) Simonsen
Hemiaulus hauckii Grunow
H. indicus Karsten
H. membranacea Cleve
H. sinensis Greville
Hemidiscus cuneiformis Wallich

Table 1. (cont.)

Luaderia annulata Gran
Leptocylindrus danicus Cleve
L. mediterraneus (H. Peragallo) Hasle
Lioloma delicatulum (Cupp) Hasle
L. elongatum (Grunow) Hasle
Lithodesmium undulatum Ehrenberg
Meuniera membranacea (Cleve) P.C. Silva
Navicula spp.
Neostreptotheca subindica Von Stosch
N. torta Von Stosch
Nitzschia longissima (Brébisson) Ralfs
N. bicapitata Cleve
Odontella mobiliensis (Bailey) Grunow
O. sinensis (Bailey) Grunow
Palmeria hardmaniana Greville
Planktoniella blanda (A. Schmidt) Syvertsen & Hasle
P. sol (Wallich) Schütt
Pleurosigma sp.
Proboscia alata (Brightwell) Sundström
Pseudoguinardia recta Von Stosch
Pseudo-nitzschia pseudodelicatissima (Hasle) Hasle
P. pungens (Grunow & Cleve) Hasle
Pseudosolenia calcar-avis (chultz) Sundström
Rhizosolenia acuminata (H. Peragallo) Gran
R. bergonii H. Peragallo
R. clevei Ostenfeld
R. curvata Zacharias
R. formosa H. Peragallo
R. hyalina Ostenfeld
R. imbricata Brightwell
R. robusta Norman
R. setigara Brightwell
R. styliformis Brightwell
Skeletonema costatum (Greville) Cleve
Stephanopyxis palmeriana (Greville) Grunow
Striatella sp.
Thalassionema frauenfeldii (Grunow) Hallegraeff
T. javanicum (Grunow in Van Heurck) Hasle
T. nitzschioides (Grunow) Mereschkowsky
Thalassiothrix longissima Cleve & Grunow
Thalassiosira bingensis Takano
T. dipporocyclus Hasle
T. eccentrica (Ehrenberg) Cleve
T. oestrupii (Ostenfeld) Hasle
T. subtilis (Ostenfeld) Gran
T. thailandica Boonyapiwat
Triceratium favus Ehrenberg

Phylum Dinophyceae (Dinoflagellate)

Alexandrium fraterculus (Balech) Balech
A. tamarense (Lebour) Balech
A. tamiyavanichi Balech
Amphidinium spp.
Amphisolenia bidentata Schroder
A. globifera Stein
Amphisolenia schauinslandii Lemmermann
Ceratium arietinum Cleve
C. azoricum Cleve
C. belone Cleve
C. biceps Claparede & Lachmann
C. boehmii Graham & Bronikosky
C. candelabrum (Ehrenberg) Stein
C. carriense Gourret
C. concillans Jörgensen
C. contortum Gourret
C. declinatum (Karsten) Jörgensen
C. deflexum (Kofoid) Jörgensen
C. dens Ostenfeld & Schmidt
C. falcatum (Kofoid) Jörgensen
C. furca (Ehrenberg) Claparede & Lachmann
C. fusus (Ehernberg) Dujardin
C. gibberum Gourret
C. hexacanthum Gourret
C. horridum (Cleve) Gran
C. incisum (Karsten) Jörgensen
C. inflatum (Kofoid) Jörgensen
C. kofoidii Jörgensen
C. longinum Karsten
C. limulus Gourret
C. lunula (Schimpe) Jörgensen
C. macroceros (Ehernberg) Vanholf
C. massiliense (Gourret) Karsten
C. pentagonum Gourret
C. praelongum (Lemmerman) Kofoid
C. pulchellum Schroder
C. ranipes Cleve
C. schmidtii Jörgensen
C. symmetricum Pavillard
C. teres Kofoid
C. trichoceros (Ehrenberg) Kofoid
C. tripos (O.F. Muller) Nitzsch
C. vulture Cleve
Ceratocorys horrida Stein
Corythodinium tesselatum (Stein) Loeblich Jr. & Loeblich
Dinophysis amygdala Balech
D. caudata Saville - Kent
D. hastata Stein
D. infundibula Schiller
D. miles Cleve
D. schuettii Murray & Whitting
Diplopsalis lenticulata Berg
Dissodium asymmetricum (Mangin) Loeblich
Dissodinium sp.
Fragilidium sp.
Goniodoma polyedricum (Pouchet) Jörgensen
Gonyaulax digitale (Pouchet) Kofoid
G. glyptorhynchus Murray & Whitting
G. polygramma Stein
G. spinifera (Claparede & Lachmann) Diesing
Gymnodinium spp.

Table 1. (cont.)

Gyrodinium spp.	*Protoperidinium conicum* (Gran) Balech
Heterocapsa spp.	*P. crassipes* (Kofoid) Balech
Histioneis spp.	*P. depressum* (Bailey) Balech
Kofoidinium sp.	*P. diabolus* (Cleve) Balech
Lingulodinium polyedrum (Stein) Dodge	*P. divergents* (Ehrenberg) Balech
Noctiluca scintillans (Macartney) Kofoid & Swezy	*P. elegans* (Cleve) Balech
Ornithocercus magnificus Stein	*P. globulum* (Stein) Balech
O. thumii (A. Schmidt) Kofoid & Skogsberg	*P. grande* (Kofoid) Balech
Oxytoxum scolopax Stein	*P. hirobis* (Abe′) Balech
Phalacroma acutoides Balech	*P. latispinum* (Mangin) Balech
P. argus Stein	*P. leonis* (Pavillard) Balech
P. doryphorum Stein	*P. murrayi* (Kofoid) Balech
P. favus Kofoid & Michener	*P. oceanicum* (Vanhoff) Balech
P. mitra Schütt	*P. okamurai* (Abe′) Balech
P. parvulum (Schütt) Jörgensen	*P. ovum* (Schiller) Balech
P. rapa Stein	*P. pallidum* (Ostenfeld) Balech
P. rotundatum (Claparede & Lachmann) Kofoid & Micherner	*P. pellucidum* Bergh
P. rudgei Murray & Whitting	*P. quanerense* (Schroder) Balech
Podolampas bipes Stein	*P. spinulosum* (Schiller) Balech
P. elegans Schütt	*P. steinii* (Jörgensen) Balech
P. palmipes Stein	*P. thorianum* (Paulsen) Balech
P. spinifera Okamura	*Pyrocystis fusiformis* Wyville - Thomson ex Blackmann
Preperidinium meunieri (Pavillard) Elbrachter	*P. hamulus* Cleve
Prorocentrum compressum (Bailey) Abe′ & Dodge	*P. lunula* species complex
P. micans Ehrenberg	*P. noctiluca* Murray ex Haeckel
P. sigmoides Bohm	*Pyrophacus horologium* Stein
	P. steinii (Schiller) Wall & Dale
	Scripsiella trochoidea (Stein) Balech

the cell count reached a maximum that caused a great bloom near the end of the Peninsular Malaysia. The ranges of cell density in Thai waters was 178 - 8,180 cells/l and in Malaysian waters was 234 - 113,336 cells/l.

Blue green algae was abundant in the upper Gulf of Thailand and in the off-shore stations in the lower Gulf. The opposite was true in Malaysian waters, where the blooms were found in the coastal areas (Fig. 7).

As in the pre-monsoon season, the patterns of diatom distribution (Fig. 8) was nearly similar to that of phytoplankton distribution. Phytoplankton bloom in Malaysian waters was dominated by diatom species.

The occurrence of dinoflagellates (Fig. 9) revealed that cell densities in Malaysian waters were higher than those in the Gulf of Thailand. There were no distinct blooms of dinoflagellates in the study area.

Occurrence of dominant species

One species of blue green algae and 17 species of diatoms dominated phytoplankton population in the study area. The illustrations of these species are shown in Fig. 10-12. Fig. 13 shows the occurrence of 9 dominant species in the pre-monsoon season. The greatest abundance of *Thalassionema frauenfeldii* occurred in the coastal areas, whereas, the blue green algae, *Oscillatoria erythraea*, was dominant covering large off-shore areas. *Chaetoceros lorenzianus* reached the maximum cell count in the coastal areas of the upper Gulf of Thailand and the end of Peninsular Malaysia. The highest cell density of *Chaetoceros pseudocurvisetus* and *Coscinodiscus jonesianus* were found in the uppermost part of the study area. *Chaetoceros compressus* was abundant in Pattani Bay and in Malaysian waters. *Bacillaria paxillifera* dominated the entire population in the lower Gulf and the off-shore stations of Peninsular Malaysia while its coastal areas were dominated by *Bacteriastrum comosum*. *Thalassionema nitzschioides* was found as the dominant species in only one station near the east coast of the Gulf of Thailand.

In the post-monsoon season, the occurrence of 15 dominant species, composed of one species of blue green algae, 7 species of *Chaetoceros* and other diatom species, are shown in Fig. 14. Many species such as *Oscillatoria erythraea*, *Thalassionema fruenfeldii* and *C. coarctatus* dominated the population in uncertain areas.*Chaetoceros pseudocurvisetus* was dominant in the same areas as it was in the pre-monsoon season. *Chaetoceros affinis*, *C. didymus* and *Pleurosigma* sp. occurred with highest cell count in the coastal areas of the Gulf of Thailand while *Proboscia alata, Pseudosolenia calcar-avis*, *Bacteriastrum comosum, Chaetoceros peruvianus* and *Cylindrotheca closterium* were abundant in the off-shore areas. *Skeletonema costatum* was abundant only at the end of Peninsular Malaysia.

The dominant species frequently found in this study were *Oscillatoria erythraea*, *Thalassionema frauenfeldii*, *Chaetoceros lorenzianus* and *C. compressus* as shown in Table 2 in which the total phytoplankton cell densities, dominant species, associated species and relative abundance of each station are recorded.

The massive bloom of *Skeletonema costatum* was considered as the most abundant species in the study area. It caused blooms with high relative abundance (90.91%) in maximum total phytoplankton density (113,336 cells/l). The highest relative abundance (91.36%) occurred with the bloom of *Pleurosigma* sp. in the coastal areas of the Gulf where total phytoplankton density was 14,223 cells/l.

For dinoflagellates, no species had high percentages of occurrence. Only one species, *Ceratium fusus*, was found as an associated species among the abundance of *Oscillatoria erythraea* in the off-shore stations of the lower Gulf in the post-monsoon season. In comparison to other dinoflagellates, the toxic dinoflagellates were rarely found. Among them, *Alexandrium tamiyavanichi* was observed with highest cell density (17 cells/l) at station 15 in the pre-monsoon season. The occurrence of *Alexandrium* spp., *Gonyaulax* spp. and *Lingulodinium polyedrum* are shown in Fig. 15-18.

Species diversity indices

The richness index which characterizes species richness reached over 2.5 at stations mainly located far from the coast in the pre-monsoon season. On the other hand, in the post monsoon season high species richnesses were found mostly at the near-shore stations. All of species diversity indices in the pre- and post-monsoon season are shown in Table 3. The range of diversity index in the post-monsoon season was wider than that in the pre-monsoon season. These indices were high in the Gulf of Thailand (Fig. 19 and 20). Low values were found in the coastal areas of the lower Gulf and at the end of the Peninsular Malaysia in the post-monsoon season. In this season, the evenness indices were high except some stations such as station 81 which was situated near the end of Peninsular Malaysia and had very low values.

Discussion and Conclusions

Previous studies of phytoplankton abundance in the Gulf of Thailand revealed that the cell density in the off-shore areas was lower than those in the estuarine and coastal areas. Using an 80 µm mesh size plankton net for collecting samples, Boonyapiwat (1982a) and Boonyapiwat *et al*. (1984) found that the maximum densities in the middle and lower Gulf were 2,800 and 4,380 cells/l and in

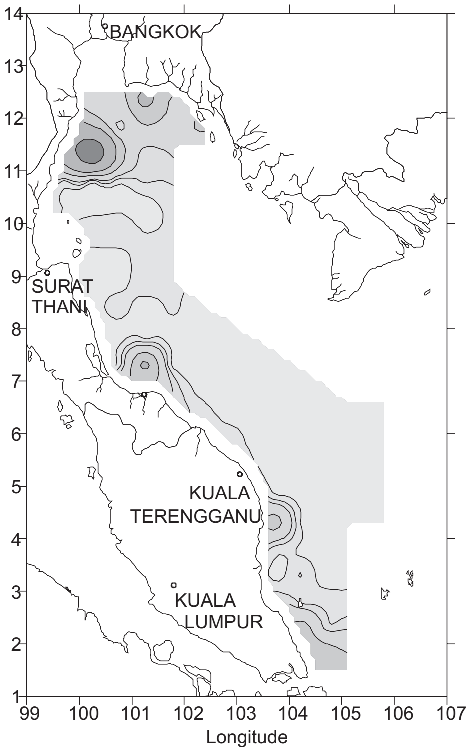


Fig. 2. Total phytoplankton in pre-NE monsoon season in the Gulf of Thailand and eastcoast of Peninsular Malaysia

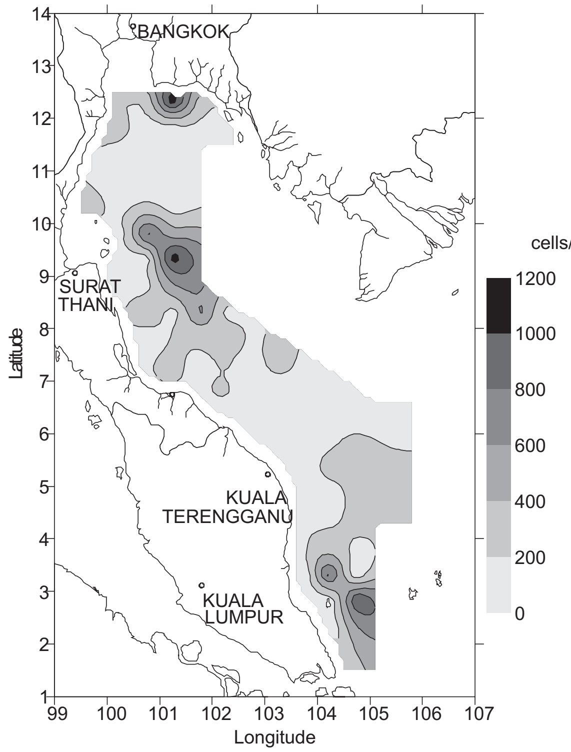


Fig. 3. Distribution of blue green algae in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

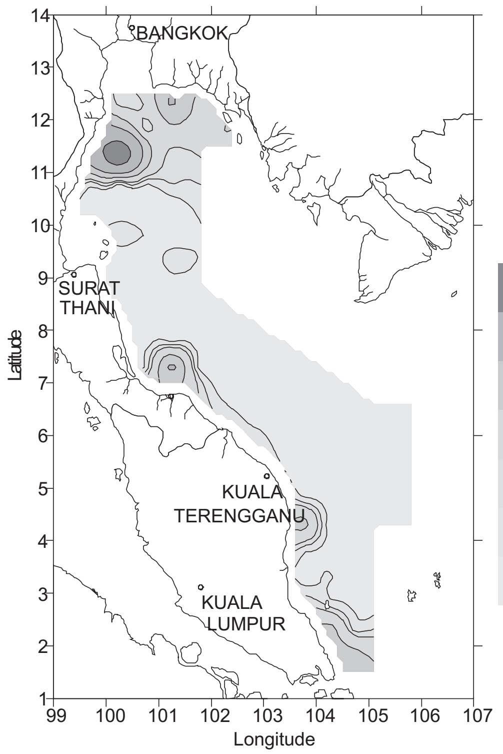


Fig. 4. Distribution of diatom in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

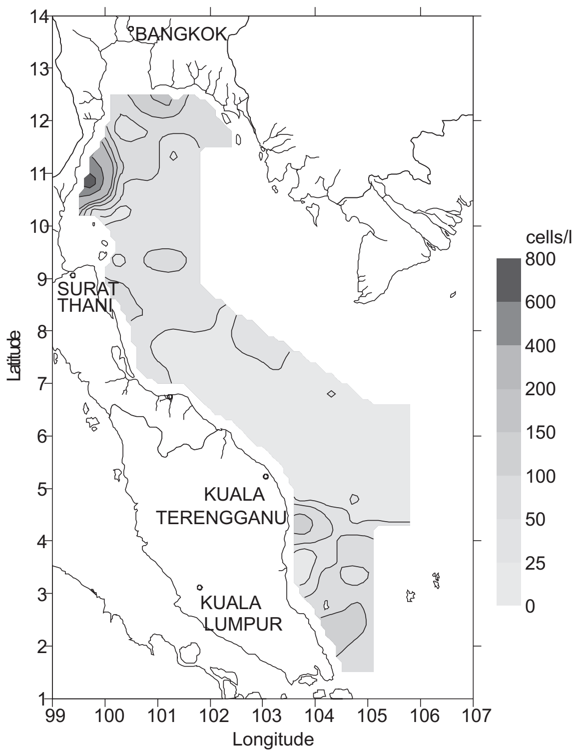


Fig. 5. Distribution of dinoflagellate in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

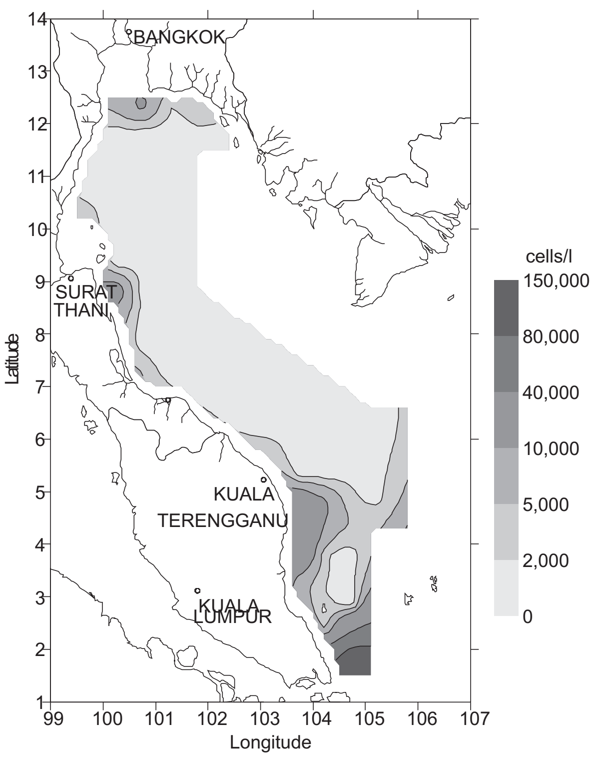


Fig. 6. Total phytoplankton in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

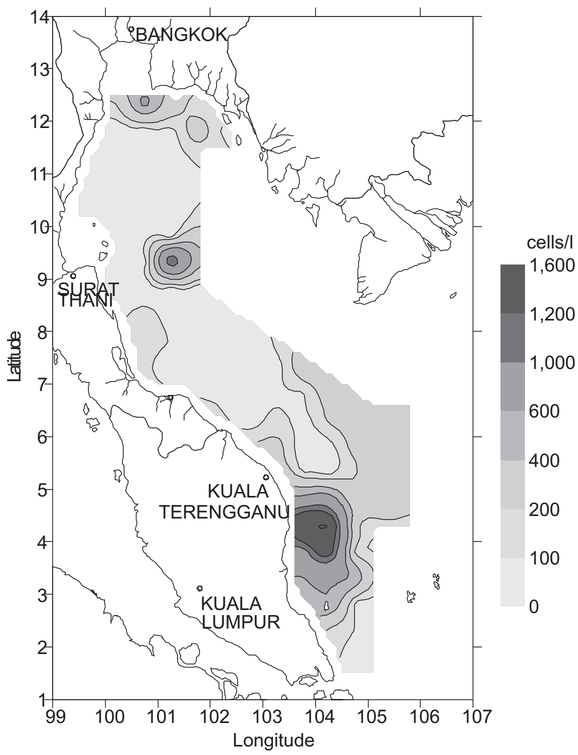


Fig. 7. Distribution of blue green algae in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

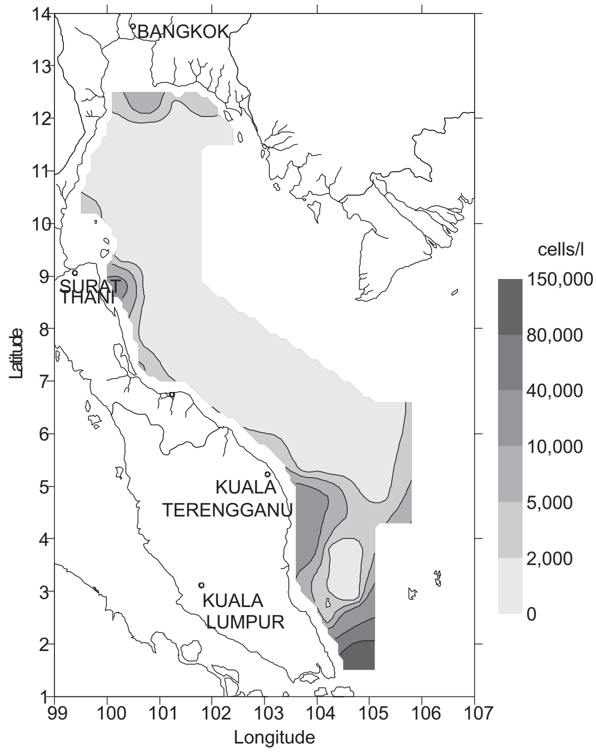


Fig. 8. Distribution of diatom in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

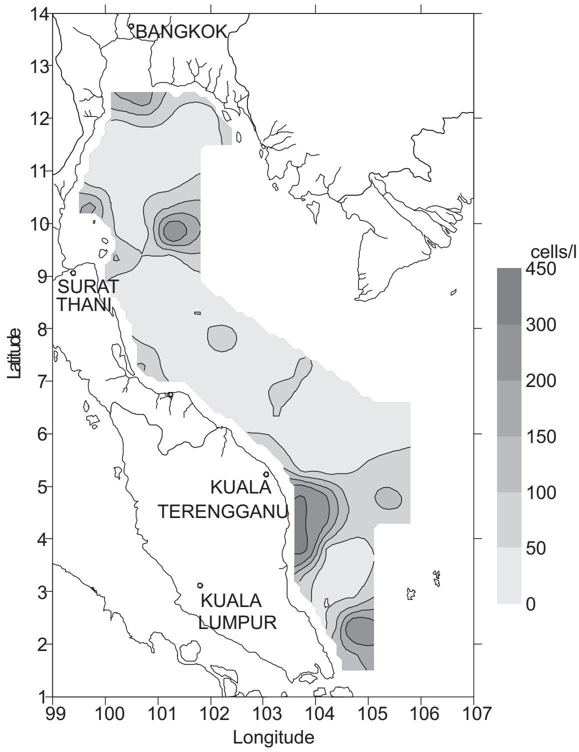


Fig. 9. Distribution of dinoflagellate in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

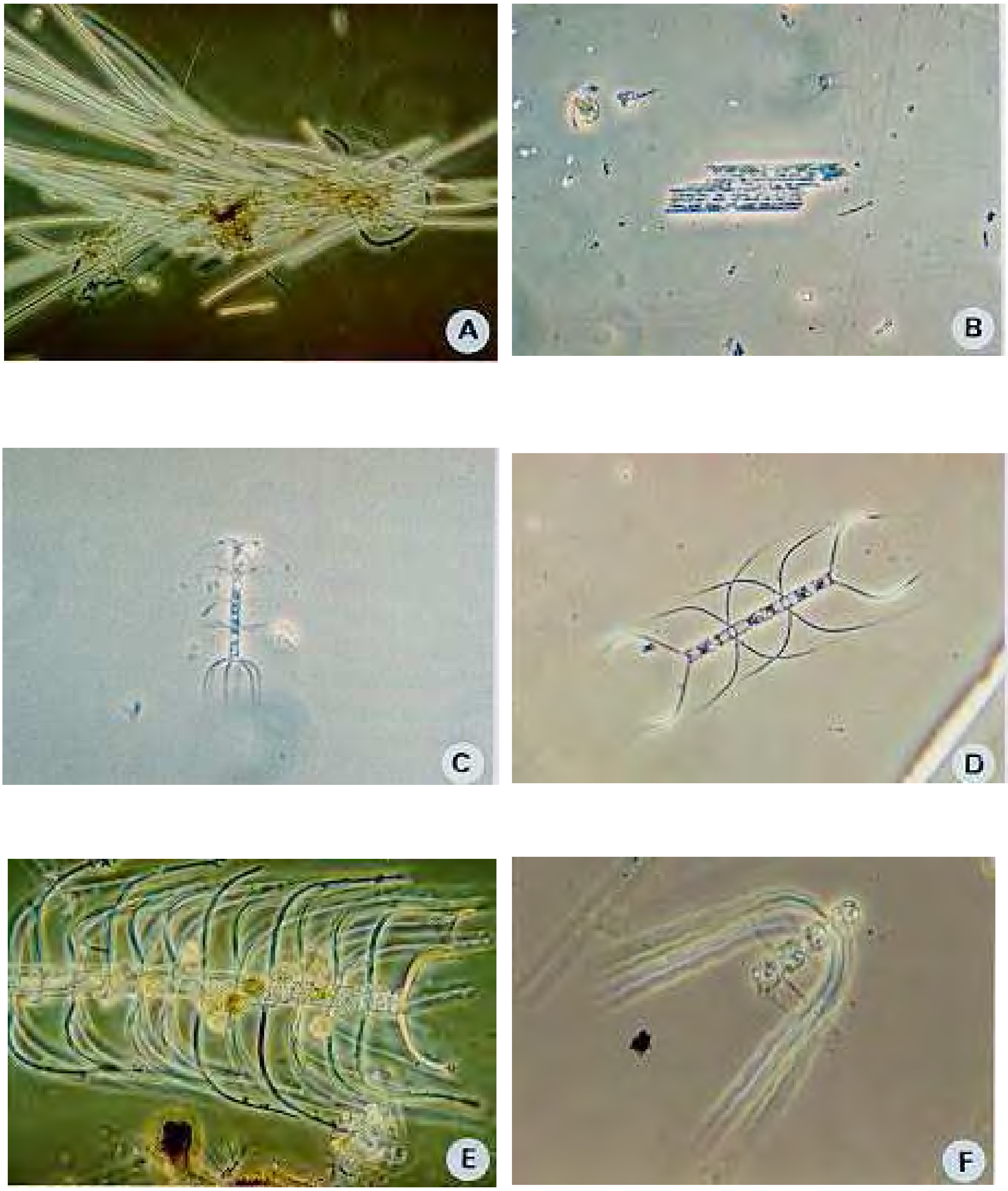


Fig. 10. Dominant phytoplankton species
(A) *Oscillatoria* (*Trichodesmium*) *erythraea*,
(B) *Bacillaria paxillifera* (O.F. Muller) Hendey
(C) *Bacterisatrum comosum* Pavillard
(D) *Chaetoceros affinis* Lauder (Ehrenberg) Kutzing
(E) *C. coarctatus* Lauder
(F) *C. compressus* Lauder

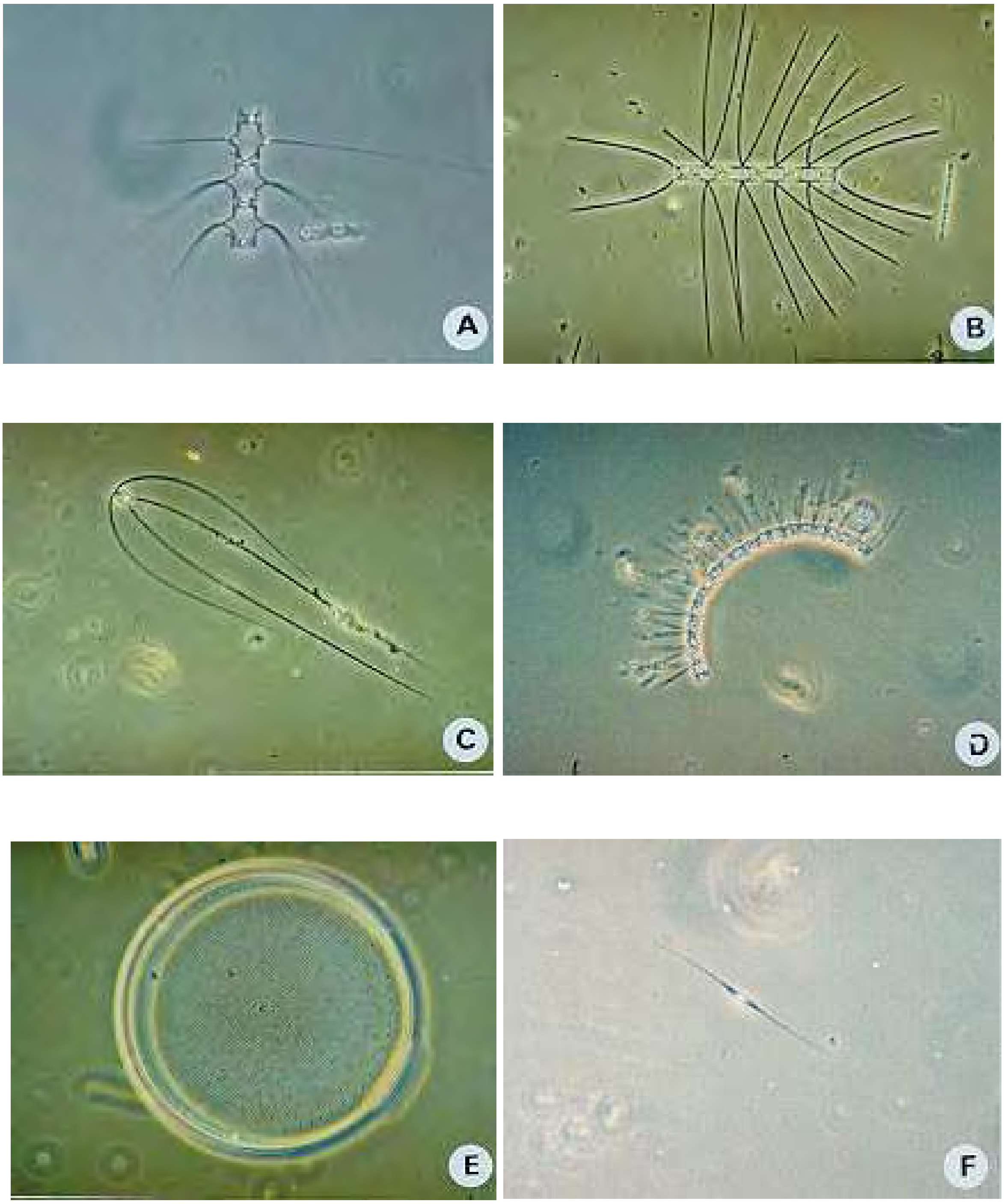


Fig. 11. Dominant phytoplankton species.
(A) *Chaetoceros didymus* Ehrenberg
(B) *C. lorenzianus* Grunow
(C) *C. peruvianus* Brightwell
(D) *C. pseudocurvisetus* Mangin
(E) *Cosinodiscus jonesianus* (Gaeville) Ostenfeld
(F) *Cylindrotheca closterium* (Ehrenberg) Reimann & Lewin

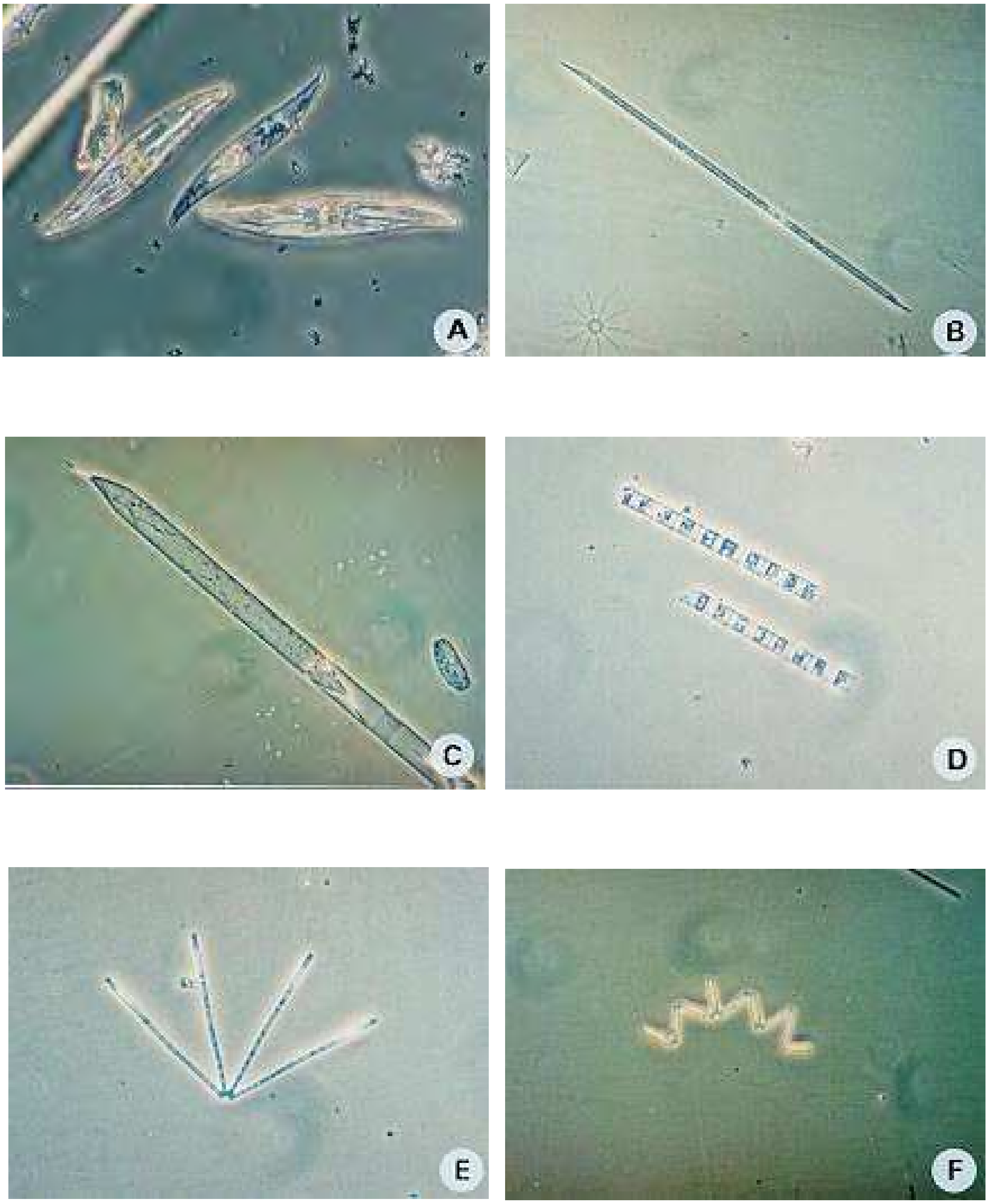


Fig. 12. Dominant phytoplankton species.
(A) *Pleurosigma* sp.
(B) *Proboscia alata* (Brightwell) Sundstrom
(C) *Pseudosolenia calcar-avis* (Schultz) Sundstrom
(D) *Skeletonema costatum* (Greville) Cleve
(E) *Thalassionema fruenfeldii* (Grunow) Hallegraeff
(F) *T. nitzschioides* (Grunow)Mereschkowsky

Table 2. Phytoplankton abundance in the Gulf of Thailand and east coast of Peninsular Malaysia
Pre = Pre-NE monsoon Post = Post-NE monsoon R = Relative abundance

St.	Season	Total	Dominant species		Associated species	
		Phyto.(cells/l)	species	R (%)	species	R (%)
1	Pre	3,176	*Chaetoceros pseudocurvisetus*	17.92	*Thalassionema frauenfeldii*	14.66
	Post	6,069	*Chaetoceros pseudocurvisetus*	10.71	*Thalassiosira thailandica*	10.40
2	Pre	3,560	*Coscinodiscus jonesianus*	13.93	*Chaetoceros pseudocurvisetus*	10.79
	Post	11,488	*Chaetoceros compressus*	19.17	*Chaetoceros lorenzianus*	15.16
3	Pre	12,464	*Cheatoceros lorenzianus*	11.30	*Azpeitia nodulifera*	10.78
	Post	2,034	*Thalassionema frauenfeldii*	36.42	*Oscillatoria erythraea*	13.81
4	Pre	5,276	*Thalassionema frauenfeldii*	27.82	*Thalassionema nitzschioides*	16.91
	Post	3,448	*Thalassionema frauenfeldii*	16.96	*Chaetoceros compressus*	16.17
5	Pre	6,412	*Thalassionema frauenfeldii*	33.25	*Thalassionema nitzschioides*	30.82
	Post	1,363	*Chaetoceros didymus*	48.53	*Chaetoceros compressus*	11.29
6	Pre	4,136	*Thalassionema nitzschioides*	28.72	*Thalassionema frauenfeldii*	24.56
	Post	1,665	*Chaetoceros didymus*	23.43	*Chaetoceros compressus*	19.71
7	Pre	5,701	*Thalassionema frauenfeldii*	24.74	*Thalassionema nitzschioides*	24.37
	Post	453	*Chaetoceros compressus*	19.21	*Oscillatoria erythraea*	12.58
8	Pre	1,926	*Thalassionema frauenfeldii*	18.44	*Bacillaria paxillifera*	15.34
	Post	507	*Chaetoceros compressus*	13.56	*Chaetoceros lorenzianus*	9.92
9	Pre	10,584	*Thalassionema frauenfeldii*	18.44	*Chaetoceros pseudocurvisetus*	15.34
	Post	425	*Chaetoceros lorenzianus*	40.36	*Proboscia alata*	14.35
10	Pre	33,520	*Chaetoceros lorenzianus*	45.01	*Chaetoceros compressus*	15.27
	Post	474	*Chaetoceros compressus*	20.00	*Bacteriastrum comosum*	16.00
11	Pre	8,446	*Thalassionema frauenfeldii*	21.44	*Chaetoceros compressus*	14.76
	Post	329	*Oscillatoria erythraea*	20.19	*Bacteriastrum comosum*	11.88
12	Pre	2,193	*Thalassionema frauenfeldii*	77.97	*Thalassionema nitzschioides*	9.94
	Post	306	*Pseudosolenia calcar-avis*	10.74	*Chaetoceros compressus*	9.40
13	Pre	2,380	*Thalassionema frauenfeldii*	77.94	*Bacillaria paxillifera*	6.55
	Post	258	*Bacteriastrum comosum*	15.87	*Thalassionema frauenfeldii*	14.81
14	Pre	1,382	*Thalassionema frauenfeldii*	30.55	*Bacillaria paxillifera*	16.40
	Post	273	*Thalassionema frauenfeldii*	29.46	*Proboscia alata*	22.32
15	Pre	985	*Thalassionema frauenfeldii*	36.25	*Bacillaria paxillifera*	10.83
	Post	200	*Chaetoceros coarctatus*	19.49	*Oscillatoria erythraea*	14.87
16	Pre	1,603	*Thalassionema frauenfeldii*	32.43	*Pleurosigma sp*	17.88
	Post	209	*Chaetoceros coarctatus*	26.42	*Oscillatoria erythraea*	11.32
17	Pre	986	*Oscillatoria erythraea*	26.94	*Chaetoceros lorenzianus*	14.61
	Post	2,805	*Chaetoceros affinis*	20.73	*Thalassionema frauenfeldii*	19.51
18	Pre	387	*Oscillatoria erythraea*	33.65	*Proboscia alata*	9.62
	Post	203	*Oscillatoria erythraea*	13.42	*Hemiaulus sinensis*	12.41
19	Pre	851	*Oscillatoria erythraea*	29.52	*Chaetoceros lorenzianus*	14.98
	Post	271	*Thalassionema freuenfeldii*	28.30	*Preudosolenia calcar-avis*	14.41
20	Pre	431	*Oscillatoria erythraea*	16.24	*Chaetoceros lorenzianus*	12.82
	Post	336	*Proboscia alata*	25.19	*Pseudosolennia calcar-avis*	18.32
21	Pre	972	*Oscillatoria erythraea*	43.62	*Thalassionema frauenfeldii*	9.47
	Post	576	*Pseudosolenia calcar-avis*	19.35	*Chaetoceros coarctatus*	15.32
22	Pre	1,908	*Oscillatoria erythraea*	45.30	*Chaetoceros lorenzianus*	13.07
	Post	278	*Thalassionema frauenfeldii*	25.75	*Oscillattoria erythraea*	23.95
23	Pre	2,093	*Thalassionema frauenfeldii*	32.27	*Thalassionema nitzschioides*	12.88
	Post	414	*Thalassionema frauenfeldii*	23.76	*Chaetoceros lorenzianus*	15.84
24	Pre	214	*Oscillatoria erythraea*	52.46	*Chaetoceros lorenzianus*	9.84
	Post	756	*Thalassionema fruenfeldii*	11.84	*Proboscia alata*	8.06
25	Pre	393	*Oscillatoria erythraea*	26.11	*Thalassionema frauenfeldii*	24.84
	Post	330	*Thalassionema frauenfeldii*	26.01	*Thalassionema nitzschioides*	16.18

Table 2. (cont.)

St.	Season	Total Phyto.(cells/l)	Dominant species		Associated species	
			species	R (%)	species	R (%)
26	Pre	1,630	*Oscillatoria erythraea*	68.30	*Thalassionema frauenfeldii*	18.00
	Post	1,392	*Oscillatoria erythraea*	93.37	*Chaetoceros coarctatus*	1.57
27	Pre	no sampling	*no sampling*		*no sampling*	
	Post	191	*Pseudosolenia calcar-avis*	18.66	*Chaetoceros didymus*	16.42
28	Pre	1,327	*Oscillatoria erythraea*	43.29	*Thalassionema frauenfeldii*	30.68
	Post	178	*Proboscia alata*	26.03	*Pscudosolenia calcar-avis*	17.81
29	Pre	833	*Oscillatoria erythraea*	15.27	*Chaetoceros lorenzianus*	11.58
	Post	278	*Proboscia alata*	17.11	*Thalassionema frauenfeldii*	12.28
30	Pre	708	*Thalassionema frauenfeldii*	34.07	*Oscillatoria erythraea*	17.58
	Post	14,223	*Pleurosigma sp.*	91.34	*Bacillaria paxillifera*	6.16
31	Pre	1,524	*Bacillaria paxillifera*	30.10	*Oscillatoria erythrea*	23.47
	Post	710	*Oscillatoria erythraea*	22.94	*Thalassionema frauenfeldii*	17.10
32	Pre	376	*Oscillatoria erythraea*	32.94	*Chaetoceros lorenzianus*	13.77
	Post	301	*Chaetoceros coarctatus*	27.49	*Oscillatoria erythraea*	23.70
33	Pre	1,222	*Oscillatoria erythraea*	51.29	*Chaetoceros lorenzianus*	11.75
	Post	568	*Pseudosolenia calcar-avis*	28.99	*Proboscia alata*	28.26
34	Pre	396	*Oscillatoria erythraea*	32.58	*Chaetoceros lorenzianus*	17.68
	Post	364	*Chactoceros compressus*	24.71	*Oscillatoria erythraea*	18.82
35	Pre	313	*Oscillatoria erythraea*	56.80	*Thalassionema frauenfeldii*	8.00
	Post	218	*Chaetoceros lorenzianus*	28.42	*Chaetoceros coarctatus*	21.86
36	Pre	667	*Oscillatoria erythraea*	47.95	*Chaetoceros lorenzianus*	22.40
	Post	257	*Cylindrotheca closterium*	31.88	*Oscillatoria erythraea*	21.74
37	Pre	371	*Oscillatoria erythraea*	64.77	*Chaetoceros lorenzianus*	3.98
	Post	287	*Chaetoceros peruvianus*	27.27	*Oscillatoria erythraea*	18.83
38	Pre	328	*Oscillatoria erythraea*	38.64	*Chaetoceros lorenzianus*	16.29
	Post	271	*Oscillatoria erythraea*	36.08	*Chaetoceros compressus*	23.71
39	Pre	380	*Oscillatoria erythraea*	30.00	*Thalassionema frauenfeldii*	16.32
	Post	452	*Oscillatoria erythraea*	26.54	*Chaetoceros compressus*	19.44
40	Pre	950	*Thalassionema frauenfeldii*	35.58	*Oscillatoria erythraea*	19.37
	Post	4,852	*Chaetoceros lorenzianus*	19.31	*Chaetoceros didymus*	17.45
41	Pre	12,104	*Chaetoceros compressus*	27.61	*Chaetoceros lorenzianus*	21.08
	Post	259	*Oscillatoria erythraea*	28.70	*Chaetoceros compressus*	21.08
42	Pre	339	*Oscillatoria erythraea*	33.02	*Chaetoceros lorenzianus*	14.15
	Post	225	*Oscillatoria erythraea*	21.58	*Thalassionema frauenfeldii*	13.16
43	Pre	280	*Oscillatoria erythraea*	76.92	*Thalassionema frauenfeldii*	8.24
	Post	225	*Thalassionema frauenfeldii*	39.75	*Oscillatoria erythraea*	13.66
44	Pre	289	*Oscillatoria erythraea*	28.82	*Thalassionema frauenfeldii*	13.30
	Post	265	*Oscillatoria erythraea*	38.12	*Chaetoceros didymus*	15.47
45	Pre	491	*Oscillatoria erythraea*	67.93	*Thalassionema frauenfeldii*	4.35
	Post	339	*Thalassionema frauenfeldii*	18.99	*Pseudosolenia calcar-avis*	17.30
46	Pre	234	*Oscillatoria erythraea*	56.86	*Pleurosigma sp.*	9.59
	Post	404	*Oscillatoria erythraea*	77.48	*Ceratium fusus*	6.19
47	Pre	277	*Oscillatoria erythraea*	26.67	*Thalassionema frauenfeldii*	8.33
	Post	453	*Oscillatoria erythraea*	57.56	*Chaetoceros compressus*	9.24
48	Pre	408	*Thalassionema frauenfeldii*	43.14	*Oscillatoria erythraea*	11.34
	Post	198	*Oscillatoria erythraea*	42.25	*Chaetoceros lorenzianus*	18.31
49	Pre	395	*Thalassionema frauenfeldii*	29.96	*Chaetoceros lorenzianus*	7.59
	Post	1,965	*Chaetoceros lorenzianus*	37.54	*Chaetoceros compressus*	11.08
50	Pre	592	*Thalassionema frauenfeldii*	44.32	*Chaetoceros lorenzianus*	13.51
	Post	286	*Oscillatoria erythraea*	35.50	*Chaetoceros lorenzianus*	21.50

Table 2. (cont.)

St.	Season	Total	Dominant species		Associated species	
		Phyto.(cells/l)	species	R (%)	species	R (%)
51	Pre	748	*Oscillatoria erythraea*	30.88	*Thalassionema frauenfeldii*	17.97
	Post	376	*Oscillatoria erythraea*	25.10	*Thalassionema frauenfeldii*	13.31
52	Pre	806	*Thalassionema frauenfeldii*	22.47	*Chaetoceros compressus*	11.99
	Post	256	*Chaetoceros lorenzianus*	39.27	*Pseudosolenia calcar-avis*	10.18
53	Pre	954	*Thalassionema frauenfeldii*	40.99	*Oscillatoria erythraea*	12.73
	Post	760	*Thalassionema frauenfeldii*	31.56	*Oscillatoria erythraea*	17.95
54	Pre	135	*Oscillatoria erythraea*	32.95	*Climacodium fruenfeldianum*	10.23
	Post	263	*Oscillatoria erythraea*	24.76	*Chaetoceros compressus*	10.95
55	Pre	301	*Oscillatoria erythraea*	23.65	*Cylindrotheca closterium*	11.58
	Post	362	*Oscillatoria erythraea*	59.54	*Rhizosolenia styliformis*	11.18
56	Pre	199	*Oscillatoria erythraea*	33.78	*Thalassionema frauenfeldii*	22.97
	Post	544	*Oscillatoria erythraea*	51.44	*Pseudosolenia calcar-avis*	12.07
57	Pre	455	*Bacillaria paxillifera*	31.76	*Thalassionema frauenfeldii*	18.24
	Post	479	*Oscillatoria erythraea*	59.18	*Chaetoceros compressus*	18.08
58	Pre	432	*Oscillatoria erythraea*	66.90	*Pseudosolenia calcar-avis*	7.83
	Post	436	*Oscillatoria erythraea*	59.02	*Chaetoceros lorenzianus*	13.11
59	Pre	302	*Oscillatoria erythraea*	52.00	*Thalassionema frauenfeldii*	9.00
	Post	234	*Oscillatoria erythraea*	25.60	*Chaetoceros coarctatus*	16.67
60	Pre	155	*Oscillatoria erythraea*	56.31	*Thalassionema frauenfeldii*	9.71
	Post	313	*Chaetoceros coarctatus*	13.75	*Oscillatoria erythraea*	12.27
61	Pre	869	*Thalassionema frauenfeldii*	17.70	*Chaetoceros compressus*	14.71
	Post	2,908	*Chaetoceros lorenzianus*	24.93	*Proboscia alata*	8.88
62	Pre	347	*Thalassionema frauenfeldii*	26.92	*Oscillatoria erythraea*	26.50
	Post	426	*Oscillatoria erythraea*	27.52	*Chaetoceros lorenzianus*	15.77
63	Pre	470	*Oscillatoria erythraea*	63.09	*Thalassionema frauenfeldii*	6.31
	Post	321	*Pseudosolenia calcar-avis*	26.67	*Oscillatoria erythraea*	11.11
64	Pre	764	*Thalassionema frauenfeldii*	35.81	*Chaetoceros compressus*	9.33
	Post	17,321	*Chaetoceros lorenzianus*	21.54	*Chaetoceros compressus*	18.46
65	Pre	194	*Thalassionema frauenfeldii*	26.72	*Oscillatoria erythraea*	25.19
	Post	10,614	*Chaetoceros lorenzianus*	26.25	*Thalassionema frauenfeldii*	20.21
66	Pre	410	*Oscillatoria erythraea*	70.21	*Thalassionema frauenfeldii*	6.38
	Post	2,842	*Chaetoceros lorenzianus*	16.17	*Thalassionema frauenfeldii*	11.19
67	Pre	349	*Oscillatoria erythraea*	72.61	*Proboscia alata*	5.94
	Post	1,673	*Oscillatoria erythraea*	21.33	*Pseudosolenia calcar-avis*	13.32
68	Pre	433	*Oscillatoria erythraea*	62.11	*Thalassionema frauenfeldii*	13.04
	Post	4,696	*Chaetoceros lorenzianus*	28.37	*Thalassionema frauenfeldii*	18.34
69	Pre	480	*Oscillatoria erythraea*	35.90	*Thalassionema frauenfeldii*	14.10
	Post	8,671	*Oscillatoria erythraea*	18.75	*Chaetoceros lorenzianus*	10.71
70	Pre	8,180	*Bacteriatrum comosum*	21.27	*Bacteriatrum furcatum*	17.11
	Post	19,810	*Chaetoceros compressus*	16.88	*Chaetoceros lorenzianus*	11.25
71	Pre	1,292	*Thalassionema frauenfeldii*	20.48	*Oscillatoria erythraea*	13.57
	Post	21,168	*Thalassionema frauenfeldii*	17.01	*Chaetoceros lorenzianus*	16.33
72	Pre	741	*Oscillatoria erythraea*	41.61	*Thalassionema frauenfeldii*	17.13
	Post	2,860	*Oscillatoria erythraea*	48.95	*Chaetoceros diversus*	5.59
73	Pre	542	*Oscillatoria erythraea*	26.19	*Chaetoceros coarctatus*	14.29
	Post	1,096	*Chaetoceros lorenzianus*	13.44	*Thalassionema frauenfeldii*	13.04
74	Pre	205	*Chaetoceros compressus*	28.09	*Chaetoceros coarctatus*	8.99
	Post	1,490	*Oscillatoria erythraea*	31.06	*Chaetoceros coarctatus*	12.34
75	Pre	2,270	*Oscillatoria erythraea*	38.83	*Thalassionema frauenfeldii*	17.35
	Post	2,936	*Oscillatoria erythraea*	19.30	*Chaetoceros lorenzianus*	15.41

Table 2. (cont.)

St.	Season	Total Phyto.(cells/l)	Dominant species		Associated species	
			species	R (%)	species	R (%)
76	Pre	311	*Thalassionema frauenfeldii*	18.32	*Chaetoceros lorenzianus*	11.88
	Post	8,047	*Thalassionema frauenfeldii*	27.30	*Proboscia alata*	16.16
77	Pre	1,209	*Thalassionema frauenfeldii*	32.84	*Chaetoceros lorenzianus*	6.86
	Post	4,210	*Thalassionema frauenfeldii*	21.85	*Oscillatoria erythraea*	14.25
78	Pre	1,656	*Oscillatoria erythraea*	62.61	*Chaetoceros coarctatus*	5.88
	Post	1,528	*Chaetoceros lorenzianus*	25.37	*Thalassionema frauenfeldii*	12.31
79	Pre	1,880	*Oscillatoria erythraea*	29.26	*Thalassionema frauenfeldii*	18.62
	Post	43,036	*Skeletonema costatum*	46.95	*Chaetoceros lorenzianus*	14.15
80	Pre	7,463	*Chaetoceros lorenzianus*	13.73	*Thalassionema frauenfeldii*	11.87
	Post	5,418	*Chaetoceros lorenzianus*	27.46	*Thalassionema frauenfeldii*	13.39
81	Pre	7,838	*Thalassionema frauenfeldii*	53.97	*Thalassiosira subtilis*	11.97
	Post	113,336	*Skeletonema costatum*	90.91	*Chaetoceros lorenzianus*	2.22

the Chao Phraya Estuary (reported by Boonyapiwat (1984)) was 38 x 10^6 cells/l. For this present study, with the use of a smaller mesh size net (20 µm), the ranges of phytoplankton density in the pre- and post-monsoon seasons were 214-33,520 and 178-14,223 cells/l, respectively, which were much lower than those in the Chao Phraya estuary. The maximum cell densities in both seasons were also lower than that of the inner Gulf being 196,200 cells/l measured by using the same method (Piromnim, 1982).

It is evident that phytoplankton in the upper part of the Gulf and the end of Peninsular Malaysia were abundant. The water run-off from the rivers around the uppermost part of the Gulf (the inner Gulf) carry domestic, industrial and agricultural wastes from land into the Gulf which is classified as a semi-enclosed bay (Piyakarnchana *et al*., 1991). This nutrient-rich water influences the abundance of phytoplankton in the upper part of the Gulf (Suvapepun *et al*., 1980; Boonyapiwat, 1983; Piromnim, 1984). Bhovichitra and Manowejabhan (1981) also concluded that phytoplankton in this area was richest compared with other areas of Thai waters.

As the sampling depth of this study was near the sea surface, phytoplankton communities were affected by surface currents and by the monsoons. In August the southwest monsoon was well developed and water upwelled along the west coast of the Gulf (Robinson, 1963). Nutrients were stirred up and were transported to more northerly locations by the strong southwesterly and southerly winds. This brought about the distinct abundance of diatoms and dinoflagellates at the west coast of the upper Gulf in September or the pre-monsoon season as reported in this paper.

The northeast monsoon was well developed in December. The upwelling occurred at the east coast of the Gulf and Vietnamese coast in January (Robinson, 1963). During this time, the surface current flows from the Vietnamese coast to the lower Gulf and also flows along the east coast of Peninsular Malaysia until March (Siripong, 1984). The nutrients in surface layer of the sea were transported and cause phytoplankton blooms at the west coast of the lower Gulf and the east coast of Peninsular Malaysia especially at the end of the peninsular in April (post-monsoon season).

Silathornvisut (1961) found 86 species of diatom in the Gulf of Thailand collected during the Naga Expedition. Suvapepun (1979) presented 93 diatom species in her check-list of Thai marine plankton. Thus, 133 species of diatom identified in this paper were more numerous. On the other hand, dinoflagellate species of some genera were less than those Wongrat (1982) and Pholpunthin (1987) reported because their samples were collected at other periods.

The species composition of phytoplankton in the Gulf of Thailand and east coast of Peninsular Malaysia were rather similar. The surface circulation in the Gulf and the South China Sea studied by

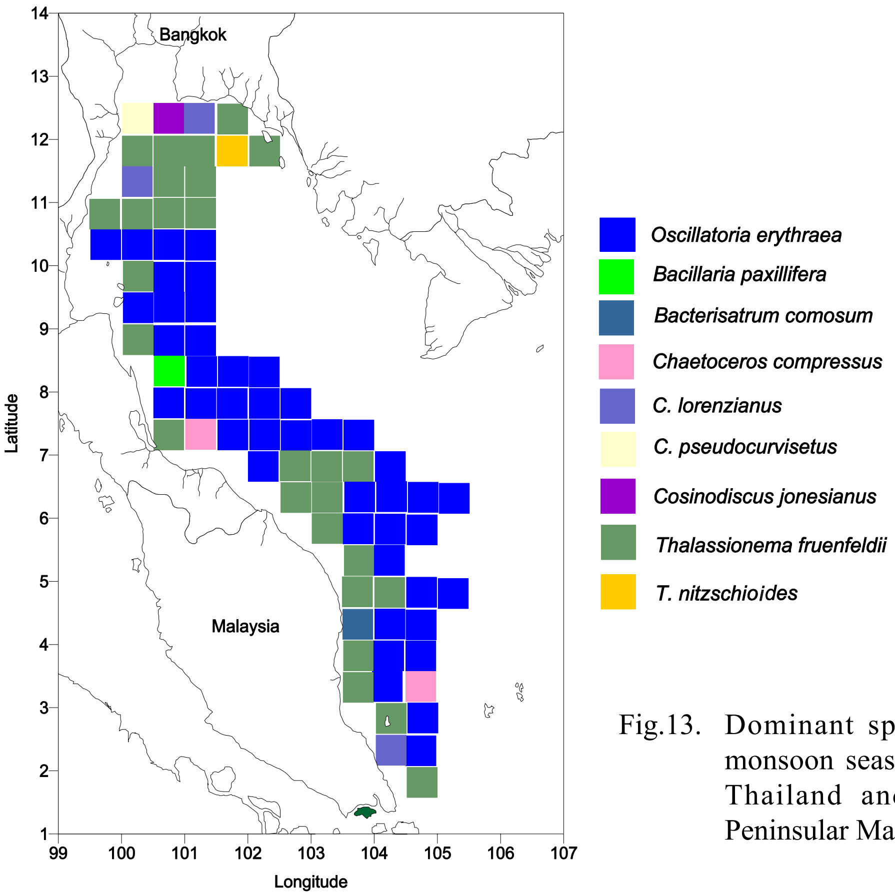


Fig.13. Dominant species in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia.

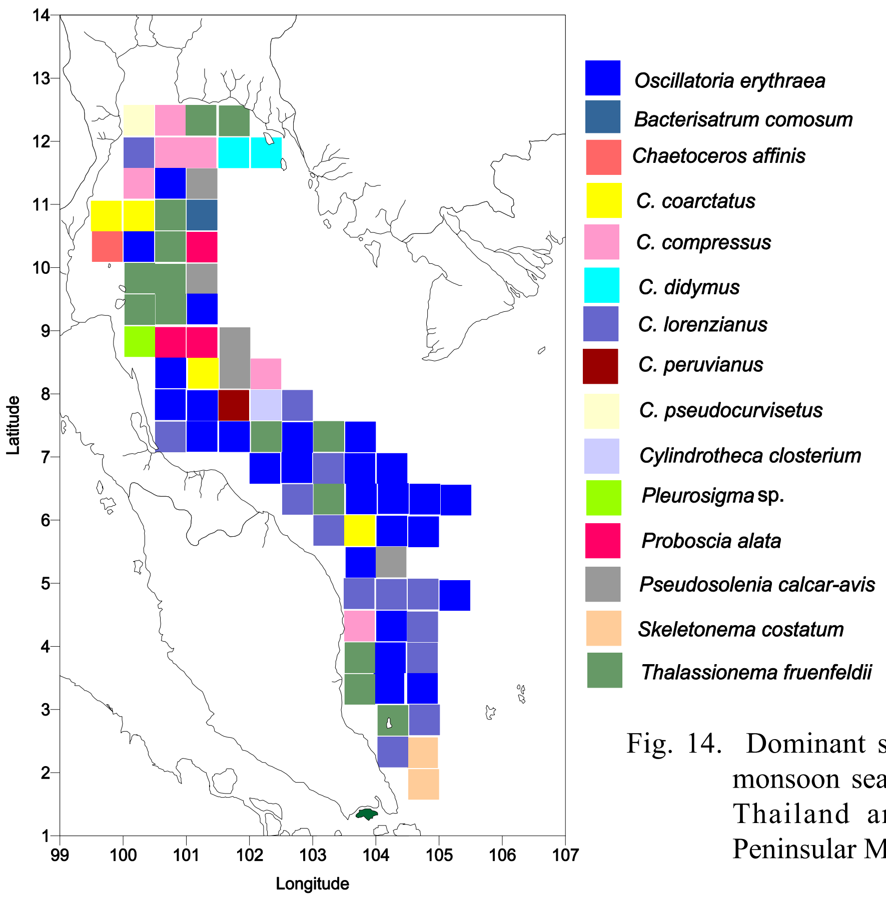


Fig. 14. Dominant species in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia.

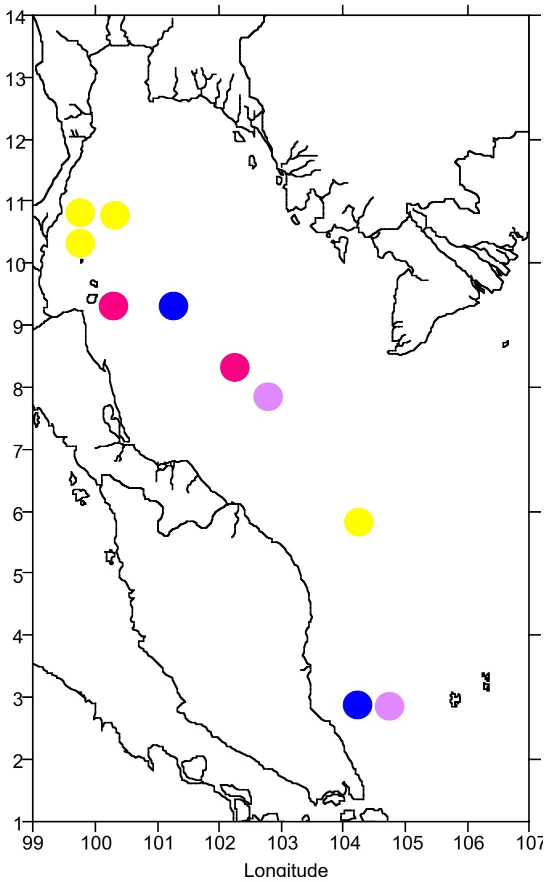


Fig. 15. Occurence of *Alexandrium* in pre-NE monsoon season (1-17 cells/l).

- *Alexandrium fraterculus*
- *A. tamarense*
- *A. tamiyavanichi*
- *A.* sp.

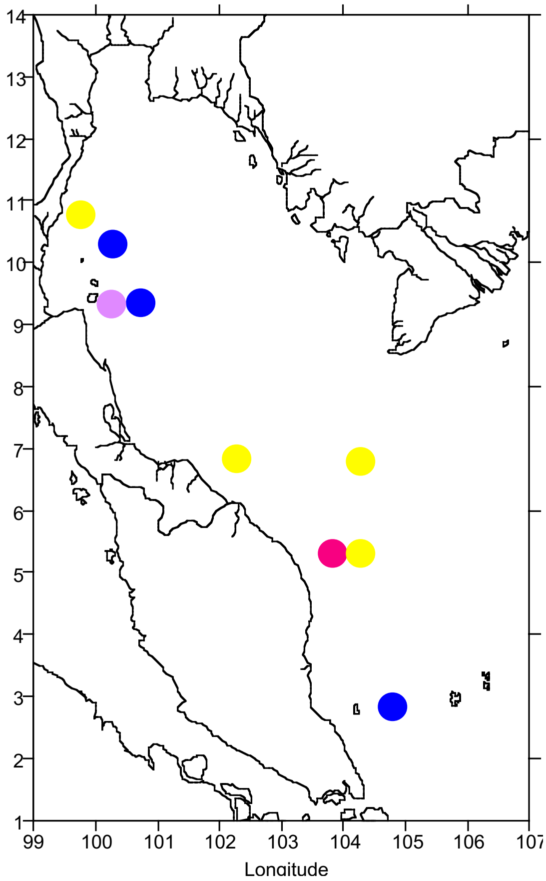


Fig. 16. Occurrence of *Alexandrium* in post-NE monsoon season (1-8 cells/l).

- *Alexandrium fraterculus*
- *A. tamarense*
- *A. tamiyavanichi*
- *A.* sp.

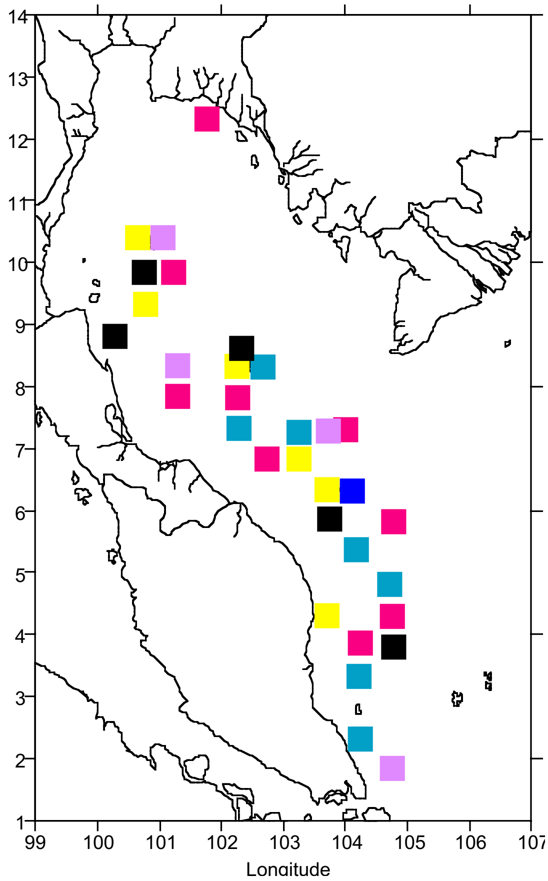


Fig.17. Occurrence of *Gonyaulax* and *Lingulodinium* in pre-NE monsoon season (1-13 cells/l).

- *Gonyaulax digitale*
- *G. glyptorhynchus*
- *G. polygramma*
- *G. spinifera*
- *G.* sp.
- *Lingulodinium polyedrum*

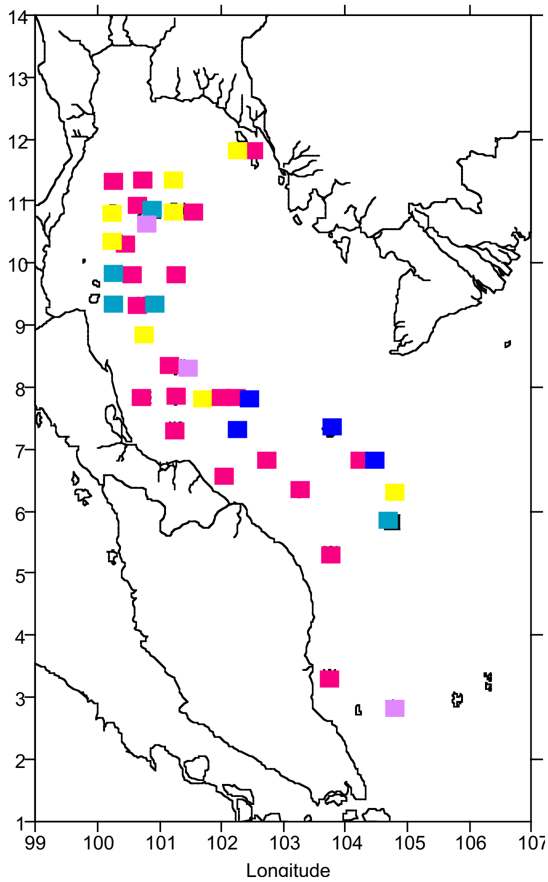


Fig. 18. Occurrence of *Gonyaulax* and *Lingulodinium* in post-monssoon season (1-13 cells/l).

- *Gonyaulax digitale*
- *G. polygramma*
- *G. spinifera*
- *G.* sp.
- *Lingulodinium polyedrum*

Table 3. Species diversity indices for two phytoplankton sampling periods in the Gulf of Thailand and east coast of Peninsular Malaysia.

Pre = Pre-NE monsoon,   Post = Post-NE monsoon

Station	Richness Indices		Diversity Indices		Evenness Indices	
	Pre	Post	Pre	Post	Pre	Post
1	2.63	1.99	2.94	3.26	0.59	0.67
2	2.65	2.05	3.30	2.77	0.65	0.60
3	2.19	1.68	3.25	2.56	0.66	0.42
4	1.60	1.90	3.59	2.93	0.53	0.55
5	1.62	2.66	2.24	3.14	0.44	0.61
6	2.02	1.39	2.58	2.34	0.44	0.65
7	1.88	2.60	2.68	2.91	0.46	0.68
8	2.28	2.11	3.32	3.20	0.57	0.71
9	1.59	1.56	2.88	2.27	0.59	0.46
10	1.18	3.10	2.21	2.92	0.35	0.62
11	2.05	1.67	2.90	2.83	0.53	0.65
12	1.07	2.09	1.02	3.06	0.35	0.81
13	1.21	2.11	1.11	2.75	0.31	0.74
14	2.27	2.08	2.63	2.23	0.60	0.62
15	2.19	2.36	2.48	2.74	0.47	0.70
16	2.05	2.14	2.49	2.62	0.48	0.35
17	2.16	2.50	2.68	2.69	0.56	0.63
18	2.26	2.01	2.38	3.01	0.57	0.71
19	2.46	2.14	2.63	2.47	0.51	0.60
20	3.14	1.92	2.97	2.36	0.73	0.71
21	1.99	2.84	2.34	2.83	0.40	0.67
22	1.48	1.63	2.10	2.17	0.41	0.67
23	2.09	2.88	2.75	2.86	0.43	0.55
24	1.79	3.21	1.82	3.67	0.48	0.72
25	2.79	2.20	2.61	2.44	0.50	0.63
26	1.22	0.65	1.21	0.41	0.43	0.29
27	no sampling	2.76	no sampling	2.80	no sampling	0.68
28	1.73	1.82	1.87	2.32	0.46	0.67
29	2.48	2.32	3.24	2.81	0.65	0.70
30	2.74	0.49	2.63	0.43	0.43	0.36
31	1.36	2.29	2.01	2.91	0.32	0.52
32	2.01	2.27	2.41	2.45	0.56	0.57
33	1.39	1.93	1.99	2.28	0.39	0.50
34	2.06	1.50	2.52	2.32	0.43	0.67
35	2.50	1.35	1.97	2.20	0.33	0.69
36	1.63	2.13	1.88	2.19	0.45	0.58
37	1.96	1.45	1.70	2.09	0.30	0.74
38	1.78	1.87	2.25	2.11	0.49	0.44
39	3.26	1.78	2.90	2.50	0.42	0.58
40	2.94	1.95	2.65	2.74	0.37	0.65

Table 3. (cont.)

Station	Richness Indices		Diversity Indices		Evenness Indices	
	Pre	Post	Pre	Post	Pre	Post
41	1.00	1.94	2.49	2.28	0.56	0.57
42	1.99	1.60	2.43	2.53	0.51	0.76
43	1.26	1.97	1.06	2.24	0.35	0.50
44	3.43	1.41	2.98	2.05	0.44	0.60
45	2.29	1.56	1.65	2.56	0.27	0.72
46	1.66	0.85	1.76	1.03	0.40	0.36
47	2.82	1.42	3.04	1.78	0.51	0.37
48	2.57	1.85	2.41	2.11	0.37	0.49
49	2.92	1.72	2.92	2.31	0.45	0.50
50	2.13	1.70	2.35	2.14	0.37	0.56
51	2.35	1.85	2.66	2.60	0.45	0.63
52	1.95	1.99	2.88	2.39	0.58	0.44
53	2.51	2.62	2.56	2.71	0.35	0.42
54	3.41	1.73	2.74	2.57	0.48	0.69
55	2.53	1.26	3.00	1.63	0.51	0.41
56	2.56	1.43	2.26	1.85	0.56	0.44
57	1.35	0.86	2.10	1.39	0.66	0.51
58	1.61	1.26	1.54	1.62	0.33	0.42
59	2.19	1.47	2.13	2.34	0.34	0.73
60	1.87	1.89	1.80	2.86	0.42	0.79
61	1.71	1.77	2.78	2.81	0.67	0.60
62	2.61	2.27	2.61	2.61	0.45	0.54
63	2.02	1.70	1.82	2.62	0.25	0.63
64	1.89	1.67	2.63	2.50	0.63	0.61
65	2.10	1.79	2.36	2.51	0.59	0.57
66	1.85	1.89	1.51	2.92	0.29	0.78
67	1.43	2.20	1.35	2.77	0.30	0.66
68	1.81	1.76	1.60	2.57	0.38	0.55
69	2.04	2.20	2.23	2.90	0.61	0.71
70	2.03	2.07	2.57	2.91	0.61	0.69
71	2.20	2.04	2.85	2.80	0.60	0.67
72	2.19	1.74	2.22	2.25	0.44	0.35
73	2.19	2.64	2.26	3.03	0.42	0.66
74	2.76	1.44	2.68	2.38	0.63	0.63
75	2.00	1.34	2.37	2.78	0.43	0.62
76	1.90	1.85	2.89	2.58	0.73	0.55
77	3.01	1.95	2.82	2.74	0.50	0.62
78	2.07	2.36	1.82	2.89	0.29	0.55
79	1.53	1.56	2.24	2.19	0.66	0.37
80	2.24	1.89	3.03	2.73	0.66	0.53
81	1.35	0.61	1.90	0.54	0.38	0.29

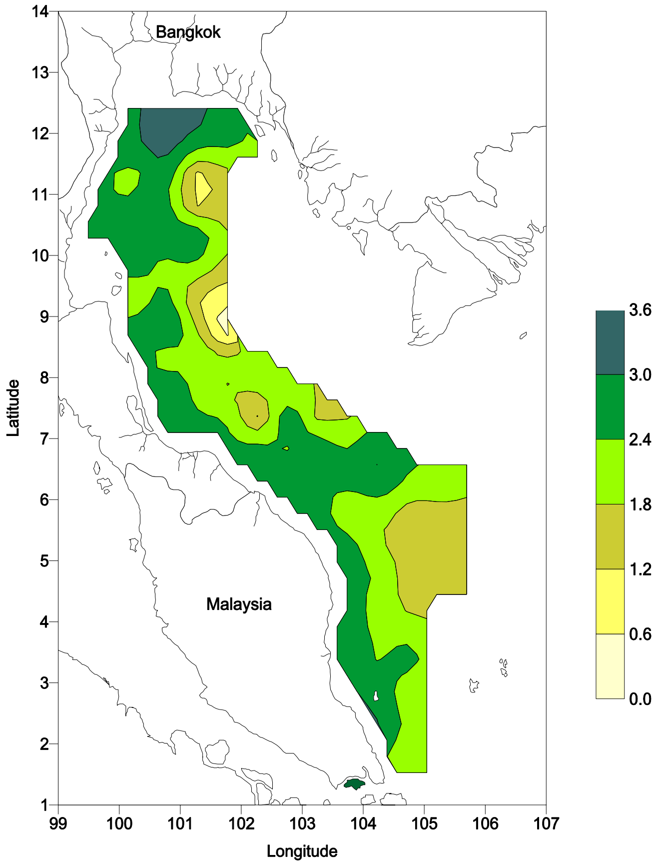


Fig. 19. Diversity indices of phytoplankton in pre-NE monsoon season.

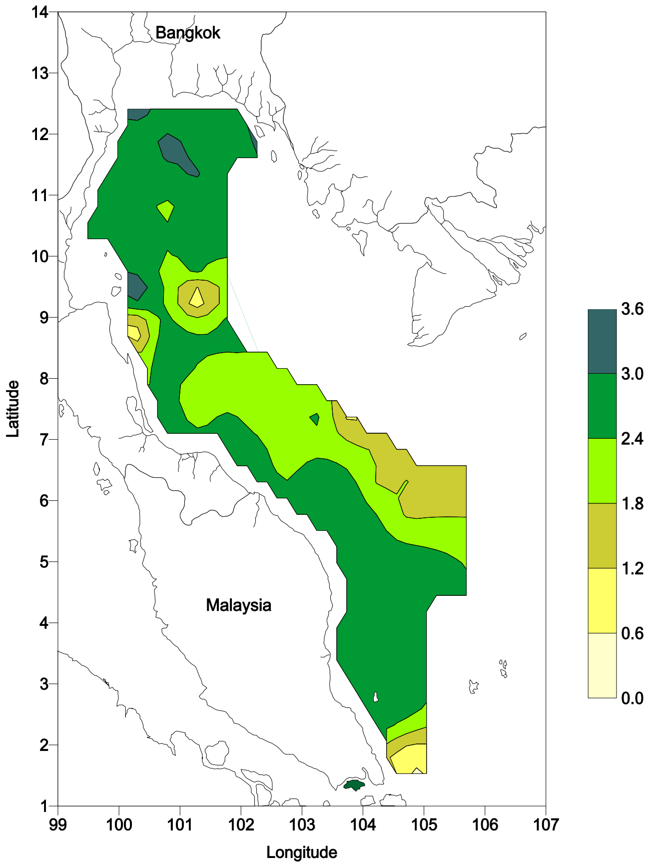


Fig. 20. Diversity indices of phytoplankton in post-NE monsoon season.

Siripong (1984) concluded that the surface current flows from the Gulf and east coast of Peninsular Malaysia to the Vietnamese coast and South Chiana Sea in April-September and flows in opposite direction in October-March. The surface current distributes phytoplankton in the surface layer throughout these areas. This paper shows wide distribution of some dominant species in the study area such as *Oscillatoria erythraea*, *Thalassionema frauenfeldii*, *Chaetoceros lorenzianus* and *C. compressus*. *Skeletonema costatum* which causes blooms with considerable cell densities near the end of Peninsular Malaysia as was recorded by Suvapepun *et al*., 1980; Boonyapiwat, 1983, 1984 as dominant species in the estuary, the area adjacent to the upper Gulf of Thailand. Boonyapiwat (1983, 1984) and Piyakarnchana *et al*. (1991) reported on the blooms of *Chaetoceros pseudocurvisetus* in the afore-mentioned areas. In the present study, this species was also abundant in the coastal area of the upper Gulf in both the pre-and post-monsoon seasons.

The blue green algae, *Oscillatoria* (*Trichodesmium*) *erythraea*, which was generally recorded as a red tide species, appeared throughout the study area. Compared with other dominant species, its densities were not likely to cause marine environment problems.

Although toxic dinoflagellates were observed with low cell densities, their distribution seemed to be wide. Abundance may occur in other periods of the year when samples were not collected.

Diversity indices in the middle Gulf were high when compared with the results which Boonyapiwat (1982a) reported. In this present study, more species could be observed and identified by a more accurate method. These showed high species richness and diversity indices. The evenness index which was computed by modified Hill's ratio was recommended by Ludwing and Reynolds (1988) as it is least ambiguous and most interpretable. From this equation, the evenness index approaches zero when a single species becomes very abundant. Then, phytoplankton blooms at station 81 led to a low evenness and diversity index.

The results of this study indicate that the monsoon was important for phytoplankton abundance, distribution and species composition. Most of the dominant species showed a wide distribution from the upper part of the Gulf of Thailand through to the east coast of Peninsular Malaysia. Toxic dinoflagellates appeared with low cell densities and some of these were distributed throughout the study area.

References

Bhovichitra, M. and A. Manowejbhan: Abundance and distribution of phytoplankton in the Thai water. in Proc. 2nd Seminar on the Water Quality and the Quanlity of living Resources in Thai Waters. NRCT, Bangkok, 1981, pp. 127-136.

Bhovichitra, M. and A. Manowejbhan: Phytoplankton in the east coast of the Gulf of Thailand. in Proc. 3rd Seminar on the Water Quanlity and the Quality of Living Resources in Thai Waters. NRCT, Bangkok, 1984. pp. 229-246.

Boonyapiwat, S.: A study on diversity index and abundance of microplankton in the Chao Phraya Estuary. Tech. Paper. No.6. Explo.Fish.Div., Fish. Depart., Bangkok, 68 p. (1978).

Boonyapiwat , S.: Phytoplankton abundance in the middle Gulf of Thailand. Tech. Paper. No. 9. Explo. Fish. Div., Fish. Depart., Bangkok, 36 p. (1982 a).

Boonyapiwat , S.: Ecological studies on the phytoplankton in the Chao Phraya Estuary. Tech. Paper. No. 10. Explo. Fish. Div., Fish. Depart., Bangkok, 30 p. (1982 b).

Boonyapiwat , S.: Abundance, species composition and distribution of phytoplankton in relation to the water conditions in the Chao Phraya Estuary and its adjacent waters. Tech. Paper. No.13. Explo. Fish. Div., Fish. Depart.,Bangkok, 49 p. (1983).

Boonyapiwat , S.: Annual cycles and species composition of phytoplankton in the Chao Phraya Estuary and its adjacent waters. in Proc. 3rd Seminar on the Water Quality and the Quanlity of Living Resources in Thai Waters. NRCT, Bangkok, 1984, pp. 375-387.

Boonyapiwat , S.: Species and distribution of phytoplankton in the Gulf of Thailand. in Proc. 3rd Seminar on Mar. Sci. NRCT, Bangkok, 1986, 21 pp.

Boonyapiwat , S.: Ultrastructure and distribution of *Thalassiosira thailandica* Boonyapiwat in Thai waters. in Proc. 4th Seminar on the Water Quality and the Quanlity of Living Resources in Thai Waters. NRCT, Bangkok, 1987, pp. 336-345 .

Boonyapiwat , S., S. Maungyai and W. Chantarasakul: A study on phytoplankton in relation to oceanographic conditions in the lower Gulf of Thailand. Report of the Thai - Japanese - SEAFDEC Joint Oceano. and Fish. Sur. in the Gulf of Thailnd on Board Nagasaki - maru. 28 Oct. - 5 Nov. 1982. SEAFDEC, Samutprakarn, 1984, pp. 27-43.

Ludwig, J.A., and J.F. Reynolds: Statistical Ecology, A Primer on Methods and Computing. A Wiley Interscience Publication. John Wiley and Sons, New York, 1988, 337p.

Ostenfeld, C.H.: Marine plankton diatoms. in Flora of Koh Chang. Contributions to the knowledge of the vegetation in the Gulf of Siam. Part VII (ed. by J. Schmidt), Bot. Tidsskr. 25 : 1-27. (1902).

Pholpunthin, P.: Taxonomy and distribution of dinoflagellates in families Dinophysiaceae, Gonyaulacaceae and Peridiniaceae in the Gulf of Thailand. M.Sc. Thesis, Chulalongkorn Univ., Bangkok, 1987, 266 p.

Piromnim, M.: Phytoplankton in the Inner Gulf of Thailand. Tech. Paper. No. 5. Mar. Fish. Div. Fish. Depart., Bangkok, 11 p. (1984).

Piromnim, M.: Distribution of phytoplankton in the central part of the Gulf of Thailand. Circulation No. 23. Mar. Fish. Div., Fish. Depart., Bangkok, 9 p. (1985).

Piyakarnchana, T., S. Wisessang, G. Wattayakorn, S. Boonyapiwat and T. Okaichi: Changes in phytoplankton populaiotn in the Chao Phraya Estuary, Thailand, during the eutrophication mechanisms studies. in Proc. 2rd I0C /WSPAC Symp. Sci. Cont. Effect. Manage. Mar. Env. in West Pac. Min. Sci. Tech. Env. Malaysia/ IOC.1991. pp. 177-192 .

Robinson, M. K.: Physical oceanography of the Gulf of Thailand. in Ecology of the Gulf of Thailand and the South China Seas. A Report on the Result of the Naga Expedition, 1959 - 1961. Scripps Inst. of Oceano., La Jolla, California, 1963, pp. 34 - 52 .

Rose, M.: Some remarks on plankton from the coast of Viet-nam and the Gulf of Siam. Imprimerie Nauvelle Albert Portail. Saigon, 1926, 7 p.

Schmidt, J.: Peridiniales. in Flora of Koh Chang. Contribution to the knowledge of vegetation in the Gulf of Siam. Part IV (ed. by J. Schmidt) Bot. Tidsskr. 24 : 212-221 (1901).

Silathornvisut, K.: Plankton Diatoms in the Gulf of Thailand. B.Sc. Thesis, Chulalongkorn Univ., Bangkok. 1961, 118 p.

Siripong, A.: Surface circulation in the Gulf of Thailand and South China Seas in 4 seasons from direct measurement. in Proc. 3rd Seminar on the Water Quality and Quality of Living Resources in Thai Waters. NRCT, Bangkok, 1984. pp.140-148.

Suvapepun, S.: Check-list of Thai marine plankton, I phytoplankton II Copepoda. Tech. Paper. No. 16. Mar. Fish. Div., Fish. Depart., Bangkok, 13 p. (1979).

Suvapepun, S., C. Tharnbupha and M. Piromnim: The relationship between phytoplankton and the environmental conditions in the Ta - Chin Estuary. Tech. Paper. No. 7 Mar. Fish. Div., Fish. Depart., Bangkok, 15 p. (1980).

Wongrat, L.: Dinoflagellate genus *Ceratium* Schrank in Thai waters. CTP No. 17. SEAFDEC, Samutprakarn, 89 p. (1982).

Primary Production Determination in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Waleerat Musikasung [1)]
Mohd Shuki Bin Yusoff [2)]
Solahuddin Bin Abdul Razak [2)]

[1)]Department of Marine Science, Chulalongkorn University, Bangkok, Thailand
[2)]SEAFDEC/MFRDMD, Fisheries Garden, Chendering, 21080, Kuala Terengganu, Malaysia

ABSTRACT

Primary production in the Gulf of Thailand and the East Coast of Peninsular Malaysia was determined from *in situ* fluorescense, light intensity in September-October, 1995 cruise, and from the uptake of radioactive carbon incubation in the October, 1996 cruise. The primary production rate was found to be 0.20–0.61 and 0.29–0.47gC/m^2/day for the Gulf of Thailand and the East Coast of Peninsular Malaysia, respectively. At nearshore stations, higher rate of primary production was found at sea surface, and it gradually decreased with depth. However, at offshore stations, where subpycnocline chlorophyll maximum was found, the rate was increased again at this layer

Key words : Primary production, South China Sea, Gulf of Thailand, Eeat coast of Peninsular Malaysia

Introduction

"Primary production limits the trophic potential of the world ocean and thus a biological limitation of future population growth of humankind" (Russell-Hunter, 1970). A broad picture of primary production over most region of the world's ocean is now available and generally considered a key characteristic of marine ecosystem and has major implications for water quality (Bermal *et al*., 1995). However, few studies of the variability of primary production have been conducted over an annual cycle in the sea because of the size of the area and the time scales. In addition, the Gulf of Thailand and the East Coast of Peninsular Malaysia are a major and rapidly developing commercial fishing site and supports a fishery, but lack of knowledge of the levels of annual primary production is particularly evident for this area.

In order to determine the extent to predict trends of primary production have occurred, some functional relationship between biological and physical factors which are the biomass of phytoplankton, light intensity at that time and the relative importance of light decrease with depth (Berman *et al.*, 1995). This study was described to estimated the distribution of the primary production in the Gulf of Thailand and in the East Cost of Peninsular Malaysia.

Materials and Methods

The location of the stations (60 stations) was shown in Fig. 1. Seawater samples were collected from several levels of depth (from sea surface to bottom). Data collection (total alkalinity, light intensity and *in situ* fluorescense) was divided into two cruises. The 1st cruise, on MV SEAFDEC in September-October 1995, which seawater samples were collected from all 60 stations in the Gulf of Thailand and the East Coast of Peninsular Malaysia. The 2nd cruise, on MV Platoo in October 1996, which samples were collected from only 15 stations in the Gulf of Thailand and only 5 station for ^{14}C. incubtion (station-7, 15, 21, 27, and 35). According to the two cruises were during the beginning of the North-East Monsoon, the primary production of the Gulf of Thailand and the East Coast of Peninsular Malaysia were extrapolated by using the data between the two cruises.

Primary production

Seawater samples from the 2nd cruise were collected for radioactive bicarbonate incubation using ^{14}C technique. Each sample was transferred into 500ml glass bottles (4 bottles of light glass which one of them is control, and 1 bottle of dark glass from each level of depth). Each bottle except control was innoculated with 2.52μCi of ^{14}C. All of bottles were incubated *in situ* at their original depth for 3 hours, and took away from sunlight before filtered by syring filtration with GF/F membranes. Membranes were kept frozen in scintillation vials until they were determined by the GC-9A, Shimadzu, β-scintillation counter.

Total alkalinity

50ml of filtered seawater from 60 stations (Fig.1) on the 1st cruise was mixed with 10ml of 0.015N HCl. The final pH of the solution was measured by pH-meter, Fisher Scientific model 1002. Total alkalinity was computed, and then the carbonate alkalinity and total carbon dioxide were calculated by

carbonate alkalinity (meq/l) = total alkalinity-0.05
total carbon dioxide (meq/l) = 0.96*carbonate alkalinity

Light intensity

Light intensity in water column from 60 stations (Fig.1) was measured in lux by an underwater lux meter, Alec Electronics model SPI-9W.

In situ fluorescense

In situ fluorescense in volt of 60 stations (Fig.1) was recorded every one meter depth by Sea Tech submersible fluorometer.

Chlorophyll-a

In situ fluorescense can be converted to photosynthetic pigment concentration by correlated linearly with the actual chlorophyll concentration by spectrophotometry on cruise.

Primary production calculations

Equation for primary production is based on radioactive carbon technique by Parson *et al.* (1984)

$$\text{Primary production (mgC/m}^3\text{/hr)} = (R_S - R_B)*W / R*N \qquad \textbf{(1)}$$

where R = total activity of 2.52 μCi of ^{14}C solution (dpm)
N = number of hours of sample incubation (hr)
R_S = the light bottle count (dpm)
R_B = the dark bottle count (dpm)
$W_{\text{(the concentration of total carbon dioxide in mgC/m3)}}$ = 12,000*TC
TC = total carbon dioxide (meq/l)

Light-Depth curve

The data of light (lux) and depth (m) from the 1st and 2nd cruise were combined and correlated linearly, then used for Light-Depth (L-D) relationship. The relationship was separated into 2 equations at the arbitrary pycnoclinal depth of 39m (Fig.2). From 0-38m depth, there was very low concentration of phytoplankton and thus allowed light to penetrate to the pycnocline. Because of thick layer of phytoplankton limited light penetration, so light intensity rapidly decreased below the pycnocline.

The overall equation for the depth 0-38m **(2)**

$L = -114.65\ Ln(D) + 426.16 \quad r^2 = 0.5628$

The overall equation for the depth 39m-bottom

$L = -0.2633D + 19.524 \quad r^2 = 0.6242$

where : L = light intensity (lux)
D = depth (m)

Primary production–Light intensity curve

Primary production and light intensity (P–I curve) was made by plotting primary production normalized to chl-a (as *in situ* fluorescense) against light intensity from the 1st cruise (Fig.3) and by the r^2 and subpycnocline chlorophyll maximum it was found that the relationship could also be separated into 2 groups at 39m.

The equation for the depth 0-39m **(3)**

$P = 3.6216\ Ln(L) - 5.8195 \quad r^2 = 0.6336$

The equation for the depth 40m-bottom

$P = 2.0891\ Ln(L) + 0.773 \quad r^2 = 0.5900$

where : P = primary production ($mgC/m^3/hr$)
L = light intensity (lux) at sample incubation depth

Light-Time curve

Light-time equation (L-T curve) was made from the time series of light at sea surface from 1st and 2nd cruise to integrate for daily primary production (Fig.4) and was separated to 2 groups.

Equation for time between 6 A.M.-12 Noon **(4)**

$L = 0.3217\ e^{0.5489t} \quad r^2 = 0.8512$

Equation for time between 12 Noon -6 P.M.

$L = 140282\ e^{-0.4737t} \quad r^2 = 0.7038$

where : L = light intensity (lux) at surface
t = time (6 A.M.-6 P.M)

Estimation of daily primary production

Photosynthetic rate in the incubated bottles was calculated for primary production rate using equation-(1) and extrapolated over the water column to obtain the rate per sq.m and integrated over 6 A.M. to 6 P.M. using the *in situ* biomass, light intensity (hourly light intensity profile) and time integrated daily primary production (assuming surface intensity to be 100%) by equation- (2), (3), and (4).

Result

The range of daily primary production was 0.20–0.61 and 0.29–0.47 gC/ m^2/day in the Gulf of Thailand and the East Coast of Peninsular Malaysia, respectively. (Table 1) Depth integrated primary production in the Gulf of Thailand was very high at the east and the west cost (station-6 and 10, Fig.5). For the East Coast of Peninsular Malaysia, the primary production was high at station-66 (Fig 5).

The contribution of primary production at the same contour line on surface, depth-10, 20, 30, 40, and 50m was shown in Fig. 6-11.

The correlation between light intensity, chlorophyll-a, and daily primary production of nearshore and offshore stations was shown in Fig. 12-13. In which the data of light intensity and chlorophyll-a were reported from Snidvongs *et al.* (1995). At nearshore stations, daily primary production was highest at the surface or near-surface (2-6m depth) and generally decreased with depth (Fig. 12). At Offshore stations, daily primary production at subsurface decreased with reduced light penetration, but where subpycnocline chlorophyll maximum was found, it tended to increase and then declined rapidly as light attenuation deminished (Fig. 13).

The extent to daily primary production which changed as followed top-down in water column by distribution of chlorophyll-a was shown in Fig. 14.

.

Discussion

The contribution of daily primary production in the Gulf of Thailand and the East Coast of Peninsular Malaysia could be high, and it occurred along water column. Stations which would have the subpycnocline chlorophyll maximum, daily primary production was reached maxima also, because in daytime, when sunlight was generally abundant, the very low concentration of phytoplankton in the surface mixed layer allowed light to penetrate to the pycnocline, and the pycnocline light intensity was usually >10% of that at the surface (Snidvongs and Rochana-anawat, 1995), and that seemed to be sufficient for photosynthesis.

Berman *et al.* (1995) indicated that the variability of primary production in Lake Kinneret, Israel was highly correlated with covariation of 3 parameters: phytoplankton biomass, photic depth and surface irradiance, which similarity to this study. However, in this area the estimated of daily primary production was greatly due to chlorophyll-a concentration (Fig. 14).

The distribution and abundance of phytoplankton had been not obvious in this study. We claimed that the dominant species of phytoplankton in this area where subpycnocline chlorophyll maximum was approximate 25-50m (Snidvongs *et al.*, 1995) were diatom. Raymont (1980) described that the different species of phytoplankton may exhibit depth preferences within the Equatorial Pacific was present in the upper 100m, diatoms were mainly in the uppermost 25m or 50m layer. According to Boonyapiwat (1997), in this area, diatom was the main group of phytoplankton, and abundance near the west coast, lower past of the Gulf of Thailand and along the coast of Peninsular Malaysia. But, the abundance of blue green algae was near the east coast and offshore of the lower Gulf of Thailand, include offshore of the east coast of Peninsular Malaysia. We suggested that, all the areas abundance in phytoplankton species, they coincided with relative high level of daily primary production.

The Gulf of Thailand and the East Coast of Peninsular Malaysia is one of the world's most primary production (Lursinsub, 1985), and it is base of the pyramid which supports a large commer-

Table 1. Depth integrated daily primary production at various stations in gC/m²/day

Station	P(gC/m²/day)	Station	P(gC/m²/day)	Station	P(gC/m²/day)
1	0.26	28	0.42	57	0.35
2	0.39	30	0.25	58	0.35
3	0.36	31	0.23	59	0.42
5	0.35	32	0.24	61	0.39
6	0.56	34	0.31	62	0.44
7	0.52	35	0.29	63	0.42
9	0.45	36	0.56	65	0.40
10	0.61	38	0.22	66	0.47
11	0.50	39	0.20	68	0.37
13	0.44	40	0.21	69	0.29
14	0.39	42	0.25	70	0.39
15	0.39	43	0.43	72	0.35
17	0.28	45	0.31	73	0.40
18	0.47	46	0.31	74	0.30
19	0.58	49	0.41	76	0.29
21	0.33	50	0.38	77	0.31
22	0.34	51	0.49	78	0.41
23	0.24	53	0.43	80	0.33
25	0.25	54	0.33	81	0.38
26	0.29	55	0.35		

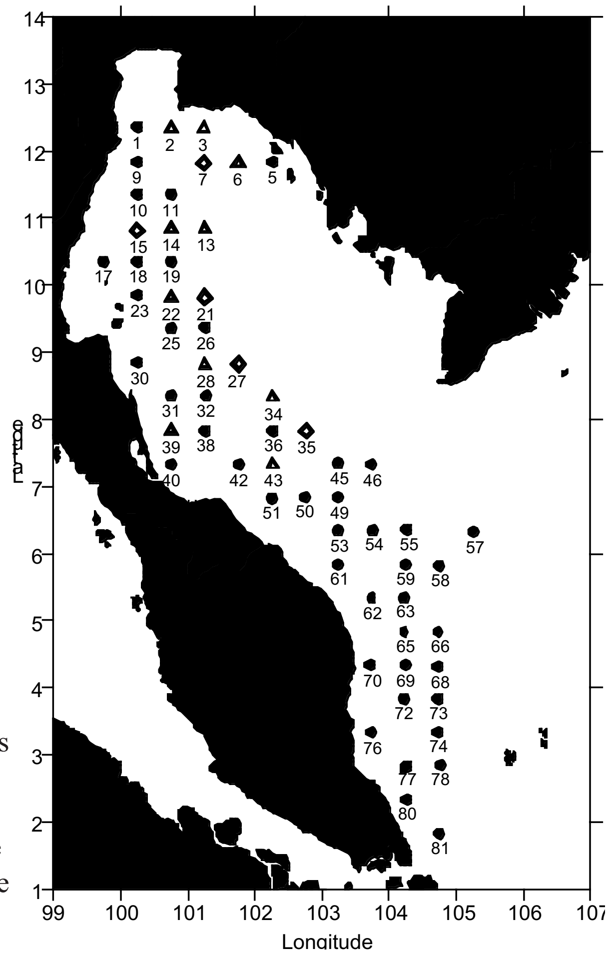


Fig.1. The location of 60 stations to previous study
circele = stations in the first cruise
triangle = stations in the and second cruise
diamon = stations in the first, second cruise and carbon - 14 incubation

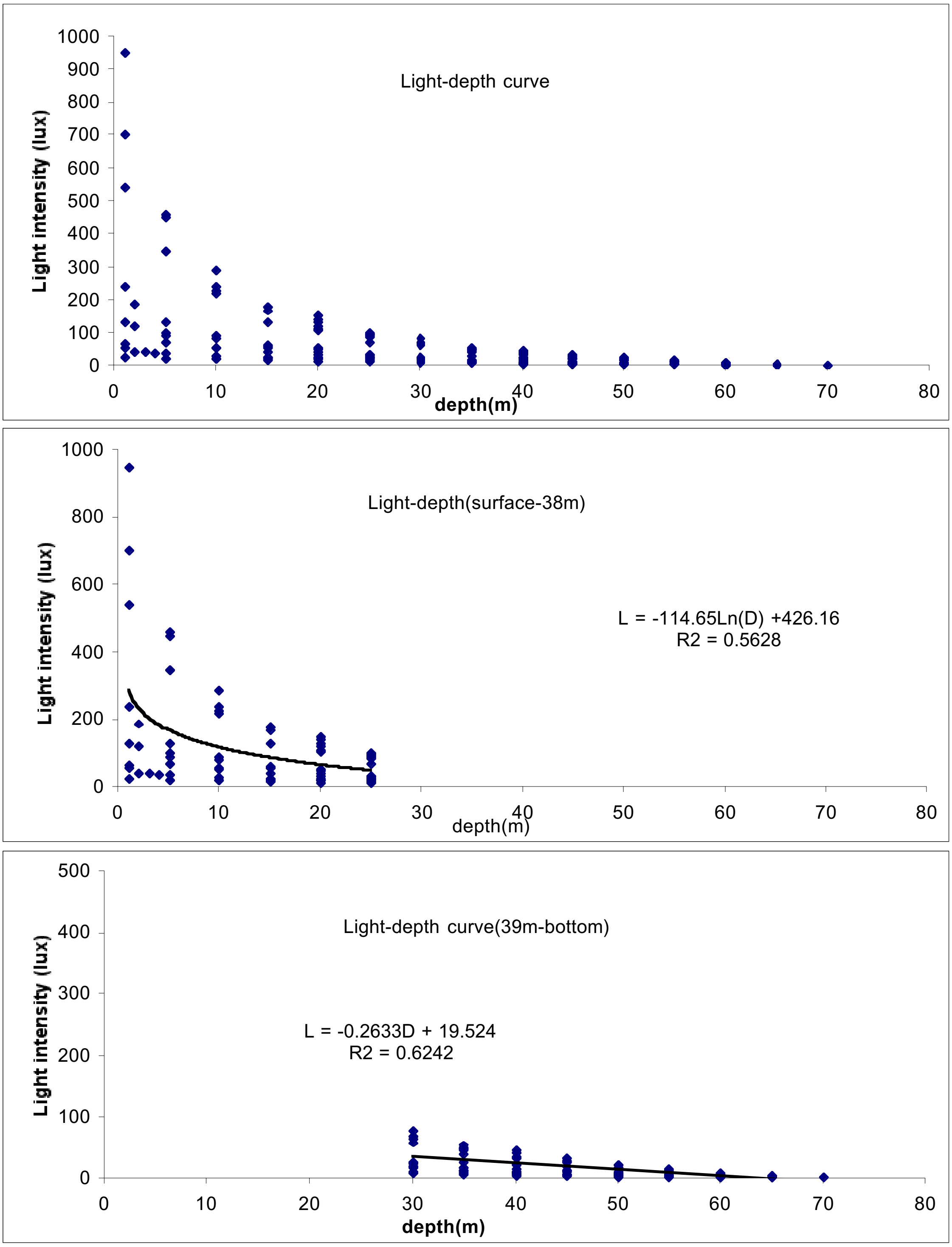


Fig. 2. Light-depth relationship and 2 equations that seperated at 38m
L = Light intensity (lux), D = Depth (m)

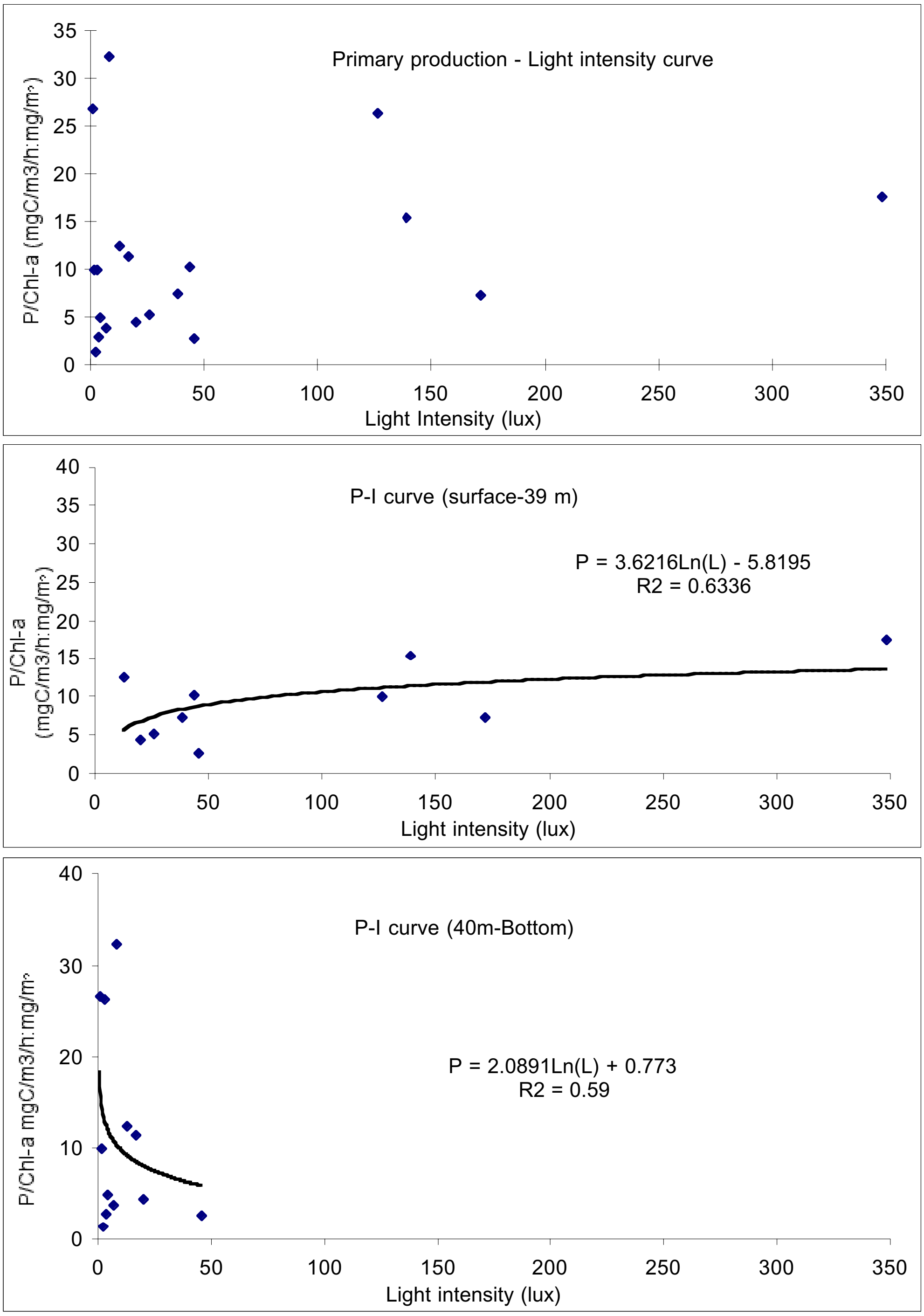


Fig. 3. Primary production normalized to biomass - light intensity relationship and 2 equations that separated at 39m

P = P/Chl-a, L = Light intensity

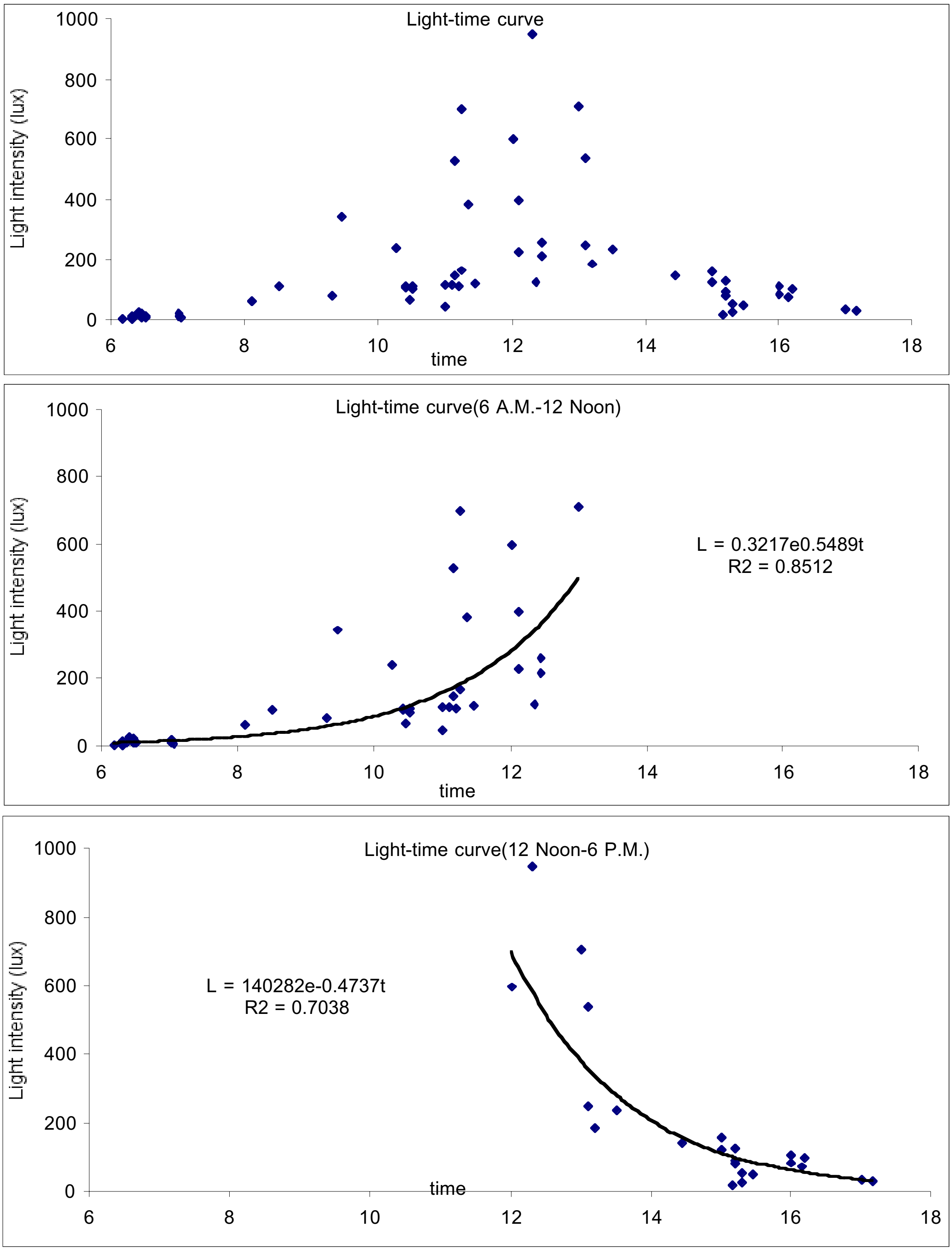


Fig. 4. Light - time relationship and 2 equations that seperated at noon
L = Light intensity (lux), t = time (6 A.M.-6 P.M.)

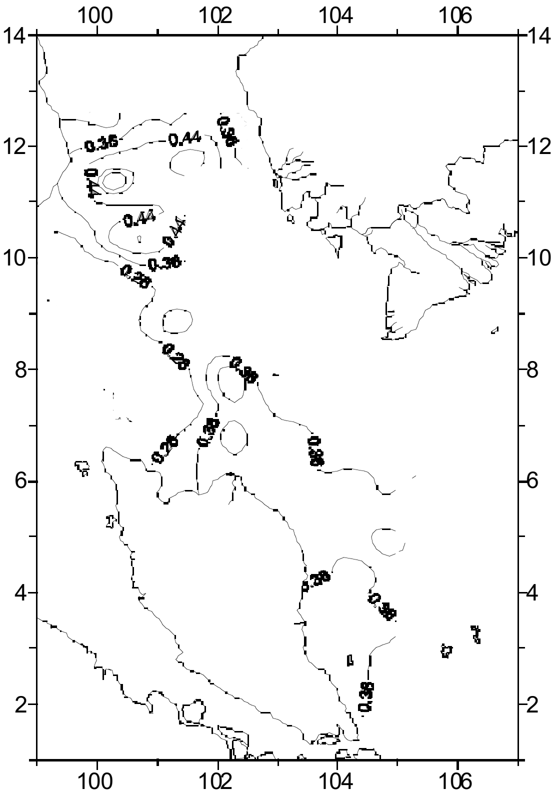


Fig. 5. Depth Integrated Primary production (gC/m^2/d)

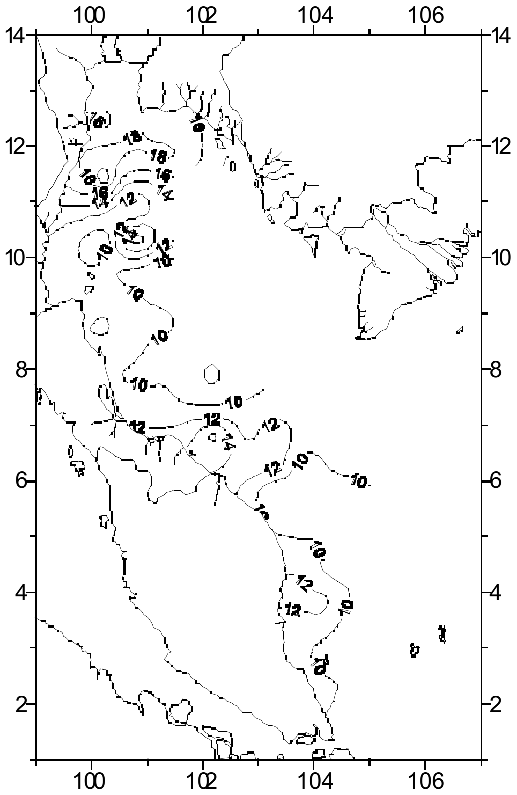


Fig. 6. Distribution of daily primary production at surface in mgC/m^3/day

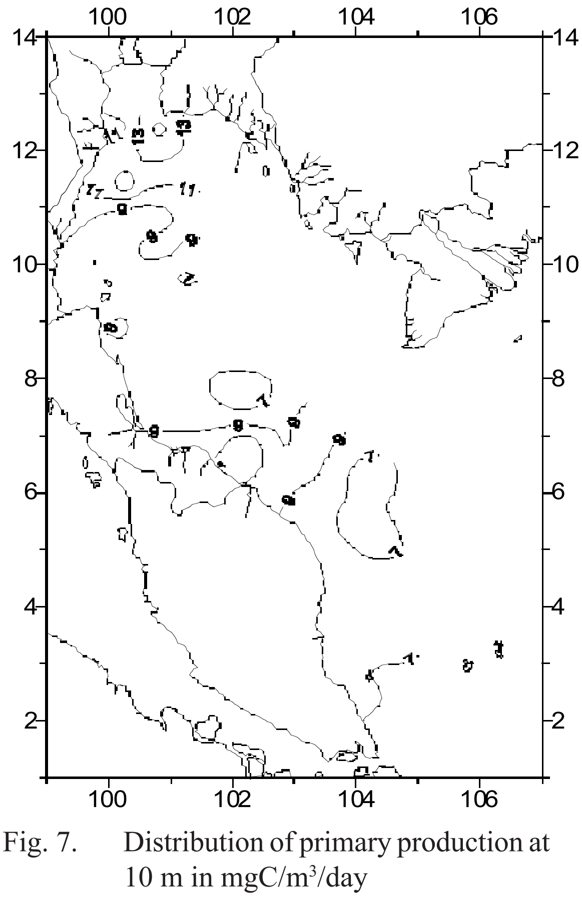


Fig. 7. Distribution of primary production at 10 m in mgC/m^3/day

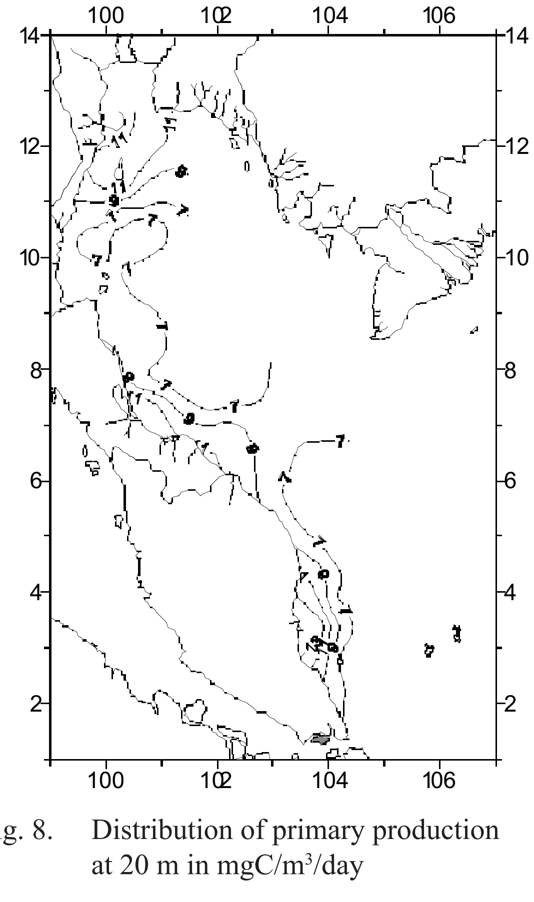


Fig. 8. Distribution of primary production at 20 m in mgC/m^3/day

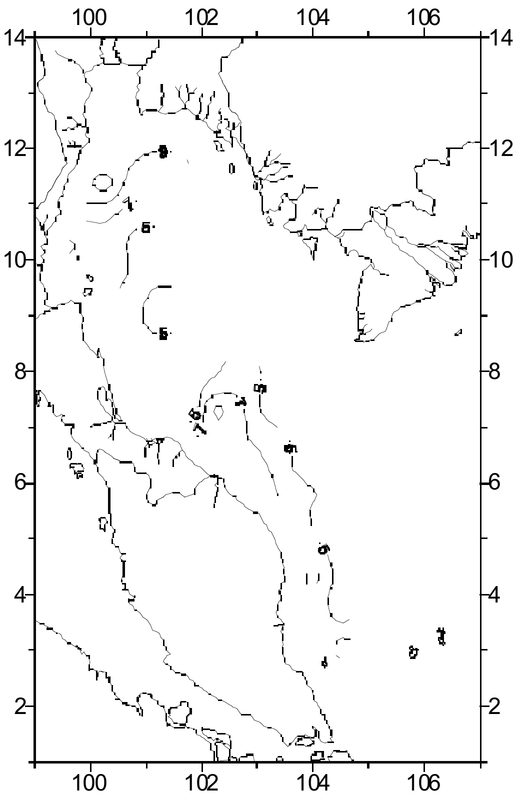


Fig. 9. Distribution of primary production at 30 m in mgC/m^3/day

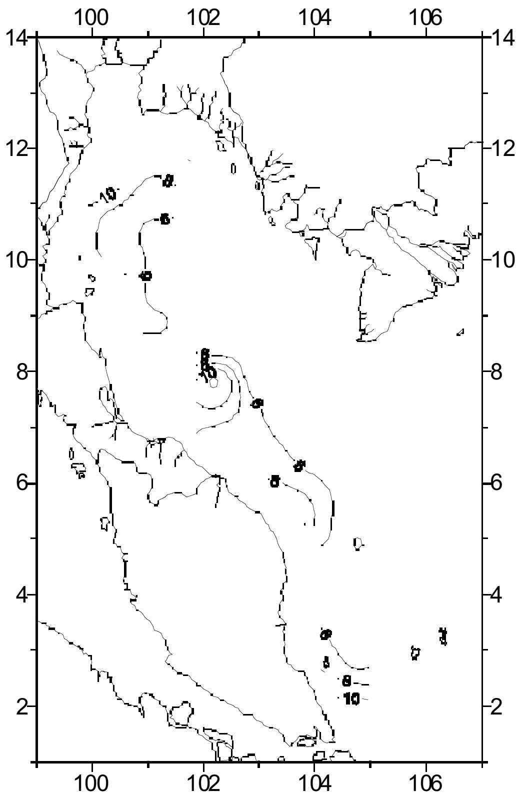


Fig. 10. Distribution of primary production at 40 m in mgC/m^3/day

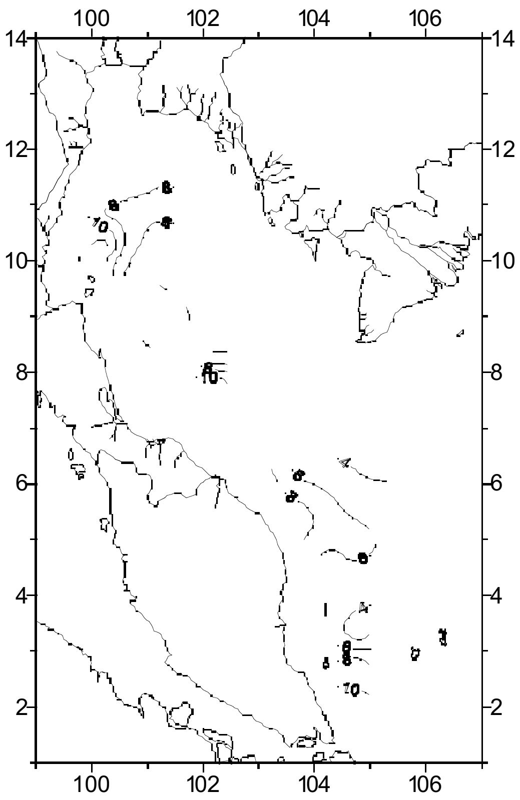


Fig. 11. Distribution of primary production at 50 m in mgC/m^3/day

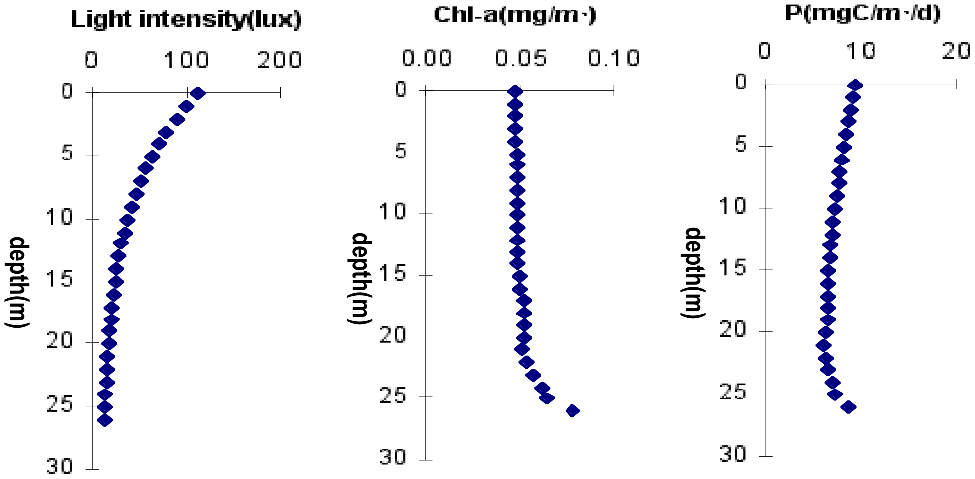


Fig. 12. Vertical distribution of light, chl-a (from Snidvongs et al., 1995) and daily primary production at station 39 (nearshore station) in September 15, 1995 at time 10.45 A.M.

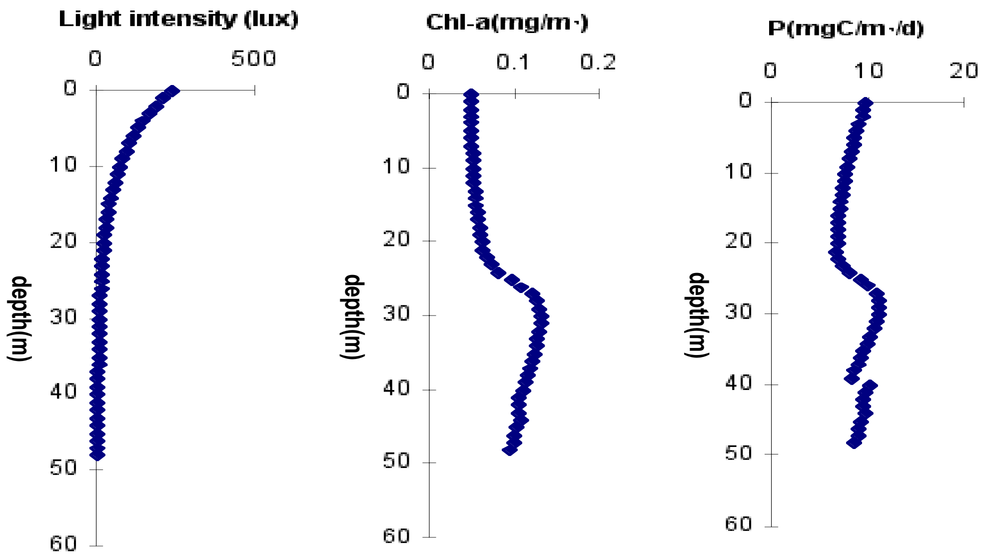


Fig. 13. Vertical distribution of light, chl-a (from Snidvongs et. al., 1995) and daily primary production at station 43 (offshore station) in September 17, 1995 at time 13.50 P.M.

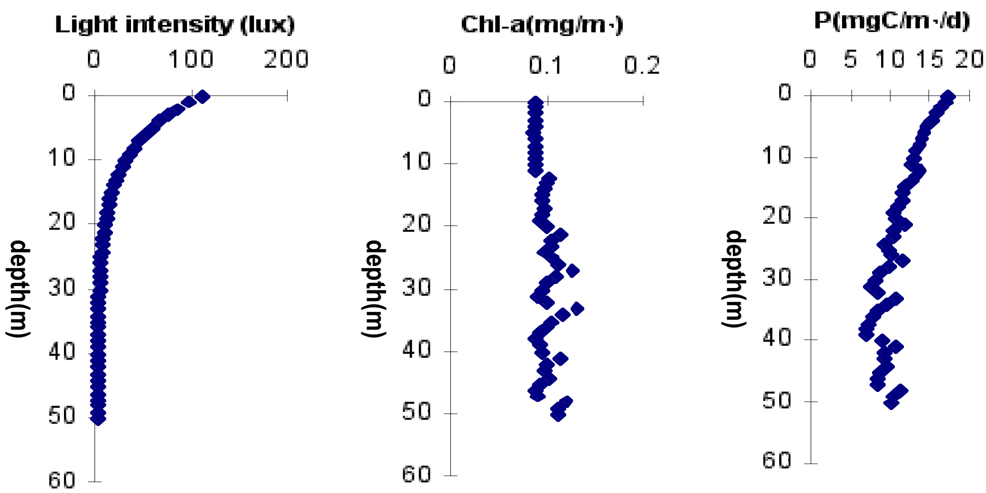


Fig. 14. Vertical distribution of light, chl-a (from Snidvongs et. al., 1995) and daily primary production at station 6 in September 6, 1995 at time 10.50 A.M.

cial fishery. The apparently high primary production does not imply the increasing marine population growth, because of the over fishing in this area. Careful management is a prerequisite to mantain future ecosystem.

Summary

1) The variability in daily primary production is closely related to change in the phytoplankton biomass.
2) A factor in adequate light penetration which may become of significance in this is attennuation due to the contribution of daily primary production.

Acknowledgement

The authors gratefully acknowledge the assistance of Dr. Anond Snidvongs, Department of Marine Science, Chulalongkorn University who collaborated in the study of the Gulf of Thailand and the East Coast of Peninsular Malaysia. And our sincere thanks due to SEAFDEC's Training Department in Thailand, the organization that funded this research, including Mr.Kijja Hutayon, the research scientist, Faculty of Science, Chulalongkorn University who counted samples by the GC-9A, Shimadzu, β - scintillation counter.

References

Berman, T., Stone, L., Yacobi, YZ., Kaplan, B., Schlichter, M., Nishri, A., and Pollingher, U. Primary production and phytoplankton in Lake Kinneret: A long-term record (1972-1993). Limnology and Oceanography, 40(6), 1995, 1064-1076.

Boonyapiwat, S. Distribution, Abundance and Species Composition of Phytoplankton in the South China Sea, Area I: The Gulf of Thailand and Malaysia Peninsular . SEAFDEC's Trainning Department,Bangkok, SEAFDEC/CRP/97/WP.16, 1997, 39pp.

Lursinsub,A. Method of Primary Productivity in the Gulf of Thailand. Upper Marine Fisheries Development Center. Department of Fisheries, Bangkok, 1985, 109pp.

Parsons, T.R., Maita, Y., and Lalli, C.M. A Manual of Chemical and Biological Methods for Seawater Analysis. Pergamon press, New York. 1984, 173pp.

Raymont, J.E.G. Plankton and Productivity in the Oceans. Second Edition. Volume 1-Phytoplankton.Pergamon Press, Oxford. 489pp.

Russell-Hunter, W.D. Aquatic Productivity: an Introduction to Some Basic Aspects of Biological Oceanography and Limnology. Collier Macmillan Publishers, London. 306pp.

Snidvongs, A., and Rochana-anawat, P. Fishery Oceanography of the Gulf of Thailand and Eastern Peninsular Malaysia During the M.V. SEAFDEC. Cruise No. 26 (September 1995): A Preliminary Summary. SEAFDEC's Trainning Department, Bangkok, 1995, 36pp.

Snidvongs, A., Rochana-anawat, P., and Laongmanee, W. The Catalogue of Oceanographic Profiles of the Western Gulf of Thailand and Eastern Peninsular Malasia in September 1995. SEAFDEC's Trainning Department, Bangkok, TD/RES/37,1995, 166pp.

Distribution, Abundance and Biological Studies of Economically Important Fishes in the South China Sea, Area I: East Coast of Peninsular Malaysia

Mansor Mat Isa[1]
Abd Haris Hilmi Ahmad Arshad[2]
Samsudin Basir[2]

[1] Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center, Chendering, 21080, Kuala Terengganu, MALAYSIA
[2]Fisheries Research Institute, Department of Fisheries Malaysia, Batu Maung, 11960 Pulau Pinang, MALAYSIA.

ABSTRACT

This paper presents species distributions, composition and biological parameters of major fish species caught from the east coast of Peninsular Malaysia during the one week surveys made in pre- and post-Northeast monsoon seasons. The fish species rankings changed over time and at different depth strata. The catch rates were decreased toward deeper water. An appearance of smaller fish group was greater during the post-Northeast than pre-Northeast monsoon season. Fish populations occurred at both seasons were represented from different spawning group. Their growths were isometric form in weight.

Key words: Catch and size composition, pre- and post-Northeast monsoon, growth in weight.

Introduction

The total productions of the fisheries sector of Malaysia in 1994 amounted to 1,181,763 MT, valued at Malaysian Ringgit 2.99 billion constituting about 1.61% of the national GDP. Of the total production, 90.15% was contributed by marine fisheries that employs over 79,800 fishers (DOF, 1995).

The total production of demersal fish of Malaysia in 1994 was estimated at nearly 182,884 MT. The west coast of Peninsular Malaysia was contributed at around 33.4% of the demersal fish, while 28.8% was by the east coast of Peninsular Malaysia. The remaining 22.7% and 15.1% were landed from Sabah and Sarawak waters respectively.

The pelagic fish are also important marine resource of Malaysia. In 1994, they were estimated at around 373,979 MT or 35.9% of the total marine catch of Malaysia (DOF, 1995). The production of pelagic fish on the east coast of Peninsular Malaysia was 128,445 MT as compared to the west coast with 143,960 MT, Sarawak with 25,169 MT and Sabah with 76,405 MT (Mansor, *in press*).

A number of demersal surveys (Anon, 1967; Pathansali *et al*., 1974; Jothy *et al*., 1975; Lam *et al*., 1975; Lamp and Shaari, 1976; Mohsin *et al*., 1986, 1987, 1988, 1990; DOF, 1987; Ahmad-Adnan, 1990) and acoustic surveys (Amin *et al*., 1984; Leong and Abdul-Hamid, 1984; DOF, 1987) have been conducted in the South China Sea, particularly in Malaysian waters. Most of the surveys were conducted to determine the distribution and abundance of the demersal and pelagic species.

The firsts trawl survey (Pathansali *et al*., 1974) has identified suitable areas for trawling, effects of hydrography regime and bottom characteristics to species distribution. In 1985-1987, the demersal and acoustic surveys were conducted simultaneously in conjunction with the deep sea fishing plan that was implemented in 1987 (DOF, 1987).

This paper attempts to discuss the distribution, abundance, species composition and biological parameters of some economically important fish species following the one week survey conducted by Malaysian fisheries research vessel on the east coast of Peninsular Malaysia, on pre- and post-

Northeast monsoon seasons.

Materials and Methods

Sampling methods

The survey was carried out on the east coast of Peninsular Malaysia between 23rd and 29th September 1995 (pre-Northeast monsoon) and between 8th and 17th May 1996 (post-Northeast monsoon) using a research vessel of the Fisheries Research Institute of Malaysia.

Samples were collected using a German designed high-opening trawl net. The net has a cod-end mesh size of 25 mm and cover net mesh size of 40 mm. The net was towed at 3 knots for one hour duration at a specific station.

During the survey the total catch of each haul were sorted out into commercial fish and trash fish without considering size categories. Subsequently the commercial fish species were sorted into demersal fishes, pelagic fishes, penaeid prawns, crabs, cephalopods, jelly fish and true trash fishes *i.e.* those have no commercial values. Each category of fish species was then weighed to the nearest kilogram using a digital hanging scale. The total lengths (TL) of individual fish were measured to the nearest mm for size compositions' studies.

The fish species from each sampling station were kept frozen and brought back to the laboratory for further examination. The following measurements were made in the laboratory: i) total length (TL) and total body weight (W) of individual fish to the nearest millimetre and gram respectively, ii) sex and maturity stage and gonad weight for estimating maturity in fish species.

Statistical analysis

The TL data were grouped in 10 mm classes. The frequency distribution patterns for a number of fish species in the combined samples from entire sampling stations were examined. The Bhattacharya's method that is available in the FiSAT module (Gayanilo *et al*., 1994) was applied on the length frequency distribution of the fish species for cohort segregation

Length/weight relationships were determined for each fish species. Equations of the form $W=aL^b$, where a and b are constants of regression, were fitted by transforming the data into logarithms and deriving the regression line by the least squares method (Sparre and Venema, 1992).

Results

Trawling activities in the east coast of Peninsular Malaysia have shown that demersal fishes were the most abundant, followed by trash fish, cephalopods and pelagic fish. They were similarly observed during the pre- and post-Northeast monsoon seasons (Table 1). Higher percentages of catches of trash fish were recorded during North-east monsoon, as compared to the demersal which was during the pre-Northeast monsoon. The higher catch of *Dasyatis* spp. from one of the station during post-Northeast monsoon season was made and this had contributed to a higher value of standard diviation.

The average catch rates of major components of fishes by depth stratum are tabulated in Table 2 and Table 3. Greater varieties of fish species were caught in the deeper water with different ranking of abundance. Their rankings in abundance in both seasons were also changed. Mullidae was the major family caught from the survey area followed by Nemipteridae, Priacanthidae, Synodontidae and small amount from of other families.

Smaller size group of fish tend to arrive in the area during the post-Northeast monsoon (Figs. 2a and b) rather than in pre-Northeast (Figs 1a and b). They were consisting of more than one spawning group. The mean lengths of each cohort of these species are as shown in Table 4 and 5.

Table 1. Catch composition of fishery group caught from the east coast of Peninsular Malaysia at pre-Northeast monsoon (September 1995) and post-Northeast monsoon (May 1996).

	Pre-Northeast monsoon			Post-Northeast monsoon		
Fishery group	**Kg/hr**	**S.D.**	**%**	**Kg/hr**	**S.D.**	**%**
Demersal fish	35.08	24.52	65.87	39.03	38.05	53.29
Pelagic fish	2.07	1.94	3.89	1.85	2.57	2.53
Paneaid prawn	0.25	0.47	0.47	0.45	0.48	0.61
Cephalopods	3.88	2.31	7.29	6.53	3.99	8.92
Trash fish	11.98	9.45	22.49	25.38	35.89	34.65
Total catch	53.26	33.61		73.24	58.40	

Table 2. Catch rates (kg/hr) distribution of fish species by depth caught from the east coast of Peninsular Malaysia during the pre-Northeast monsoon season, in order of abundance.

Species name	**Family**	**Depth(meters)**				**Mean**
		30-40	**40-50**	**50-60**	**60-70**	
Upeneus bensasi	Mullidae			5.71	3.49	4.60
Gerres spp.	Gerreidae			7.78	0.88	4.33
Nemipterus thosaporni	Nemipteridae			4.87	3.31	4.09
Pentaprion longimanus	Gerreidae			6.97	0.90	3.93
Priacanthus macracanthus	Priacanthidae			3.32	3.98	3.65
Priacanthus tayenus	Priacanthidae			2.93	3.74	3.34
Loligo spp.	Loliginidae	1.46		3.54	1.33	2.11
Nemipterus nemurus	Nemipteridae			1.92	2.24	2.08
Parupeneus heptacanthus	Mullidae	0.04			4.00	2.02
Saurida tumbil	Synodontidae			1.20	1.93	1.56
Upeneus sulphureus	Mullidae			2.47	0.35	1.41
Sepia spp.	Sepiidae	0.04		1.81	1.82	1.22
Saurida undosquamis	Synodontidae			1.37	1.07	1.22
Carangoides malabaricus	Carangidae			1.38	0.28	0.83
Lutjanus vitta	Lutjanidae			0.83		0.83
Alutera monocerus	Monacanthidae			1.12	0.43	0.77
Selaroides leptolepis	Carangidae	1.27			0.01	0.64
Lutjanus lutjanus	Lutjanidae			0.49	0.77	0.63
Gymnocranius griseus	Pentapodidae			0.50	0.65	0.58
Nemipterus peronii	Nemipteridae			0.79	0.28	0.54
Carangoides gymnostelthus	Carangidae	1.20		0.35	0.02	0.52
Decapterus maruadsi	Carangidae	0.12			0.86	0.49
Scolopsis spp.	Scolopsidae			0.60	0.22	0.41
Nemipterus nematophorus	Nemipteridae			0.40	0.16	0.28
Nemipterus tambuloides	Nemipteridae			0.06	0.43	0.25
Average catch (kg/hr)		0.69		2.29	1.38	

Table 3. Catch rates (kg/hr) distribution of fish species by depth caught from the east coast of Peninsular Malaysia during the post-Northeast monsoon season, in order of abundance.

Species name	Family	Depth(meters)					Mean
		20-30	30-40	40-50	50-60	60-70	
Dasyatis zugei	Dasyatidae	1.10	59.70	1.25	1.07		15.78
Upeneus bensasi	Mullidae	5.30	3.00	5.40	4.23	2.85	4.16
Nemipterus nemurus	Nemipteridae		0.13	3.00	4.97	6.75	3.71
Loligo spp.	Loliginidae	0.40	5.32	5.19	2.90	2.75	3.31
Sepia spp.	Sepiidae	1.80	6.86	1.72	3.59	0.89	2.97
Tracheynocephalus myops	Synodontidae	3.50	1.80				2.65
Pristipomoides multidens	Lutjanidae			0.02	3.75	1.88	
Saurida undosquamis	Synodontidae	0.22	0.36	2.70	3.13	2.85	1.85
Nemipterus furcosus	Nemipteridae	0.02	4.60	1.95	0.06		1.66
Pentaprion longimanus	Pentapodidae			3.77	0.06	0.26	1.36
Nemipterus thosaporni	Nemipteridae			0.07		2.58	1.32
Selaroides leptolepis	Carangidae	0.24	0.80	3.79	1.12	0.30	1.25
Priacanthus tayenus	Priacanthidae		0.90	1.99	0.71	1.25	1.21
Nemipterus nematophorus	Nemipteridae					1.00	1.00
Lutjanus malabaricus	Lutjanidae				1.00	1.00	
Octopus spp.	Octopodidae	0.02	3.26	0.52	0.02		0.95
Nemipterus bathybius	Nemipteridae					0.59	0.59
Nemipterus tambuloides	Nemipteridae					0.52	0.52
Synodus hoshinonis	Synodonthidae	0.09	0.14	0.61	0.67	0.90	0.48
Lutjanus lutjanus	Lutjanidae	1.10	0.04	0.17		0.44	
Gynocranius elongatus	Pentapodidae		0.72			0.06	0.39
Alutera monoceros	Monacanthidae		0.12	0.14	0.78	0.30	0.33
Scolopsis taeniopterus	Scolopsidae	0.45	0.26	0.60	0.27	0.07	0.33
Thennus orientalis	Scyllaridae	0.70	0.20	0.13	0.48	0.08	0.32
Sepioteuthis lessoniana	Loliginidae	0.05	1.04	0.02	0.14	0.33	0.32
Average catch (kg/hr)		1.07	5.02	1.83	1.88	1.45	

The length-weight relationships of the dominant species caught during the survey are summarised in Table 6 and 7. The *b* values obtained for many of species were close to or bigger than 3 indicating parabolic growth in weight.

Discussion

Sea bed and environmental conditions play a significant role in determining the distribution of fish species (Bailey, 1992). The sea beds of the east coast of Peninsular Malaysia have been classified as sandy due to patchy coral reefs stretching from the North to the South of the coast (Chuang, 1961). The east coast of Peninsular Malaysia can be also classified as coral area, uneven mud-clay grounds and trapped fishing but change in the sea bed is always occur as a result of strong tidal, coastal current and wave action (Jothy *et al*., 1975).

Previous surveys (Pathansali *et al*., 1974; Jothy *et al*., 1975; Lam *et al*., 1975; Lamp and Shaari, 1976; Ahmad-Adnan, 1990) concluded that progressive decline in yield occurred in the deeper zones. The depths from 21 to 40 meters usually were more productive area. The fish resources off the east coast of Peninsular Malaysia appear to be poor beyond the 40 mile's line. This was due to poor of chlorophyll *a*, zooplankton and fish larvae (Mohsin *et al*., 1987). Present studies indicated that the averages catch at different depth strata was lower towards deeper area.

The demersal species caught in this survey was found to be dominated by the family Nemipteridae, Priacanthidae, Mullidae and Synodontidae, while the pelagic fish was the family Carangidae. All these family groups seem to be dominated in all demersal surveys but in different ranking. Their catch rates were not effected by seasons which was also indicated by Adnan (1996), where Loliginidae and Mullidae were the most abundant species followed by Synodontidae and Nemipteridae.

Many of the fish species collected during this one week survey in pre-Northeast and in post-Northeast 1996 were from more than one spawning group. The smaller size groups of immature fish tend to be the majority of fish caught in the area. The populations of the larger groups of fish were found to be less abundant as they are vulnerable to fishing pressure or are probably emigrating for spawning activities in the areas close to shore. Appearance of smaller fish group in the survey area during the post-Northeast monsoon season had also reported by Mansor and Abdullah (1995). They believed to have been effected by the mixing of the northeast and southeast current which influence

Table 4. Summary of cohort's analysis by application of the Bhattacharya's method on fish species collected from the east coast of Peninsular Malaysia in pre-Northeast monsoon season.

Species name	Number of cohort	Mean length (mm) of cohort	S.D.	R^2
Nemipterus thosaporni	2	136.7	8.83	0.96
		200.4	12.98	0.99
Nemipterus nemurus	2	153.6	18.57	0.99
		211.5	12.52	0.99
Priacanthus macracanthus	3	138.6	13.94	0.89
		173.8	11.21	0.79
		250.8	15.53	0.94
Upeneus bensasi	2	130.8	11.97	0.86
		202.1	12.69	0.99
Pricanthus tayenus	2	152.8	24.74	0.93
		207.1	14.45	0.84
Paurpeneus pleurospilus	1	196.7	12.76	0.85
Selaroides leptolepis	1	134.1	9.57	0.85
Saurida undosquamis	2	224.4	10.93	0.87
		289.1	15.26	0.84
Nemipterus bathybius	1	124.2	14.28	0.65
Saurida tumbil	1	232.8	11.32	0.63
Caranx spp.	2	138.7	14.55	0.69
Pentaprion longimanus	1	108.9	10.65	0.99
Decapterus russelli	1	183.6	9.96	0.72

Table 5. Summary of cohort's analysis by application of the Bhattacharya's method on fish species caught in the east coast of Peninsular Malaysia during the post-Northeast monsoon season.

Species name	Number of cohort	Mean length (mm) of cohort	S.D.	R^2
Upeneus bensasi	1	132.5	12.158	0.98
Nemipterus nemurus	2	138.6	12.204	0.91
		171.3	13.148	0.77
Selaroides leptolepis	2	117.8	7.671	0.95
		153.9	8.256	0.90
Pentaprion longimanus	1	117.4	8.522	0.96
Saurida undosquamis	2	119.7	16.437	0.99
		213.8	21.853	0.73
Nemipterus furcosus	2	115.4	14.080	0.92
		176.9	7.016	0.99
Priacanthus tayenus	3	107.6	9.790	0.96
		149.3	7.047	0.92
		219.1	19.798	0.77
Synodus hoshinonis	1	166.4	14.370	0.90
Dasyatis zugei	1	190.9	13.946	0.92
Nemipterus thosaporni	1	135.0	18.091	0.78
Trachinonocephalus myops	1	125.9	9.930	0.93
Lutjanus lutjanus	2	88.7	9.780	0.93
		160.0	8.970	0.96
Gymnocranius griseus	2	97.4	9.183	0.86
		170.0	9.320	0.68
Scolopsis taeniopterus	1	161.9	18.230	0.92
Parupeneus heptacanthus	2	132.6	16.675	0.89
		174.7	11.410	0.81
Caesio chrysozona	1	126.6	7.505	0.99
Aluterus monoceros	1	160.9	24.005	0.99
Nemipterus tambuloides	2	129.1	13.061	0.75
		173.5	6.920	0.88

plankton blooms. Furthermore, influxes of nutrient from the land during raining season has activate the process.

Details community analysis of a series surveys' data will give better understanding on the fish community in the South China Sea area.

Acknowledgements

Authors wish to thank research staff of Marine Fishery Resources Development and Management Department of SEAFDEC and Fisheries Research Institute, Department of Fisheries Malaysia for their assistance in the data collection. Last but not least many thanks to Mr. Syed Abdullah, Mr. Che Omar and Mr. Abd

Table 6. Summary of the length-weight relationships of major species caught from the east coast of Peninsular Malaysia in pre-Northeast monsoon season.

Species name	N	Sizes range (mm)	Weights range (gm)	a S.E.	b S.E.	R^2
Nemipterus thosaporni	367	87-215	7-113	-4.5866 0.0324	2.8532 0.0279	0.97
Nemipterus nemurus	203	98-236	11-157	-4.9610 0.0433	3.0229 0.0361	0.96
Priacanthus macracanthus	193	120-270	22-234	-4.8818 0.0333	2.9987 0.0333	0.98
Upeneus bensasi	123	140-260	34-212	-5.2980 0.0269	3.1793 0.0512	0.97
Priacanthus tayenus	106	117-250	23-175	-4.3206 0.0340	2.7429 0.0467	0.97
Parupeneus pleurospilus	64	150-280	41-268	-4.8762 0.0360	2.9262 0.0859	0.95
Nemipterus bathybius	46	120-185	21-79	-4.7302 0.0328	2.9260 0.0911	0.96
Nemipterus nematophorus	28	104-212	13-110	-4.8805 0.0411	2.9801 0.1049	0.97
Nemipterus peronii	27	152-240	40-186	-5.3775 0.0200	3.1984 0.0361	0.98
Nemipterus tambuloides	27	153-240	39-164	-4.9795 0.0330	3.0212 0.1488	0.94

Table 7. Summary of the length-weight relationships of major fish species caught from the east coast of Peninsular Malaysia in the post-Northeast monsoon season

Species name	N	Sizes range (mm)	Weights range (gm)	a S.E.	b S.E.	R^2
Nemipterus nemurus	440	105-223	16-135	-4.6354 0.0726	2.8809 0.0726	0.94
Saurida undosquamis	234	83-340	5-385	-5.0010 0.0910	2.9196 0.0430	0.98
Selaroides leptolepis	227	90-180	Sep-67	-5.0494 0.0747	3.0355 0.0353	0.98
Pentaprion longimanus	221	79-143	4-40	-5.1041 0.1436	3.1143 0.0693	0.90
Nemipterus thosaporni	204	98-202	11-104	-4.7759 0.1026	2.9474 0.0478	0.95
Upeneus bensasi	158	61-182	2-64	-4.9891 0.1593	3.0147 0.0741	0.91
Synodus hoshinonis	155	103-305	7-257	-5.5931 0.1307	3.1994 0.0589	0.95
Nemipterus furcosus	155	80-243	7-192	-4.5782 0.1303	2.8466 0.0619	0.93
Dasyatis zugei	139	126-301	48-662	-3.2829 0.2185	2.4541 0.0959	0.83
Priacanthus tayenus	120	85-253	11-137	-3.8518 0.0799	2.5285 0.0368	0.97
Trachynocephalus myops	85	102-276	9-168	-5.1535 0.1010	3.0230 0.0459	0.98
Lutjanus lutjanus	68	73-170	4-79	-5.1324 0.1220	3.1294 0.0614	0.98
Gymnocranius griseus	52	66-190	8-128	-4.4218 0.1228	2.8513 0.0611	0.97
Parupeneus heptacanthus	51	99-279	12-316	-5.5047 0.1182	3.2649 0.0534	0.99
Nemipterus nematophorus	48	103-180	16-78	-4.6788 0.2028	2.9022 0.0955	0.95
Caesio chrysozona	40	103-140	11-28	-5.0926 0.3462	3.0562 0.1654	0.90
Nemipterus tambuloides	35	110-191	17-81	-4.4610 0.1762	2.7845 0.0814	0.97
Scolopsis taeniopterus	31	142-224	45-146	-4.5414 0.3034	2.8664 0.1367	0.94

Rahman Majid for the data processing.

References

AHMAD-ADNAN, N. 1990. Demersal fish resources in Malaysian waters-16. Fifth trawls survey of coastal waters off the east coast of Peninsular Malaysia (June-July 1981). *Fisheries Bulletin*. No. 60. Department of Fisheries, Ministry of Agriculture Malaysia. 37 p.

AHMAD-ADNAN, N. 1996. Changes in the species composition of demersal fish trawl surveys in the east coast of Peninsular Malaysia. Proceeding, Seminar on Fisheries Research. 8-10 July 1996. Fisheries Research Institute, Department of Fisheries Malaysia.

AMBAK, M. A., MOHSIN, A.K.M. and MOHD-SAID, M. Z. 1986. Growth characteristics of Lutjanidae off the east coast of Peninsular Malaysia. Ekspedisi Matahari '85.

AMIN, E. M. LEONG, C. H., SELVANATHAN, S. and ABDUL-HAMID, Y. 1984. Acoustic survey of pelagic fish resources in the waters off the east coast of Peninsular Malaysia. Fisheries Bulletin, Department of Fisheries, Ministry of Agriculture Malaysia. No. 28. 23p.

ANON. 1967. Result of the joint Thai-Malaysian-German trawling survey off the east coast of the Malay Peninsular. Prepared by the marine fisheries laboratory Department of Fisheries, Ministry of Agriculture Bangkok, Thailand and the Fisheries Research Institute, Fisheries Division, Ministry of Agriculture and Cooperation Malaysia. 64 p.

BAILEY, R. S. 1992. The global pelagic fish resource and its biological potential. *In*: Burt, J. R., Hardy, R. and Whittle, K. J. (eds). Pelagic fish: the resource and its exploitation. Fishing news books 352p.

CHUANG, S. H. 1961. On Malayan shores, Singapore, Muwu Shosa, 255p.

DOF, 1995. Annual Fisheries Statistics 1994, Department of Fisheries, Ministry of Agriculture Malaysia.

DOF, 1987. Deep-sea fisheries resource within the Malaysian EEZ, R.V. RASTRELLIGER, Department of Fisheries, Ministry of Agriculture Malaysia.

MOHSIN, A.K.M, MOHD-IBRAHIM, M. and AMBAK, M.A. 1986. EKSPEDISI MATAHARI '85. A study on the offshore waters of the Malaysian EEZ. Faculty of Fisheries and Marine Science, University Pertanian Malaysia, No. 3. 233p.

MOHSIN, A.K.M., ABDUL-RAHMAN, R. and AMBAK, M.A. 1987. EKSPEDISI MATAHARI '86. A study on the offshore waters of Malaysian EEZ. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia. No.4. 197p.

MOHSIN, A.K.M. and MOHD-IBRAHIM, M. 1988. EKSPEDISI MATAHARI '87. A study on the offshore waters of the Malaysian EEZ. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia. No.8.

MOHSIN, A.K.M., MOHD-SAID, M. Z. and MOHD-IBRAHIM, M. 1990. EKSPEDISI MATAHARI '89. A study on the offshore waters of the Malaysian EEZ. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia. No.9.

GAYANILO, JR. F. C., SPARRE, P. AND PAULY, D. 1994. The FAO-ICLARM stock assessment tools (FiSAT). User's guide, FAO, Rome. 126p.

JOTHY, A.A., RAUCK, G., MOHD. SHAARI S.A. LATIFF, ONG KAH SIN, LEONG PIT CHONG and CARVALHO, J. L. 1975. Demersal fish resources in Malaysian waters. Second trawl survey of the coastal waters off the east coast of Peninsular Malaysia. *Fisheries Bulletin* No. 4., 35p.

LAM WAH CHANG, WEBER, W., LEE AIK KEAN, ONG KAH SIN and LIONG PIT CHONG 1975. Demersal fish resources in Malaysia water-7. 3rd east coast trawl survey off the east coast of Peninsular Malaysia (14th August-20th September 1972). *Fisheries Bulletin.* No. 9. Ministry of Agriculture and Rural Development, Malaysia. 19 p.

LAMP, F. and MOHD SHAARI S. A. LATIFF 1976. Demersal fish resources in Malaysia waters-10. Fourth trawl survey of coastal waters off the east coast of Peninsular Malaysia (13th July-12th August 1971). *Fisheries Bulletin*. No. 12, Ministry of Agriculture and Rural Development, Malaysia. 25p.

LEONG, C. H. and ABDUL-HAMID, Y. 1984. Report on the second hydro-acoustic survey of the South China Sea off the east coast of Peninsular Malaysia. *Fisheries Bulletin*, Jabatan Perikanan, Kementerian Pertanian Malaysia, No. 29. 19p.

MANSOR, M.I. and ABDULLAH, S. 1995. Growth and mortality of Indian mackerel, *Rastrelliger kanagurta* and Slender scad, *Decapterus russelli* off the east coast of Peninsular Malaysia. *Sci. Mar*. 59(3-4): 533-547.

MANSOR, M. I. (*in press*). Population structure of small pelagics off the east coast of Peninsular Malaysia. *Fisheries Bulletin*, Department of Fisheries Malaysia.

MOHD-SAID, M.Z., AMBAK, M.A. and MOHSIN, A.K.M. 1986. Status of Threadfin bream in the offshore waters off the Terengganu coast. *In:* Mohsin, A.K.M., Mohd-Ibrahim, M. and Ambak, M.A. (eds). Ekspedisi Matahari '85 - A study on the offshore waters of the Malaysian EEZ. Faculty of Fisheries and Marine Science, University Pertanian Malaysia, No. 3.

MOHAMED, M. I. H. 1986. Temporal differences in the trawl catch of 'Matahari Expedition '85'. *In:* A.K. M. Mohsin, M.I.H. Mohamed and M. A. Ambak (eds). Ekspedisi Matahari '85 - A study on the offshore waters of the Malaysian EEZ. Faculty of Fisheries and Marine Science, University Pertanian Malaysia. Occasional Publication, No. 3.

PATHANSALI, D., RAUCK, G., JOTHY, A.A., MOHD SHAARI B. S. A. LATIFF and CURTIN, T.B. 1974. Demersal fish resources in Malaysian waters. Trawl survey of the coastal waters of the east coast of West Malaysia. *Fisheries Bulletin*, No. 1, 47p.

SPARRE, P. and VENEMA, S. C. 1992. Introduction to tropical fish stock assessment. Fisheries Technical Paper 306/1, Rev. 1, FAO, Rome. 337pp.

Temporal Changes in the Abundance of Macrobenthos in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Montira Piamthipmanus

Department of Fisheries

ABSTRACT

The ecology of macrobenthic fauna in the Gulf of Thailand and the east coast of Peninsular Malaysia was studied for two periods of time at pre NE monsoon (4 Sep.- 4 Oct. 1995) and post NE monsoon (23 Apr. -23 May, 1996).

It was found that the overall abundance of macrobenthic fauna presented the highest density at station 52 (920 ind.m^{-2}). Polychaete was the dominant group in the benthic comunities.

The result of the survey of the ecology of benthic fauna shows that the fauna density increases with a decreasing water depth. Polychaete, Crustacea and Echinoderm groups displayed a marked change in density with the during period of the monsoon and the diversity index showed different patterns during the pre and post NE monsoon periods.

Key Words : Macrobenthic fauna, Abundance, Gulf of Thailand, East Coast of Peninsular Malaysia

Introduction

The abundance of benthic fauna is a biological parameter that may indicate overall aquatic fertility of the bottom sediments. They are also the main source of food for both migratory and permanent fauna, higher predators in the food chain. Moreover, benthic communities are widely used in monitoring the effect of marine pollution as the organism are mostly sessile and integrate the effects of pollutants over time (Gray *et al*., 1990). It is also suggested that benthic fauna can be used as an integrating indicator of water quality within an area (Wass, 1967; Reish, 1972; Holland *et al*.,1973). Any fluctuation in either their quality and quantity will directly affect the abundance of demersal fishes which are an important fishery resource in the sea. Therefore, a benthic study may be used as baseline information to evaluate the existing demersal stocks and may also serve as a baseline study of future investigations on environmental changes in this area.

The present investigation of macrobenthic fauna is part of the biological oceanographic data survey under a collaborative research project between SEAFDEC's Training Department (TD) in Thailand and Marine Fisheries Resources Development and Management Department (MFRDMD) in Malaysia. The objectives of the collaborative research project are to collect and analyze data in order to provide information necessary for management of the environment and fishery resources in the South China Sea. The first survey area was the western part of the Gulf of Thailand and the east coast of Peninsular Malaysia within the exclusive economic zones of Thailand and Malaysia.

Macrobenthic studies have been previously conducted in the Gulf of Thailand by Charoenruay and Nateewathana,1978; Piyakarn *et al*.,1978; Charoenruay and Ketsamut,1979; Ketsamut *et al*.,1980 a and b; Charoenruay and Piamthipmanus,1981; Thanapong and Mhordee,1982; Charoenrauy *et al*.,1983; Piamthipmanus *et al*.,1984; Piamthipmanus,1984; Piamthipmanus *et al*.,1985.

The purpose of this study is to report the qualitative distribution and faunal composition of the macrobenthos in the Gulf of Thailand and east coast of Peninsular Malaysia, and also to examine changes in the density and diversity of macrobenthic fauna between the pre and post NE monsoon, providing preliminary information on benthic communities.

Materials and methods

Sampling

Sampling area

The survey areas are in the Gulf of Thailand and east coast of Peninsular Malaysia (Lat.12.20.00-01.48.54 N; Long.100.15.00-104.45.26 E; Fig.1). A total of 81 survey stations were set up for the collaborative research project (Fig.2). Two monsoon seasons can be distinguished: SW monsoon period from June to October and NE monsoon season from November to February. The collaborative research project was carried out on board MV SEAFDEC from 4 September-4 October, 1995 and 23 April-23 May, 1996. The first cruise was in the pre NE monsoon and the second was in the post NE monsoon period.

Sampling methods

At each station (station 27 excluded in the first cruise), two random samplings of bottom sediment were collected using a Smith-McIntyre grab (area coverage 0.05 m^2). The sediment was washed through a set of sieves, the smallest one with a mesh size of 0.5 mm. Benthic animals were collected and fixed in 10 % formaldehyde solution in sea water on board and were subsequently sorted and preserved in 70% ethyl alcohol in the laboratory. The sorted macrobenthic fauna was identified and counted separately for each taxa. The number of individuals of six taxonomic groups (Polychaeta, Crustacea, Mollusca, Echinodermata, Fishes and Other groups) were recorded.

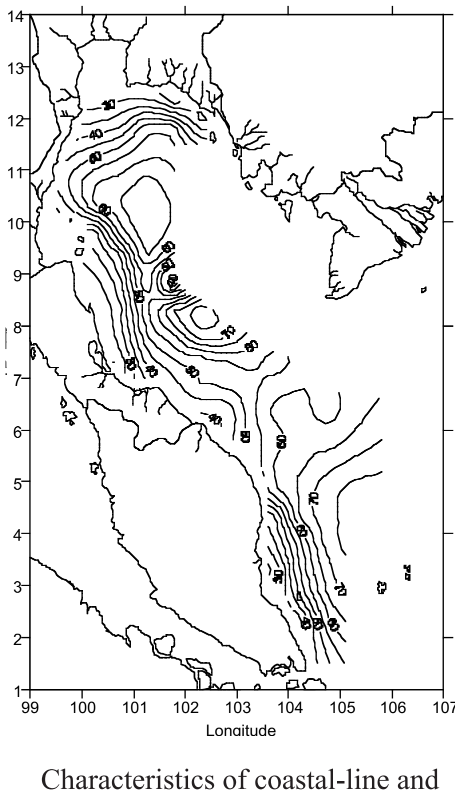


Fig. 1. Characteristics of coastal-line and water depth (m) of study area

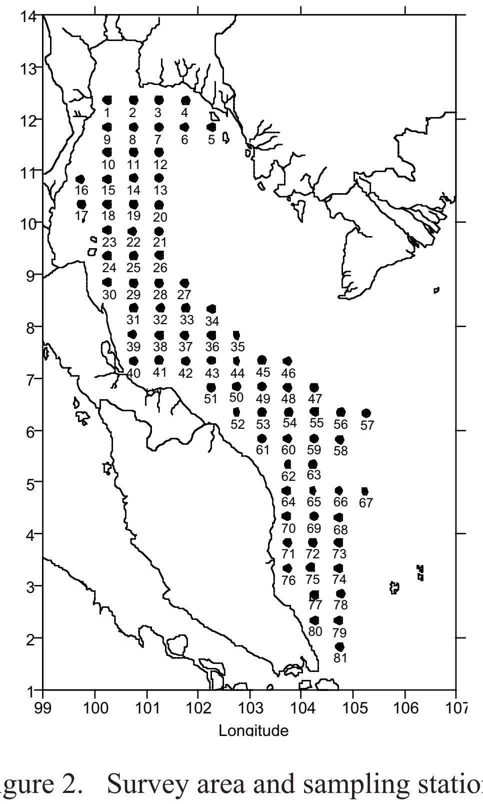


Figure 2. Survey area and sampling stations

Sediment Analysis

A sample of approximately 200 g sediment was collected from the surface of the grab sample to determine grain size composition (clay, clayey sand, sandy clay and sand) by the Wentworth scale (1922) and Shetard (1954) methods.

Analysis

i) Estimation of the difference in abundance of macrobenthic fauna (ind.m^{-2}) in the Gulf of Thailand and the east coast of Peninsular Malaysia between pre NE monsoon and post NE monsoon periods. The results of these calculation are summarised in the table (- decrease, 0 no difference, + increase).

ii) Estimation of species diversity of macrobenthic fauna in the Gulf of Thailand and the east coast of Peninsular Malaysia for 4 different types of sediment were calculated from Shannon and Weaver's (1949) formula.

Diversity Index or Shannon' Index (H')

$$H' = -\sum (P_i \ln P_i)$$

Results

The abundance and distribution of macrobenthic fauna

The six groups of macrobenthic fauna found in the Gulf of Thailand and the east coast of Peninsular Malaysia are Polychaeta, Crustacea, Mollusca, Echinodermata, Fishes and Others, composed of 57.8 % polychaete, 25.4 % crustacea, 8.6 % echinoderm, 5.4 % other groups, 1.6 % fishes and 1.1 % of mollusca (Table 1). The overall average of the benthic fauna abundance in the Gulf of Thailand and the east coast of Peninsular Malaysia was 88 ind.m^{-2} in the pre NE monsoon period and 97 ind.m^{-2} in the post NE monsoon. Polychaete and Crustacea were the numerically dominant taxa in the benthic communites; all other taxa being relatively sparse. The total average abundance of macrobenthic fauna varied from 0 to 590 ind.m^{-2} in the pre NE moonsoon period and 0 to 700 ind.m^{-2} in the post NE monsoon. High density areas of total macrobenthic fauna occurred at station 76 in the pre NE monsoon and station 52 in the post NE monsoon (Fig. 3 and 4).

Table 1 Average abundance of the macrobenthic fauna in the pre and post NE monsoon periods.

Macrobenthic fauna	Abundance ind.m^{-2}(%)		Total
	pre	post	
Polychaete	48 (54.6%)	59 (60.8)	107 (57.8%)
Crustacea	24 (27.3%)	23 (23.7%)	47 (25.4%)
Mollusca	1 (1.1%)	1 (1.0%)	2 (1.1%)
Echinodermata	9 (10.2%)	7 (7.2%)	16 (8.6%)
Fishes	1 (1.1%)	2 (2.1%)	3 (1.6%)
Others	5 (5.7%)	5 (5.2%)	10 (5.4%)
Total	88 (100%)	97 (100%)	185 (100%)

Polychaete

The polychaetes dominated the macrobenthic communities and were well represented at almost every station except stations 14, 23, 27 and 30. Their average abundance was 48 ind.m^{-2} (54.6%) varying from 0 to 340 ind.m^{-2} in the pre NE monsoon cruise and 59 ind.m^{-2} (60.8%) varying from 0 to 390 ind.m^{-2} in the post NE monsoon period. High density areas of polychaetes occurred at station 76 in the pre NE monsoon and station 52 in post NE monsoon period (Table 1 and 2). A total of 35 families of polychaetes were identified and Syllidae were present in most stations (Table 3).

Crustacea

The crustaceans were the second most abundant group of macrobenthos. They live on the sediment surface, and dwell in a hole or in a tube, or burrow freely within the sediment. The fast moving and swimming species were seldom caught by grab. Generally, the crustaceans were of small size, i.e. amphipods, isopods and ostracod, while larger crabs and shrimps were rare, only small shrimp *Callianassa* spp. were found to be most abundant in the survey area. Crustaceans averaged 24 ind.m^{-2} (27.3%) varying from 0 to 130 ind.m^{-2} and 23 ind.m^{-2} (23.7%) varying from 0 to 210 ind.m^{-2} in pre and post NE monsoon periods respectively with the highest density occurring at station 52 both in the pre and post NE monsoon (Table 1 and 2).

Mollusca

The molluscs were mostly of small size and not economically important. They were very few in number. They were missing completely from most of the samples. Mollusca averaged only 1 ind.m^{-2} (1.1%) both in pre and post NE monsoon periods; ranging from 0 to 10 ind.m^{-2} and 0 to 20 ind.m^{-2} (Table 1 and 2).

Echinodermata

Brittle stars and heart urchin were found in large numbers at station 71 and 76 in pre NE monsoon period. The echinoderms averaged 9 ind.m^{-2} (10.2%) ranging from 0 to 150 ind.m^{-2} in the pre NE monsoon and 7 ind.m^{-2} (7.2%) ranging from 0 to 50 ind.m^{-2} in post NE monsoon cruise. Densities of 150 ind.m^{-2} of heart urchin were found at station 76 (Table 1 and 2).

Fishes

The menbers of this group are gobiid fish and eels which live in holes or burrow in the sediment. The average abundance was only 1 ind.m^{-2} (1.1%) in the pre NE monsoon and 2 ind.m^{-2} (2.1%) in the post NE monsoon periods, ranging from 0 to 10 ind.m^{-2} both in the pre and post NE monsoon periods (Table 1 and 2).

Others

This category includes the nemerteans, sipunculans, anthozoa and the cephalochordata amphioxus. On average these groups contributed 5 ind.m^{-2} (5.7% and 5.2%) both in the pre and post NE monsoon periods, ranging from 0 to 40 ind.m^{-2} and 0 to 120 ind.m^{-2} in pre and post NE monsoon respectively. Densities of 120 ind.m^{-2} were found at station 70 (Table 1 and 2).

Sediment Characteristics

The dominant characteristic of sediment in the Gulf of Thailand and the east coast of Peninsular Malaysia consists mainly of clay, clayey sand, sandy clay and sand. Sandy clay was the largest sediment fraction in the whole survey area . It accounted for 50% total for the survey area. The latter

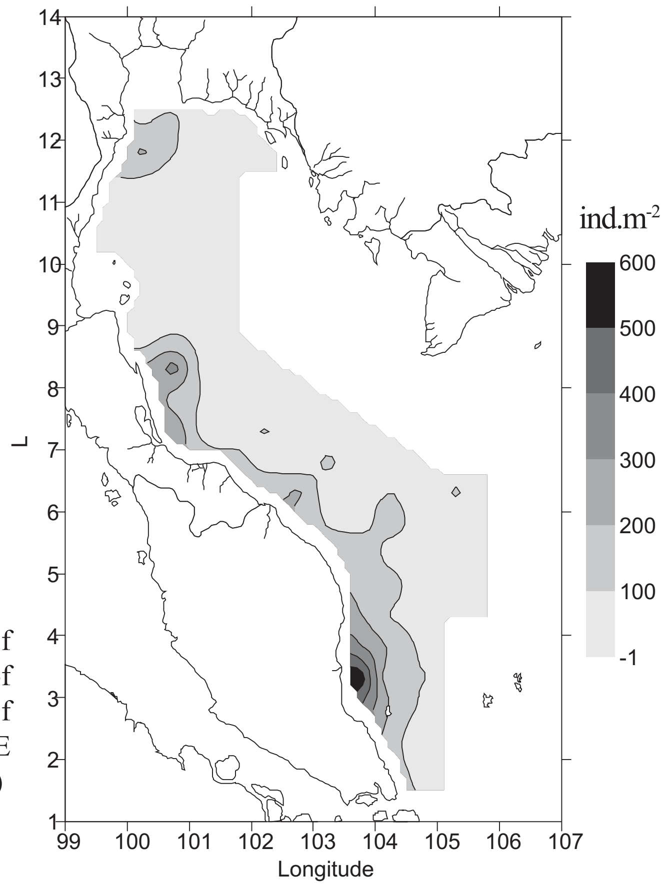


Figure 3 Abundance and distribution of macrobenthic fauna in the Gulf of Thailand and esat coast of Peninsular Malaysia in pre NE monsoon (4 Sept. - 4 Oct. 1995)

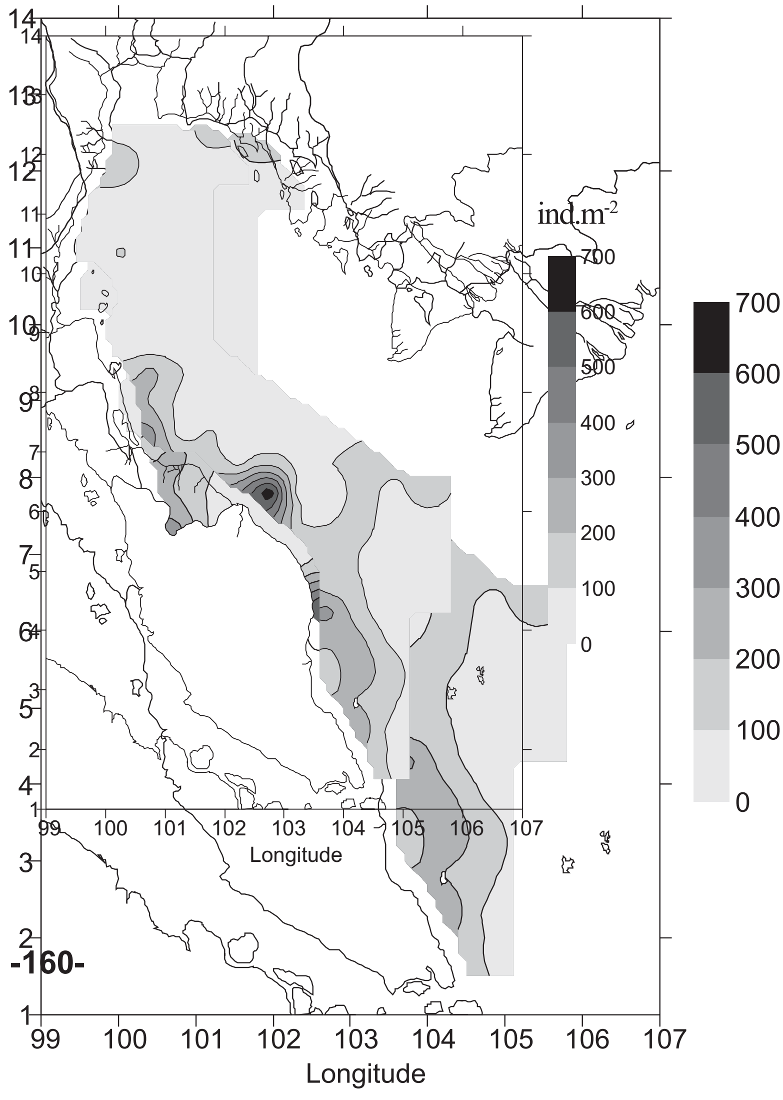


Figure 4 Abundance and distribution of macrobenthic fauna in the Gulf of Thailand and esat coast of Peninsular Malaysia in post NE monsoon (23 April - 23 May, 1996)

are clay and clayey sand which account for 28.75% and 15% respectively. About 6.25% or 5 of 81 stations of the survey area accounted for sand sediment which is the lowest sediment fraction in the survey area (Table 4 and Fig. 5).

Analysis

The difference in abundance of macrobenthic fauna between the pre and post NE monsoon periods in the Gulf of Thailand and the east coast of Peninsular Malaysia.

According to the results of the analysis of change in abundance of macrobenthic fauna in the Gulf of Thailand and the east coast of Peninsular Malaysia between the pre and post NE monsoon periods, it was found that Polychaete, Crustacea and Echinoderm groups show a marked difference in abundance between the pre NE monsoon (4 Sep.- 4 Oct 1995) and the post NE monsoon period (23 Apr. -23 May 1996). Meanwhile the abundance of Mollusc and fishes have remain steady for both the pre and post NE monsoon (Table 5).

Polychaete

In about half of the survey area it was found that the abundance of Polychaete during post NE monsoon increased during the pre NE monsoon whereas about 31% of the survey area shows a decline in abundance of this group during the post NE monsoon period when compared to the abundance during the pre NE monsoon. Only 18.75% of the area showed no difference in abundance between the pre and post NE monsoon periods (Table 5).

The increase in abundance of polychaete ranged from 10 to 120 ind.m^{-2}, except at station 52 (330 ind.m^{-2}). Mostly the increase in abundance was found to be 10 ind.m^{-2}. In addition, 50% of the increase in abundance was found to be 40 ind.m^{-2} (Fig. 6a). On the other hand, in about 31% of the survey area it was found that the abundance of this group decreased from the numbers in the pre NE monsoon period. The decrease in abundance ranged from 10 to 70 ind.m^{-2}, except at station 76 (240 ind.m^{-2}). About 50% of decreased abundance was found to be 30 ind.m^{-2} (Fig. 6b).

Crustacea

As can be seen from Table 5, about 32% of the survey area showed increased abundance, whereas, 41.25% of the surveyed area showed a decline of abundance of crustacea during the post NE monsoon period. Meanwhile, 26.25% of the survey areas showed that the abundance of crustacea during the post NE monsoon was no different compared to the abundance during the pre NE monsoon. The increase in abundance of this group ranged from 10 to 120 ind.m^{-2} and were mostly found to be 10 ind.m^{-2}. About 50% of the increase in abundance was 20 ind.m^{-2}. Whereas the decrease abundance ranged from 10 to 80 ind.m^{-2} and were mostly found to be 10 ind.m^{-2}. About 50% were 10 ind.m^{-2} (Fig.7a and b).

Echinoderm

About 46% of the survey area showed a change in abundance of echinoderm between the pre and post NE monsoon periods, whereas, about 50% of the abundance of echinoderm remained more or less at the same level between the pre and post NE monsoon periods. The increase in abundance of this group ranged from 10 to 30 ind.m^{-2} except at stations 71 and 76 (100, 150 ind.m^{-2}), whereas the decrease abundance ranged from 10 to 50 ind.m^{-2} and was mostly found to be 10 ind.m^{-2} (Fig.8 a and b).

Mollusca and Fishes

The abundance of these 2 groups was found to change slightly. About 85% of the survey area showed no difference in abundance between the pre and post NE monsoon periods with only a

Table 2 Average abundance of macrobenthic fauna (ind.m^{-2}) between the pre NE monsoon and post NE monsoon.

St.	Depth	Polychaeta		Crustacea		Mollusca		Echinodermata		Fishes		Others	
	(m)	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
1	27	40	50	40	20	0	0	0	0	0	0	0	0
2	30	50	30	60	0	0	0	0	20	0	0	0	10
3	31	50	40	0	0	0	0	0	0	0	0	0	0
4	23	0	110	30	50	0	0	0	0	0	0	0	0
5	34	60	40	10	0	0	0	0	0	0	0	0	10
6	51	30	10	10	0	0	0	0	0	0	10	10	10
7	54	10	20	0	0	0	0	0	0	0	0	0	0
8	40	60	30	50	30	0	0	0	0	0	0	0	0
9	36	90	130	130	50	0	0	0	0	0	0	0	0
10	48	40	50	30	10	10	0	0	0	0	10	0	0
11	54	10	20	0	10	0	0	0	0	0	0	0	0
12	58	0	20	0	0	0	0	0	0	0	0	0	0
13	62	20	0	10	0	0	0	0	0	0	0	0	0
14	61	0	0	20	10	0	0	10	10	0	0	0	0
15	56	30	20	10	20	0	0	10	10	0	10	0	0
16	50	0	40	0	0	0	0	0	0	0	0	10	0
17	46	40	10	10	0	0	0	0	0	0	0	0	0
18	61	0	90	20	20	0	0	0	10	0	0	0	0
19	63	20	0	30	10	10	0	0	10	0	0	0	0
20	71	30	30	0	0	0	0	0	10	0	0	10	0
21	69	10	0	0	0	0	0	0	0	0	0	0	10
22	59	40	30	0	0	0	0	0	0	0	0	0	0
23	34	0	0	0	0	0	0	0	10	0	0	0	0
24	29	0	10	10	0	0	0	10	0	0	0	0	0
25	40	60	20	10	0	0	0	0	10	0	0	0	10
26	66	40	10	0	10	0	0	10	0	0	0	0	0
27	78	-	0	-	20	-	0	-	0	-	10	-	0
28	58	10	10	20	10	0	0	0	0	0	0	0	10
29	32	100	30	10	0	0	0	0	0	0	0	0	0
30	24	0	0	0	0	0	0	30	0	0	0	0	0
31	29	220	160	120	70	0	0	0	10	10	0	0	0
32	55	20	80	10	20	0	10	0	0	0	0	0	0
33	73	20	20	10	0	0	0	0	0	0	0	0	0
34	78	10	10	10	0	0	10	0	0	0	0	10	0
35	72	10	10	0	0	0	0	0	10	0	0	0	0
36	72	10	20	0	0	10	0	0	0	0	0	10	0
37	58	0	10	0	0	0	0	0	0	0	0	10	0
38	49	30	40	40	20	0	0	0	0	10	0	0	0
39	28	100	170	40	20	10	0	0	0	0	0	10	0

Table 2 continue

St.	Depth	Polychaeta		Crustacea		Mollusca		Echinodermata		Fishes		Others	
	(m)	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
40	22	210	310	80	20	0	10	0	10	0	0	0	0
41	41	30	30	0	20	0	0	0	0	0	0	0	0
42	49	50	80	40	30	0	0	0	0	0	10	0	0
43	51	60	20	30	10	0	0	10	0	0	0	10	0
44	56	0	50	0	0	0	0	0	0	0	0	0	0
45	57	10	30	0	0	0	0	0	20	0	10	0	0
46	52	30	40	10	0	0	0	0	0	0	0	10	0
47	60	0	100	10	30	0	0	10	10	0	0	0	0
48	58	10	70	0	0	0	0	0	20	0	0	0	10
49	56	90	40	10	10	0	0	20	0	0	0	10	0
50	51	0	90	10	60	0	0	0	0	0	0	0	0
51	48	30	40	20	20	0	0	0	0	10	0	0	0
52	39	60	390	130	210	0	0	10	50	0	0	20	50
53	53	20	10	10	0	0	0	0	20	0	0	0	0
54	61	0	20	30	0	0	0	30	10	10	0	0	10
55	61	30	30	50	70	0	0	20	30	0	0	0	0
56	58	20	60	0	10	0	0	0	0	0	0	10	10
57	62	70	120	20	0	0	0	0	0	0	0	20	0
58	62	40	40	0	10	0	0	0	0	0	0	0	10
59	64	80	80	60	30	0	0	10	30	0	0	10	10
60	57	40	70	0	20	0	0	10	0	0	0	0	0
61	52	50	40	10	20	0	0	20	30	0	10	0	0
62	61	120	90	50	80	0	0	0	0	0	0	20	10
63	64	40	50	0	40	0	0	0	0	10	10	0	0
64	59	110	70	10	20	0	0	40	20	0	0	10	0
65	66	50	50	80	30	0	0	20	30	0	0	0	0
66	73	20	40	10	0	0	0	10	0	0	0	0	0
67	76	0	70	0	10	0	0	0	10	0	0	0	0
68	71	40	0	10	30	0	0	10	0	0	0	0	0
69	67	60	120	20	10	0	0	0	0	0	0	10	10
70	39	100	140	40	50	0	10	40	20	0	0	30	120
71	35	180	150	10	30	10	20	100	0	0	0	10	10
72	55	100	100	70	40	0	0	0	50	0	0	20	50
73	72	40	40	40	40	0	0	0	0	0	0	10	10
74	72	40	80	40	60	0	0	30	0	0	0	0	10
75	50	30	90	50	170	0	0	20	20	0	10	10	0
76	25	340	100	70	30	0	0	150	0	0	0	30	0
77	48	90	60	70	100	10	0	0	10	0	0	10	20
78	65	60	90	20	20	0	0	10	0	0	10	0	0
79	59	10	60	10	10	0	0	0	10	10	0	0	0
80	34	50	170	30	100	10	0	10	0	0	0	40	10
81	51	60	70	10	20	0	0	0	0	0	0	0	0

Table 3 List of macrobenthic fauna in the Gulf of Thailand and east coast of Peninsular Malysia

Macrobenthic fauna	Stations
Phylum Coelenterata	
Class Anthozoa	72
Phylum Nemertea	2,5,6,16,20,21,25,28,36,37,39,43,48,52,54,56,57,58,59,62,64,69,,72,74,76,77,80
Phylum Sipuncula	34,46,49,52,57,62,71,72,73,75,76,80
Phylum Mollusca	
Class Gastropoda	19,70
Class Bivalvia	10,32,34,36,39,40,70,71,77,80
Phylum Annelida	
Class Polychaeta	
Fam. Orbiniidae	1,2,40,47,57,67
Fam. Paraonidae	1,6,9,10,29,31,42,49,69,72,74,75,76,80
Fam Cossuridae	
Cossura sp.	10,16,66
Fam. Spionidae	
Prionospio spp.	2,6,7,9,18,29,31,32,38,39,40,48,51,52,62,67,69,70,71,76,77,79,80
Fam. Magelonidae	
Magelona sp.	56,62,80
Fam. Trochochaetidae	
Trochochaeta sp.	31
Fam. Poecilochaetidae	
Poecilochaetus sp.	9,25,31,39,52,61,70,75
Fam. Cirratulidae	5,6,9,17,31,32,33,35,39,40,41,42,43,47,49,51,52,61,62,64,67,69,74,77,78,80
Fam. Capitellidae	1,2,3,8,9,15,18,20,29,31,32,35,39,40,41,42,43,45,46,49,51,52,55,57,59,60,61,62,63,64,66, 67,68,69,71,73,74,75,76,78,80,81
Fam. Arenicolidae	
Arenicola sp.	80,81
Fam. Maldanidae	5,10,18,20,22,25,29,31,32,39,40,41,42,43,44,46,48,49,51,52,54,57,58,59,62, 63,64,68,69,70,72,74,76,77,78,79,81
Fam.Opheliidae	
Armandia sp.	4,8,52,70,71,76,81
Ophelina sp.	4,32,72
Fam. Scalibregmidae	32,36,40,44,45,51,80
Fam. Phyllodocidae	72
Fam. Aphroditidae	3,77
Fam. Polynoidae	1,4,38
Fam. Sigalionidae	5,20,21,32,42,46,49,57,65,70,71,75,76,81
Fam. Hesionidae	78
Fam. Pilargiidae	17
Fam. Syllidae	3,20,22,26,29,33,34,36,39,40,41,43,46,47,48,49,50,52,55,56,57,58,59,60,62,64,66,69, 72,73,74,76,77,78,79,80,81
Typosyllis sp.	70,71
Fam. Nereidae	3,4,31,39,40,52,53,56,59,62,63,71,72,74,76
Fam. Glyceridae	
Glycera sp.	2,3,18,25,29,31,40,42,48,52,55,56,57,69,70,71,72,73,77,80,81
Fam. Goniadidae	38,49,60,65,72,77
Fam. Nephtyidae	
Micronephtys sp.	57,59,60
Aglaophamus sp.	1,4,7,9,12,16,40,50,70,78,80

Table 3 Con't

Macrobenthic fauna	Stations
Fam. Amphinomidae	
Chloeia sp.	70,72
Fam. Onuphidae	1,4,18,24,39,45,52,64,65,66,69,70,71,76,79,80
Fam. Eunicidae	
Eunice sp.	31,39,44,49,50,52,53,58,64,68,71,78,81
Marphysa sp.	4,5,9,10,63,80
Lysidice sp.	47,55,58,69,77,81
Fam. Lumbrineridae	
Lumbrineris sp.	1,2,8,9,25,26,29,31,40,42,43,44,47,50,52,59,60,61,66,71,72,73,74,75,76,77,80,81
Fam. Sternaspidae	
Sternaspis sp.	17,39,47,50,67
Fam. Flabelligeridae	
Piromis sp.	31
Pherusa sp.	28,50,54,55,57
Fam. Sabellariidae	8
Fam. Terebellidae	5,10,11,34,39,40,46,52,59,75,78,80
Fam.Trichobranchidae	
Terebellides sp.	8,9,12,13,16,18,25,26,31,38,42,56,57,60,62,70,81
Fam. Sabellidae	70,78
Fam. Serpulidae	69,70
Unidentified Polychaeta	1,2,3,5,6,7,8,9,10,11,13,15,17,18,19,20,22,25,26,28,29,31,33,36,37,38,39,40,41,43,44,46, 48,49,50,51,52,53,55,56,57,58,59,61,62,63,64,65,66,67,69,70,71,72,73,75,76,77,78,79,81
Crustaceans	
Class Ostracoda	8
Class Malacostraca	
Order Stomatopoda	9,42,73,77
Order Decapoda	
Metapenaeus sp.	1,76
Trachypenaeus sp.	80
Alpheus sp.	1,2,4,6,10,13,19,27,32,38,42,43,46,49,50,61,62,63,64,67,70,75,77,80
Leptochela sp.	28,52,70,78,80
Callianassa spp.	1,2,8,9,10,14,15,18,19,31,38,39,40,41,42,43,47,51,52,53,54,55,58,59,60,61,62,63,65,66,68, 69,70,72,73,74,75,77,78,79,81
Upogebia spp.	2,4,8,9,10,14,15,18,25,26,28,31,32,38,40,47,50,51,52,54,55,61,62,68,70,71,73,74,75,77,80
Unidentified shrimp	5,14,38,40,43,65,72,73,75,76,77
Unidentified crab	1,2,4,8,9,11,17,24,28,29,31,33,34,39,40,49,50,52,59,60,62,64,70,71,72,74,76,77,78, 79,80,81
Order Amphipoda	2,4,9,15,18,31,38,42,52,55,56,57,59,62,64,65,69,70,71,74,75,76,77,80
Order Isopoda	32,50,52,65,72,74,80
Phylum Echinodermata	
Class Ophiuroidea	2,14,15,18,19,20,24,25,26,35,40,43,45,47,48,52,53,54,55,59,61,64,65,66,67,68,70,71,72, 74,75,77,78
Class Echinoidea	30,71,76
Class Holothuroidea	2,23,31,45,49,55,59,60,75,79,80
Phylum Chordata	
Amphioxus	52,69,70,71,76,80
Fishes	6,10,15,27,31,38,42,45,51,54,61,63,75,78,79

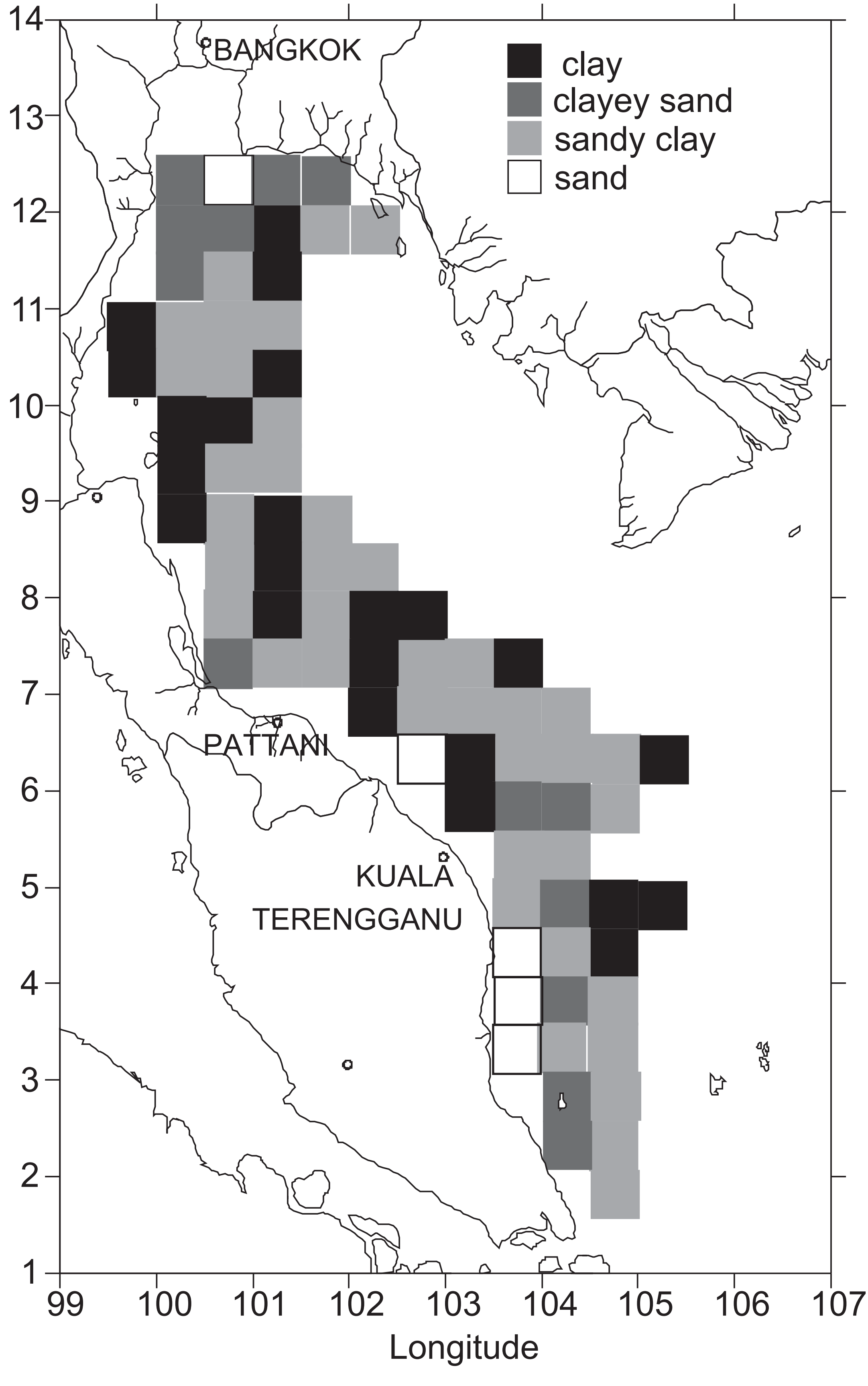


Fig. 5 The sediment types of the study area.

Table 4. The sediment types of each sampling station.

Sediment types	Station number
Clay	7, 12, 16, 17, 20, 22, 23, 24, 28, 30, 32, 35, 36, 38, 43, 46, 51, 53, 57, 61, 66, 67, 68
Clayey sand	1, 3, 4, 8, 9, 10, 40, 59, 60, 65, 72, 77, 80
Sandy clay	5, 6, 11, 13, 14, 15, 18, 19, 21, 25, 26, 27, 29, 31, 33, 34, 37, 39, 41, 42, 44, 45, 47, 48, 49, 50, 54, 55, 56, 58, 62, 63, 64, 69, 73, 74, 75, 78, 79, 81
Sand	2, 52, 70, 71, 76

Table 5 Changes in abundance of macrobenthic fauna between post NE monsoon (23 Apr. - 23 May 1996) and pre NE monsoon (4 Sep.- 4 Oct. 1995)

Diff. bet. post	no. of st.					
& pre NE monsoon	Polychaete	Crustacea	Mollusca	Echinoderm	Fishes	Others
+	40(50%)	26(32.5%)	5(6.25%)	16(20%)	5(6.25%)	13(16.2%)
0	15(18.75%)	21(26.25%)	69(86.25%)	43(53.8%)	67(83.8%)	52(65%)
-	25(31.25%)	33(41.25%)	6(7.5%)	21(26.2%)	8(10%)	15(18.8%)

slightly change for 15% of the survey area (Table 5).

Variation in abundance with depth

The total abundance gradually decreased with increasing water depth below 22 meters (Fig.9). At less than 30 meters, the average abundance was 183 ind.m^{-2} in the pre NE monsoon and 135 ind.m^{-2} in the post NE monsoon period; 31-60 m, 76 ind.m^{-2} in pre NE monsoon and 102 ind.m^{-2} in post NE monsoon; and 63 ind.m^{-2} (pre NE monsoon),70 ind.m^{-2} (post NE monsoon) at 61-90 depth.

Changes in diversity of macrobenthic fauna between the pre and post NE monsoon periods.

More than 64 species of macrobenthic fauna were identified. The shanon diversity index never exceeded 3.3 both in pre NE and post NE monsoon periods. The lowest value (2.87 for 28 species) was recorded in sand areas during the pre NE monsoon. During the pre NE monsoon, the diversity index increased from the sand areas to clayey sand. Meanwhile, during the post NE monsoon the diversity index showed a slight increase from clay areas to clayey sand (Fig. 10).

Discussion

The results show that the quantity and species diversity of macrobenthic fauna were more abundant near shore rather than in offshore areas, in both the pre and post NE monsoon periods. This finding corresponds with the Piamthipmanus, 1984's study using a similar methodology to this study. It should be noted that most benthic community studies in the Gulf of Thailand have been carried out near shore using a dredge apparatus while this study is offshore using a Smith McIntyre grab. More than 50% in numbers of macrobenthic organisms were polychaete, but the overall abundance of macrobenthic fauna never exceeded 920 ind.m^{-2}. The density and diversity of macrobenthic fauna on the east coast of Peninsular Malaysia were more abundant than in the Gulf of Thailand both in the pre and post NE monsoon periods (Figs. 3 and 4). This is probably due to the bottom sediment in the Gulf of Thailand being disturbed by heavy trawl fishery. .

Bakus (1990), also stated that the effect of depth, sediment grain size, salinity and predation

Frequency	Stem & Leaf		
12.00	1	.	000000000000
4.00	2	.	0000
3.00	3	.	000
5.00	4	.	00000
3.00	5	.	000
4.00	6	.	0000
2.00	7	.	00
.00	8	.	
2.00	9	.	00
2.00	10	.	00
1.00	11	.	0
1.00	12	.	0
1.00 Extremes			(330)

Stem width : 10
Each leaf: 1 case (s)

a) increase (40 stations)

Frequency	Stem & Leaf		
2.00 Extremes			(-240) , (-70)
1.00	-6	*	0
.00	-5	.	
1.00	-5	*	0
.00	-4	.	
4.00	-4	*	0000
.00	-3	.	
6.00	-3	*	000000
.00	-2	.	
5.00	-2	*	00000
.00	-1	.	
6.00	-1	*	000000

Stem width : 10
Each leaf: 1 case (s)

b) decrease (25 stations)

Fig. 6. Stem and Leaf plot of changes in abundance of polychaete for 65 stations between the pre and post NE monsoon periods

density are factors in controling the population density of macrobenthos and the most important factors are sediment size and predator density. Another indirect factor for faunal distribution and abundance is the monsoon. Hylleberg et al. (1985), reported that the amplitude and direction of the monsoon wind and the shifting of the monsoon has a considerable impact in terms of sediment disturbance, this would have an effect directly on the density and diversity of macrobenthic fauna. Different species react differently to changes of environment. As can be seen from this study, the density of polychaete, crustacea and echinoderm are greatly influenced by the monsoon. It was notable that the density of echinoderm was high at stations 71 and 76 in the pre NE monsoon. It was found that Ophiuroidea (brittle stars) and Echinoidea (heart urchin) were most abundant at station 71 and Echinoidea (heart urchin) was also found in great abundance at station 76 in the pre NE monsoon, but cannot be found in the post NE monsoon period. In addition , at station 76 the population density of polychaete (Onuphidae) was in much higher abundance during the pre NE monsoon than in the post NE monsoon period. Meanwhile, the abundance of mollusc and fish have remained more or less steady. .

Moreover, the diversity index of macrobenthic fauna presented slightly different patterns between the pre and post NE monsoon periods. During the pre NE monsoon, the diversity index showed a marked increase from sand area (2.87) to clayey sand (3.2). Whereas during the post NE monsoon the diversity index in sand and clay were equal and then started to slightly increase from clay to clayey sand.

It can be concluded that the duration of the monsoon will partly affect the density and diversity of macrobenthos in the Gulf of Thailand and the east coast of Peninsular Malaysia.

Acknowledgements

The author would like to extend thanks to the Captain and crew of the M.V.SEAFDEC, Dr. Yuttana Theparoonrat, Ms. Penjan Rochana-anawat, Ms. Suvimon Sae-Koe and Ms. Siriporn

Frequency	Stem	&	Leaf
11.00	1	*	00000000000
.00	1	.	
8.00	2	*	00000000
.00	2	.	
2.00	3	*	00
.00	3	.	
1.00	4	*	0
.00	4	.	
1.00	5	*	0
3.00 Extremes			(70) , (80) , (120)

Stem width : 10
Each leaf: 1 case (s)

a) increase (26 stations)

Frequency	Stem	&	Leaf
5.00 Extremes			(-80) , (-60) , (-50)
3.00	--3	*	000
.00	-2	.	
8.00	-2	*	00000000
.00	-1	.	
17.00	-1	*	00000000000000000

Stem width : 10
Each leaf: 1 case (s)

b) decrease (33 stations)

Fig. 7. Stem and Leaf plot of changes in abundance of crustacea for 59 stations between the pre and post NE monsoon periods

Frequency	Stem	&	Leaf
8.00	1	*	00000000
.00	1	.	
4.00	2	*	0000
.00	2	.	
2.00	3	*	00
2.00 Extremes			(100) , (150)

Stem width : 10
Each leaf: 1 case (s)

a) increase (16 stations)

Frequency	Stem	&	Leaf
2.00 Extremes			(-50.0) , (-40.0)
5.00	-20	.	00000
.00	-19	.	
.00	-18	.	
.00	-17	.	
.00	-16	.	
.00	-15	.	
.00	-14	.	
.00	-13	.	
.00	-12	.	
.00	-11	.	
14.00	-10	.	00000000000000

Stem width : 1

Each leaf: 1 case (s)

b) decrease (21 stations)

Fig. 8 Stem and Leaf plot of changes in abundance of echinoderm for 37 stations between the pre and post NE monsoon periods.

Seurungreong, SEAFDEC staff, for their kind co-operation during the survey and to all research scientists both Thai and Malaysian who worked together on board M.V.SEAFDEC.

The author is also grateful to Ms. Sopana Boonyapiwat, Mrs. Jutamas Jivaluk, Mr. Paitoon Pewkao and Dr. Apichart Termvichakorn for sorting and participation in the field work and to Mr. Sommart Niemnil for the sediment analysis.

The author would like to thanks Ms. Kanchana Jirapanpipat through personal discussions on conceptual aspects, Mr. W.R.B. Elstow for his improvement to the English text.

The collaborative research project was supported by the Government of Japan and SEAFDEC

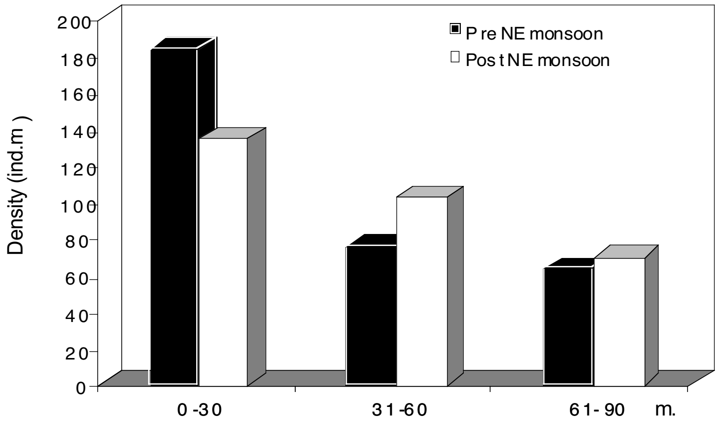


Fig. 9. The density (ind.m^{-2}) of macrobenthic fuana as a function of depth (m) in the Gulf of Thailand and East Coast of Peninsular Malaysia

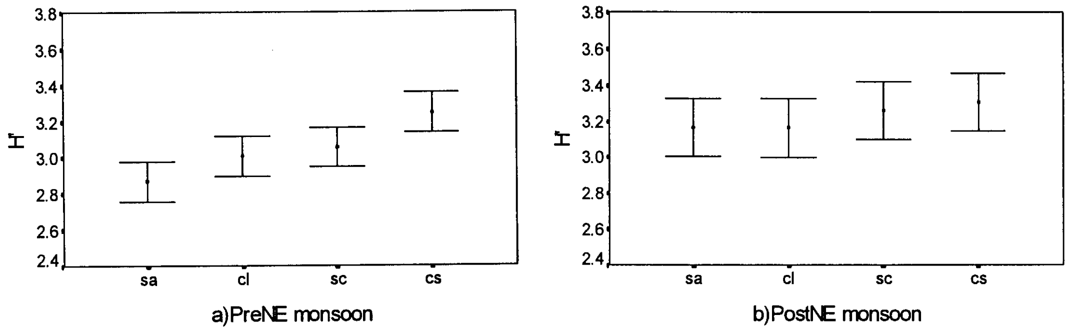


Fig. 10. Shannon diversity (mean and 95 % confidence limit) for the macrobenthic fauna in the Gulf of Thailand and the east coast of Peninsular Malaysia during the pre and post NE monsoon periods on 4 different types of sediment (cl:clay, cs:clayey sand, sc:sandy clay, sa:sand).

Reffernces

Bakus, G. J. (1990). Quantitative ecology and marine biology. Oxford & IBH publishing Co. Pvt. Ltd., New Delhi, 159 pp.

Charoenruay, M.and A.Nateewathana, 1978. Benthos in the Inner Gulf of Thailand,1976. Technical Report No.20/11,Marine Fisheries Laboratory, Marine Fisheries Division,48 pp.(in Thai)

Charoenruay, M. and S. Ketsamut, 1979. Benthos in the Inner Gulf of Thailand,1977. Technical report No.21/12 Marine Fisheries Laboratory, Marine Fisheries Division 9 pp.(in Thai)

Charoenruay, M and N. Piamthipmanus,1981. Benthos in the Gulf of Thailand, Surajthani province. Technical report No.23/6, Marine Fisheries Laboratory, Marine Fisheries Division, 12 pp.(in Thai)

Charoenruay, M., N. Piamthipmanus and J. Sanguansin,1983. Benthic animals in Chong Angtong,1981.Technical Report No.25/8, Marine Fisheries Laboratory, Marine Fisheries Division, 25 pp.(in Thai).

Grey, J. S., K. R. Clarke, Warwick, G. Hobbs. (1990). Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Elfisk oilfields, North sen. Mar. Ecol. Prog. Ser 66: 285-299.

Holland, J.S., J.M. Nancy and C.H.Oppenheimer, 1973. Galveston Bay benthic community structure as an indicator of water quality. Contr.Mar.Sci.,17:169-188.

Hylleberg, J., Nateewathana, A. & Chatananthawei, B., 1985. Temporal changes in sediment characteristics on the west coast of Phuket Island. Phuket Mar. Biol. Cent. Res. Bull., 37, 16 pp.

Ketsamut, S., N.Piamthipmanus and M. Charoenrauy, 1980 a. Benthic animals off the west coast of the Gulf of Thailand,1977. Technical Report No.22/13 Marine Fisheries Laboratory, Marine Fisheries Division, 25 pp.(in Thai).

Ketsamut, S., N. Piamthipmanus and M. Charoenrauy ,1980 b. Benthic animals off the east coast of the Gulf of Thailand, 1979.Technical Report No.22/15, Marine Fisheries Laboratory, Marine Fisheries Division, 29 pp.(in Thai).

Piyakarnchana, T., S. Tamiyavanich, N. Jirarochana and N. Setti. 1978. On the density and biomass of the marine benthos of the Gulf of Thailand and Andaman Sea.In: Proceeding of the Symposium on marine pollution research in Thai water, 20-23 March 1978, NRCT.pp.209-222.(in Thai).

Piamthipmanus, N.1984.Benthic animals in the western Gulf of Thailand.In: Report of The Thai-Japanese-SEAFDEC joint oceanographic and fishing survey in the Gulf of Thailand on board Nagasaki-Maru, 28 Oct.-5 Nov. 1982, TD/RP/13, pp. 19-26.

Piamthipmanus N.,M. Charoenruay and J. Sanguansin,1984. Benthic animals off the west coast of the Southern-part in the Gulf of Thailand,1982.Technical Report No.26/8, Marine Fisheries Laboratory, Marine Fisheries Division, 16 pp.(in Thai).

Piamthipmanus N.,M. Charoenruay and J. Sanguansin ,1985. Benthic animals in the east coast of the Gulf of Thailand, 1983. Technical Report No. 27/1, Marine Fisheries Laboratory, Marine FisheriesDivision, 29 pp.(in Thai).

Reish, D.J.1972. The use of marine invertebrates as indicators of varying degree of marine pollution. In: M.Ruivo(ed). Marine Pollution and Sea life.pp.203-207., Fishing news(Books), London.

Thanapong, C and R. Mhordee.1982. The benthic fauna and bottom environment in the middle Gulf of Thailand(Area I). Technical Report ,Marine Exploratory Division, 25 pp.

Wass, M.L.1967. Indicators of pollution.In: T.A. Olson and F.J. Burgess(eds).Pollution and Marine Ecology.pp.271-284, Interscience Publisher, New York.

Species composition and Diversity of Fishes in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Chavalit Vidthayanon

Department of Fisheries, Bangkok 10900, Thailand

ABSTRACT

The collaborative research on species composition and diversity of fishes in the Gulf of Thailand and eastern Malay Peninsula was carried out by R. V. Pramong 4 in Thai waters and K.K. Manchong, K.K. Mersuji in Malaysian waters, through otter-board trawling surveys. Taxonomic surveys also done for commercial fishes in the markets of some localities. Totally 300 species from 18 orders and 89 families were obtained. Their diversity are drastically declined, compare to the previous survey from 380 species trawled. The station point of off Ko Chang, eastern Gulf of Thailand and off Pahang River shown significantly high diversity of fishes57 and 73 species found. Demersal species form the main composition of the catchs. The lizardfish *Saurida undosquamis, S. miropectoralis*, the bigeye *Priacanthus tayenus* and *P. macracanthus*, the rabbitfish *Siganus canaliculatus* and hairtail *Trichiurus lepturus* were the most abundant economic species found in mast of the sampling stations. Fishing efforts were 34 hours and 49 hours for the cruises I and II, with average catch per hour of 12.04 and 34.79 kg. respectively. The maximum catch per hour was 175.3 kg in Malaysian waters, the minimum was 4.33 kg in Thai waters. The average percentage of economic fishes is higher than that of trash fishes in Malaysian waters, it ranged from 55.45 to 81.92 %.

Key words; Species composition, Diversity, Fishes, Gulf of Thailand, Eastern Malay Peninsula

Introduction

The collaborative surveys of fishery and oceanography in the South China Sea; subject of fish diversity and species compositions was launced in 1995 and started from the areas of Gulf of Thailand and Malay Peninsula through the orgasnizing by SEAFDEC/TD, DOF Thailand, and MFRDMD, DOF Malaysia. The objective of these surveys are; to update the status of the diversity and productivity of economic fishes in the South China Sea and prepare for the annotated checklist of fish species obtained in this survey.

The fishery resource in the South China Sea, the western part (Gulf of Thailand and West Malay Peninsula) has been investigated since 1903 by Johnstone. The natural history has been greatly emphasized after the result of oceanographic survey of R. V. Stranger under the well known Naga Expedition in 1959-1961, then Rofen (1963) reported to 122 economic species found in the Gulf and 400 species were noticed.

The Department of Fisheries of Thailand and Malaysia have launced the joint surveys since 1967, the result of species diversity and catching were reported (Anon., 1967; Wongratana, 1968). Previously, several report on fish diversity in many areas of this region. Johnstone (1903), Annandale (1911) and Hora (1924a,b) wrote the classic reports on the fishe of the Lake Songklha and the updated was done by Sirimontraporn (1984, 1990); Anon. (1969) published the guidebook on edible marine animal including fish. In the South China Sea and adjacent areas, the ichthyological surveys and fieldguide for species was done by Fisher & Whitehead (1974) for the first FAO identification sheets; Rau & Rau (1980) for the Philippines; Chen (1993) for Taiwanese waters, and Kuiter & Debelius (1994) for the southeast asian reef fish. The fishery resource assesment through the Otter-board Trawlnet surveys in this area was reported since 1965 by Tiew, and then by Tiew et al. (1967), Isarankura & Kuhlmorgan-Hille (1966), Ritrugsa et al. (1968, 1969), Anon. (1968,1969, 1980), Kuhlmargan-Hille & Ritrugsa (1972), Poreeyanond & Pokapunt (1980) and Wongratana (1985).

.

Materials and Methods

***Cruising and survey methods*.**

1. The survey for species diversity of the South China Sea fishes in the first phase was carried out in the Gulf of Thailand and East Malay Peninsula. Two cruises were conducted, during 4 September-6 October, 1995 and 24 April-17 May, 1996; by the M.V. Pramong 4 in Thai waters and K.K. Manchong , K.K. Mersuji in Malaysian waters. The modified high opening Otter-board bottom trawlnets was applied in these surveys, 2-3 hours in Thai waters and 1 hour in Malay waters. Both cruise selected 24 and 23 points of 81 oceanographic station for trawling surveys as shown in Fig. 1.

2. During the port of call periods at Songkhla and Ko Samui, additional surveys for economic fish diversity were conducted through purchasing and collecting in the fishing piers and markets.

***Collecting, recording and specimens handling*.**

1. All species of each haul were recorded and collected for species representative. Each species representative was collected covering their sizes, sex and varietions. Some huge and uneffordable specimens was photo recorded or partially collected for its important part e.g. shark and ray.

2. The representative species were photographed, by Ektachrome slides. Each specimens was posturized in lateral plane and fin setting by pin out and rubbed with conc formalin. The dry transparancy box and grey or white board background was applied, except the larger specimens used only background paper or in site background.

3. The specimens was preserved in 10% Formalin for 1 to 3 weeks and transferred to 50 and 75% Ethanal gradually. Each station sampling is stored in the separated bottle, the larger specimens are stored in the drum with locality label. All specimens in these survey have been deposited in the Aquatic Natural Resources Museum, Dept. of Fisheries.

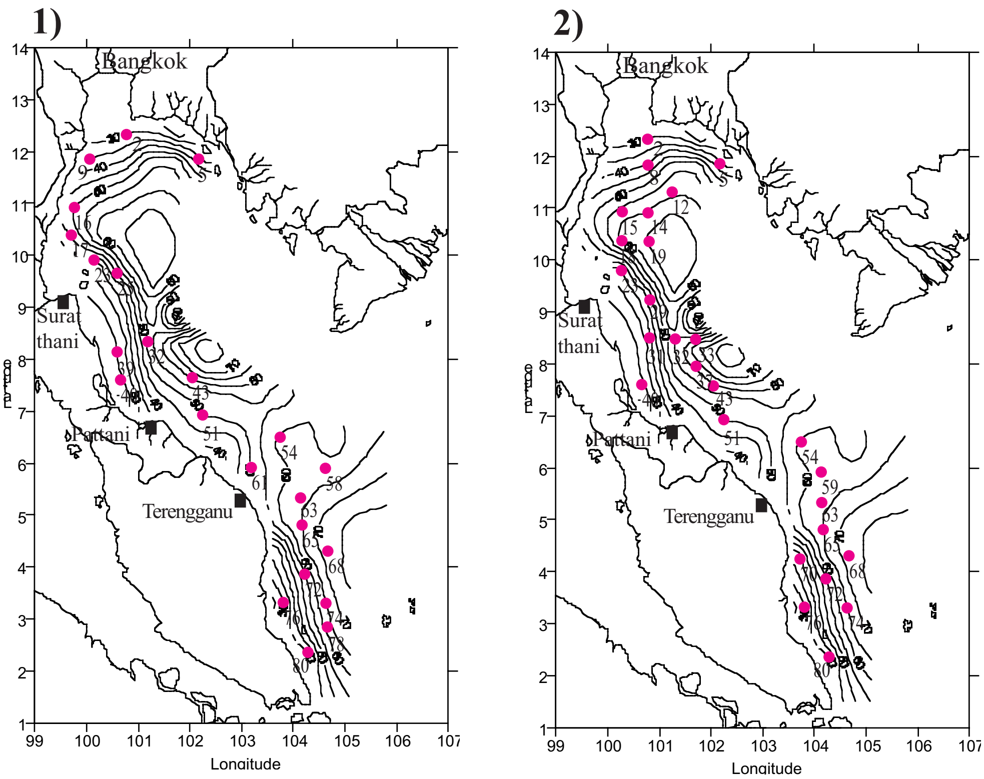


Fig. 1 The trawling station points and depth (m) in the cruise I (1) and cruise II (2).

Identification and classifications.

The classifications in this systematic account was follow Nelson (1994) for bony fishes and Compagno (1991), Last and Stevens (1994) for elasmobranches. Their identifications of each family was followed to several updated or previous references indicated in the text.

Results

Totally 300 species were obtained, at least 122 economic species were trawled and 32 species were collected in the markets. Eigth stations of each cruise were cancelled and changed due to unpermitted conditions of bottom and climate; station 10, 12, 28, 34, 35, 47, 57 and 67. The catching results was provided in the Table 1-4 and Fig. 2, 3.

Table 1. The average catch per hour made by different research vessels in the Gulf of Thailand. The figures showing the catch in kilogrammes per hour may effect also by method of operation, mesh opening, area of study, etc., however, they were chiefly declined according to the overexplotation demersal fishes of the resource. (From Wongratana, 1985 and Fishery Statistic Subdivision 1988-1996)

Author (s)	Year of survey	Vessel (tonnes)	Area visited	No. of Trawl hour	Depth range (m)	Average catch (kg) per hour
Tiews (1965)	1961	Pramong 2(76)	Prachuab-kirikhan	266	10-50	297.8
		Pramong 3(50)				
Tiews (1965)	1963-64	Pramong 2(76)	Entire Gulf	520	10-50	248.9
		Pramong 3(50)				
Isrankura & Kuhlmorgen-Hill	1964	Pramong 3(50)	Trad, Songkhla	282	-	225.6
(1969)						
Israkura & Kuhlmorgen-Hill	1965	Pramong 2(76)	Trad, Prachuab-	192	-	179.2
(1969)			kirikhan			
Ritragsa et al. (1968)	1966	Pramong 2(76)	Entire Gulf	713	10-44	130.77
		Pramong 1(50)				
Ritragsa et al. (1969)	1967	Pramong 2(76)	Entire Gulf	713	10-44	115.05
Ritragsa & Pramokchutima(1970)	1968	Pramong 2(76)	Entire Gulf	719	10-44	105.92
Dhamniyom & Vadhanakul (1970)	1968-69	Asa (40.92)	off Cholburi	712	10-41	43043
Kuhlmorgen-Hille & Ritragsa	1971	Pramong 2(76)	off Narathiwat,	21	12-54	134.77
(1972)		Penyelidex I (96)	Thai-Malaysian	21		133.76
			comparative survey			
Boonyubol (1979)	1971	Pramong 2(76)	Entire Gulf	-	10-50	66.3
Boonyubol (1979)		Pramong 2(76)	Entire Gulf	-	10-50	63.1
Boonyubol (1979)		Pramong 2(76)	Entire Gulf	-	10-50	51.9
Boonyubol (1979)		Pramong 2(76)	Entire Gulf	-	10-50	57.7
Boonyubol (1979)		Pramong 2(76)	Entire Gulf	-	10-50	47.0
Boonyubol (1979)		Pramong 2(76)	Entire Gulf	-	10-50	57.2
Tanapong & Boonyapiwat (1981)	1976	Exploratory 1 (131)	Inner Gulf	16	10-30	38.65
Tanapong & Boonyapiwat (1981)	1977	Exploratory 1 (131)	Inner Gulf	16	10-30	38.24
Tanapong & Boonyapiwat (1981)	1979	Exploratory 1 (131)	Inner Gulf	16	10-30	35.28
Tanapong & Boonyapiwat (1981)	1980	Exploratory 1 (131)	Inner Gulf	16	10-30	18.93
Poreeyanond & Pokapunt (1980)	1980	Nagasaki-Maru (586)	Entire Gulf	11	32-74	77.62
Poreeyanond et al. (1981)	1981	Exploratory 1 (131)	Inner Gulf	6	9-28	16.72
Wongratana (1985)	1982	Nagasaki-Maru (586)	off Songkhla and	14	33-53	61.80
			Nakhon Si Thammarat			
Fish. Statistic subdiv. 1990	1988	Commercial trawlers	Entire Gulf	-	-	54.15
Fish. Statistic subdiv. 1991	1989	Commercial trawlers	Entire Gulf	-	-	59.27
Fish. Statistic subdiv. 1992	1990	Commercial trawlers	Entire Gulf	-	-	34.42
Fish. Statistic subdiv. 1994	1991	Commercial trawlers	Entire Gulf	-	-	62.09
Fish. Statistic subdiv. 1995	1992	Commercial trawlers	Entire Gulf	-	-	51.22
Fish. Statistic subdiv. 1996	1993	Commercial trawlers	Entire Gulf	-	-	57.13
Recent Survey	**1996**	**RV Pramong 4 &**	**Entire Gulf**	**81**	**30-80**	**26.10**
		K.K. Manchong				

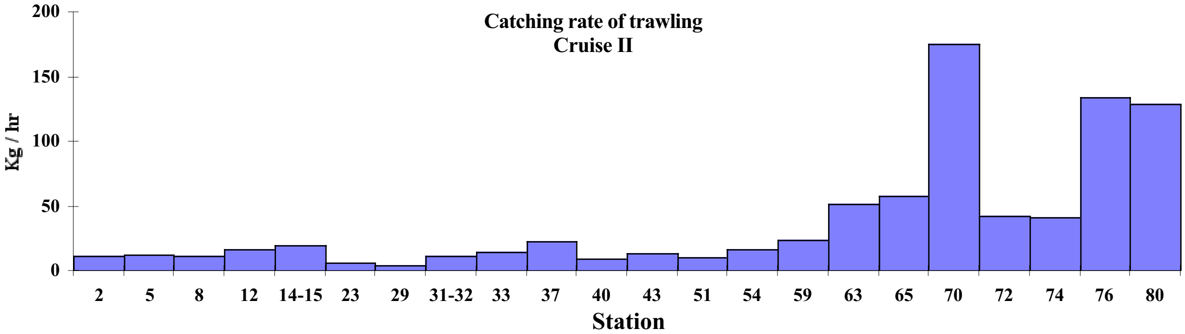


Fig. 2. Catching rate of trawling in Cruise II

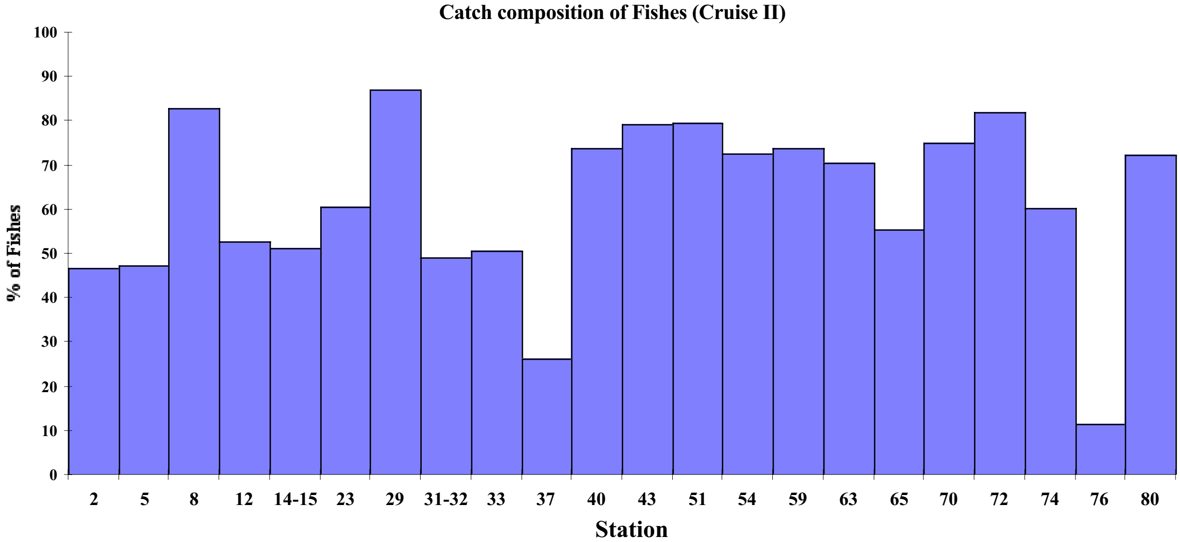


Fig. 3. Catch composition of fishes from Cruise II

Diversity

At least 18 orders, 89 families and 300 species were found. There systematic account with brief description were available below.

Systematic Account

1) Elasmobranchs

At least 13 orders, 34 families, 149 species known to Thailand and adjacent areas, mainly from coastal habitats. This survey obtained 18 species from 9 families and 5 orders. References; Compagno (1984 a,b); Michael (1993) and Last & Stevens (1994).

Order Orectolobiformes

Family Stegostomatidae

1. Stegostoma fasciatum (Hermann, 1783)

An unmistakable shark with a very long, blade-like caudal fin, two ridger along side of body flank and yellowish brown colouration peppered with numerous, dark brown spots.

Head broad and stout, bluntly rounded. Fin broadly rounded, small eyes. Size attaining to 2.35m.

Distributed throughout Indo-West Pacific coasts. Only a 1 m. Specimens obtained off Malay Peninsular.

Randall (1995) suggest that *S. fasciatum* possibly junior synonym of *S. varium* (Seba, 1758).

Family Hemischyllidae

2. Chiloscyllium punctatum Mueller & Henle, 1838

A slender shark with relatinely long barbels, two equal-sized dorsal fins with bases almost equal to the interdorsal space, the first dorsal fin partly over the pelvic-fins base.

Snout blunt, nasoral groove present, large spiracles. Large adults uniformly brownish or greyish above, pale ventrally, juveniles pale with 10 dark, vary bands, peppered with small dark spots. Size attaining to 10.5 cm.

Distributed throughout Indo-West Pacific, seldomly obtained along Malay peninsular, size 45-70 cm.TL.

Family Schliorhinidae

3. Atelomycterus marmoratus (Bennett, 1830)

Very slender, narrow headed catshark with variegated colour pattern, gray saddle marking obselete, black spots enlarged and merging togetter to form clash and bar marks that bridge saddle areas, large white spot scattered on sides and back. Anterior nasal flaps greatly expauded and extending to mouth. First dorsal with origin about opposite or slightly in front of pelvic insertion, second dorsal fin subequal to first dorsal.

Distributed throughout Indo-West Pacific. Size attaining to 70 cm., 55-60 cm. Specimens was obtained around Ko Kra by hand-line and trawl net.

Order Carcharhiniformes

Family Triakidae

4. Hemitriakis sp.

Body slender, head short, snout moderately long and bluntly angular in lateral view. Pectoral and pelvic fins relatinely small. Uniform gray or grey-brown above, light below, with numerous white spots on dorsal area. Size attaining to 117 cm. Seldomly obtained off Malay Peninsula, 70 cm.SL. specimens.

Known from Philippines (Compagno in litt, 1997)

Family Hemigaleidae

5. Hemipristis elongatus (Klunzinger, 1871)

Body fusiform and moderately slender. Snout long with protrading teeth (the upper long, curved and serrated on both edges), fulcate fins and a second dorsal fin about two-thirds the size of the first dorsal fin. Bronge to grayish brown dorsally, pale ventrally. Second dorsal and upper caudal fins with a dark blotch. Size attaing to 2.3 m.

Distibuted throughout Indo-West Pacific, one specimen 1.5 m. Was obtained of Malay peninsula. It is cousidered to be among the best shark to eat.

Family Carcharhinidae

6. Carcharhinus dussumieri (Valenciennes, 1834)

A small gray shark with moderately long rounded snout, fairly large horizontally oval eye, a black spot on the second dorsal fin but no other marking, Small semifulcated pectoral fins, a small triangular first dorsal fin with a short near tip and a moderately large second dorsal. Size attaining to 70 cm., one specimen of 40 cm. was obtained.

Distributed from northern Indian Ocean to Western Pacific. Commonly marketed for meat and shark’s fin.

Order Rhinobatiformes

Family Rhinobatidae

7. Rhyncobatus aff. *djiddensis*

Disc wedge-shaped; center of disc raised evenly; snout moderately long, broadly triangular; disc margin concave beside eye. Dorsal fins widely spaced fulcated with deeply concave posterior. Upper surface mostly yellowish brown; 10-30 distinctive white spots extending from mid pectoral fin to posterior tip of first dorsal fin; Ventral surface uniformly pale.

Size attaining to 3 m., one specimen of 1 m. Obtained. Distributed throughout Indo-West Pacific. Highly economic important.

note : *R. djiddensis* is restricted distribute to Red, this species is possibly *R. australiae* Whitley, 1939 or an undescribed species (Compagno, pers comm. 1997).

Order Torpediniformes

Family Narcinidae

8. Narcine maculata Shaw, 1804

Body depressed; disc oval; eye small; the disc length equal to the tail. Tail elongated. Tapering gradually; dorsal fins spaces closely. Upper body surface pale brown with nummerous redish or dark brown, rounded spots; 3 pairs of dark brown bloch along the disc flanks. Size attaning 42 cm. Uncommon, taken by trawl-net, considered as trash.

9. Temera sp. 1

Disc oval, tapering gradually with tail; eye small; dorsal fin ; pelvic fin large. Upper surface dark brown; disc and fins marginal pale, ventral uniform pale. Size attaining to 15 cm. One specimens found off Malay pennisula.

Order Myliobatiformes

Family Dasyatidae

10. Dasyatis kuhli (Mueller & Henle, 1841)

Disc rhomboidal, with short thorns on the midline; tail with prominent dorsal and ventral fold. Dorsal surface grayish brown with bluish spots and dark tronsperse bone about the eyes, the tail is banded

Size attaining to 38 cm.width. Distributed throughout Indo-West Pacific, seldomly obtained by trawl net off Malay Peninsula. This ray is Economic edible species.

11. Dasyatis zugei (Mueller & Henle, 1841)

Snout distinctinely produced into acute angle; disc widest at the middle of length; short upper and lower fold on tail, usually single spine. Upper surface pale. Size attaining to 20 cm. (Disc width); commonly obtain throughout Gulf of Thailand.

12. Dasyatis sp.1

Snout distinctively pointed, widest at the middle of its length; anterior mid-dorsal surface with single raw of thorns; tail slightly longer than disc, with two spine near the mid-length. Upper surface pale brown. Size attaining to 20 cm. Width.

Less common than other small species.

13. Dasyatis sp.2

Similar to D. Sp.1 but more pointed snout; tail with a raw of short thorns granules (5-6) on anterior half; two spines. Upper surface dark or reddish brown. Size attaining to 20 cm .Width. Seldomly abtained off Malay Peninsular.

14. Dasyatis sp.3

Similar to *D. kuhli* but without bluish spot on dorsal surface, the tail was less bands. Size attaining to 35 cm.width, more common than *D. kuhli*, of tenly trawled off Malay Peninsula and fished near Ko Kra.

15. Himantura gerradi (Gray, 1851)

Disc rhomboidal with pointed snout; pectoral fin apex angular; midline of dorsal with short raw of thorns, tail several times longer than disc without fold. Upper surface grayish or dark brown with numerous pale spots, tail dark with several white spots.

Maximum size attaining 90 cm.width, commonly taken from off Malay Peninsula. Distributed in central Indo-West Pacific. Commonly found in fishes markets.

16. Himantura jenkinsi (Annandale, 1909)

Disc rhomboidal, pectoral fins with rounded apex; snout angular; tail shorter than disc length midline of trunk with a row of enlarged, spear shaped thorns and a narrow band of closely-spaced denticle extend along the head, back and tail. Upper surface uniformly yellowish brown, tail dark. Attains to 1.5 m. disc width.

17. Himantura undulata (Bleeker, 1852)

Disc quadrangular, trunk deep; pectoralfin apex narrowly rounded point: longer than disc length, upper surface granular in adult; one enlarge scapular thorn with as associated thorn patch retending onto nuchal area. Upper surface sandy brown with dark rays, leopard-like spots covering upto tail, before sting; ventral surface white.

Size attening to 1.4 m. on disc width. Distributed in Indo-West Pacific.

18. Himantura walga (Mueller & Henle, 1841)

Snout pointed; disc widest at anterior half of its length; tail shorter than disc; two spine on anterior posterior of tail. Upper surface uniform dark brown ventral pale with yellow margin.

Maximum size to 25 cm. width. Distributed in central Indo-Pacific, commonly taken with other small stingray species.

2) Bony fishes

At least 30 orders, 192 families and around 2375 species of bony fish known to Thailand and 1880 marine bony fish known to Thai waters. In this survey, 13 orders, 80 families and 282 species were collected.

Order Anguilliformes

Family Muraenidae

The moray eels are distinguished by elongated body; without pectoral and pelvic fins; caudal fin jointed with elongated dorsal and anal fin; gill opening very small; large mouth gap with prominent canine teeth. There are more than 30 species known to South China Sea; four species found in this survey, this identification is followed Allen & Swainston (1993).

19. Gymnothorax javanicus (Bleeker)

A moray eel with yellow-brown head with small dark spots and large dark patch at gill opening, some adoult possesses leopard-like spotting on body. Body robust, eel-like with connected dorsal, caudal and anal fins, large head with prominent jaws and canine teeth.

Size attaining to 2.5 m , 60-70 cm specims were obtained by hand-like and trawled. Distributed throughout Indo-Pacific coasts.

20. Gymnothorax sp.2

Similar to *G. javanicus* but lack of brownish-black patch on gill opening; body with pale mottled on dark brown background. One species of 65 cm was obtained off Malay Peninsular.

21. Siderea thryssoidea (Richardson)

Head relatnely small; moray-eel like body form. Head dark brown with silvery eye, body yellowish pale with dark brown mottlinge, gill opening dark.

Size attaining to 35 cm , only one species obtained off Malay Peninsular. Distributed throughout Indo-West Pacific.

22. Echidna sp.

A very elongated eel with pale body color; dark mottlings. Two specimens were collected off Malay Peninsular, but almost damaged, unidentified. Not illustrated.

Family Congridae

23. Conger myriaster (Brevoort)

Body elongate, head small; upper lip with upturned labial large. Lateral line pores each placed in a whitish spot. Tip of tail flexible and tapering. Body pale grey, fins pigmented hyaline.

Size attaining to 1 m, two species of 25 cm obtained. Distributed in East Chaina Sea.

Family Muraenesocidae

The pike eel have a stout body; well developed median fins; pectoral fin large; moderately large crescentic gill opening; large mouth gap, slender and prominently pointed snout. Castle (1984) reviewed the species found in Western Indian Ocean, two species were found in this survey.

24. Muraenesox cinereus (Forsskal,1775)

Body elongate, cylindrical in front, compressed along tail. Head sharply conical, with the snout and lower jaw lengthened forward so that the mout is large, extending to beyond eye, teeth generally large, conspicuous, sharp, more or less in 3 longitudinal rows on jaws and vomer; those on middle row of lower jaw and of vomer triangular, laterally compressed, with a prominent basal cusp in front and beind. Lateral line pores befores level of anus 39 to 47.

Colour: light to dark greyish-brown above, lighter below; dorsal and anal fins with narrow black edges.

Maximum: 80 cm ; common about 50 cm.

Distributed in Indo-West Pacific, only one species of 50 cm SL. was obtained.

25. Congresox talabonoides (Bleeker,1853)

Head very sharply conical, with the snout and lower jaw markedly lengthened forward so that the mouth is very large, extending to well beyond eye; no lips; outer tooth row on lower jaw leaning outward; teeth on middle row of vomer prominant, needle-likie; pectoral fins relatively small, their length about 4 times in length of head . Lateral line pores before level of anus 41 to42. Vertebrae 132 to 145.

Colour: head and body olive to golden-yellow; vertical fins with narrow dusky edges.

Order Clupeiformes

Known as sardines and anchovies, four families occur in this region. Mainly inhabit pelagic and coastal, occasionally obtained by trawling but mainly caught by purse sein nets, most species are economic important. References; Whitehead (1985) and Whitehead, Nelson & Wongratana (1988).

Family Engraulididae

26. Encrasicholina heteroloba (Ruppell, 1837)

Body rather cylindrical, belly rounded, with 4 to 6 sharp needle-like prepelvic scutes, anal fin begins under last dorsal fin ray. Maxilla tip pointed, projecting beyond second supra-maxilla and reaching to sub-operculum. Lower gillrakers 22 to 30, anal fin short, dull silvery/grey band on flank, the back beige.

Distribued throughout Indo-West Pacific.

Size: To at least 8 cm.

27. Stolephorus dubiosus Wongratana, 1983

Body somewhat compressed, belly with 4 to 7 small needle-like prepelvic scutes. Gillrakers 25 to 31, usually 26 to 28. Anal fin short, iii 18 or 19 finrays, its origin below about middle of dorsal fin base. A double pigment line on back behind dorsal fin.

Distributed from Eastern Indian Ocean to western Pacific. The species of engraulid are rarely obtained by trawl, but mainly by coastal fishing gears . There are highly economic group to Malaysia and Southeast Asian contries.

Size: attaining 7.5 cm.

28. Stolephorus indicus (van Hasselt, 1823)

Body slender, elongate, rather round in cross-section, belly rounded, with 2 to 6 pre-pelvic scutes. Lower gillrakers 20 to 28. Anal fin short, with usually iii 16 to 18 finrays, its origin below centre of dorsal fin base. Body light transparent fleshy brown, with a silvery stripe down flank; no dark pigment lines on back between head and dorsal fin.

Widespread in Indo-West Pacific.

Size: To 15.3 cm.

29. Stolephorus insularis Hardenberg, 1933

Body somewhat compressed, belly with 4 to 8 , small pre-dorsal spine . A double pigment line on back behind dorsal fin; tail deep yellow

in Indo-West Pacific.

Size: To 6.4 cm.

<u>Family Chirocentridae</u>

30. Chirocentrus dorab (Forsskal,1775)

Pectoral fin shorter than distant between mid-orbital to edge of opercle and the black marking og the upper part of the dorsal fin, also some black on the anterior part of the anal fin.

Geographical Distribution: throughout the warmer coastal waters of Indo-Pacific.

Size: To about 100 cm of standard length.

31. Chirocentrus nudus (Swainson, 1839)

Longer pectoral fin (than distant of mid-eye to opercular edge) absence of black markings on the dorsal fin tip and on the anterior part of the anal fin.

Geographical Distribution: Probably similar to that of *C. dorab*, but occure in coastal areas mainly. Recently rare in Thai waters.

Size: to about 100 cm.

<u>Family Clupeidae</u>

32. Ilisha megaloptera (Swainson, 1839)

Body rather deep; belly with 28-35 total scutes; eye large; lower jaw strongly projecting; dorsal fin origin near midpoint of the body; anal fin with 38-53 finrays, origin below hind part of the dorsal fin. Body silvery with yellosh tint; fins yelloish hyalin; pectoral and caudal fin yellow, the caudal with dusky margin.

Attains to 27 mm, usually 20 cm.

Distrbuted in coastal of India to the South China Sea.

***33. Sardinella fimbriata* (Valenciennes, 1847)**

Body somewhat compressed, total number of scutes 29 to 33. Lower gillrakers 54 to 82. A dark spot at dorsal fin origin.

Distributed in Indo-West Pacific,

Size: To 13 cm.

***34. Amblygaster sirm* (Walbaum,1792)**

Body slender, belly rather rounded, scutes not prominent. A series of 10 to 20 gold spots down the flank, lower gillrakers 33 to 43.

Distributed in Indo-West Pacific.

Size: To 23 cm.

***35. Nematalosa nasus* (Bloch, 1795)**

Body rather deep, belly with total 28 to 32. Mouth inferior, lower jaw strongly flared outward. Last dorsal finray filamentous pectoral axillary scale present.

Geographical Distribution: Indian Ocean to soutern Japan or southern tip of Korea.

Size: To 21 cm, usually about 15 cm.

Order Aulopiformes

Family Synodontidae

Lizardfishes are aptly named for their reptile-like head; large mout and numerous needdle like teeth; body cylindrical; no spine in the fins; high dorsal fin, small adipose fin; pelvic fin are large, caudal fin fork. Three genera and 6 species were found.

***36. Saurida longimanus* Norman, 1939**

Body dusky olive above, silvery white below. Pectoral fin dark brown, its inner side dusky, reaching to or beyond line drown between dorsal and ventral fin origin. About three rows of teet in anterior part of outer palatine tooth band

***37. Saurida micropectoralis* Shindo & Yamada, 1972**

Body fawn above, white below, with traces of dark blotces across back; brown spot at base of adipose fin; upper half of inner pectoral fin dusky and black bar across ventral fin. Pectoral fin short, never reaching ventral fin origin. Three or more rows of teeth in anterior part of outer palatine band.

***38. Saurida tumbil* (Bloch, 1795)**

Distinguished from *S. micropectoralis* in the pectoral fin tip is just reach to pelvic fin origin. Coloration and other charactor is similar to the above species. Attain at least 40 cm. Distributed in Indo-Pacific.

***39. Saurida undosquamis* (Richardson, 1842)**

Body plain olive brown above, silvery white below; upper edge of caudal fin with row of 4 to 9 black checks. Pectoral fin reaching ventral fin origin when laid toward it. Two rows of teeth on anterior part of outer palatine tooth band.

***40.. Synodus hoshinonis* (Tanaka, 1917)**

Prominent black area on upper of operculum spilt above into 3 or 4 branches. Brown bars across back. Pale peritoneum with 12-13 black spots. Anterior teeth of palatine band longer than posterior ones.

***41. Trachinocephalus myops* (Forster, 1801)**

Snout blunt, shorter than eye diameter. Anal fin base longer than dorsal fin base. Body with alternating narrow light blue and dark-edged yellow stripes, shading to whitish ventrally; a large diagonally elongate black bloch behind upper end of gill opening. **Order Ophiiformes**

Family Ophiidae

42. Serembo jerdoni **(Day, 1988)**

Head large; median fin confluened. Head and bady yellowish gray crossed by 4 or 5 oblique dark brown bands anteriorly, eac connecting with its partner over head and nape; dorsal fin with 3 or 4 dark brown bloches anteriorly followed by dark band, anal fin white with dark band. Short spine on operculum; small cycloid scales cover head and body; ventral fin base below posterior half of eye. Six or 7 oblique scale rows between lateral line and dorsal fin.

43. Serembo sp.

Head longer than S. jerdoni, robust body with 4 oblique dark-brown bands: dorsal fin with 3 dark blotches dorsally and submarginal dark band continuos to anal fin. Single species taken off Malay Pennisular.

Order Siluriformes

Family Ariidae

The sea catfish is the one of two siluroid families inhabit in the sea. Their head covered with a bony sheild, often rugose; dorsal and pectoral fins with a strong, serrate spine. Jayaram (1983) reviewed the Indian Ocean species; up to 20 species known from this area; this survey found 3 species.

44. Arius bilineatus **(Valenciennes 1840)**

Snout broadly rounded and short, differ from *A. thalassinus* (pointed). head shield granules relatively coarse. Color, dark grey; silverly to bronze ventrally, with 6-7 silverly verticle bands laterally. fins pale grey. Attains about 80 cm., usually 30-45 cm. Distributed in central Indo-Pacific area.

45. Arius maculatus **(Thunberg,1792)**

Dorsal profile of head as a steep slope to first dorsal fin base; 3 pairs of barbels around mouth, the maxillary pair extending to pectoral fin base, head shield rugose and granulated from middle of or near posterior margin of orbit to supraoccipital process; supraoccipital process longer than broad at base with a median keel, palate teeth granular or molarlike, in a single large, fully elliptical or semioval patch on each side, first dorsal fin ray often produced into a long filament; total anal fin rays 19 to 22. Maximum size is 61 cm; common between 20 and 40 cm.

Colour: dark brown above, sides grey and belly whitish with dusky spots, the whole boby with a bright sheen. All fins black tipped. Pectoral and pelvic fins dusky above, adipose mainly blackish.

Distributed from eastern Indian Ocean to South China Sea. Commonly found in market of coastal areas.

46. Arius thalassinus **(Ruppell,1837)**

Dorsal profile of head sharply rising from occiput to first dorsal fin base; snout in males acute, pointed, with upper jaw longer than lower, in females rounded, jaw more or less equal, head shield weakly granulated and a prominent preorbital conical protuberance tapering as a wide V posteriorly, outer pelvic fin rays sometimes thickened in females; total anal fin rays 15 to 18. Maximum size is 185 cm, common between 25 and 70 cm.

Colour: dark-red-brown to bluish-grey above, densely pigmented below, the whole body with a bronze lustre; numerous narrow, parallel transverse viridescent crossbands of greenish colour, distal part of dorsal adipose, anal and caudal fins, as well as upper surface of pectoral and pelvic fins, dark.

Distributed throughout Indo-West Pacific. Highly ecomomic species.

Family Plotosidae

The eel catfish is distinguished by continuous secon dorsal fin to caudal and anal fin; four pairs of barbel; a slender, strong spine in the dorsal and pectoral fins. Over 4 species known from the South China Sea, 3 species were found. Reference; Gomon (1983).

47. Plotosus caninus **Hamilton-Buchanan,1822**

Head moderately large, profile straight from tip of snout to dorsal fin origin; 4 pairs of barbels, the nasal barbels extending well behind eyes almost to nape, eyes small, teeth in upper jaw pointed, in 2 rectangular patches of 3 rows each, pectoral fins with 11 to 14 soft rays. Dendritic organ present posterior to anus.

Maximum: reportedly 150 cm; common to 80 cm.

Colour: Dorsal of body olive dark-brown, pale ventrally; fins dark or dark brown.

Distributed from eastern Indian Ocean to Western Pacific. Common economic species in estuary areas.

48. Plotosus lineatus **(Thunberg,1787)**

Head moderately large, profile slightly arched from tip to snout to dorsal fin origin, the nasal barbels not extending well beyond posterior borders of eyes, dorsal procurrent caudal fin with 69 to 115 rays, anal fin with 58 to 82 soft rays

Colour: brown or black above, whitish below, with 2 or 3 stripes (white or yellow in life); 2 of the stripes extend from snout to near caudal peduncle, margin of median fins blackish.

Maximum: about 30 cm; common to 25 cm.

Distributed throughout Indo-West-Pacific, commonly obtarnd by trawl-net in large school.

49. Plotosus **sp.1**

Head small, nasal barbels not reaching gill opening; body robust; second dorsal fin origin above pelvic fin.

color: silvery grey, 2 pale longitudinal stripes from head to casudal finbase. First dorsal fin with black tip, second dorsal and anal fin with dark margin.

Size; 16 cm. found at Songkhla fishmarket, only single specimens.

Order Beloniformes

<u>Family Belonidae</u>

The needdlefishes are very elongate body; extremely long, poited jaws bearing numerous needdle-like teeth; the fins lack of spines; the dorsal and anal fins are posterior in position; scales small, deciduous. Over 5 species of 4 genera known in this area, 2 species found (References; Collette, 1984a; Petchsathit, 1992). The beloniforms fish is surface inhabitant, usually obtained by purse sein, drift gillnet and scoop net.

50. Ablennes hians **(Valenciennes,1846)**

Body elongate and greatly compressed laterally. Upper and lower jaws greatly elongated and studded with small sharp teeth. Gillrakers absent. Anterior parts of dorsal and anal fins with high falcate lobes; anal fin rays numerous 24 to 28 , pectoral fins falcate.

Colour: bluish green above, silvery white below. A broad dark blue stripe along sides and about 12 to 14 prominent dark vertical bars on body; tip of lower jaw red. Scales and bones green.

Maximum: at least to 120 cm total length and 90 cm body length ; common to 70 cm body length

Distributed throughout Indo-West Pacific; commonly obtained by purse seine and dipnet

51. Tylosurus crocodilus crocodilus **(Peron & LeSueur,1821)**

Body elongate, rounded in cross section. Upper and lower jaws greatly elongated and studded with sharp teeth, anterior part of dorsal and anal fins with relatively high lobes, anal fin rays 19 to 22, a small black lateral keel on caudal peduncle.

Colour: dark bluish green above, silvery below. A dark blue stripe along sides.

Maximum: at least to 124 cm standard length; common to 90 cm standard length.

Distributibution: A worldwide species in tropical and warm-temperate waters.

Family Hemiramphidae

The halfbeaks are differ from needdlefishes in having a short, triangular upper jaw and prolonged lower jaw; well develop gill rakers. Five genera and over 22 species known in the South China Sea, 4 species were obtained by scoop net and from fish market. References; Collette, 1984b; Petchsathit, 1992.

***52. Euleptorhamphus viridis* (van Hasselt)**

Body slender and strongly compressed. Pectoral fin longer than head, but not reaching to pelvic fin origin. Dark blursh above, bluish silver below, fins hyaline, pectoral and anal fin dusky. Attains 50 cm. Widely distributed in the Indian and Pacific Ocean.

***53. Hemiramphus far* (Forsskal,1775)**

An elongate fish with a greatly prolonged, beak-like lower jaw; upper jaw short. No spines in fins, anal fin rays 10 to 12, pectoral fins short, not reaching past nasal pit when folded forward.

Colour: dark bluish above, silvery white below, with 3 to 9 (usually 4 to 6) vertical bars on the sides. Beak dark, with a bright red flesy tip.

Maximum: about 44 cm total length; Common to 27 cm standard length.

Distribution: An Indo-Pacific species.

***54. Hyporhamphus (Reporhamphus) dussumieri* (Valenciennes,1846)**

An elongate fish with beak-like lower jaw, equal to or longer than head length; upper jaw short, triangular, and scaly, preorbital ridge present; dorsal and anal fin rays 14 to 16, caudal fin forked, with lower lobe longer than upper. Anterior part of dorsal fin and all of anal fin covered with scales.

Colour: green above, silvery white below. Fleshy tip of beak red.

Maximum: about 29.5 cm standard length. Common to 19.0 cm standard length.

***55. Rhynchorhamphus malabaricus* Collette,1976.**

An elongate fish with a greatly prolonged, beak-like lower jaw; upper jaw about as long as wide; domed, and covered with scales, dorsal plus anal rays 25 to 29, pectoral fins short, caudal fin distinctly forked, lower lobe longer than upper. Two branches of lateral line running from ventral outline of fish toward pectoral fin base.

Colour: bluish-green above, silvery white below. Fleshy tip of beak red.

Maximum: about 35 cm total length, common to 20 cm standard length.

Distribution: Known from eastern Indian Ocean, found in local market at Ko Sarmui, the Gulf of Thailand.

Family Exocoetidae

***56. Cypselurus oligolepis* (Bleeker, 1866)**

Body oblong, dorsal and anal fins posterior in position, pectoral fin enlarge, reaching to anal fin; pelvic fin large, caudal fin deeply forked, the lower lobe much longer.

Color: bluish dark dorsally, flank and abdomen silverly, pectoral fin black except tip and about lower fifth which are hyaline, pelvicfin hyaline. Size: attains to 27 cm. , commonly 15 cm. pelagic, usually taken by purse sein fishing or clipnets.

Order Gasterosteiformes

Family Fistulariidae

57. Fistularia commersoni **Ruppell, 1835**

Body and snout more slender than F. petimba, elongate bony plate on the body; interorbital space convex. Body pink or olive, silvery below.

58. Fistularia petimba **Lacepede, 1803**

Slender body plates embeded in skin along midline of back. Upper ridges on snout parallel, those above and behind eye strongly serrated. Interorbital space concave. Skin granular at all sizes; small sharp spines along posterior part of lateral line. Body pink or red above, silvery below.

Family Centriscidae

59. Centriscus scutatus **(Devis, 1885)**

Body appears transparent and silverly-yellow with a dark longitudinal stripe and 8-10 vertical bars on lower sides. First dorsal fin spine tip not jointed. Top of head with longitudinal striations and groove along interorbital space. Attains to 20 cm TL.

Family Syngnathidae

60. Hippocampus kuda

Body compressed; head almost at right angle to body trunk; no caudal fin; a cluster of 5 blunt spines ("coronet") on top of head, the ridge behind it spineless. Dorsal fin base elevates. Body reddish brown, black or banded. Attains to 20 cm, usually 10 cm. Threatened by overfishing for chinese traditional medicines.

61. Hippocampus sp.

Differ from *H. kuda* in having fewer trunk rings; spine relatively longer; body yellowbrown, goldish with dark brown spots.

62. Corythoichthys sp.

Body very elongate, head and snout snort, dorsal fin close to head than to caudal. Body greyish brown, pale ventrally; fins hyaline.

Family Pegasidae

63. Pegasus laternarius **Cuvier, 1816**

Rostrum of male club-shaped, horizontal; in female short; carapace surface with paired, dorsomedial ridges. pectoral fin wide, horizontally spreaded. Body olive brown or darky brown with numerous dark spots, fin hyaline with dark brown, small rings. Attain to 8 cm. Distributed in Indo-west Pacific. Reference; Palsson & Pietsch (1989).

Order Scorpaeniformes

Family Scorpaenidae

The scorpionfishes are named for the venomous fin spines possesed by many of the species. Head usually large, with extended bony platee passing from the suborbital bone across the cheek below the eye to preopercle; mouth large; dorsal fin often strongly notched between spinous and soft portions. Over 15 genera and 40 species known in this region, 12 species found (References; Eschmeyer, Hallacher & Rama-Rao, 1979; Eschmeyer, Rama-Rao & Hallacher, 1979; Gloefelt-Tarp & Kailola, 1984; Masuda et al., 1984; Randall, 1995).

64. Apistus carinatus **(Bloch, 1801)**

Head and body fawn, white below. Large black white ringed ocellus over posterior dorsal fin spines. Inner pectoral fin charcoal, lower rays and near axil orange. Three chin barbels; body scales with rough edges. Pectoral fin very long, lowermost rays free on rodlike.

***65. Brachypterois serrulata* (Richardson, 1848)**

Head large with numerous serrate ridge, body slightly compress; dorsal spines short, pectoral fin long, reaching to base of caudal fin, caudal fin long. Body reddishh with five blackish bars, large dark spot on opercle, pectoral fin membrane black, soft dorsal, anal, caudal and pelvis fin with orange-red spots. Size attains to 11 cm. Known from Red sea, Indo-China and Philippines, the specimens taken of Malay Peninsula and Borneo.

***66. Inimicus sinensis* (Valenciennes, 1833)**

Elongate, naked body; snout equal to or longer than postorbital distance. Dorsal fin spines almost free from membrane exept for first three; lowermost two pectoral fin rays rodlike and free from rest for fin. Inner pectoral fincolour dark brown or black with large orange or cream spots, base of rays bright yellow, spotted brown.

***67. Minous coccineus* Alcock, 1890**

Body nake,. Second lachrymal spine must longer than first. First spine must shorter than second spine; lowermost pectoral fin ray rodlike and free from rest of fin. Body dark pink; dorsal fin crossed by diagonal brown bands; caudal fin plian pink. Inner pectoral fin yellow or pink, crossed by rows of oval tan or brown spots.

***68. Minous trachycephalus* (Bleeker, 1854)**

Head large, body tapering. Both lachrymal spines about equal in length. Body pink to yellow, brown mottling on back tending to form longitudinal bands. Caudal fin finely barred or pale. Inner pectoral fin bright yellow, axil and rays red or pink, large white spots in axil.

***69. Minous pictus* Gunther, 1880**

Body nake, slightly oblong. Body yellow or fawn, streaked above with dark brown oblique lines and bloches extending onto dorsal fin. Caudal fin plain; inner pectoral fin pink or yellow, gray or brown stripes and spots spreading along fin rays to margin.

***70. Minous monodactylus* (Bloch & Schneider, 1801)**

Body nake; large head, lacrymal bone with two spurs extending over maxilla; pectoral fin reaching at middle of anal fin. Body mottled brown grey or yellowish grey; pale ventrally; a large black spot distally on anterior of soft dorsal fin; anal and pair fins dark brown distally; caudal fin with two broad dark bars. Attains about 12 cm.,commonly 5 cm. Distributed in Indo-Pacific regain.

***71. Pterois russelli* Bennett, 1831**

Dorsal fin spined long, membrane only at bases. Pectoral fin long, reaching to above anal fin, all it rays simple . Scale cycloid. Crimson or brownish red bands over head and body. Soft dorsal, anal and caudal fin plain yellow or red with no trace of spots; alternating rows of black and white spots and checks over ventral fin.

***72. Pterois* sp.**

Similar to *P. russelli* but shorter pectoral fins and dorsal spines. Body with rosy red bands on pale base, ventral pale. Less common than the above species, taken from The Gulf of Thailand and Malay Peninsula.

***73. Scorpaenodes scaber* (Ramsey & Ogilby, 1886)**

No palatine teeth; spines present on interorbital and on coronal ridge; head and body scales ctenoid. Second anal fin spine equal to or more than alf head length. Soft dorsal, anal, caudal and pectoral fins finely spotted brown; 3 to 5 irregular bars over bsck; four dark bars radiate from eye. 43-46 scale rows above lateral line.

***74. Scorpaena neglecta* Heckel, 1840**

Dark brown to brownish purple; a white bar sometimes present below dorsal fin. Fins completely dark brown, or margins banded yellow, pink or orange; inner pectoral fin bright yellow or orange in axil and along edges, broad black band along hind margin and lower rays crimson; skin rosy underneath pectoral fin. Neck humped before dorsal fin origin; occipital pit present on upper part of head behind eyes.

***75. Scorpaenopsis cirrhosa* (Thunberg)**

Dark brown, rosy ventrally; mandible, eye and dorsal spines tip with fleshy papilae. Body oblong; large pectoral fin. One specimens, 12 cm. taken by Hand-line at Ko-Kra.

***76. Choridactylus multibarbatus* Richardson, 1848**

Head blunt the dorsal profile of snout nearly vertical; two pairs of barbels on lower jaws; posterior of two lacrymal spines and upper of two preopercular spine very long. Body deep, no scales, pectoral fin lorge with tree detached and free rays, dorsal fin with 12-14 spines, caudal fin small.

Color: mottled reddish brown, a diagonal white band between fourth and sixth dorsal spines, caudal fin white with brown submaginal and basal dark bars. Size attains to 12 cm. single specimens 8.5 cm. found. Distributed in Indo-Pacific.

Family Triglidae

***77. Lepidotrigla spiloptera* Guenter, 1880**

Head large, rostral process of preobital with series of 7 spines, one closly longer than the rest. Pectoral fin upper portion and hind border dark pink, base and lower rays cream or creamy pink; mid and lower part of fin lime-green with charcoal stippling or small spots within. Pectoral fin moderate. Dorsal fin with large red blotch at the posterior portion. Breast and belly fully scaled. Pectoral fin slender.

Family Dactylopteridae

Body moderately elongate. Head large and blunt, bones on top of head united to form a shield which produced backward from top of head into a long post-temporal spine and a long spine from preopercular angle. Pectoral fin enormous and wing-like. Caudal fin lunate or emarginate. References; Gloefelt-Tarp & Kailola (1984).

***78. Dactyloptena papilio* Ogilby, 1910**

Post-temporal spine elevated above body profile. five to 7 enlarged scales on lower sides. Two single free spines before first dorsal fin. Large black patch containing blue spots near base of inner pectoral fin.

***79. Dactyloptena orientalis* (Cuvier, 1829)**

Post-temporal spine lies flat against body. Two to 4 enlarged scales on lower sides. Two single free spines before first dorsal fin. Inner pectoral fin with many olive and charcoal blotches over all of fin.

Family Platycephalidae

The flatheads have elongated and depressed body; head more depress and broader than body, with bony ridges usually bearing serration or spines; without venomous spiny finray. More than 60 species of 19 genera known fron Indo- Pacific, 7 species found (references; Wongratana, 1975; Gloefelt-Tarp & Kailola, 1984; Randall, 1995).

***80. Elates ransonneti* (Steindachner, 1876)**

Body very elongate, head depressed. One very long preopercular spine reacing past edge of operculum. Caudal fin emarginate, upper lobe usually with filament. Head and body almost translucent cream, row of mauve blotches along mid-sides.

81. Inegocia japonicus **(Tilesius, 1812)**
Two low spines below eye on suborbital ridge; iris lappet a half-circle with long, branched cirri; upper preopercular spine sligtly longer than lower; lower opercular flap well-developed and acute. Body fawn; caudal fin orangishh wit 3 or 4 series of distinct black spots across it.

82. Sorsogona tuberculata **(Cuvier, 1829)**
Head ridges very finely serrated, suborbital ridge expanded and overanging ceek; 3 to 5 preocular spines present; 5 or 6 preopercular spines. Body pale brown, nape pale; lower pectoral fin and outer ventral fin with patches of black, their margins white.

83. Rogodius pristiger **(Cuvier, 1829)**
Head large, depressed, with fine serrated ridges, preopercular spines usually four, teeth on vomer and palatines somewhat enlarge. color: brown dorsally, shading to pales ventrally with 4-5 dark blotch on paired five. Attains about 17 cm., 15 cm. SL. specimens found off Malay peninsula.

84. Kumococius rodericensis **(Cuvier, 1829)**
Head with spinous bony ridges, stout; the suborbital ridges with four or more species; uaually three preopercular spines, the uppermost much the largest, reaching to or beyond edge of opercle; pectoral fin sligtly fulcate. Color; brown with four or five faint dark bars on back; fins dusky, the rute part of caudal fin and edges of pectoral fins darker. Attain about 20 cm. , commonly 15 cm. Dictributed in Indo-West Pacific.

85. Platycepalus indicus **(Linnaeus, 1758)**
Head short, depressed, with smooth ridge; single small preopercu;ar spines; two preopercular spines, the upper shorter than lower and angling dorsally; body depressed tapering. Color; olinanaceaus light brown with numerous dark spots, caudal fin yellow with dark irregular stripes. Size attains to 70 cm.; commonly 40 cm. Distributed in Indo-West Pacific, economic species of the family.

86. Thysanophrys macracanthus **(Bleeker, 1876)**
Suborbital ridge ventrally but outwards; preopercular spine long extending to posterior alf of opercle; anterior scales of lateral line spiny. Body light brown, with paint irregular cross bands on back, upper part of pectoral and caudal fins spotted with dark brown. Attains to 20 cm., commonly 15 cm. Known from Indo-West Pacific.

Order Lophiiformes
<u>Family Lophiidae</u>
87. Lophiomus sp.
Dusky iliac above, white below; inside of mouth white, tongue and floor of mouth with network of black lines. Three to 4 rows of teeth in jaw. Gill opening behind and below pectoral fin "elbow"

<u>Family Antennariidae</u>

88. Antennarius striatus **(Shaw & Nodder, 1794)**
Body short, bulky and slightly compressed. Head large; mouth large, oblique or vertical; eye lateral, teeth slender: gill opening pore-like; pectoral fin modified and single, wit distinct "elbow". Dark brown streaks spread across head and obliquely over body; fins spotted or striped dark brown.

Tip of illicium with 2 or 3 simple filament: second dorsal fin spine noticeably shorter tham illicium; soft dorsal fin rays simple, last 2 or 3 branched. Anal and caudal fin rays branched; pectoral fin rays simple.

***89. Antennarius nummifer* (Cuvier, 1817)**

Similar to A. striatus in bsdy shapes but sorter fins. Body color varies, yellow, orange or pale brown; a prominent dark spot presene at base of soft dorsal fin. Attain to 12 cm., 7 cm. specimens taken from Malay peninsula.

Family Ogcocephalidae (reference; Gloefelt-Tarp & Kailola, 1984)

***90. Halieutaea stellate* (Vahl, 1797)**

Many strong sharp spine over dorsal surface, ventral surface smooth except for scattered fine spines around ventral fin bases; disc sligtly wider than long, slightly flattened behind eyes; roof of rostral cavity dose not reach disc edge. Dorsal surface rosy or dusky pink, usually patterned with black spots forming crescentic lines or red with black margins.

Order Perciformes

Family Priacanthidae

***91. Priacanthus macracanthus* Cuvier, 1929**

Preopercular spine long and narrow. Body silver-red but varies a lot. Dorsal, anal and ventral fins with horizontal rows of dusky-yellow-green spots. Caudal fin truncate, red and with black edge.

***92. Priacanthus tayenus* Richardson, 1846**

preopercular spine long and slender. Body colour silver-red. Fourth and 5th dorsal rays produced in young specimen; anal fin deeply emarginate with pointed lobes. Ventral fins wit numerous brown blotch of various sizes.

Family Callionymidae

Small fishes with depressed head and trunk. Mouth small and protractile; small, fine teeth in jaws; eye large; well-developed spine on preoperculum wit barbs along margin, no opercular nor subopercular spine. Gill opening a small pore near top of head or on upper sides; gill membranes united to isthmus. No scales; lateral line well-developed. Usually two dorsal fins. Ventral fin large, its base before base of large pectoral fin, last ray usually connected to it by a broad membrane. References; Gloefelt-Tarp & Kailola (1984); Masuda et al., (1984).

***93. Callionymus japonicus* Houttuyn, 1782**

Preopercular spine 6-13 serrae along inner margin, 2 rough bony patches above and behind eye. First 2 dorsal spines produced and filamentous (male), caudal fin very long, median rays produced, the fin equal to or more than body lengt. First dorsal with dark brown streaks, black blotch on 3rd membrane, back margin on anal fin, caudal fin crossed by dark brown bars, lower part of fin black; large black spot on breast.

***94. Callionymus filamentosus* Valenciennes, 1837**

First dorsal spine produced into filament and detaced from rest of fin (male) connected with 2nd spine and not filamentous (female); median rays of pointed caudal fin filamentous (male). Pearly and dark brown spots over upper two-thirds of body, dark bars across cheek, dusky patch on pectoral base; 2nd to 4th membranes of first dorsal black with white streaks or with some large, white-edged black ocelli (male). Second dorsal, caudal and ventral fins spotted with brown.

***95. Callionymus* sp.**

Male with high, filamentous first dorsal fin ray, the first dorsal fin jet black, second dorsal fin hyaline with dusky and pale spots; anal fin dark with white margin.

96. Dactylopus dactylopus **Valenciennes, 1837**

Snout short. Spinous dorsal high, beginning before gill opening; usually all dorsal rays divided. Body olive above, marbled reddish brown and blue; soft dorsal and upper caudal fins barred with charcoal; blue-ringed ocellus on spinous dorsal membrane; ventral spotted dark blue.

97. Repomucenus virgis **(Jordan & Fowler)**

First dorsal broad and high in male; dorsal spine filamentous; preopercular spine short with an anterior process at base, 2-4 very short upward process on inner side. Pale greenish above, first dorsal fin olive hyaline with pale vermiculation fins yaline, with dark spots; pectoral fin dusky. Distributed in West-Pacific. Attains to 15 cm.

<u>Family Champsodontidae</u>

98. Champsodon arafurensis **Regan, 1908**

Elongate, slightly compressed bodies. Mouth very large, oblique, lower jaw prominent; eye high on head with a short cirrus; angle of preoperculum ends in a long slender spine; gill openings wide. Scales small. Ctenoid and granular; 2 indistinct lateral line with transverse branches. Two well-separated dorsal fins, pectoral fins small; ventral fins large, caudal fin forked. Outer part of first dorsal and caudal fins stippled brown; dusky base on caudal fin.

<u>Family Centropomidae</u>

99. Lates calcarifer **(Bloch1790)**

Body elongate, compressed with a deep caudal peduncle. Mouth large, slightly oblique, upper jaw reaching to behind eye. Head pointed with a concave profile. Dorsal fin with a deep notch almost separating soft part of fin. Colour either olive brown with silvery sides and belly or green/blue with silver sides. Common in Indo-Pacific region, especially near caostal waters. A highly economic species, found in all markets.

<u>Family Serranidae</u>

The groupers, coralcods and anthias are the large family, consist of four subfamilies in the South China Sea. The largest size is subfamily Epinephelinae, over 70 species known from the region. The groupers and coralcods is characterized in having of large mouth, the maxilla not forming the part of gape; lower jaw usually projecting anterior to the upper; preopercular margin always serrate and opercle with three flat spines; scales small and ctenoid. Seven species were found in this survey (references; Masuda et al., 1984; Randall & Hoese, 1986; Randall & Heemstra, 1991; Heemstra & Randall, 1993).

100. Cephalopholis boenak **(Bloch, 1790)**

Body depth less than head length , preopercle rounded, very finely serrate; no enlarged spines at angle , pectoral fins longer than pelvic fins , pelvic fins usually reaching to or beyond anus , caudal fin well rounded. Body scales ctenoid, without auxillary scales; lateral-line scales 46 to 51

Colour: Dark brown, usually with 7 or 8 dark bars on body, black spot between upper and middle opercular spines; soft dorsal , anal and caudal fins darker distally, with a pale bluish line on the edge.

Geographical Distribution: *C. boenak* is primarily continental in its distribution, occurring from Kenya to the western Pacific.

Size: Maximum total length 26 cm.

101. Epinephelus areolatus **(Forsskal, 1775)**

Body depth less than head length, preopercle angular, with 2 to 7 enlarged serrae at the angle;

upper edge of operculum straight or slightly convex, maxilla extending to below rear half of eye , pelvic fins reaching to or nearly to anus; adults with auxiliary scales; lateral-line scales 49 to 53.

Colour: Head, body and fins pale, covered with numerous close-set brown, brownish yellow, or greenish yellow spote, those on front of head smaller than those on operculum. Pectoral fins pale, with small dark spots on the rays. Posterior edge of caudal fin with a distinct white margin.

Geographical Distribution: Indo-West Pacific.

Size: Maximum 31 cm standard length.

***102. Epinephelus bleekeri* (Vaillant, 1877)**

Body elongate, preopercle angle with 2 to 9 enlarged serrae, caudal fin truncate or slightly convex. Lateral-body scales ctenoid; adults with a few small auxiliary scales.

Colour: Head and body brownish, reddish brown or purplish grey, covered with numerous reddish orange, gold, or yellow spots; dorsal fin and upper third of caudal fin with spots like those on body; lower two-thirds of caudal fin dusky, pectoral and pelvic fins and distal part of anal fin dusky; dark streak along maxillary groove.

Geographical Distributed in Indo-West Pacific.

***103. Epinephelus coioides* (Hamilton, 1822)**

Body moderately elongate, but little compressed; teeth on mmidside of lower jaw in two rows; scale on body alrgely ctenoid; caudal fin rounded.

Colour, ligth greyish brown, shading to whitish ventrally, with numerous brownish orange or brownish yellow spots onhead, body and fins, five slightly diagonal greyish brown bars on body which bifurcate ventrally.

Distributed from Red Sea to Western Pacific. Very economic important, widespread cultured in the Southeast Asia. Had long been misidentified as *E. tauvina*. Commonly found in fish markets througout the areas.

***104. Epinephelus heniochus* Fowler, 1904**

Body elongate, dorsal head profile distinctly convex; preopercle angular, with 2 to 4 large spines at the angle. Dorsal fin with XI spines and 14 or 15 rays, the third or fourth spine longest, caudal fin rounded. Lateral-body scales ctenoid, without auxiliary scales; lateral-line scales 54 to 60.

Colour: Head and body pale brown dorsally, shading to whitish or pale pink ventrally with minute brownish black dots on body and rear part of head; faint dark brown stripe from eye to end of operculum, pectoral fins hyaline greyish yellow; lower part of caudal fin sometimes darker than rest of fin; margin of interspinous dorsal-fin membranes yellow.

Geographical Distribution: Tropical western Pacific to South of Japan.

Size: Attains at least 35 cm standard length.

***105. Epinephelus quoyanus* (Valenciennes,1830)**

Body moderatly elongate, compressed , dorsal head profile evenly curved, preopercle rounded or subangular; upper edge of operculum almost straight. Dorsal fin with XI spines and 16 to 18 rays, caudal fin rounded. Lateral-body scales ctenoid; auxiliary scales present; lateral-line scales 48 to 52.

Colour: Head and body pale, mostly covered with large, close-set, hexagonal to roundish, dark btown spots, dorsally the spots are so close together that the pale interspaces from a reticulum, dark spots on head smaller than anteriorly , ventral edge of anal and caudal fins and leading edge of pelvic fins with white line and broad blackish submarginal band, pectoral fins mostly dusky with indistinct dark spots.

Geographical Distributed from Eastern Indian Ocean to Western Pacific

Size: Maximum known 31 cm standard length.

***106. Epinephelus sexfasciatus* (Valenciennes, 1828)**

Dorsal head profile convex; preopercle with 2 to 4 greatly enlarged serrae at the angle. Dorsal fin with XI spines and 14 to 16 rays, caudal fin rounded; caudal-peduncle deep.

Colour: Head and body pale greyish brown; 5 dark brown bars on body and 1 on nape; scattered pale spots may be present on body, and some faint small brown spots are often visible on the edges of the dark bars; soft dorsal, caudal , and pelvic fins dusky grey, the pectoral fins freyish or dusky orange-red; jaws and ventral parts of head pale reddish brown.

Geographical Distribution: Known only from the tropical western Pacific Ocean.

Size attaining to 30 cmSL.

***107. Plectropomus leopardus* (Lacepede, 1802)**

Body elongate, robust, preopercle broadly rounded, with 3 large, ventrally-directed spines, interopercle and subopercle smooth. Dorsal fin with VII or VIII slender spines and 10 to 12 rays, pectoral fins subequal to pelvic fins, caudal fin emarginate, Lateral-line scales 89 to 99.

Colour: Olivaceous to head and median fins; more than 10 spots on cheek, pectoral fins reddish or hyaline with darker rays.

Geographical Distributed in Western Pacific.

Size: Attains 70 cm SL.

Family Apogonidae

The cardinalfishes are known as mouth brooder; distinctive body form with large mouth; dorsal fin fully separeted; oblong, compress body and long caudal peduncle. About 250 species of 23 genera are known worldwide, over 100 species known from South China Sea, 13 species found (references; Gloefelt-Tarp & Kailola, 1984; Masuda et al., 1984; Kuiter, 1992; Allen & Swainston, 1993; Randall, 1995).

***108. Apogon albomaculosus* Kailola, 1976**

Head mottled and checked wit brown; rows of large distinct yellow or cream spots along body. Large black yellow-rimmed ocellus on soft dorsal and anal fins near bases. Caudal fin rounded.

***109. Apogon aureus* (Lecepede, 1802)**

Head dark brownish-red with thin blue lines from snout to operculum; broad black band around caudal peduncle. Red tips on soft dorsal, anal and caudal fin lobes.

***110. Apogon fasciatus* (Shaw, 1790)**

Preopercular edge fully serrate; preopercular ridge of adult usually irregular, caudal fin slightly emarginate; grey dorsally, shading to silvery white on sides and ventrally, with two blackish stripes, the narrow first from interorbital along back to upper edge of caudal peduncle, the second from front of snout through eye along side a little above middle of body to end at posterior end of caudal of caudal fin.

***111. Apogon lineatus* Temminck & Schlegel, 1842**

Round corner of preopercle and most of ventral edge serrate; posterior edge largelysmooth; preopercular ridge smooth; mouth strongly oblique; body depth 2.7-2.9 in standard length. Caudal fin slightly rounded; light grey dorsally, the edge of the scales dusky, shading to silver on sides and ventrally, with ten dusky bars on body narrower than pale interspace; a dusky bars from below posterior or part of eyes and another longer bars from behind upper parts of eye to concer of preopercular; front of snout and chin dusky; outer half of first dorsal fin blackish; second dorsal and caudal fins alightly dusky. Attain at least 9 cm.

***112. Apogon niger* Doderlein**

Body and head robust; Scales large. Body yellowish to dusky; fins dark excep caudal fin hyaline. Known from South China Sea.

***113. Apogon poecilopterus* Kuhl & van Hasselt, 1828**

Outer part of first dorsal fin black; 2 to 3 irrgular brown bands along soft dorsal fin; caudal fin dark. Dark line from eye to preopercular angle; nine to 10 brown vertical bands on body.

***114. Apogon quadrifasciatus* Cuvier, 1828**

Two dark bands along body from head: first from snout above eye to upper caudal peduncle; 2 nd through eye to tail and continuing across caudal fin to its margin.

115. Apogon sealei

Body slightly elongate; rosy pink wit two faint dark stripes from opercle to base of caudal and inditinct brownish stripe from snout along midbody; dark spot on caudal base; fins hyaline furst dorsal fin dusky anteriory, the second with dusky stripes above the fin base; caudal fin rosy hyaline. Specimens of 3.0-4.0 cm. were taken.

***116. Apogon semilineatus* Temminch & Schlegel, 1846**

Dark brown horizontal stripe from snout to below soft dorsal fin and a thinner shorter stripe from above eye. Large black spot at caudal fin base; tip of first dorsal fin black. Preopercular margin serrated.

***117. Apogon septemstriatus* Guenther, 1880**

Black line from snout along head midline to first dorsal fin origin; 2nd black line from nape to below first dorsal fin bases; 3rd black line from snout along black to upper caudal fin base; 4t and most prominent band horizontal: from snout to mid-caudal fin base and across fin to margin. Caudal fin truncate.

***118. Apogon truncatus* Bleeker, 1854**

First dorsal black over outer alf; black margin on soft dorsal , anal and caudal fins; black line along mid-height of soft dorsal and anal fins. Black line from eye to preoperculum angle; underside of head and body silvery, densely stippled black. Caudal fin rounded. The well known *A. ellioti* Day, 1878 is junior synonym (Randall, 1995).

***119. Cheilodipterus macrodon* (Lacepede, 1802)**

Jaw wit canine teeth. About 8 brown horizontal stripes from head to tail; dark brown band from pectoral fin to base to ventral fin base; broad indistinct black band around caudal peduncle at caudal fin base, upper and lower margins of caudal fin black. Soft dorsal, anal and caudal fins red.

***120. Rhabdamia gracilis* (Bleeker, 1856)**

Body translucent pink or yellow, sometimes with fine black stripe from operculum to tip of pectoral fin.

<u>Family Sillaginidae</u>

The family was reveiwed by Mckay (1992), two genera and 9 species known from the South China Sea, 3 species found.

***121. Sillago aeolus* Jordan & Evermann, 1902**

First dorsal fin with XI spines and second dorsal fin with I spine and 18 to 20 soft rays. Swimbladder with three rudimentary anterolateral extentions

Colour: The most posterior mid-lateral dark brown blotch elongate and reaching caudal flexure.

Geographic distribution: distributed throughout the Indo-West pacific

Size: to 30 cm.

***122. Sillago ingenuua* McKay, 1985**

First dorsal fin with IX spines (last spine very short) and second dorsal fin with I spine and 17 soft rays; anal fin with II spines and 17 soft rays. Lateral-line scales 66 to 70; cheek scales ctenoid.

Geographic distribution: Known from the Gulf of Thailand, Taiwan, northern Australia and India .

Size: To 20 cm.

***123. Sillago sihama* (Forsskal, 1775)**

First dorsal fin with IX spines and second dorsal fin with I spine and 20 to 23 soft rays; anal fin with II spines and 21 or 23 soft rays. Lateral-line scales 66 to 72.

Colour: Body light tan, silvery yellow-brown, sandy brown, or honey coloured; paler brown to silvery white below; a midlateral, silvery, longitudinal stripe normally present; dorsal fins dusky terminally with or without rows of dark brown spots on the second dorsal-fin membrane; caudal fin dusky terminally; other fins hyaline.

Geographical Distribution: A wide ranging species throughout the Indo-West Pacific.

Size: to 30 cm standard length.

Family Rachycentridae

***124. Rachycentron canadus* (Linnaeus, 1768)**

Body elongate, slender; head broad, depressed, mouth wide. Scale small, embedded in thick skin. Dorsal fin long, precedes by 6-9 sort and broad spines, anal fin moderately long; caudal fin emarginate. Size attaining to 1 m. Circumtropical species. Body dark brown, pale yellow on lower sides; tips of soft dorsal and anal fins and caudal fin lobes white.

Family Echeneididae

***125. Echeneis naucrates* Linnaeus, 1758**

Body elongate, slender; head depressed. Lower jaw projecting well beyond upper. Large oval-saped sucking disc on top of head, with paires transverse ridges, second dorsal fin long-bases, without spines, beginning; anal fin opposite and similar. Broad black band from snout to tail; caudal tips white. Size attaning to 90 cm, circumtropical distribution, considered as trash.

Family Carangidae

The jacks and travellies are charaterized in having of lateral scutes or freshy keel on caudal peduncle; two anal detached spines; long, crescent pectoral fins; body forms highly variable, from fusiform to deeply compressed. Seventeen genera and about 70 species known from Indo-Pacific, 24 species found. References; Gushiken (1983), Smith-Vaniz (1984), Randall (1995).

***126. Alectis cilliaris* (Bloch,1788)**

Body deep, becoming more elongate with growth, and very compressed. Profile of nape and head broadly rounded; compressed. Profile of nape and head broadly rounded, anterior soft rays of dorsal and anal fins extremely long and filamentous in young

Colour: mostly silvery with a light metallic bluish tinge on upper thrid of body and head.

***127. Alectis indicus* (Ruppell,1830)**

Body deep. Profile of nape and head somewhat angular; gillrakers (excluding rudiments) 8 to 11 upper, 21 to 26 lower and 29 to 37 total on first gill arch. Dorsal fin with 6 short spines, anterior soft rays of dorsal and anal fins extremely long and filamentous in young, fork length.

Distributed throughout Indo-West Pacific, seldomly obtained.

Colour: mostly silvery with a dusky green tinge dorsally; juvenile with dark bars on body.

***128. Alepis kleinii* (Bloch, 1793)**

Body oval, strong compress, with ventral profile distinctly more convex than dorsal adipose eyelid well develop on posteriorly half of eye only; upper jaw anteriorly with 2 irregular rows of short conical teeth, posteriorly inner surface of jaw paved with blunt teeth; lower jaw with a single row of short, conical teeth except 2 rows anteriorly; straight part with 0 to 2 scales and 35 to 45 scules: total scales and scutes in lateral line 72 to 86.

Colour: bluish-grey to green above, silvery below; large black spot on upper margin of opercle and adjacent area of shoulder. Caudal fin dusky to bright yellow, other fins mostly pale to hyaline.

Distributed throughout Indo-Pacific, *Caranx kalla* Cuvier and *C. para* Cuvier are synonyms (Randall, 1995).

***129. Alepes melanoptera* Swainson,1839**

Body oblong, compressed, adipose eyelid well developed on posterior half of eye only. Lateral line strongly arched anteriorly, with junction of curved and straight parts below second dorsal fin between origin and third soft ray, total scales and scutes in lateral line (excluding caudal scales) 95 to 114.

Colour: grey-blue above, silvery to white below; a diffuse dusky blotch on margin of opercle, not bordered above by a white spot. Spinous dorsal fin jet-black. Caudal fin dusky yellow, with darker trailing edges, other fins pale.

***130. Atropus atropos* (Schneider,1801)**

Body strongly compressed, almost ovate; nape strongly convex; belly with a deep median groove, accommodating pelvic fins, anus and anal-fin spines, pelvic fins conspicuously long

Colour: bluish-green above, silvery below. Membranes pelvic fins black, with the rays white basally; other fins pale.

***131. Atule mate* (Cuvier,1833)**

Body elongate oval, moderately compressed, with dorsal and ventral profiles almost evenly convex; snout pointed. Adipose eyelid well developed and completely covering eye except for a vertical slit centred on pupil, terminal dorsal and anal rays finlet-like in adults. Lateral line gently arched anteriorly, with junction of curved and straight parts below second dorsal fin below 6th to 8th soft rays; total scales and scutes in lateral line (extending caudal scales) 92 to 103.

Colour: bright olive-green dorsally, yellowish-green laterally and whitish ventrally; dorsolaterally 9 or 10 faint, grey bars, wider than pale interspaces. A black spot, slightly smaller than eye, on upper margin of opercle.

***132. Carangoides armatus* (Ruppell,1830)**

Body strongly compressed and deep. Head profile very steep in adults but relatively straight from snout to nape; lobe of second dorsal fin elongate and filamentous in adult. Breast naked ventrally to behind origin of pelvic fins; laterally, naked area of breast extends diagonally to naked base of pectoral fin

Colour: bluish-grey above, silvery below; blackish blotch on upper margin of opercle. Spinous dorsal fin blackish; second dorsal and anal fins pale to dusky

***133. Carangoides malabaricus* (Bloch & Schneider,1801)**

Body strongly compressed, almost ovate; dorsal profile of head strongly elevated to nape, almost straight. Lateral line anteriorly with a moderate regular arch, chord of curved part of lateral line longer than straight part with 31 to 55 total scute elements.

Colour: generally silvery with bluish-grey above, silvery white below; opercle with small black spot on upper margin. Caudal fin, soft dorsal and anal fins pale greenish-yellow to dusky; interradial membranes of soft anal-fin rays often with a white spot basally.

***134. Carangoides caeruleopinnatus* (Ruppell,1830)**

Body strongly compressed, almost ovate; dorsal profile of body more strongly convex than ventral profile, nape moderately curved. Lobe of second dorsal fin filamentous in young, becoming shorter with age, in mature adults distinctly shorter than head length. Straight part of lateral line with 20 to 38 scutes.

Colour: bluish-green above, silvery grey below; sides with numerous, small yellow spots; small black blotch on upper margin of opercle.

***135. Carangoides gymnostethus* (Cuvier, 1833)**

Body ovate and compressed, becoming elongate-ovate and slightly subcylindrical with age; profile of head and nape gently convex becoming less steep with age. In adult mouth cleft at level wit lower margin of eye, diameter of eye amaller than snout lengt; both jaws with bands of viliform teeth, the bands widest anteriorly. Two separate dorsal fin, the first with 8 spines, the second with 1 spine and 28 to 30 soft rays. Lateral line anteriorly with a low regular arc, with junction of curved and straight parts below second dorsal fin between 16th to 20th soft rays; chord of curved part of lateral line longer tan straight part of lateral line, straight part of lateral line with 14 to 25 scales followed by 20 to 31 small scutes. Breast naked ventrally to distinctly beind origin of pelvic fins; laterally naked area of breast extends diagonally to naked base of pectoral fin base.

Colour: olive-green above, silvery wite below with a few brown or golden spots sometimes present midlaterally; opercular spot dusky and inconspicuos. Dorsal, anal and caudal fins pale olive-green to greenis-grey, leading edge and distal margin of anal fin white. Attain 80 cm., commonly 50 cm. Widely distributed througout Indo-Pacific.

***136. Carangoides hedlandensis* (Whitley,1933)**

Body strongly compressed and deep; head profile extremely steep in adults with a distinct break in contour “bump” in the interorbital region which becomes more pronounced with increasing size. Lobe of second dorsal fin elongate and filamentous, longer than head length. Straight part of lateral line with 17 to 29 weak scutes.

Colour: greenish-blue above with dusky tinge, shading to silvery grey below; blackish blotch on upper margin of opercle. Spinous dorsal fin, elongated dorsal rays and edges of caudal fin blackish; filamentous lobe of anal fin either blackish or pale brownish, elongated rays always pale brownish.

***137. Carangoides talamparoides* Bleeker,1852**

Body strongly compressed, almost ovate; dorsal profile of head strongly elevated to nape, almost straight in profile. Chord of curved part of lateral line longer than straight part of lateral line, with 20 to 32 weak scutes. Breast naked ventrally to distinctly behind pelvic fins, often to origin of second anal fin; laterally, naked area of breast extends diagonally to naked base of pectoral fin, including small area anteriorly just above pectoral-fin base.

Colour: generally silvery, bluish-grey above, silvery white below;opercle with a small black spot on upper margin. Fins dusky; caudal fin with central ray dusky yellow with black distal margin.

***138. Carangoides uii* Wakiya,1924**

Body strongly compressed; dorsal profile of body more strongly convex than ventral profile, nape moderately curved. Lobe of second dorsal fin elongate, in largest adults may exceed length of second dorsal fin base.chord of curved part of lateral line longer than straight part of lateral line, with 16 to 26 weak scutes

Colour: bluish-grey above, silvery below; opercle spot industinct. Spinous dorsal fin and lobe and margins of second dorsal fin dark; anal fin spotted with yellow and tipped with white. Pelvic fins and caudal fin yellowish, the latter with dusky edges.

***139. Caranx sexfasciatus* Quoy & Gaimard, 1824**

Body oblong, compressed; dorsal profile moderately convex to second dorsal fin. Adipose eyelid well developed, upper jaw with outer row of strong canines widely spaced in adults. Straight part of lateral line with 27 to 36 strong scutes.

Colour: head and body silvery olive to iridescent blue-green above, silvery olive to whitish below; a small blackish spot, much smaller than eye diameter, at upper margin of opercle. Second dorsal fin olive to blackish, the lobe with a white tip; anal and caudal fins yellowish to black. Lateral line scutes dark to black. In juveniles and young adults, head, body and scutes more silvery and fins paler.

***140. Decapterus macrosoma* Bleeker, 1851**

Body very elongate, slender and nearly rounded. Scales on top of head do not extent forward to beyond posterior margin of pupil; terminal dorsal and anal soft rays each consisting of a widely detached finlet; pectoral fin short; stright part with 14 to 29 scales, folloeed by 24 to 40 scutes.

Colour: metallic blue above, silvery below; small black blotch on margin of opercle near upper edge. Caudal fin hyaline to dusky fins mostly pale.

***141. Decapterus russelli* (Ruppell, 1830)**

Body elongate, moderately slender and slightly compressed. Terminal dorsal and anal soft rays each consisting of a widely detached finlet. Total scales and scutes in lateral line 77 to 102.

Colour: bluish-green above, silvery below; small black blotch on margin of opercle near upper edge. Caudal fin hyaline to dusky brown.

***142. Decapterus kurroides* Bleeker, 1855**

Body elongate, moderately slender and slightly compressed. Eye moderate, with adipose eyelid well developed, completely covering eye except for a vertical slit centred on pupil. Shoulder girdle margin with 2 small papillae, the lower papillae the large. pectoral fin moderately long, tip of appressed fin typically extending to or slightly beyond a vertical line from second dorsal fin origin. Lateral line anteriorly with a low regular arch, with junction of curved and strigt parts below second dorsal fin between 11th to 13th soft rays; scales in curved part of lateral line 47 to 55; scutes in curved part 0 to 2 ; straight part witout anterior scales, and with 31 to 36 scutes;

Colour: Bluish-green above, silvery white below; moderate black blotch on margin of opercle near upper edge. Caudal fin yellowish orange in the taken specimens. spinous dorsal and second dorsal fin lobe sometimes dark, anal and pelvic fins pale dusky to white. Attains to 40 cm., common to 25-30 cm. Distributed in Indo-West Pacific.

***143. Megalaspis cordyla* (Linnaeus,1758)**

Body elongate, subcylindrical, with caudal peduncle strongly compressed with a marked medial keel; snout and lower jaw pointed. Eye moderate, with well developed adipose eyelid completely covering eye except for a vertical slit centred on pupil, posterior 7 to 9 rays of second dorsal and 8-10 of anal consisting of detached finlets.

Colour: head and body bluish-grey to green dorsally, sides and belly silvery; large black opercular spot. Dorsal and anal fins pale to yellow, distally dusky; pectoral and pelvic.

***144. Parastromateus niger* (Bloch,1795)**

Body deep and compressed; dorsal and ventral profiles of body strongly and equally convex. Mouth terminal with upper jaw unrestricted dorsally dorsally and ending below and slightly before anterior margin of eye. Dorsal fin with 4 or 5 short spines (embedded and not apparent in adults) followed by 1 spine and 41 and 44 soft rays; anal fin with 2 spines followed by 1 spine and 35 to 39 soft rays; profile of second dorsal and anal fins nearly identical, with elevated, broadly rounded anterior lobes; pelvic fins absent in specimens larger than about 10 cm fork length. Pectoral fins long and falcate. Straight part of lateral line with 8 to 19 weak scutes, forming a slight keel on caudal peduncle; scales small and deciduous.

***145. Scomberoides tol* (Cuvier,1832)**

Body oblong to elliptical, strongly compressed; dorsal and ventral profiles nearly equal, snout pointed with dorsal profile of head and nape slightly concave. Upper jaw extends to posterior margin of pupil in adults, posterior soft dorsal-and anal-fin rays consisting of semidetached finlets. Lateral line only slightly irregular. No scutes; scales on midbody below lateral line partially embedded and lanceolate.

Colour: body bluish dorsally, white ventrally; adults with 5 to 8 oval or vertically oblong black blotches, the first 4 or 5 of which intersect lateral line. Distal half of dorsal fin lobe abruptly and heavily pigmented.

***146. Scomberoides commersonianus* Lacepede, 1802**

Body oblong, snout blunt with dorsal profile of head nape slightly convex; upper jaw extends well beyond posterior margin of eye; scales on midbody below lateral line, partially embeded and broadly lanceolate.

Colour; side of adult with 5-8 large, plumbeous blotches above or touching lateral line, first two intersect of lateral line; ventral yellowish gold to pale silvery.

***147. Selaroides leptolepis* (Cuvier,1833)**

Body elongate, oblong and compressed; dorsal and ventral profiles equally convex. Adipose eyelid moderately developed on posterior half of eye. Chord of curved part of lateral line longer than straight part with 13 to 25 scales. Breast completely scaled.

Colour: metallic blue above, silvery white below, with a broad yellow stripe from upper margin og eye to caudal peduncle; prominent black opercular spot encroaching onto shoulder.

***148. Selar crumenophthalmus* (Bloch,1793)**

Body elongate and moderately compressed, with lower profile slightly more convex than upper. Eye very large, with a well developed adipose eyelid completely covering eye expept for a vertical slit centred on pupil. Dorsal and anal fins without a detached terminal finlet; pectoral fins shorter than head straight part with 29 to 42 scutes; total scales and scutes in lateral line (excluding caudal scales) 84 to 94.

Colour: upper third of body and top of head metallic blue or bluish-green; tip of snout dusky or blackish; lower two thirds of body and head silvery or whitish; a narrow, yellowish stripe may be present from edge of opercle to upper part of caudal peduncle. First dorsal fin dusky on margins with rest of fin clear.

***149. Selar boops* (Valenciennes)**

Body elongate, similar to Selar crumenophthalmus; eye much larger more than 40% head length (v.s ca. 30%HL); stright part of lateral line with 29 - 42 large scutes.

Upper third of body and top of head blurish bronge, silvery with below, yellowish orange stripe from edge opercle to upper part of caudal peduncle, fins hyaline.

***150. Seriola rivoliana* Valenciennes,1833**

Body elongate, moderately deep and slightly compressed. Upper jaw very broad at end (with very broad supramaxilla), anal fin with 2 detached spines (reduced or completely embedded in large fish). No scutes; caudal peduncle grooves present

Colour: brown or olivaceous to bluish-green above, sides and belly lighter, with brassy or lavender reflections; the nuchal bar often persistent in adults, and a faint amber lateral stripe extending backward from eye frequently present, pectoral fins entirely dark with the margins dusky.

***151. Seriolina nigrofasciata* (Ruppell,1829)**

Body elongate, moderately shallow and slightly compressed, with head profile rising steeply to interorbital. Anal fin with 1 detached spine (usually embedded). No scutes; caudal peduncle grooves present.

Colour: head and body bluish-grey to black dorsally, white to dusky below; young with 5 to 7 dark oblique bands and blotches on upper body that fade with age. Spinous dorsal fin black; second dorsal and anal fins dusky brown, tips of anterior lobes white, except in large adults.

***152. Uraspis helvola* (Forster,1801)**

Body oblong and compressed; dorsal profile strongly convex, ventral profile slightly convex to isthmus then nearly straight to origin of second dorsal fin; snout broadly rounded. Anal fin with 2 detached spines followed by 1 spine and 19 to 22 soft rays, pelvic fins very long in young but becoming relatively shorter with edge; straight part of lateral line with 23 to 40 scutes; in fish smaller than about 20 cm fork length some of the scutes with spines directed anteriorly. Breast naked ventrally to origin of pelvic fins; lateral line naked area of breast separated from naked base of pectoral fin by a broad band of scales.

Colour: tongue, roof and floor of mouth white or cream-coloured, the rest blue-black; head dusky to black,with a large, diffuse black opercular blotch; body dusky to black dorsally, lighter below and with 6 wide, dark bars and narrow pale interspaces. Pelvic fins generally black in specimens smaller than 10 cm fork length, rapidly becoming pale-whitish at larger sizes.

***153. Uraspis uraspis* (Gunther, 1860)**

Body oblong and compressed; dorsal profile strongly convex, ventral profile slightly convex to ischmus. Straight part of lateral line with 24 to 39 scutes. Breast naked ventrally to origin of pelvic fin; laterally naked area of breast extends diagonally to naked base of pectoral fin

Colour: tongue, roof and floor of mouth white or cream-coloured, the rest blue-black; body and head dusky to black dorsally, shading to dusky or pale grey ventrally; juveniles and occasionally adults with 6 dusky or blue-black bars. In small specimens of 8 to 13 cm fork length, pelvic fins whitish with distal half to one-third black, becoming pale white in adult. Caudal fin pale to dusky with trailing edges dusky.

<u>Family Ariommatidae</u>

One dorsal fin, distinctly separated into spinous and soft-rayed portions.Scales cycloid. Caudal peduncle square in cross-section, wit very low lateral keels (reference; Gloefelt-Tarp & Kailola, 1984).

***154. Ariomma indicum* (Day, 1870)**

Body oval, compress. Pectoral fin long, reaching past anal fin origin. Ead iridescent blue-mauve, body fawn, fins dusky olive.

<u>Family Menidae</u>

***155. Mene maculata* (Bloch & Schneider, 1801)**

Body disc-like, very compressed, with almost straight dorsal profile and a deep curved and sharp belly profile; mouth protractile, pointing upward. A single long dorsal fin witout spines; anal fin long, first ventral fin ray prolonged in adults. Body blue-green above, silvery white below; black spots on head and back.

<u>Family Leiognathidae</u>

The ponyfishes are characterized by a compress body; small mouth which highly protractile and tubular when protruded; three bony ridges dorsally on head which converge on nape, and a median bony ridge on nape anterior to dorsal fin origin. Known only from the Indo-Pacific region; 3 genera and about 24 species, 14 species found (references; Premcharoen, 1993; Randall, 1995).

***156. Gazza achlamys* Jordan & Starks, 1917**

Canine-like teeth in mouth. Greatest body depth 1.9-2.2 in SL as opposed to the more slender. *G. minuta*. Irregular bands on upper part of body reaching a little below lateral line. Outer part of dorsal spines black, edge of soft dorsal grey, caudal fin margin dusky, all other fins colorless.

***157. Gazza minuta* (Bloch, 1797)**

Greatest body depth 2.2-3.1 in SL. Irregular markings on upper part of body reaching nearly yo mid-line of body. Edge of spinous dorsal black, soft dorsal and anal fins grey on edges.

***158. Leiognatus bindus* (Valenciennes, 1835)**

Scales on breast but none on cheeks. A very deep-bodied and compressed species. Upper part of body wit dark irregular semi-circular markings. Outer half of spinous dorsal bright orange wit a black line beneath, anal spines tipped orange; soft dorsal greyish, other fins hyaline.

***159. Leiognathus blochi* (Valenciennes, 1835)**

Body depth 2.4-2.7 in SL. Te grey vertical lines on back do not reach the lateral line. A distinct brown blotch on nape. Outer half of spinous dorsal black, soft dorsal , anal and caudal fin lobes yellow wit grey edges . Pectoral and ventral fins yaline.

***160. Leiognathus elongatus* (Gunther, 1874)**

Breast fully scaled but no scales on ceeks. Body very slender. Dorsal part dusky wit irregular dark blotches extending to below lateral line. Snout pointed and sharp.

***161. Leiognathus equulus* (Forskal, 1775)**

Large scales on breast but decidowise. Body deep upper side of body wit many close-set bars. A dark saddle on caudal peduncle; soft dorsal with black margin, caudal edge dusky, all other fins sligtly grey. Is the largest of the leiognathids at size 15-20 cm.

***162. Leiognathus fasciatus* (Lecepede, 1803)**

Superficially resembles a small *L. equulus* but the dark vertical lines on upper of body are more widely spaced; yellow oval spots in horizontal rows following the lateral line. Soft dorsal and anal spines elongated. Posterior margin of caudal lobes dusky to black.

***163. Leiognathus leuciscus* (Gunther, 1860)**

Irregular, sometimes semi-circular markings on back; in large specimens several round to oval yellow marks on body below lateral line. Dorsal and anal fins and caudal lobe with yellow markings. Second dorsal spine prolonged and second anal spine elongated.

***164. Leiognathus splendens* (Cuvier, 1829)**

Faint vertical lines on upper part of body in adults. Scales on lateral line bright yellow. Outer part of dorsal spines often with a dark blotch, dorsal and anal fin margins yellow, margin of caudal fin dusky.

***165. Leiognathus lineolatus* (Valenceinnes, 1835)**

Body elongated oval in shape; scales on brast but none on cheeks; eye moderately large; snout short; upper body with irregular semi-circular markings on silvery base; fins hyaline; dorsal and anal fins with yellow tip.

***166. Leiognathus stercorarius* Evermans & Seale, 1907**

Breast and cheeks with scales. Body slender. Irregular markings on upper part of body, females do not display the blue horizontal line on mid-body.

***167. Secutor ruconius* (Hamilton-Buchanan, 1822)**

Body very deep. Distinct broad metallic blue-green bars on upper side of body extend to mid-side of body. Lateral line terminates below middle of soft dorsal.

***168. Secutor insidiator* (Bloch, 1787)**

Body deep. The bars on upper side are III-formed but on anterior part more like blue spots or bloches.

Family Gerreidae (references; Sirimontraporn, 1987; Premcharoen, 1993).

***169. Gerres abbreviatus* Bleeker, 1850**

Body deep, body oblong and compressed. Mouth can be extended into a downward-pointed tube.Scales large, thin and decidious. Pectoral fin long and pointed. Caudal fin deeply forked. Pectoral fin reaches anal fin origin or father. Dark longitudinal lines along scale rows. Ventral fin yellow; white tips on anal fin and lower lobe of caudal fin; black edge on dorsal fin. 32-36 lateral line scales to caudal fin base only.

***170. Gerres acinaces* Bleeker, 1854**

Body slender. Pectoral fin reaches anal fin origin or farther. Caudal fin deeply forked. Second dorsal fin spine greater than head without snout. Plain silverly-white, dusky above.

***171. Gerres filamentosus* Cuvier, 1829**

Second dorsal fin spine produced into a filament, spine length about equal to body depth. Pectoral fin reaches anal fin origin or father. Seven to 8 vertical bars of brown blotch or cheeks over sides; a row of brown checks along mid-dorsal fin and second dorsal fin spine dark brown.

***172. Pentaprion longimanus* (Cantor, 1850)**

Body silvery, pale pink or grey when scales lost. Body soft and shabby; anal fin base longer than soft dorsal fin base.

Family Lutjanidae

The snappers are distinctive in having moderate large mouth; dosal fin continuous or weakly notched; body usually compress; jaws with strong canine teeth anteriorly. At least 30 species known in the Indo-Pacific (Allen, 1985; Allen & talbot, 1985), 11 species found.

***173. Lutjanus johnii* (Bloch, 1792)**

Body moderately deep. Dorsal profile of head steeply sloped, posterior profile of dorsal and anal fins rounded, caudal fin truncate or slightly emarginate.

Colour: generally yellow with a bronze to silvery sheen, grading to silvery-white on belly and underside of head; centre of each scale often with a reddish-brown spot, giving an overall appearance of series of horizontal lines on side of body; a round black spot, larger than eye, on back, mainly above lateral line.

Geographical Distribution: Widespread in the Indo-West Pacific.

Size: Maximum total length about 70 cm.

***174. Lutjanus lutjanus* Bloch,1790**

Body fusiform, slender. Dorsal profile of head gently sloped; posterior profile of dorsal and anal fins angular, caudal fin truncate or slightly emarginate. Scale rows on back rising obliquely above lateral line.

Colour: upper back golden-brown; sides silvery-wite; a broad yellow to brownish stripe from eye to caudal fin base; a series of yellow horizontal lines on lower half of body, and similar lines running obliquely above lateral line; fins pale yellow to whitish.

Geographical Distribution: Widespread in the Indo-West Pacific.

Size: Maximum total length about 30 cm.

175. Lutjanus lineolatus **(Ruppell, 1829)**

Similar to *L. lutjanus* but all lngitudinal lines of the body dre in the same width, yellowish hyaline, pectoral fin yellow on the upper margin.

176. Lutjanus malabaricus **Schneider, 1801.**

Body relatively deep. Dorsal profile of head steeply sloped; snout profile straight or slightly concave, posterior profile of dorsal and anal fins slightly rounded to angular, caudal fin truncate. Scale rows on back rising obliquely above lateral line.

Colour: back and sides red or red-orange, lighter on lower parts; fins reddish; juveniles.

Geographical Distribution: Widespread in the Indo-West Pacific.

Size: Maximum total length about 100 cm, common to 50 cm.

177. Lutjanus monostigma **(Cuvier, 1828)**

Body moderately deep to somewhat slender. Dorsal profile of head gently to moderately sloped, posterior profile of dorsal and anal fins rounded to somewhat angular, caudal fin truncate. Scale rows on back rising obliquely above lateral line.

Colour: generally yellowish to pinkish with dusky scale margins; grey or brown on upper back and dorsal portion of head; a black spot, sometime faint or absent, on back below anterior soft dorsal rays; fins yellowish.

Geographical Distributed: Widespread in the Indo-West Pacific.

Size: Maximum total length about 60 cm; common to 50 cm.

178. Lutjanus russelli **(Bleeker, 1849)**

Body moderately deep to somewhat slender. Dorsal profile of head steeply to moderately sloped, posterior profile of dorsal and anal fins rounded, caudal fin truncate or slightly emarginate. Scale rows on whitish with a silvery sheen lateral line.

Colour: back and upper side brownish; lower sides and belly pink to whitish with a silvery sheen; a black spot, mainly above lateral line, below anterior rays of soft dorsal fin.

Geographical Distribution: Widespread in the Indo-West Pacific.

Size: Maximum tatal length about 45 cm; common to 30 cm.

179. Lutjanus sebae **(Cuvier, 1828)**

Body very deep. Dorsal profile of head steeply sloped, snout profile straight or slightly convex, posterior profile of dorsal and anal fins distinctly pointed. Scale rows on back rising obliquely above lateral line.

Colour: generally red or pink in adults; juveniles and smaller adults pink with a dark red band from first dorsal spine through eye to tip of snout; a second band from middle of spinous part of dorsal fin to pelvic fin; and a third band from base of last dorsal spine running obliquely downward across caudal peduncle and along lower edge of caudal fin.

Distributed in Indo-West Pacific.

Size: Maximum total length to at least 100 cm; common to 60 cm.

180. Lutjanus vitta **(Quay & Gaimard, 1824)**

Body moderately deep. Dorsal profile of ead moderately sloped; caudal fin slightly emarginate or truncate. Scale rows on back rising obliquely above lateral line. Colour: back and upper sides brown, lower sides and belly witish or pink; narrow longitudinal brown lines, a dark brown to blackish stripe along middle of side from eye to upper alf of caudal peduncle; fin yellow except pelvics whitis. Size: Maximum total length about 40 cm; common to 25 cm.

181. Pristipomoides filamentosus **(Valenciennes, 1830)**

Body elongate, robust, lower jaw slightly protruding; both jaws with an outer row of conical and canine teeth, bases of dorsal and anal fins scaleless, their last soft rays extended into short filaments; pectoral fins long, reaching level of anus, caudal fin forked. Scales relatively small, about 60 to 65 in lateral line; scale rows on back parallel to lateral line.

Colour: back and sides variable, ranging from brownish to lavendar or reddish-purple; snout and interorbital space with narrow yellow lines and blue spots often; dorsal and caudal fins light blue or lavendar with reddish-orange margins.

Geographical Distribution: Widespread in the tropical Indo-Pacific.

Size: Maximum total length about 80 cm; common to 50 cm.

182. Pristipomoides multidens **(Day, 1870)**

Body elongate, robust, bases of dorsal and anal fins scaleless, their last soft rays extended into short filaments; pectoral fins long, caudal fin forked. Scales moderate-sized about 6 broken, golden stripes on sides; side of snout and cheek with a series of chevron-shaped yellow bands with apexes directed anteriorly; dorsal fin with yellowish stripes or rows of spots.

Geographical Distribution: Widwly distributed in the tropical Indo-Pacific Ocean.

Size: Maximum total length about 90 cm.

183. Pristipomoides typus **Bleeker,1852**

Body elongate, robust, bases of dorsal and anal fins scaleless, their last soft rays extended into short filaments; pectoral fins long, caudal fin forked. 48 to 52 in lateral line.

Colour: body and fins rosy red; top of head with longitudinal vermiculated lines and spots of brownish yellow; dorsal fin with wavy yellow lines.

Size: Maximum total length about 70 cm.

Family Caesionidae (reference; Carpenter, 1987)

184. Dipterygonotus balteatus **(Valenciennes, 1830)**

Body slender, fusiform, elongate and moderately compressed. Scales in lateral line 68 to 80; dorsal and anal fins without scales, supratemporal band of scales indistinct,

Colour : Upper body brownish bronze; a thin, stripe about 1 scales wide from orbit to caudal fin, directly above lateral line on caudal peduncle; above and parallel to this stripe 2 thin, irregular, and usually interupted stripes of te same colour; lower body silverly white; dorsal, anal, pelvic and pectoral fins clear to pinkish ; axil of pectoral fin black; caudal fin tan to pinkish

Geographical Distribution: widespread in the Indo-Pacific

Size: Attains a total length of about 14 cm.

185. Pterocaesio chrysozona **(Cuvier,1830)**

Body fusiform, elongate and moderately compressed. Scales in lateral line usually 64 to 69 , predorsal scales usually 23 to 26 , dorsal and anal fins scaled

Colour: upper body light blue to brownish, lower body whith to pinkish; a bright yellow band directly below lateral line for most of its length, from behind eye tobase of caudal fin, fins white to pinkish; axil of pectoral fin black; dorsal fin slightly dusky distally; tips of caudal lobes black.

Geographical Distribution: Widespread in the Indo-West Pacific.

Family Haemulidae

The grunts consist of two subfamilies; Haemulinae: *Pomadasys* spp. and Plectorhynchinae: *Plectorhynchus* spp. (Randall, 1995). The family name is senior synonym of Pomadasyidae. Over 25 species known from the Indo-Pacific, 4 species was found.

***186. Diagramma pictum* (Thunberg, 1792)**

Body plain grey-blue, sometimes with darker spots and blotches on back posteriorly; dark brown or black spots on soft dorsal and caudal fins. Head profile moderately steep, caudal peduncle slender; dorsal fin spines highest anteriorly, 2nd spine longest and twice or more the length of first spine.

***187. Plectorhinchus gibbosus* (Lacepede, 1802)**

Plain reddis brown to dull green or grey, bronze sheen on lower head and body; fins charcoal. Lips thick, swollen and fleshy in larger fish. Dorsal fin deeply notched between spined and rayed portions, spines strong.

***188. Pomadasys kaakan* (Lecepede, 1802)**

Eight to 12 vertical bars of black spots over upper sides, spots arranged into blotches or grouped in pairs, bars faded in large fish; 3 to 4 conspicuous rows of black spots along dorsal fin; ventral , anal and lower lobe of caudal fin deep yellow. Eyes less than snout length; second dorsal spine longest, dorsal fin deeply notched.

***189. Pomadasys maculatus* (Bloch, 1797)**

Silvery green, broad wedge-shaped black band across nape to just below lateral line; usually about 6 larger and smaller similar bars across back above lateral line. Fins yellow, large black blotch on dorsal fin anteriorly.

<u>Family Nemipteridae</u>

The theadfin and monocle breams are remarkable in its uniformity of the number of dorsal and anal finrays, all have X, 9 and III, 7 respectively. The orbital with single flat spine ; thhe second suborbital with a free margin. Russell (1990) reviewed the family, 5 genera and 64 species were recognized, 17 species of 4 genera were found in this survey.

***190. Nemipterus aurorus* Russell, 1993**

Snout length equal to eye diameter, pectoral fins moderately long; caudal fin forked, tip of fin slightly rounded; scale rows on body below lateral line upward-curved anteriorly. Maximum size is 20 cm SL., commonly 15 cm SL.

Colour: Body pinkish above, shading through pale mauve to silvery on ventral half; sides with 4 or 5 longitudinal, upward-curved silvery-white stripes along the middle of each scales row below lateral line, from behind head to caudal peduncle; head pinkish with golden-yellow reflections on opercle; upper lip with yellow edge; dorsal fin pale translucent yellow, with lemon-yellow margin and pale mauve submarginal stripe; broad bicoloured submedial stripe, yellow above orange below, anal fin transparent, with pale lemon submedial stripe above base of fin; caudal fin yellowish pink, upper tip rosy.

Distributed in West Pacific.

***191. Nemipterus balinensoides* (Popta,1918)**

Snout length equal to or less tan diameter of eye, pelvic fins moderately long; reaching to or just beyond anus, caudal fin forked; upper lobe slightly longer than lower lobe; 3 or 4 pair of small, recueved canines anteriorly in upper jaw.

Colour : pale silvery-rose on upper part of body, silvery below; 2 or 3 pale yellowish stripes along sides, a distinct golden-yellow spot, edged red above and below, just above upper pectoral-fin base at beginning of second stripe, dorsal fin pinkish, edged with greenish-yellow, pectoral fins rosy, pelvic fins pale yellow, caudal fin pale yellowish-pink; upper tip dark pink in some specimens.

Distributed in West Pacific, including Andaman Sea

***192. Nemipterus bathybius* Snyder,1911**

Snout length equal to or a little less than diameter of eye, preopercle naked width 1.6 to 2.2 in scaly width, pectoral fins long, caudal fin forked; upper lobe falcate;usually long and ribbon-like in adult. Maximum size is 20 cm SL., commonly 16 cm SL.

Colour: upper part of body pinkish, silvery below; 2 yellow lateral stripes, a pair of yellow stripes, united anteriorly, from the dorsal fin pink, edged with yellow, with a mediam stripe of yellowish undulating lines, anal fins transparent, pinkish near outer margin, caudal fin pink, upper lobe and filament yellow; bases of pelvic fins bright sulphur-yellow.

Distributed throughout Indo-West Pacific.

***193. Nemipterus furcosus* (Valenciennes,1830)**

Pectoral fins moderately long; reaching to or just short of level of anus, pelviv fins moderately long; reaching to or just short of level of anus, caudal fin deeply forked. Maximum size is 22.5 cm SL., commonly 18 cm SL.

Colour: head and body pale iridescent pink, paling on sides to silvery-white below; back with 9 indistinct cross bars, third bar somewhat darker and more distinct yellowish stripes along body, cheeks and opercle silvery. Upper jaw rosy, lower jaw silvery; eye rosy; dorsal fin pale rosy, with yellowish tinge, anal fin bluish white, with row of transparent or faint yellowish spots near base; caudal fin pale rosy, with yellow tinge, lower margin of fin white; pelvic fins and axillary scales white, pectoral fins rosy.

Distributed in West Pacific from southern Japan to northeastern Australia, and Indian Ocean, Sri Lanka.

***194. Nemipterus hexodon* (Quoy & Gaimard,1824)**

Suborbital depth, pectoral fins long, caudal fin forked; upper lobe slightly longer than lower; 3 or 4 pair of small recurved canines anteriorly in upper jaw. Maximum size 21 cm SL., commonly 15 cm SL.

Colour: upper part of body pinkish, paling to silvery white on ventral surface; 6 to 8 pale yellow stripes on sides from below lateral line; blood red, ovoid spot below origin of lateral line, bordered below by bright yellow; yellow stripe on either side of ventral midline, golden reflections behind eye, on cheeks and opercle, dorsal fin translucent whitish, with a yellow margin; a narrow yellow stripe beginning anteriorly near base of fin and extending backwards to just above midposterior margin, caudal fin pinkish, upper lobe tipped with yellow, anal fin translucent, pectoral and pelvic fins pale translucent pink; base of pelvic fins and axillary scale lemon-yellow.

Distributed throughout Indo-West Pacific

***195. Nemipterus japonicus* (Bloch,1791)**

Snout length greater than eye diameter, pectoral fins very long, caudal fin moderately forked; upper lobe slightly longer than lower and produced into a short or moderately long filament. Maximum size is 25 cm SL., commonly 15 cm SL.

Colour: upper part of body pinkish, becoming silvery below; top of head behind eye with a golden sheen; 11 to 12 pale golden-yellow stripes along body from behind head to base of caudal fin; a prominent red-suffused yellow blotch below origin of lateral line; dorsal fin whitish, margin of fin yellow, edged with red; a pale lemon stripe near base of dorsal fin, this stripe narrow anteriorly and widening on posterior part of fin; anal fin whitish with pale lemon broken lines or scribblings over most of fin; pectoral fin translucent pinkish; pelvic fins whitish with yellow axillary scale; caudal fin pink, upper tip and filament yellow.

Distributed in Widespread throughout the Indian Ocean and West Pacific.

196. Nemipterus mesoprion **(Bleeker,1853)**

Snout length greater than diameter of eye, pectoral and pelvic, fins long, reaching to between level of anus and origin of anal fin, caudal fin forked. Maximum size is 14 cm SL., commonly 13 cm SL.

Colour: upper part of head and body pinkish, silvery white below; head with oblique golden yellow stripe from beneath eye to middle of upper jaw, and less distinct oblique yellow stripe from anterior of eye to near tip of snout; interspace between these stripes pinkish mauve; upper lip pale mauve; opercle with golden reflections; back with indistinct golden stripe beneath dorsal fin; red shoulder spot beneath third to fifth lateral-line scales; golden stripe, broader and tapering posteriorly, from base of pectoral fins to midcaudal base; spinous dorsal fin with red margin, soft-rayed part of fin with yellow margin, caudal fin pinkish, upper and lower margins tinged yellowish; median area yellow.

Distributed known from southern Indonesia and the Gulf of Thailand.

197. Nemipterus nematophorus **(Bleeker,1853)**

Snout length about equal to eye diameter, dorsal fin with anterior pair of spinous rays close together, almost fused and produced into a long, trailing filament;, caudal fin forked, upper lobe produced into a trailing filament. Maximum size is 20 cm SL., comonly 15 cm SL.

Colour: upper part of head and body pinkish, silvery-white below; broad golden-yellow stripe beneath lateral line, with distinct gold patch anteriorly beneath origin of lateral line; 3 narrow golden-yellow stripes laterally along ventral half of the body; yellow stripe on either side of ventral midline; dorsal fin translucent pinkish, anterior dorsal filament and margin of fin yellow, faint yellow or orange stripe along fin extending from near base of first spine to middle , caudal fin pink, upper tip and caudal filament yellow

Distributed in Indo-West Pacific.

198. Nemipterus nemurus **(Bleeker,1857)**

Snout length a little more than eye diameter, caudal fin forked, the upper rays produced into a trailing filament.

Colour: body pinkish above, with distinct, broad, pale yellow stripe from behind eye to caudal base, ventral half of body pearly-white, head pinkish, with pale golden reflections on cheeks and opercle; golden yellow stripe from posterior nostril extending through eye, and similar stripe from anterior margin of upper lip to lower margin of eye; iris pink; dorsal fin pale yellow, interspinous membrane of first two dorsal spines bright red superiorly; anal fin white, with series of yellow spots or irregular yellow stripe submedially; caudal fin pinkish, posterior margin red; lower lobe of fin suffused with yellow, upper rays and filament yellow

Distributed in West Pacific, including the Philippine.

199. Nemipterus peronii **(Valenciennes,1830)**

Dorsal-fin spines elongate, interspinous membrane deeply incised; pectoral fins short, caudal fin forked, upper lobe pointed and slightly longer than lower. Maximum size is 26.5 cm SL., commonly 17 cm SL.

Colour: upper part of body pinkish, with 7 or 8 indistinct darker pink saddles reaching to or just below the lateral line; lower part of body silvery, with faint golden lines following each scale row; a diffuse pale reddish spot below and just behind origin of lateral line; a golden-yellow stripe on snout in front of eye passing through nostrils; upper lip yellow; dorsal fin pale whitish-pink, with a pale yellow line or series of spots just above base of fin; tips of spinous part of fin reddish-yellow; caudal fin pinkish.

Distributed in Indo-West Pacific.

***200. Nemipterus tambuloides* (Bleeker,1853)**

Snout length greater than eye diameter; pectoral and pelvic fins long; caudal fin forked, upper lobe pointed.

Colour: upper part of head and body rosy, paling to silvery-wite on ventral surface; 5 well-defined sulphur-yellow stripes along body; sulphur-yellow stripe along either side of ventral midline from isthmus to lower caudal-fin base; head with two yellow stripes beneath eye; cheeks and opercle with golden and mauve reflections; dorsal fin translucent pink, with yellow margin and bluish grey inframarginal stripe; narrow sulphur-yellow stripe extending just above base of dorsal fin; anal fin translucent bluish-white with pale yellow stripe near base of fin, this stripe bent posteriorly and extending out to tip of last anal ray; caudal fin bright rosy, upper tip sulphur-yellow.

Distributed in Andaman Sea, South China Sea.

***201. Nemipterus thosaporni* Russell, 1991**

Snout length about equal eye diameter, pectoral fins long, caudal fin forked; upper lobe produced into a short filament.

Colour: upper part of body rosy, silvery-white below, head with a narrow yellow stripe from below nostrils to eye and from middle of upper jaw to eye; a broad yellowish-orange stripe, divided above pectoral fin, along body from below origin of lateral line to upper part of caudal peduncle, Dorsal margin yellowish, anal fin pale bluish; caudal fin reddish, its upper tip yellowish; pelvic fins pink; pectoral fins translucent

Distributed in West Pacific, including Southern coasts of Sumatra to the Solomon Islands.

***202. Parascolopsis tanyactis* Russell, 1986**

Head scales reaching forward slightly; lower limb of preopercle naked; suborbital naked, 1 or 2 tiny spines at upper corner. Maximum size is 20.5 cm SL., commonly 15 cm SL.

Colour: pinkish, darker on back and becoming silvery on ventral surface; four dark brownish-pink saddle or bars on back; pale lemon-yellow stripe on either side of ventral midline from base of pelvic fins to base of caudal fin; dorsal fin pink with dursy reticulated markings, anteriormost three saddles on back.

Distributed in Western Pacific, including the Sarawak coast.

***203. Pentapodus setosus* (Valenciennes,1830)**

Head scales reaching forward to between level of anterior margin of eyes and posterior nostrils; suborbital naked; ; caudal fin forked, upper lobe produced into a very long trailing filament. Maximum size is 17.5 cm SL., commonly 15 cm SL.

Colour: pale brownish on back; lower part of body whitish; a blue stripe along base of dorsal fin; a yellow stripe from behind eye, gradually arching on back and terminating in a black spot on upper caudal peduncle; a narrow blue line running through yellow stripe; two bluish stripes across snout, top of snout dusky; caudal fin pinkish, filament pinkish-brown

Distributed in Philippines, South China Sea.

***204. Scolopsis monogramma* (Kuhl & Van Hasselt,1830)**

Antrorse suborbital spine absent, caudal fin forked or lunate, upper lobe a little longer than lower (lobes produced to form short filamentous extensions. Maximum size is 26 cm SL., commonly 18 cm SL.

Colour: greyish on back, white below; brown longitudinal steaks on back above lateral line, and oblique yellow streaks below lateral line; a brown midlateral stripe, expanded in the middle; 3 blue stripes on snout; interspaces between stripes yellow; a blue stripe on preopercle behind eye; a blue chevron-shaped stripe running upwards onto opercle from below eye and bending downwards towards pectoral-fin base; space between stripes on preopercle and opercle yellow, unpaired fins pale yellow. Edged with blue.

Distributed in West Pacific to northeastern Australia.

205. Scolopsis taeniopterus **(Kuhl & Van Hasselt,1830)**

Pelvic fins long, reaching to or beyond level of anus; caudal fin emarginate. Maximun size is 20 cm SL., commonly 15 cm SL.

Colour: greyish-yellow on upper part of body, whitish below; sides of body with faint oblique blue and yellow lines, a narrow blue stripe joining eyes just behind nostrils; upper part of pectoral-fin base with a reddish-orange spot; fins yellowish; dorsal fin with a blue stripe along its middle area; upper tip of caudal fin bright yellow; upper base of caudal fin with a blue spot.

Distributed in Indo-West Pacific.

206. Scolopsis vosmeri **(Bloch,1792)**

Body depth, lower limb of preopercle scaly; antrorse suborbital spine present beneath eye; caudal fin forked. Maximum size is 16 cm SL., commonly 15 cm SL.

Colour: variable, usually brownish with a reddish-purple tinge; a broad white vertical bar from top of head onto opercle; scales on sides with dark spots; opercular membrane blood-red; fins greyish, tinged red.

Distributed in Indo-West Pacific.

Family Lethrinidae

The emperors differ from the nemipterids in having of no free margin on suborbital bone, variuos types of dentition on jaws. Allen (1989) revised and regcognized 39 species of Indo-Pacific, 4 species found.

207. Gymnocranius elongatus **Senta,1973**

Body oblong. Head profile evenly rounded, snout somewhat pointed, eye large, its diameter usually about equal to length of snout; interorbital space convex, about equal to eye diameter, caudal fin deeply forked with pointed tips, the median rays shorter than eye diameter. Lateral-line scales 46 to 48 plus 2 to 4 tubed scales extending on to base of caudal fin.

Colour: overall silvery, sometimes slightly brownish dorsally; about 8 transverse brown bars on sides, the first crossing through eye, the remainder below dorsal fin and across caudal peduncle; scattered blotches and speckling sometimes evident on sides; fin clear to yellow-orange; caudal margin and tips often deep red.

Geographical Distribution: Coastal and shelf waters of the western Pacific and eastern Indian oceans

Size: Maximum total length about 35 cm.

208. Gymnocranius griseus **(Schlegel, 1844)**

Body oblong, deep. Dorsal and ventral profile of head evenly convex or ventral profile slightly straighter, eye relatively large, its diameter about equal to or slightly larger than preorbital and interorbital widths; mouth relatively small, caudal fin moderately forked with ponted tips, the median rays slightly longer than eye diameter. Lateral-line scales 46 to 48 plus 2 or 3 additional tubed scales extending on to base of caudal fin.

Colour: overall sivery, frequently with a diffuse to vivid pattern of 5 to 8 narrow dark bars on side, including one through eye and across cheek; fins mainly clear to yellowish, sometimes diffuse mottling or spotting on dorsal, caudal , and anal fins; few scattered blue spots or scribbling on the snout and cheek.

Geographical Distribution: Southern Japan to the Indo-Malaysian region.

Size: Maximum total length has been reported at 80 cm.

***209. Lethrinus lentjan* (Lacepede, 1802)**

Body moderately deep, dorsal profile near eye nearly straight; snout moderately short, interorbital space convex, lateral teeth in jaws either rounded, rounded with tubercle, simple molars, anal fin with 3 spines and 8 soft rays, the first soft ray usually the longest. Lateral-line scales usually 46 to 47.

Colour: body greenish or grey, shading to white below, centers of scales on upper sides often white; posterior margin of opercle and sometimes base of pectoral fin red; pectoral fin white, yellow or pinkish; pelvic and anal fins white to orange; dorsal fin white and orange mottled with a reddish margin; caudal fin mottled orange or reddish.

Geographical Distribution: Widespread in the Indo-West Pacific, including the Red Sea.

Size: Maximum size to about 50 cm total length.

***210. Lethrinus microdon* Valenciennes,1830**

Body relatively elongate, dorsal profile near eye nearly straight; snout moderately long, cheek not high, anal fin with 3 spines and 8 soft rays, the first soft ray usually the longest. Lateral-line scales 47 or 48; cheek without scales.

Colour: body bluish grey or brown often with scattered irregular dark blotches on sides, fins pale or orangish.

Geographical Distribution: Wide-spread in the Indo-West Pacific.

Size: Maximum size to around 70 cm.

Family Sciaenidae (references; Trevawas, 1977; Lal Mohan, 1984 and Sirimontraphorn, 1987).

***211. Otolithes ruber* (Schneider, 1801)**

Body slender species. Snout longer than eye diameter, its upper profile rising evenly to dorsal fin origin or slightly concave before eye; mout large, terminal, slightly upturned; rostral pores absent. teeth in 2 series in upper jaw with 1 or 2 pairs of strong caninesat front; a pair of canine teeth at tip of lower jaw. Dorsal fin with 9 or 10 spines, followed by a notc, second part of the fin with 1 spine and 27 to 30 solf rays; anal fin wit 2 spines and 7 solf rays, the second spine short and weak, its base behind middle of solf part of dorsal fin; caudal fin rhomboid. Scales cycloid, but a few ctenoid lower part of hind end of body; lateral line scales reaching to tip of caudal fin. Colour: browish above, silvery wit a golden sheen on flanks and belly,often with oblique dark streaks dorsally.Size: maximum 70 cm, common to 40 cm. Widely distributed throught Indo-Pacific. An economic importist species.

***212. Pennahia macrophthalmus* (Bleeker,1850)**

A small, rather deep-bodies species, with a large, terminal, oblique mouth , rostral pores absent or minute, mental pores in 2 pair, pectoral fins rather long , anal fin with 2 spines and 7 or 8 soft rays, caudal fin truncate. Scales cycloid on snout elsewhere ctenoid. Swimbladder carrot-shaped with 18 to 22 arborescent appendages

Colour: body silvery white, back blue/grey; nape with a diffused dusky blotch; upper 2/3 of spinous dorsal fin dusky.

Maximum: 30 cm; common to 18 cm.

Distribution: along the West coast of the Indian subcontinent to China.

Family Mullidae

The goatfishes have the most distinctive feature in the pair of long mental barbels. Over 20 species known in the Indo-West Pacific, 7 species found (references Gloefelt-Tarp & Kailola; Allen & Swainston, 1993 and De Bruin et al., 1994).

***213. Parupeneus cinnabaricus* (Cuvier)**

Head large, nape are dorsal profile connex. Bright red spot 1-2 scales wide below lateral line and above pectoral fin. Blue horizontal stripes on head; back with pearly blue spots or broad mauve band. Barbels pale pink. Barbels extend beyond preoperculum.

***214. Upeneus bensasi* Temminck & Schlegel, 1824**

Barbels pale yellow or white. Two or 3 orange bars across dorsal fins; pectoral, ventral and anal fin pale. Upper caudal fin lobe crossed by 3-5 oblique bars; lower lobe plain dusky orange with pale margin. First dorsal fin spine longest.

***215. Upeneus luzonius* Jordan & Seale, 1907**

Up to 5 broad, dusky saddles on back, those below dorsal fins and on caudal peduncle more distinct. Red spots on scales and head fade soon after death. Barbels yellow. Both dorsals, anal and ventral fins crossed by 3-5 orange to brown-crimson bands. Each caudal fin lobe crossed by 5-7 dusky crimson bars. Barbels reach preopercular margin; second dorsal fin spine longest.

***216. Upeneus moluccensis* Bleeker, 1855**

Bright yellow horizontal band through eye to caudal fin base. Barbels white or pink. Dorsal fins crossed by 3-4 orange or red bars; anal, ventral and pectoral fins pale. Upper lobe of caudal fin with 5-6 orange-black bars, lower lobe plain yellow with dark margin. First dorsal fin spine minute, 2nd longest.

***217. Upeneus sulphureus* Cuvier, 1829**

Two orange-yellow horizontal bands from head to caudal peduncle. Both dorsal fins crossed by 2-3 olive bars; tips of fins black or dark brown. Anal, ventral and pectoral fins pale. Caudal fin plain dull yellow-ind margin dusky, lower lobe tipped white. Barbels white. First dorsal fin spine minute.

***218. Upeneus sundaicus* Bleeker, 1855**

Olive-yellow horizontal band from eye to caudal peduncle. Dorsal fins blotched crimson; ventral , anal and pectoral fins plain white and pink. Caudal fin crimson withh green rays and broad dark brown margin to lower lobe. Barbels brigt yellow or orange. First dorsal fin spine minute.

***219. Upeneus tragula* Richardson, 1845**

Many orange-brown spots over ead and body; red or yellow band from eye to caudal fin base. Barbels wite or pale yellow. Both dorsald, anal and ventral fins crossed by red bars or rows of blotches. Brown or red crossbars on caudal fin: 4-6 on upper lobe, 5-8 on lower lobe. Third or 4th dorsal fin spine longest. Barbels do not reach preopercular margin.

Family Cepolidae

***220. Acanthocepola abbreviata* (Valenciennes, 1835)**

Body silvery red, head and belly paler; orange crossbands sometimes present on sides; fins brilliant dark red. Dark stripe in premaxillary groove and narrow black edge on caudal and anal fins. Strong spine on angle of preoperculum, 3 or 4 along lower limb. Scales increase slightly in size posteriorly.

Family Teraponidae (reference; Vari, 1976).

***221. Terapon jarbua* (Forsskal, 1775)**

Oblong, compressed bodies. Upper jaw reaching beyond middle of eye; preopercular margin sharply serrated; 1 or 2 strong spines on operculum, the lower spine longest. Scales strongly ctenoid. Single dorsal fin, with 11-14 strong spines, slightly notched from soft part of fin. Three or 4 curved dark brown bands along body. Large black blotc on spinous dorsal fin. Caudal fin barred, each lobe black tipped.

Widely distributed in Indo-Pacific coasts.

***222. Terapon theraps* (Cuvier, 1829)**

Four straight brown bands along body. Large black blotch on spinous dorsal fin and caudal fin barred. Scales moderate in size.

Family Ephippidae

***223. Drepane punctata* (Linnaeus, 1758)**

Body silvery green, dusky above; 4 to 10 vertical rows of dark brown spots on upper sides; fin margins dusky. Mouth protractile into a downward-pointed tube; maxilla exposed posteriorly; predorsal body profile evenly connex at nape. Pectoral fin very long and falcate, reaching well over anal fin. Attains to 35 mm, usually 25 mm. Distributes througout Indo-West Pacific, this economic species commonly seen in Songkhla markets.

***224. Platax batavianus* Cuvier, 1831**

Two or 3 black cross bands on silvery, dusky green body; firt as broad as eye passes through eye to throat, 2nd through pectoral fin base to ventral fin; fins yellowish, dusky basally, ventral fin charcoal. Maxilla hidden posteriorly; predorsal body profile angular, concave above and below eye. Scales on predorsal reach to eyes. Dorsal fin spines grade into elevated anterior fin rays, posterior spines longest.

Family Labridae

***225. Xiphocheilus typus* Bleeker, 1856**

Body compressed. One pair of canine teeth on upper and lower jaw. Body dusky green wit a pale blue margin of each scale forming many oblique wavy lines across body; yellow markings on head, 2 brown-edged blue lines on snout, blue line from mouth to beyond lateral line origin. Fins green or yellow, anal and caudal fins crossed by many slightly wavy, oblique, pale blue lines. Thin, compressed upper lip covered by suborbital when mouth closed. Lateral line continuous.

226. Xirichthys sp.

Head and body very compress, rectangular in lateral shape; mouth small, mets a pair of canine teeth on ech jaws; dorsal and anal fins with long base; body greyish pale-brown, abdominal pale with large pinkis patc around anal; fins hyaline, anal fin with red margin, caudal fin dusky. A single specimens, 12 cm. taken from off Malay peninsula

Family Chaetodontidae

***227. Coradion chrysozonus* (Kuhl & Van Hasselt,1831)**

Body white with 5 yellow bands across, anterior ones dark brown ventrally: first band from nape through eye to isthmus; second and third bands close together, from spinous dorsal fin to belly; fourth band between soft dorsal and anal fins; fifth band dark brown, on caudal peduncle. Black ocellus on rounded mid-soft dorsal fin. Snout short.

Family Pomacentridae

***228. Pristotis jerdoni* (Day, 1873)**

Body ovate and compressed. Mouth small. One nostril on each side of snout. Scales ctenoid. Dusky olive or fawn on back, pearly white below. Black spot on upper pectoral fin base and black edge on dorsal fin. Margin of preoperculum and suboperculum serrated; one row of teeth in jaws.

229. Pristotis sp.

Similar to above species but yellow fins, possibly juvenile or non-nuptial from of *P. jerdoni?*

Family Siganidae

The rabbit fishes or spinefoot is very compressed, oval body. Mouth small, teeth small and close together. Body covered with small, cycloid scales. Single dorsal fin with 13 spines, an antrorse spine at fin origin. Woodland (1990) reviewed the family, recognized 27 species; this survey obtained 3 species.

230. Siganus canaliculatus **(Park, 1787)**

Grey green above to silvery below, covered with numerous pale spots on sides arranged into horizontal rows; fin marbled with brown. Rounded soft dorsal and anal fins low, caudal fin emarginate, forked in larger fish.

231. Siganus guttatus **(Bloch, 1787)**

Blue grey above to silvery below; pupil-sized golden orange spots over side, closer together and "honey-combed" on nape; large yellow patc on body below base of soft dorsal fin; soft portion of unpaired fins with rows of dark spots. Head profile slightly concave on nape. Rayed portion of dorsal and anal fins little higher than spinous portions; caudal fin truncate emarginate in larger fish.

232. Siganus javus **(Linnaeus, 1758)**

Body oval, strongly compressed. Depth 1.8-2.3. Mouth small, jaws with close-set teeth. Scales small, minute. A small forward-directed spine in front of spinous dorsal. Pelvic fins with two spines. Spots on lower part of sides elongated and wavy.

Family Scombridae

The scombroids mackerels are characterized in having a streamline fusiform to elongate body; caudal peduncle keeled; caudal fin stiff, deeply fork or lunate; posterior dorsal and anal fins with 5-12 finlets. Collette & Nuaen (1983) reviewed the family, over 25 species known from the South China Sea; 5 species found.

233. Rastrelliger brachysoma **(Bleeker,1851)**

Body very deep, head equal to or less than body depth. Gillrakers very long, visible when mouth is opened. Intertine very long, 3.2 to 3.6 times fork length.

Colour: spinous dorsal fin yellowish with a black edge, pectoral and pelvic fins dusky, other fins yellowish.

Distribution: Central Indo-West Pacific.

Size: Maximum fork length is 34.5 cm, common from 15 to 20 cm.

Remark*: R. necglectus* is possibly not a synonym of this species but separated, the further study on the two species is needed.

234. Rastrelliger faughni **Matsui, 1967**

Body slim, head longer than body depth. Gillakers shorter than snout; when mouth is opened wide. Intestine short, less or about equal to fork length.

Colour: belly yellowish silvery; 2 to 6 large spots at base of first dorsal fin, visible from above; two faint stripes at level of lateral line in some specimens; a black blotch behind pectoral fin base.

Distributed central part of the Indo-West Pacific.

Size: Maximum size is at least 20 cm fork length.

235. Rastrelliger kanagurta **(Cuvier, 1817)**

Body moderately deep. Maxilla partly concealed, covered by the lacrimal bone, gillrakers very long, visible when mout is opened. Intestine 1.4 to 1.8 times fork length.

Colour: narrow dark longitudinal bands on upper part of body (golden in fresh specimens) and a black spot on body near lower margin of pectoral fin; dorsal fins yellowish with black tips, caudal and pectoral fins yellowish; other fins dusky.

Distribution: Widespresd in the Indo-West Pacific.

Size: Maximum fork length is 35 cm, common to 25 cm.

***236. Scomberomorus commerson* (Lacepede, 1800)**

Body elongate, compressed, second dorsal and anal fins followed by 10-11 finlets. Gillrakers on first arch few. Lateral line abruptly bent downward below end of second dorsal fin.

Colour: sides silvery grey marked with transverse vertical bars of a darker grey; bars narrow and slightly wavy, bars number 40 to 50 in adults , first dorsal fin bright blue rapidly fading to blackish blue; pectoral fin light grey turning to blackish blue; caudal fin lobes, second dorsal, anal , and dorsal and anal finlets pale greyish white turning to dark grey.

Distribution: Widespread throughout the Indo-West Pacific.

Size: Maximum fork length is about 220 cm, common to 90 cm. Highly comercial species throghout its range.

***237. Scomberomorus guttatus* (Bloch & Schneider, 1801)**

Body moderately deep, strongly compress. Gillrakers on first arch moderate: 1 or 2 on upper limb. Lateral line with many fine auxillary branches extending extending dorsally and ventrally in anterior third, gradually curving down toward caudal peduncle.

Colour: sides silvery white with several longitudinal rows of round dark brownish spots scattered in about 3 irregular rows along lateral line. First dorsal fin membrane black, pectoral, second dorsal and caudal fins dark brown; pelvic and anal fins silvery white.

Distributed along te shores of continental Indo-West Pacific.

Size: Maximum fork length is 76 cm.

<u>Family Trichiuridae</u>

The hairtail or cutlassfish is the close related family to the scombrids; characterized by the very long, extremly compressed, silvery body; mouth large with long, copress canine teeth on jaws; caudal fin small or filamentous. Nakamura & Parin (1993) revised the family and their relatives; at least 5 species known in this region, 3 species found.

***238. Eupleurogrammus glossodon* (Bleeker,1860)**

A pair of fangs on tip of lower jaw. Eye small, its diameter about 7 or 8 times in head length, located close to dorsal profile of head. A black spot just behind dermal process on bottom of lower jaw. A faiely noticeable black blotc on base of anterior margin of pectoral fins. Body extremely elongate and compressed, ribbon-like

Colour: body steely blue with metallic reflections, dorsal-fin membrane slightly tinged with black along spines, dorsal side of posterior part slightly tinged with black.

Distributed in Indo-West Pacific.

Size: Maximum 50 cm total length, common 15 to 40 cm.

***239. Tentoriceps cristatus* (Klunzinger, 1884)**

Body strongly compressed, tapering to a point. Dorsal profile of head evenly convex; mouth large with a dermal process at tip of each jaw, pectoral fins sort, posterior part of body tapering to a point.

Colour: body silvery white each jaw, dorsal and anal-fin bases sooty.

Distributed in Indo-West Pacific.

Size: Maximum 90 cm total length.

***240. Trichiurus lepturus* Linnaeus, 1758**

Body extremely elongate and strongly compressed, ribbon-like, tapering to a point, position of anus nearer snout than posterior tip of body, eye large, 2 or 3 pairs of enlarged fangs with barbs nearer tip of upper jaw. Dorsal fin rather high and long, pelvic and caudal fins absent.

Colour: steel blue with silery reflection, pectoral fins semi-transparent, other fins sometimes tinged with pale yellow.

Distribution: Throughout tropical and temperate waters.

Size: Maximum 120 cm total length, common from 50 to 100 cm. This species isthe most important commercially caught triciurid.

<u>Family Stromateidae</u>

***241. Pampus argenteus* (Euphrason, 1788)**

One continuous dorsal fin 10 small blade-like spines before dorsal fin rays very decideous scales. Body compressed and muscular. Maxilla ends under eye. Ventral fin never present. Dorsal and anal fins high anteriorly, falcate, their tips produced. Caudal fin deeply forked, tips sarp, lower lobe slightly longer. Body and fins iridescent blue-grey, back and fin margins dusky. Size attaining to 35 cm SL. Distributed from eastern Indian Ocean to West Pacific, Higly economic species.

***242. Pampus chinensis* (Euphranson, 1788)**

Dorsal and anal fins elevated anteriorly but not produced into falcate lobes. Caudal fin forked, tips blunt. Body and fins bluish green, back and fin margins dusky. No spines before unpaired fins. Distributed same as *P. argenteus.*

<u>Family Polynemidae</u>

***243. Eleutheronema tetradactylum* (Shaw,1804)**

Body more or less elongate and compressed. Snout projecting, mouth very large, with small teeth; lips absent, except for lower lip near corner of mouth; eye large. Pectoral fins in 2 parts, upper part with all rays unbranched, lower with 4 free filamentous rays of which the upper filament is the longest. Caudal fin forked with lobes equal. Scales small, ctenoid. Maximum size in 200 cm; common to 50 cm.

Colour: body silvery green above, cream below; dorsal and caudal fins grey, dusky at edges, pelvic and anal fins orange, pectoral filamentous rays white.

Highly economic species of coastal areas from eastern India Ocean to Western Pacific.

<u>Family Sphyraenidae</u> (reference; Gloefelt-Tarp & Kailola, 1984; Masuda et al., 1984 and Randall, 1995)

***244. Sphyraena forsteri* Cuvier, 1829**

Body elongate, slightly compressed or subcylindrical. Mouth large, lower jaw longer. Teeth strong and fang-like, of unequal size. Two well separated dorsal fins. Caudal fin forked. Body plain, back olive brown, sometimes marbled with brown; lower sides silvery white. Fins yellow, outer half of second dorsal, anal and caudal fins brown. Preopercular edge rounded. Eye very large.

***245. Sphyraena obtusata* Cuvier, 1829**

Olive-brown above, silvery white below. Two dusky yellow stripes along mid-sides from head to tail base. Fins yellow or pale, second dorsal, anal and caudal fins edged brown. Preopercular edge rectangular. Pectoral fin reaches past first dorsal fin origin.

***246. Spyraena jello* Cuvier,1829**

Lateral line scales 130-140; eye not large; conner of preopercle rounded, without a membranous flap; opercle with two flexible flat spines; no pointed cartilaginous knob at front of lower jaw; maxilla reaching to below front edge of eye; teeth erect; origin of first dorsal fin sligthly posterior to origin of pelvic fins and anterior to tip of pectoral fins; caudal fin deeply fork, without inner lobe; dusky blue-green on back, silvery on sides, with about 20 dark bars on body about equal in width to pale interspaces, those posterior to second dorsal and anal fins faint; caudal fin yellow. Reaches about 140 cm. Red Sea and coast of East Africa to the western Pacific.

<u>Family Blenniidae</u>

***247. Xiphasia setifer* Swainson, 1839**

Body elongate, eel-like. Teeth fixed, slender; very long canine posteriorly in lower jaw; gill membranes broadly united with throat, gill opening a small pore on side. Dorsal fin begins before eye; caudal united with dorsal and anal fins. Dusky green or grey, black and dorsal base crossed by about broad dark brown bands;black spots anteriorly on dorsal fin, first one smaller.

Family Gobiidae

***248. Oxyurichtys* aff. *papuensis* (Valenciennes, 1837)**

Scales ctenoid to below origin of second dorsal fin, cycloid anteriorly; scales present on chest and side of nape, but not on prepectoral region, cheek, or opercle; a fleshy ridge medially on nape; no tentacle on eye; body elongate, upper part of higher than dorsal profile of head; caudal fin long and pointed, nearly twice length of head; pelvic fins united, with a frenum; greenish dorsally, shading to witish ventrally, with irregular golden lines above midbody; fins hyaline, anal fin dusky.

***249. Yongeichthys nebulosus* (Forsskal, 1775)**

Longitudinal scale series 26-30; scales on body ctenoid except abdomen and prepelvic area where cycloid; no scales on head or nape except for a few ventrally on nape extending a short distance anterior to gill opening; gill opening ending at level of lower edge of pectoral fin base;several longitudinal rows of papillae on cheek; second dorsal spine filamentous, caudal fin rounded, a little shorter than head length; pelvic fin united; pelvic fin frenum present; whitish, the head and upper two-thirds of body mottled with brown; four large dark brown blotches in a row on side of body, dorsal and caudal fin with numerous dark brown spots; anal fin with a dark brown margin. Red Sea south to the western pacific. Said to have toxic skin.

Family Pinguipedidae

***250. Parapercis filamentosa (*Steindachner)**

Body elongate, cylindrical. Depth 5-5.6. Mouth slightly oblique, lower jaw projecting slightly. Caudal slightly rounded. The first 5-6 dorsal rays long filamentous. Body goldish-brown with 6 indistinct dark brown bloth; fins hyaline, pelvic fin dusky. Two specimens of 10-13 cm. talen from off Malay peninsula.

***251. Parapercis pulchella* (Schlegel, 1843)**

Body elongated, cylindrical; caudal fin emarginate only upper lobe; body rosy with 5-6 indistinct brown banded; pale ventrally, dorsal and caudal fins hyaline with yellowish stripes; anal fin and lower margin of caudal fin rosy red. Attaining to 25 cm, usually 15 cm. Commonly obtained almost every trawling stations. Distributed in Indo-West Pacific.

Family Uranoscopidae

***252. Uranoscopus oligolepis* Bleeker, 1878**

Moderately elongate, robust fishes. Head large, "square" flattened above; body compressed. Mouth large. Eyes practically on top of head which is often covered by bony plates. Caudal fin rounded or truncate. Usually a strong spine on "shoulder" above pectoral fin base which may be venomous. Plain olive brown over upper head and back. Spinous dorsal fin black but base of entrire fin white. Pectoral fin dusky olive, lower border yellow-orange. Humeral spine strong, exposed. Nape naked. Flap of tissue along inside of lower jaw forming a very long filament. One pair of preventral spines plus anterior bucklers.

Order Pleuronectiformes

The flatfishes consist of 7 families in the Indo-West Pacific, about 60 species known from the South China Sea. This order is recognized by its sideway compressed and have both eyes oddly situated on the same side; fin with soft spiney rays except in the Psettodidae. Seven families and 23 species were found in this survey. References; Punpoka (1964); Mongkolprasit (1967); Menon (1977); Gloefelt-Tarp (1984); Masuda et al. (1984); Chen (1993) and Randall (1995).

Family Psettodidae

253. Psettodes erumei **(Bloch & Schneider, 1801)**

Eyed side plain brown or dark green, sometimes with broad crossbands and scattered white spots. White edge on caudal fin. Mouth large, teeth strong. Upper eye near dorsal profile and in front of lower eye. Caudal fin wedge-shaped. Left eyed side in tropical populations.

Family Citharidae

254. Branchypleura novaezeelandiae **Guenthher, 1862**

Eyed side mottled pale brown with about 3 rows of dark near fin bases, small dark spots on fins. Mouth large, gill rakers long. Scales easily lost, none on front third of head; lateral line distinctly curved above pectoral fin. Anterior dorsal fin rays filamentous in male; both ventral fins short based, that of eyed side well before ventral fin on blind side.

Family Paralichthyidae

255. Pseudorhombus diplospilus **Norman, 1926**

Large double black ocelli on body ringed with yellow spots-2 above and 2 below lateral line. Dorsal fin begins just behind posterior nostril (blind side); head profile notched; 4-10 teeth on blind side of lower jaw; gill rakers short, broad and with spiny margins.

256. Pseudorhombus arsius **(Hamilton-Buchanon, 1822)**

Brown with dark spots and rings; large dark blotch on lateral line at beginning of straight part, sometimes 1 or 2 smaller blotches on line posteriorly. Dorsal fin begins just before nostrils or over space between nostrils; teeth strong, widely spaced, 6-13 on blind side of lower jaw.

257. Pseudorhombus elevatus **Ogilby, 1912**

Four to 5 rows of dark rings along body; large dark blotch on lateral line at beginning of straight part, sometimes i or 2 more on line posteriorly. Dorsal fin begins above or in front of front nostril; notc in ead profile before eyes; teeth small. All scales ctenoid on eyed side.

258. Pseudorhombus quinquocellatus **Weber & de Beaufort, 1929**

Five dark brown single ocelli on body, ringed wit yellow spots and brown line-2 above, 2 below, 1 posteriorly on lateral line. Teeth strong, widely space, 12-14 on blind side of lower jaw. Caudal peduncle twice longer than deep. Dorsal fin begins above nostrils. Sharp spine projects horizontally before anal fin origin.

259. Pseudorhombus malayanus **Bleeker, 1866**

Head notched in front of upper eye; snout as long as eye diameter; maxilla extending to below posterior part of lower eye. Body plain brown; dark blotch at beginning of straight part of lateral line. Body scales ctenoid on both sides. Attains to 17 cm, usually 15 cm. Known from Oman coast to the South China Sea.

Family Bothidae

260. Grammatobothus polyophthalmus **(Bleeker, 1866)**

Interorbital narrow and concave; lateral line well-developed on both sides of body. Second to 7t dorsal fin rays produced. Brown wit pale blue and brown spots; three large black and yellow ocelli on body: 2 above and below pectoral fin, another on middle of straight part of lateral line; broad dark and pale bars across pectoral fin.

***261. Engyprosopon grandisquama* (Temminck & Schlegel)**

Interorbital concave(male with spine on snout and orbital spines.) Scales on eyed side teebly ctenoid, also covering membrane between operculum and pectoral fin base. Body tan to dark brown mottled and spotted; fine spots on dorsal and anal fins; 2 conspicuous black spots in middle of upper and lower caudal fin margins.

***262. Engyprosopon multisquama* Amaoka, 1963**

A pair of jet-black bloches on caudal fin placed between 2nd and 4th rays counted from above and below respectively. Body narrow, its dept less than 1/2 of SL. Pectoral fin long, upper rays elongated into filaments, its length longer than head length. More scales in lateral line and less pectoral rays than in *E. grandisquama*. Distributed from Japan to South China Sea.

***263. Laeops parviceps* Gunther, 1850**

Mouth small, maxilla ending opposite front eye border, fine teeth present only on blind side of jaws. Upper body profile nearly straight behind eyes; slightly separated from rest of fin. Plain brown, fin edges darker; first two dorsal fin rays white.

264. Arnoglossus aspilos

Eyes separated by bony ridge; lateral teeth of both jaws small, close together, front teeth of upper jaw only slightjy larger; body depth 2.7-3.0 in SL. Second to 4th dorsal fin rays produced. Body fawn, dark spots on body and fins; a blotch on straight part of lateral line anteriorly.

<u>Family Pleuronectidae</u>

***265. Samaris cristatus* Gray, 1831**

Eyed side mottled pale brown with about 3 of rows dark bloches; row of bloches along dorsal and anal fin bases, several rows across caudal fin. Mouth small, stright lateral line present only on eyed side; ventral bases rather elongate, fin rays produced, tips expanded, first ray free; all caudal rays simple.

266. Samaris sp.

Similar to *S. cristatus* but darker colour and more oblong body; dorsal and anal fin ray shorter. Single specimens of 10 cm., taken off Malay peninsula.

<u>Family Soleidae</u>

***267. Aesopia cornuta* Kaup, 1858**

Body and fins pale orange, crossed by 13 or 14 dark brown bands which may be divided; banded caudal fin yellow. First dorsal fin ray thickened and prolonged. Scales cycloid or feebly ctenoid, in form of short papillae on blind side of head. Dorsal and anal fins united with caudal fin; pectoral fin very short and bround; ventral fin free from anal fin.

***268. Aseragodes dubius* Weber, 1913**

Eye small, close together, antherior nasal take short, not reaching anterior rim of eye; caudal fin separated from other fins, pectoral fin absent. Colour; fawn with pale brown mottling and dark checken blotch on the eye side. A specimen of 9 cm. taken off Malay peninsula.

***269. Pardachirus pavoninus* (Lecepede, 1802)**

Tan or reddish-brown, body and fins covered with cream spots which often have dark brown central spot and dark brown border. Eyes Serparates by scaled interorbital; scales feebly ctenoid. Dorsal and anal fins free from caudal fin; an open pore at base of each dorsal and anal ray. No pectoral fins; ventral fin bases unequal, the right fin often joined to anal fin.

270. Liachirus melanospilus **(Bleeker)**

Anterior nasal tube moderately long, usually reaching anterior rim of lower eye, when tube depressed posteriorly. Scales cycloid. Caudal fin free from other vertical fins, pectoral fins absent.

Family Cynoglossidae

271. Cynoglossus arel **(Bloch & Schneider, 1801)**

Eyed side tan, fins brown. Two lateral lines on eyed side, none on blind side. Eyes separated by narrow scaly space; corner of mouth midway between snout tip and gill opening. Scales ctenoid on eyed side.

272. Cynoglossus kopsi **(Bleeker, 1851)**

Eyed side tan, mottled darker brown; fins dark. Two lateral lines on eyed side, upper one often incomplete; none on blind side. Eyes not separated by scaly space; corner of mout nearer snout tip than gill opening, below middle of eye. Ctenoid scales on both sides of body.

273. Cynoglossus lingua **Hamilton-Buchanon, 1822**

Eye serparated with narrow scaly space. Lateral lines complete; body elongate, tapering posteriorly and pointed caudal fin. Eye side dark grey, fin greyish, dusky posteriorly. specimens obtained with 19 cm. size.

274. Cynoglossus sp.

Siimlar to *C. arel* but more robust body, longer scales and rounded snout. Eye side yellowish brown, dusky, fin hyaline brown, wit dusky rays. Specimens taken with 20 cm. size.

275. Paraplagusia bilineata **(Bloch, 1874)**

Lips withh fringes of branched tentacles. Body olive-green or brown on eyed side; fins fawn wit narrow white margins. Scales ctenoid on blind side of body. Two or 3 lateral lines on eyed side, upper two separated by 16-19 scales.

Order Tetraodontiformes

This order consist of 9 families in 2 suborders: Balistoidei; triggerfishes, tripodfishes; and Tetraodontoidei; puffers. The order is characterized in having of small mouth, large head; gill opening small and low number of vertebrae. Over 80 species known from the South China Sea. References; Tyler (1968), Gloefelt-tarp & Kailola (1984), Masuda et al. (1984), Kumchirtchuchai (1985), Chen (1993) and Randall (1995).

Family Triacantidae

276. Pseudotriacanthus strigilifer **(Cantor, 1850)**

Body grey, dark silvery above, pale below, oblong golden or orange blotches on sides; lower 1/3 to 1/2 of first dorsal fin pale, outer portion black. Bony pelvis broad anteriorly between ventral fin bases, tapering to point posteriorly. Length of 2nd dorsal spine more than half first spine length.

277. Tripodicthys oxycepalus **(Bleeker, 1851)**

Body short, rectangular, with elongated caudal peduncle; dorsal spine very long with short second to fourth species; snout produces elongate. Body silvery grey wit yellowish gold longitudinal dash; first dorsal spine membrane dark distally; fins hyaline.

278. Trixiphictys weberi **(Chauduri, 1910)**

Silvery blue body, orange blotc on base of and below first dorsal fin, dusky golden elongate blotches in roughly 3 bands along body; outer 1/3 of first dorsal fin black, remainder white. Bony pelvic almost as wide anteriorly between ventral fin bases as near its tip; snout concave and long, postorbital distance short.

<u>Family Balistidae</u>

***279. Abalistes stellatus* (Lecepede, 1798)**

Deep groove before eye; teeth uneven and notched; caudal peduncle depressed. Third dorsal spine well-developed; tips of caudal fin produced. Many pale blue-green spots and dashes along body and over head; large cream blotches often present on back; unpaired fins banded yellow, green and brown.

<u>Family Monacantidae</u>

***280. Aluterus monoceros* (Linnaeus, 1758)**

First dorsal spine slender, placed above eye; snout profile convex; body ovate; no ventral flap; caudal fin shorter than head, lobes produced with age. Body green-olive, darker above, often with dark brown spots and/or white reticulations.

***281. Anacanthus barbatus* Gray, 1831**

Body very elongate. Fleshy barbel on lower jaw; mouth opens dorsally. First dorsal spine sort and weak; caudal fin long, wedge-saped. Green or brown body wit cream mid-lateral band and spotted ventral flap. Anather robust specimens was taken, possibly differents species or varistion of *A. barbatus.*

***282. Chaetoderma penicilligera* (Cuvier, 1817)**

Skin roughened; long skin filaments, some branched, scattered over head and body; ventral fin rudiment at tip of pelvic movable. Teeth in upper jaw often protrude from mouth; first dorsal spine irregularly-shaped and often twisted. Caudal fin large, wedge-saped. Body pale or dark brown wit thin longitudinal dark brown lines from mout to tail base; body blotched brown, 2 black blotches above pectoral fin. Rows of small dark spots along unpaired fins, dark patches and dark margin on caudal fin.

***283. Pseudomonacanthus macrurus* (Bleeker, 1857)**

Ventral fin rudiment at tip of pelvic not movable but pelvis itself very movable; ventral flap large. Gill opening almost entirely below eye. First dorsal spine placed above posterior half of eye; caudal fin rounded. Body yellowish brown to pale brown, covered with small, crowded dark brown spots much smaller than pupil; net-work of dark lines on ventral flap; caudal fin wit broad brown crossband and dark brown border.

***284. Paramonacanthus japonicus* (Tilesius, 1801)**

Elongate and slender movable ventral fin rudiment at tip of pelvic. Body moderately slender. First dorsal spine slender, originating over posterior half of eye; dorsal and anal fins elevated anteriorly (much higher in male); rounded caudal fin, upper ray produced into filament. Fawn or grey-green body wit yellow patches on snout, dusky spots and vague patches over head and sides; either 3 or 4 dusky brown bands from head to tail base. Two or 3 brown bands across pale caudal fin.

***285. Paramonacanthus* sp.1**

Body deep, skin roughten with minute spines. Body fawn with indistinct dark bloches; fins hyaline; caudal fin with fainted dusky band. Taken in large amouts of Pahang river mouth and mixed with other 2 unknown species, possibly sexual variations. Size attains to 10 cm.

***286. Paramonacanthus* sp.2**

Similar to species 1 , but skin smoother; body fawn with out dark bloches.

***287. Paramonacanthus* sp.3**

Body retunely deeper; caudal fin longer and pelvicfin flap dark.

Family Ostraciidae

***288. Rhynchostracion nasus* (Bloch, 1785)**

Body 5-cornered in cross-section, ridges moderately sharp-edged but without spines, median dorsal ridge distinct; snout projects beyond mouth. Anal fin begins behind dorsal fin. Pale green, orange or grey body with scattered large or smaller brown spots, one on each plate; spots extending onto caudal peduncle and fin.

***289. Tetrosomus gibbosus* (Linnaeus, 1758)**

Body roughly 3-cornered or triangular in cross-section; large, hig, flattened spine on dorsal ridge, short upward-pointing spine above eye and 4 or 5 short, strong, backward-pointing spines along ventro-lateral ridge. Olive, grey-blue or brown body wiyh black blotches on lower sides, base of dorsal spine, caudal peduncle, dorsal and anal fin bases.

Family Tetraodontidae

***290. Lagocephalus gloveri* Abe et Tabeta, 1983**

Body oblong, covered with prickles. Prickles on dorsal surface do not reach origin of dorsal fin. Caudal fin double emarginate, Dorsal half of body blackish-brown, ventral silver. Pectoral and dorsal fins dark; anal fin white; caudal fin black with upper and lower white tips. Attains 35 cm. Distributed in the West Pacific.

***291. Lagocephalus inermis* (Temminck et Schlegel, 1850)**

Dorsal surface of body without prickles, belly covered with prickles. Black gill opening. Attain 90 cm. Distributed in the East China Sea, the South China Sea to the Indian Ocean.

***292. Lagocephalus lunaris* (Bloch & Schneider, 1801)**

Body round in cross-section, nostril a raised papilla with 2 openings; caudal fin moderately emarginate. Body naked except for patch of spinules on back from above eye to 3/4 or all the way to dorsal fin and another patch ventrally from throat to halfway along belly. Caudal peduncle deeper than wide. Top of head and back tan or green, sides silvery pale yellow; caudal fin tan, tipped white.

Attains 45 cm. Distributed in the East China Sea and the Indian Ocean.

***293. Lagocephalus sceleratus* (Gmelin, 1788)**

Body elongate and streamlined. Caudal peduncle depressed. A wide silver stripe running from mouth to caudal peduncle. Dorsal dark gray with many small black spots, Ventral silver. Attain 110 cm. Distributed to the Indo-West Pacific.

***294. Lagocephalus spadiceus* (Richadson, 1845)**

Body round. Caudal fin slightly lunate. Body naked except for patch of spinules on back from eye to halfway before dorsal fin and another patch ventrally from throat to halfway along belly. Caudal peduncle deeper than wide. Three broad brown bands across back; sides silvery yellow. Dorsal and pectoral fins yellow, caudal fin dusky, tips white. Anal fin white.

***295. Torquigener pallimaculatus* Hardy, 1933**

Nostrill a raised papilla with 2 openings. Caudal fin truncate; eye free from body skin except dorsally. Sort spinules on back, sides and ventrally to about level of dorsal fin; lower half of gill opening edge with several papillae. Back wit orange-brown large and small spots and large grey spots surrounded by spots. Large spots scattered over lower sides.

***296. Arothron immaculatus* (Bloch et Schneider, 1801)**

Body round, nostril as pair of short thick tentacle; lateral line not branched above anal fin.

Dusky olive above, grey or white below. Gill opening and pectoral fin base dark brown, hind margin of caudal fin brown, other fins plain. Upper and lower borders of caudal fin conspicuously dark brown or black.

297. Arothron stellatus **(Bloch et Schneider, 1801)**

Body round in cross-section; nostril a pair of short thick tentacle; lateral line not branched above anal fin. Few or many black or dark brown spots over fawn or yellow-green upper half of body. Gill opening black or with large black spots; anus ringed black. Black spots on dorsal and anal fins; sometime caudal fin spotted or dorsal fin plain. Size attain to 60 cm. commonly 30 cm. Distributed thoughout Indo-Pacific. Poisonous species.

Family Diodontidae

298. Diodon holocanthus **Linnaeus, 1758**

Body covered with many long erectile spines. Several dark-brown blothes on body. Attains 30 cm. Circumtropical distribution.

299. Diodon hystrix **Linnaeus, 1758**

Body covered with many long erectile spines. Body and fins covered with many small black spots and with no large dark markings. Attains 57 cm. Circumtropical distribution.

300. Tragulichthys orbicularis **(Bloch, 1785)**

Head and body fawn or olive above, white below; 3 or 4 rounded spots on sides-one between eye and gill opening, other above and behind pectoral fin; fins plain. Body spines mostly 3-rooted and fixed; 4 or 5 very long and erectile spines in pectoral fin axil; spines on sides longest, arising near bases of unpaired fins and reacing over caudal preduncle. distributed thoughout Indo-West Pacific.

Discussion

In this survey, 300 species including 122 economic species were obtained, their diversity is drastically decrease, in compare with the survey done by Wongratana (1968, 1985), they were 380 species obtained in the same areas, only by trawling method.

Four of the 24 station are highly species-richness areas, there are Station 70 (73 species), St. 80 (66 species), St. 5 (57 species) and St 14-15 (54 species). Off Ko Chang (37 m depth) in the Gulf of Thailand and off the Pahang River (50 m) in the eastern Malay Peninsula are represented for high diversity areas (Table 1).

Demersal fish forms the main composition of the trawls despite the modification of the 10-metre high opening made to the net. The lizardfish *Saurida undosquamis, S. miropectoralis*, the bigeye *Priacanthus tayenus* and *P. macracanthus*, the rabbitfish *Siganus canaliculatus* and hairtail *Trichiurus lepturus* were the most abundant economic species found in mast of the sampling stations.

Fishing efforts were 34 hours and 49 hours for the cruises I and II, with average catch per hour of 12.04 and 34.79 kg. respectively. The maximum catch per hour was 175.3 kg in Malaysian waters, the minimum was 4.33 kg in Thai waters. The average percentage of economic fishes is higher than that of trash fishes in Malaysian waters. It ranged from 55.45 to 81.92 %, with the exception of station 76, which was 11.4% due to the massive landing of small filefishes *Paramonacanthus* spp. Economic fishes formed 26.1-89.9% of the catch in the Gulf of Thailand, but total catch was low, with 8.2-68 kg and 13-69 kg for the cruise I and II respectively. All the results see Table 1-4 and Fig. 2-3.

Table 2. Species list of fishes collected in the Cruise I (Gulf of Thailand and east coast of Peninsular Malaysia). SK = Songkhla market

Species	Station																								
	2	5	9	16	17	23	25	30	32	39	40	43	51	54	58	61	63	65	68	72	74	76	78	80	SK
Order Orectolobiformes																									
Family Hemiscylliidae																									
Chiloscyllium punctatum	*																*								
Family Scyliorhinidae																									
Aetomycterus marmoratus								*	*																
Order Carcharhiniformes																									
Family Hemigaleidae																									
Hemipristis elongatus																					*				
Order Rhinobatiformes																									
Family Rhinobatidae																									
Rhynchobatus djiddensis																							*		
Order Torpediniformes																									
Family Narcinidae																									
Narcine sp.																*									
Order Myliobatiformes																									
Family Dasyatidae																									
Dasyatis zugei					*		*		*																
Dasyatis sp.1													*		*										
Dasyatis sp.2				*									*	*							*				
Dasyatis sp.3								*																	
Himantura sp.								*																	
Order Anguilliformes																									
Family Muraenidae																									
Gymnothorax javanicus	*																								
Gymnothorax sp.1						*																			
Echidna ? sp						*																			
Family Congridae																									
Conger sp.														*											
Family Muraenisocidae																									
Murenesox cinereus																					*				
Congresox talabonoides																					*				
Order Clupeiformes																									
Family Engraulidae																									
Stolephorus insularis							*					*													
Endrasicholina heteroloba		*				*	*		*							*					*				
Family Chirocentridae																									
Chirocentrus dorab		*			*	*			*	*	*	*	*			*	*		*	*	*	*			
Chirocentrus nudus											*														
Family Clupeidae																									
Amblygaster sirm							*																		
Sardinella frimbriata	*				*		*		*	*											*			*	
Order Aulopiformes																									
Family Synodontidae																									
Saurida micropectoralis			*	*		*		*	*	*	*	*	*		*		*	*		*	*		*		
Saurida longimanus		*		*	*	*	*			*		*						*		*	*				
Saurida undosquamis	*		*	*		*	*	*	*	*			*		*		*	*	*	*	*			*	
Synodus hoshinonis		*										*		*	*			*					*		
Trachinocephalus myops																								*	
Order Ophidiiformes																									
Family Ophiidae																									
Sirembo jerdoni													*												
Order Siluriformes																									
Family Ariidae																									
Arius sp.																		*		*					
Family Plotosidae																									
Plotosus lineatus																									*
Plotosus sp.																									*
Order Beloniformes																									
Family Belonidae																									
Ablenes hians															*										*
Tylosurus crocodylus																									*
Euleptoramphus viridis																		*							

Table 2. continue

Species	Station																							
	2	5	9	16	17	23	25	30	32	39	40	43	51	54	58	61	63	65	68	72	74	76	78	80	SK
Family Hemiramphidae																									
Hemiramphus far																									*
Hyporamphus dussumieri								*																	*
Family Exocoetidae																									
Cypselurus oligolepis													*										*		*
Order Gasterosteiformes																									
Family Pegasidae																									
Pegasus laternarius		*																							
Family Centriscidae																									
Centriscus scutatus											*							*							
Family Syngnathidae																									
Hippocampus kuda			*																						
Corythoichthys sp.																				*					
Famiry Fistulariidae																									
Fistularia petimba		*		*		*				*		*	*	*		*	*		*		*		*		
Order Scorpaeniformes																									
Family Scorpaenidae																									
Apistus carinatus		*				*			*												*		*		
Pterois miles		*	*			*	*						*	*	*			*							
Scorpaenopsis cirrhosa								*																	
Scorpaenodes sp.					*																				
Scorpaenodes scaber												*	*								*				
Minous menodactylus					*			*		*	*														
Minous coccineus													*												
Inimiscus sinensis	*		*		*		*	*						*											
Family Platycephalidae																									
Elates ransoneti							*		*						*	*							*		
Platycephalus indicus																									*
Sarsogona tuberculata							*				*							*							
Thrysanophrys macracanthus									*						*	*				*	*		*	*	
Grammoplites scaber		*											*								*				
Inegocia japonicus																				*					
Family Triglidae																									
Lepidotrigla sp.														*	*			*	*				*		
Family Dactylopteridae																									
Dactyloptena papilio									*						*		*	*	*	*					
Dactyloptena orientalis		*	*	*																					
Order Perciformes																									
Family Priacanthidae																									
Priacanthus tayenus		*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*		*		
Priacanthus macrocanthus							*		*	*		*	*			*	*	*	*		*		*	*	
Family Callionymidae																									
Repomucenus virgis																*				*					
Calliyichthys japonicus														*	*				*	*	*				
Dactylopus dactylopus												*		*	*					*			*		
Family Serranidae																									
Cephalophlis boenak								*																	
Epinephelus sexfasciatus					*	*			*			*	*												
Epinephelus quayanus		*																							
Epinephelus heniochus									*				*												
Epinephelus areolatus								*						*	*			*	*						
Family Apogonidae																									
Apogon septemstriatus	*					*							*					*							
Cheilodopterus macrodon	*																								
Apogon semilineatus	*									*					*		*	*							
Apogon quadrifasiatus					*								*	*		*					*		*		
Apogon sp. 1					*								*		*										
Apogon elioti									*									*						*	
Apogon poecilopterus			*		*				*	*	*						*		*	*			*		
Apogon sealei				*		*	*				*		*												
Apogon albimaculosus																					*				

Table 2. continue

Species	Station																							
	2	5	9	16	17	23	25	30	32	39	40	43	51	54	58	61	63	65	68	72	74	76	78	80	SK
Family Sillaginidae																									
Sillago sihama										*															*
Family Rachycentridae																									
Rachycentron canadum																								*	
Family Carangidae																									
Parastromateus niger					*				*								*				*		*		
Selar boops											*										*				
Selar cruemenophthalmus				*			*		*					*		*	*		*		*		*		
Alectis cilialis												*	*												
Alepes para												*													
Alepes melanoptera				*				*	*	*	*			*		*		*					*		
Carangoides gymnostethus																	*							*	
Carangoides armatus						*		*			*		*							*			*		*
Carangoides talamparoides															*									*	*
Carangoides malabaricus					*		*		*	*							*		*		*				
Carangoides uii								*																	*
Decapterus russelli																	*		*						
Uraspis helvola															*										
Atule mate		*					*		*			*				*									
Selaroides leptolepis		*				*	*		*	*	*		*				*								
Seriolina nigrofasciata												*	*			*		*	*		*				
Scomberoides sp.																				*					*
Scomberoides tol												*													
Family Ariommatidae																									
Ariomma indicum																*				*					
Family Echeneidae																									
Echeineus naucrates																								*	
Family Meneidae																									
Mene maculata				*	*																				
Family Gerreidae																									
Gerres macrosoma										*			*												
Gerres filamentosus			*										*												
Pentaprion longimanus				*	*									*	*	*	*		*	*			*		
Family Leiognathidae																									
Leiognathus bindus				*								*		*	*	*							*		
Leiognathus equalus											*														*
Leiognathus stercorarius	*		*								*	*	*	*	*		*			*			*		
Leiognathus leuciscus						*	*			*			*	*			*						*		
Leiognathus brevirostris		*		*		*	*					*	*			*			*		*		*		
Secutor indicus				*	*		*						*												
Gazza minuta					*		*					*		*		*									
Family Lutjanidae																									
Lutjanus sebae														*			*								
Lutjanus malabaricus		*		*	*									*		*		*							
Lutjanus monostigma								*																	
Lutjanus johni																									*
Lutjanus lutjanus							*	*	*				*			*		*							
Lutjanus russelli																									*
Lutjanus quinqueradiatus																								*	
Lutjanus vittus													*				*						*		
Pristipornoides filamentosus								*							*			*							
Pristipornoides multidens								*			*			*	*	*	*	*	*						
Pristipornoides typus														*	*				*						
Pterocaesio chrysozona															*			*							
Dipterygonotus bateatus															*			*			*		*		
Family Lethrinidae																									
Gymnocranius elongatus																	*	*		*					
Lethrinus lentjan		*																							

Table 2. continue

Species	Station																								
	2	5	9	16	17	23	25	30	32	39	40	43	51	54	58	61	63	65	68	72	74	76	78	80	SK
Family Haemulidae																									
Diagramma pictum		*								*	*	*	*					*					*		
Plectorhynchus gibbosus																									*
Pomadasys maculata												*				*									*
Pomadasys kakaan								*																	
Family Nemipteridae																									
Nemipterus furcosus		*									*	*	*			*	*		*						
Nemipterus hexodon										*			*			*	*	*	*						
Nemipterus nemurus														*	*			*	*		*		*		
Nemipterus mesoprion				*	*	*	*		*	*		*	*		*		*		*		*		*		
Nemipterus bathybius																		*	*						
Nemipterus tambuloides														*							*		*		
Nemipterus japonicus					*																				
Nemipterus nematophorus																*	*		*				*		
Nemipterus balinensoides														*	*										
Nemipterus sp1.																		*							
Pentapodes setosus											*			*						*				*	
Scolopsis monogramma								*																	
Scolopsis taeniopterus	*			*	*				*	*	*	*	*		*		*	*						*	
Family Mullidae																									
Upeneus sulphureus	*													*		*			*				*		
Upeneus moluccensis														*											
Upeneus bensasi							*				*	*			*		*		*						
Upeneus tragula		*		*									*												
Upeneus sp.								*			*	*		*			*	*	*						
Parupeneus cinnabaricus		*				*						*	*	*		*			*						
Family Cepolidae																									
Acanthocepola abbreviata							*																		
Family Teraponidae																									
Pelates quadrifasciatus		*																							
Therapon theraps		*								*	*		*												
Family Labridae																									
Xiphocheilus typus							*						*	*	*			*	*	*	*		*		
Family Chaetodontidae																									
Coradion chryszonus																*									
Family Pomacentridae																									
Pristotis sp.											*				*			*		*	*			*	
Daya jerdoni														*	*			*		*			*		
Family Siganidae																									
Siganus canalicalatus	*	*	*	*	*	*	*	*	*	*	*		*	*		*	*	*		*	*		*		
Siganus guttatus																									*
Family Scombridae																									
Rastelliger kanagurta		*			*	*	*		*	*															
Rastelliger brachysona					*		*		*																
Scomberomorus commerson					*			*	*	*		*	*				*								
Scomberomorus guttatus							*					*		*			*								
Family Trichiuridae																									
Trichiuras lepturus				*	*		*	*	*			*		*	*		*						*		
Eupleurogrammus glossodon				*		*				*															
Tentoriceps cristatus																*									
Family Sphyraenidae																									
Sphyraena jello									*					*											
Sphyraena forsteri					*	*	*			*		*								*					
Sphyraena obtusata				*						*								*		*					
Family Gobiidae																									
Trypauchen vagina											*														
Oxyurichthys papuensis											*														
Glossogobius sp.											*														
Family Pinguipedidae																									
Parapercis sp.											*			*	*	*	*	*	*						

Table 2. continue

Species	Station																							
	2	5	9	16	17	23	25	30	32	39	40	43	51	54	58	61	63	65	68	72	74	76	78	80	SK
Family Champsodontidae																									
Champsodon (cf) arafurensis																			*	*			*		
Family Uranosopidae																									
Uranoscopius oligolepis												*		*											
Order Pleuronectiformes																									
Family Bothidae																									
Engyprosopon multisquama	*																*			*			*		
Engyprosopon grandisquama														*										*	
Arnoglossus aspilos													*												
Grammatobothus polyophthalm	*		*						*			*	*		*	*		*		*	*		*		
Laeops parviceps						*									*				*						
Family Paralichthyidae																									
Pseudorhombus arsius	*	*			*		*				*			*	*								*		
Pseudorhombus elevatus																			*	*					
Family Citharidae																									
Branchypleura novaezeelandiae		*					*					*	*	*	*	*	*		*	*			*		
Family Pleuronectidae																									
Sarmaris sp.											*									*					
Family Soleidae																									
Aesopia cornuta																		*					*	*	
Aseraggodes dubius											*														
Liachirus melanospilus										*															
Family Cynoglossidae																									
Cynoglossus lingua																									*
Cynoglossus (cf) arel							*		*																
Paraplagusia bilineata																									*
Order Tetraodontiformes																									
Family Triacanthidae																									
Trixiphchthys weveri																		*							
Family Balistidae																									
Abalistes stellatus															*		*	*			*				
Family Monacanthidae																									
Pseudomonacanthus macrurus	*																								
Paramonachantas sp.			*	*	*		*					*	*	*	*					*			*		
Paramonacanthus japonicus																			*						
Aluterus monoceros		*	*										*	*		*		*							
Chaetoderma penicilligeral	*																								
Anacanthus barbatus											*													*	
Anacanthus sp.																								*	
Monacanthus chinensis		*									*														
Family Ostraciidae																									
Tetrosomus gibbosus														*											
Rhyncostracion nasus		*	*																						
Family Tetraodontidae																									
Lagocephalus lunaris		*	*				*					*													
Lagocephalus scleratus	*			*	*	*			*			*	*	*	*		*			*	*		*		
Lagocephalus gloveri												*													
Lagocephalus sp. 1													*												
Lagocephalus sp. 2												*													
Arothron immaculatus	*		*	*	*		*					*					*						*	*	
Family Diodontidae																									
Diodon holacanthus														*	*			*	*				*		
Tragulichthys orbicularis									*				*	*	*	*	*		*				*		

Table 3. The species list of fishes collected in the Cruise II (Gulf of Thailand and east coast of Peninsular Malaysia).

Species	Station (SM= Koh Samui; SK= Songkhla)																							
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80	SM	SK
Order Orectolobiformes																									
Family Stegostomatidae																									
Stegosoma varium																				*					
Family Hemiscylliidae																									
Chiloscyllium punctatum			*		*				*										*			*			
Family Scyliorhinidae																									
Aetomycterus marmoratus													*												
Order Carcharhiniformes																									
Family Triakidae																									
Mustelus manazo																			*						
Family Carcharhinidae																									
Carcharhinus dussumieri																		*							
Order Torpedeniformes																									
Family Narcinidae																									
Narke dipterygea																						*	*		
Order Myliobatiformes																									
Family Dasyatidae																									
Dasyatis zugei	*				*														*				*		
Dasyatis kuhli																							*		
Dasyatis sp. 1																		*	*	*					
Dasyatis walga					*														*	*		*			
Dasyatis imbricatus					*	*																			
Himantura jenkinsi																			*				*		
Himantura uarnak																			*						
Himantura gerraddi																*	*		*			*	*		
Order Anguilliformes																									
Family Muraenidae																									
Gymnothorax javanicus	*																								
Siderea thryssoidea																	*								
Echidna sp.						*																			
Family Congridae																									
Conger sp.																				*					
Order Clupeiformes																									
Family Engraulididae																									
Encrasicholina heteroloba									*																
Stolephorus dubiosus												*													
Stolephorus indicus		*						*																	
Stolephorus insularis		*																							
Family Chirocentridae																									
Chirocentrus dorab		*				*	*	*			*	*	*	*	*										
Family Clupeidae																									
Sardinella frimbriata		*				*			*			*										*			
Anodontosoma nasus												*													
Order Aulopiformes																									
Family Synodontidae																									
Saurida longimanus					*			*	*	*	*	*	*	*	*										
Saurida micropectoralis			*	*	*	*			*		*		*	*	*	*	*	*	*	*					
Saurida undosquamis	*		*	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*		*	*		
Synodus hoshinonis	*	*	*		*					*	*		*	*		*	*	*	*	*	*	*			
Trachinocephalus myops																						*	*		
Order Ophidiiformes																									
Family Ophiidae																									
Sirembo sp.																			*						
Order Siluriformes																									
Family Ariidae																									
Arius biliniata																			*		*				
Arius thalasinus													*												*
Arius maculata																									*
Family Plotosidae																									
Plotosus caninus													*												
Plotosus lineatus																		*	*	*			*		

Table 3. continue

Species	Station (SM= Koh Samui; SK= Songkhla)																								
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80	SM	SK
Order Beloniformes																									
Family Belonidae																									
Ablenes hians																						*			
Tylosurus crocodylus																									*
Euleptorhamphus viridis																									*
Family Hemiramphidae																									
Hemiramphus far																									*
Rhynchorhamphus malabaricus																								*	
Order Gasterosteiformes																									
Family Pegasidae																									
Pegasus laternarius																						*	*		
Family Centriscidae																									
Centriscus scutatus					*												*	*	*						
Family Syngnathidae																									
Hippocampus kuda		*																							
Hippocampus sp1								*												*		*			
Famiry Fistulariidae																									
Fistularia petimba		*	*	*	*	*			*		*		*		*		*	*	*		*				
Order Scorpaeniformes																									
Family Scorpaenidae																									
Apistus carinatus			*								*								*	*		*	*		
Brachypteroides serrulata				*	*				*				*												
Chloridactylus multibarbatus																						*			
Iminiscus sinensis	*	*	*		*				*		*					*				*			*		
Minous coccineus																									
Minous monodactylus		*																	*						
Minous pictus																			*						
Minous trachycephalus																			*						
Pterois russelli	*	*	*		*	*										*	*		*						
Scorpaenodes scabra				*					*		*		*					*							
Scorpaenopsis neglecta																							*		
Family Platycephalidae																									
Elates ransoneti		*	*	*	*				*	*															
Grammoplites scaber		*	*	*						*	*														
Platycephalus indicus																									*
Sargosogona tuberculata																	*		*			*			
Sarsogona sp. 1					*														*	*					
Thysanophys macracanthus		*																							
Family Triglidae																									
Lepidotrigla spiloptera																		*			*				
Family Dactylopteridae																									
Dactyloptena papilio	*			*									*				*		*	*			*		
Dactyloptena orientalis		*																							
Order Lophiiformes																									
Family Antenaridae																									
Antennarius mummifer						*													*						
Antennarius striatus		*								*									*						
Family Lophiidae																									
Lophiomus sp.																*		*			*				
Family Ogcocephalidae																									
Halieuteae sp.																					*				
Order Perciformes																									
Family Priacanthidae																									
Priacanthus tayenus	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*				
Priacanthus macrocanthus				*	*	*	*	*	*	*	*	*		*		*		*		*	*				
Family Callionymidae																									
Callionemus filamentosus														*								*	*		
Callionemus sp.																							*		
Callyichthys japonicus																			*	*		*	*		
Dactylopus dactylopus																				*					
Repomucenus virgis																		*							

Table 3. continue

Species	Station (SM= Koh Samui; SK= Songkhla)																								
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80	SM	SK
Family Centropomidae																									
Lates calcarifer																									*
Family Ambassidae																									
Ambassis kopsii																								*	*
Family Serranidae																									
Cephalophlis boenak																									
Epinephelus areolatus	*	*			*					*						*			*		*	*			
Epinephelus bleekeri					*																				
Epinephelus heniochus		*		*	*	*																			
Epinephelus quayanus																									
Epinephelus sexfasciatus		*				*		*	*		*			*		*									
Plectopomus leopardus																		*							
Family Apogonidae																									
Apogon aureus																			*						
Apogon elioti	*		*							*			*		*				*	*			*		
Apogon fasciatus				*			*			*	*				*				*						
Apogon lineatus									*		*	*													
Apogon niger																						*			
Apogon poecilopterus				*			*	*	*			*													
Apogon quadrifasiatus	*			*	*				*								*		*						
Apogon sealei																	*					*			
Apogon semilineatus															*					*					
Apogon septemstriatus												*											*		
Apogon taeniophorus																							*		
Rhabdamia gracilis																			*						
Family Sillaginidae																									
Sillago aeolus																								*	
Sillago ingenuua																							*		
Family Rachycentridae																									
Rachycentron canadum										*	*								*						
Family Carangidae																									
Alectes ciliatus	*				*									*	*		*								
Alectes indicus		*																							
Alepes melanopterus				*				*	*	*					*										
Alepes melanopterus		*					*											*							
Atule mate		*		*	*	*	*	*	*		*	*	*		*								*		
Carangoides gymnosthetus																				*					
Carangoides armatus					*			*	*	*	*		*	*					*		*				*
Carangoides caeruleopinnatus																									*
Carangoides hedlandensis																			*		*				*
Carangoides malabalicus										*		*						*			*				
Carangoides talamparoides											*									*					
Carangoides uii													*												*
Caranx sexfasciatus											*								*						
Decapterus kurroides																							*		
Decapterus russelli									*					*		*									
Megalaspis cordyla		*					*		*			*													
Parastromateus niger			*					*			*	*													
Scomberoides tol													*												
Selar cruemenophthalmus				*	*	*	*		*	*	*	*	*	*	*		*	*		*			*		
Selaroides leptolepis		*	*				*	*	*		*	*	*		*	*		*	*	*		*	*		
Seriola rivuliana										*															
Seriolina nigrofasciata				*	*			*		*	*		*					*	*		*				
Uraspis uraspis																				*					
Family Ariommatidae																									
Ariomma indicum																					*				
Family Echeneidae																									
Echeineus naucrates										*	*			*			*								
Family Meneidae																									
Mene maculata							*		*																

Table 3. continue

Species	Station (SM= Koh Samui; SK= Songkhla)																								
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80	SM	SK
Family Gerreidae																									
Gerres abbriviatus																									*
Gerres macrosoma																			*						
Gerres filamentosus		*	*																						
Pentaprion longimanus		*	*	*	*	*	*		*	*	*		*	*				*	*	*	*				
Family Leiognathidae																									
Gazza achlymis					*		*																		
Gazza minuta			*				*																		
Leiognathus bindus			*	*	*	*	*	*		*	*	*	*	*	*						*				
Leiognathus blochi																									*
Leiognathus brevirostris												*													*
Leiognathus elongatus																	*	*							
Leiognathus equalus																									*
Leiognathus fasciatus																			*						
Leiognathus leuciscus	*	*	*					*									*		*	*			*		
Leiognathus splendens												*													
Leiognathus stercorarius	*	*	*					*			*						*		*	*					
Leognathus lineolatus				*	*										*			*							
Secutor insidiater									*		*		*		*										
Secutor ruconius		*			*																				
Family Lutjanidae																									
Dipterygonotus balteatus											*						*		*						
Lutjanus johni																									*
Lutjanus lineolatus	*																				*				
Lutjanus lutjanus	*				*									*			*		*		*		*		
Lutjanus malabaricus		*																*			*	*			
Lutjanus monostigma	*	*	*																						
Lutjanus quinqueradiatus																							*		
Lutjanus russelli																									*
Lutjanus vittus		*			*							*		*											
Pristipornoides multidens				*						*						*	*	*			*				
Pristipornoides typus																	*								
Pterocaesio chrysozona				*							*		*				*						*		
Family Lethrinidae																									
Gymnocranius elongatus																	*			*	*		*		
Gymnocranius griseus																*		*			*		*		
Lethrinus microdon																						*			
Lethrinus lentjan			*																				*		
Family Haemulidae																									
Diagramma pictum	*							*											*		*		*		
Plectorhynchus gibbosus																									*
Family Nemipteridae																									
Nemipterus balinensoides																		*	*						
Nemipterus bathybius					*													*			*				
Nemipterus furcosus	*	*	*							*							*		*	*		*	*		
Nemipterus hexodon		*	*	*	*				*																
Nemipterus japonicus						*								*											
Nemipterus marginatus					*	*				*			*	*		*	*	*			*		*		
Nemipterus mesoprion	*	*	*	*	*			*	*	*	*	*	*	*	*						*		*		
Nemipterus nematophorus			*	*	*	*				*			*								*				
Nemipterus nemurus			*		*										*	*	*	*	*	*	*		*		
Nemipterus peroni																			*						
Nemipterus tambuloides					*											*		*			*				
Parascolopsis tanyactis																							*		
Pentapodus setosus	*	*	*																*	*			*		
Scolopsis monogramma																		*							
Scolopsis taeniopterus	*	*			*			*	*	*	*	*		*	*	*	*		*	*	*	*	*		
Scolopsis vosmeri																							*		
Family Sciaenidae																									
Pennahia macrophthalma																				*					
Otolithoides ruber							*																		

Table 3. continue

Species	Station (SM= Koh Samui; SK= Songkhla)																							
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80	SM	SK
Family Mullidae																									
Parupeneus cinnabaricus		*										*				*	*	*	*	*	*	*	*		
Upeneus bensasi	*	*	*	*		*		*				*				*	*	*	*	*	*	*	*		
Upeneus sondaicus	*	*		*	*	*		*		*	*	*	*	*								*			
Upeneus sulphureus					*	*	*	*	*	*	*		*	*	*				*						
Upeneus tragula	*	*	*		*	*			*																
Family Cepolidae																									
Acanthocepola abbreviatus															*										
Family Teraponidae																									
Therapon jarbua								*																	
Therapon theraps												*												*	*
Family Ephippidae																									
Platax batavianus		*																							
Family Drepenidae																									
Drepene punctata																									*
Family Pomacentridae																									
Pristotis jerdoni																*				*		*			
Family Labridae																									
Xilichthys sp.																						*			
Xiphocheirus typus								*	*	*	*			*	*		*	*		*	*				
Family Siganidae																									
Siganus javus												*													
Siganus guttatus																									*
Siganus canaliculatus	*	*	*	*	*		*	*	*		*	*	*	*					*	*			*		
Family Scombridae																									
Rastelliger brachysona		*		*		*		*	*																
Rastelliger kanagurta		*		*		*	*	*	*	*	*	*	*	*	*										
Rastelliger faughti		*																				*			
Scomberomorus commerson		*							*		*	*	*	*											
Scomberomorus guttatus							*			*															
Family Trichiuridae																									
Trichiurus lepturus				*			*		*	*			*												
Eupleurogrammus glossodon											*			*										*	
Tentoiceps cristatus										*	*			*											
Family Stromateidae																									
Pampus argenteus							*																		
Pampus chinensis							*																		
Family Polynemidae																									
Eleutheronema tetradactylum																								*	*
Family Sphyraenidae																									
Sphyraena jello					*																				
Sphyraena forsteri																					*				
Sphyraena obtusata		*							*				*	*					*						
Family Blenniidae																									
Xiphasia setifer																	*	*					*		
Family Gobiidae																									
Oxyurichthys papuensis			*				*																		
Yongiichthys nebulosus																							*		
Priolepis sp.																					*				
Family Pinguipedidae																									
Parapersis filamentosa																							*		
Parapercis pulchella															*		*	*		*	*				
Family Champsodontidae																									
Champsodon (cf) *arafurensis*				*						*															
Family Uranoscorpidae																									
Uranoscopius oligolepis										*	*		*			*						*			
Order Pleuronectiformes																									
Family Psettodidae																									
Psettodes erumei																						*			

Table 3. continue

Species	Station (SM= Koh Samui; SK= Songkhla)																								
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80	SM	SK
Family Bothidae																									
Engyprosopon grandisquama																*	*		*	*			*		
Engyprosopon multisquama	*																								
Arnoglossus aspilos																		*			*				
Grammatobothus polyophthalm	*	*	*						*	*			*	*		*	*		*						
Laeops parviceps																				*					
Family Paralichthyidae																									
Pseudorhombus arsius																					*		*		
Pseudorhombus diplospilus																	*		*	*					
Pseudorhombus elevatus																		*							
Pseudorhombus quinqueocellatus														*											
Pseudorhombus malayanus																		*					*		
Family Citharidae																									
Branchypleura novaezeelandiae					*				*				*		*						*				
Family Pleuronectidae																									
Sarmaris cristatus	*			*																*					
Sarmaris sp.		*		*										*			*								
Family Soleidae																									
Aesopia cornuta																							*		
Aseraggodes dubius																						*			
Pardachirus pavoninus																						*	*		
Liachirus melanospilus																						*	*		
Synaptera orientalis																									*
Family Cynoglossidae																									
Cynoglossus (cf) *arel*		*																							*
Cynoglossus lingua																									*
Cynoglossus kopsii																			*						*
Paraplagusia bilineata																									*
Order Tetraodontiformes																									
Family Triacanthidae																									
Pseudotricanthus strigilifer																						*			
Tripodichthys oxycephalus																	*			*					
Trixiphichthys weveri																					*				
Family Balistidae																									
Abalistes stellatus																*	*	*		*					
Family Monacanthidae																									
Aluterus monoceros	*	*	*	*	*				*	*	*			*		*	*	*	*	*	*		*		
Anacanthus barbatus																				*					
Paramonacanthus sp.1																			*	*		*			
Paramonacanthus sp.2																			*	*		*			
Paramonacanthus sp.3																						*			
Family Ostracionidae																									
Tetrosomus gilobosus																*									
Rhyncostracion nasus	*	*																*	*			*	*		
Family Tetraodontidae																									
Arothron immaculatus	*	*	*		*				*	*	*		*			*	*	*		*			*		
Arothron stellatus																	*		*			*			
Lagocephalus lunaris		*	*	*	*	*	*	*	*	*	*	*	*	*											
Lagocephalus scleratus	*	*		*	*		*		*	*	*		*	*		*	*	*		*	*	*	*		
Lagocephalus spadiceus									*		*														
Torquigener pallimaculatus																			*						
Family Diodontidae																									
Diodon histrix																						*			
Diodon holocanthus																*	*	*	*	*		*			
Tragulichthys orbicularis	*	*													*	*	*	*	*	*					

Table 4. Operation results of the first cruise during 4 Sept. - 6 Oct. 1995

Station No.	Total (Kg)	Catch/hr	% of Fishes	Species No.	depth (m)
2	11.2	11.2	86.6	19	27
5	32.8	16.4	96	31	34
9	16.1	16.1	95.77	17	23
16	9.7	9.7	92.47	28	46
17	8.2	8.2	93.88	31	45
23	20	10	67.87	25	34
25	68	34	88.69	39	37
32	61.45	20.48	91	36	32
39	14.2	7.1	96.7	29	27
40	34.73	17.35	74	34	21
43	17.7	5.9	94	41	46
51	24.7	8.2	79.12	46	46
54	no data			48	
58	no data			42	
61	no data			36	
63	no data			41	
65	no data			47	
68	no data			37	
72	no data			35	
74	no data			36	
76			Jellyfish only		
78	no data			47	

* Fishes : includes economic cephalopods and crabs

Table 5. Operation results of the second cruise during 24 Apr. - 17 May 1996

Station No.	Total (Kg)	Fishes *	Trash fish	% of Fishes	Catch/hr	Species No.	depth (m)
2	35.4	16.5	18.9	46.6	11.8	34	28
5	38.6	18.2	18.44	47.15	12.2	57	37
8	28.1	23.3	4.8	82.9	11.24	36	38-43
12	50.5	26.6	23.85	52.67	16.83	41	53
14-15	59.2	30.4	28.8	51.35	19.77	54	57
18-19	14.8	Emergency haul				29	64
23	18.8	11.4	7.5	60.63	6.13	27	34-35
29	13	11.3	1.74	86.9	4.33	27	30
31-32	34	16.7	17.3	49.1	11.33	47	33-37
33	44.6	22.6	21.96	50.67	14.86	43	54
37	69	18	51.1	26.1	22.96	44	55
40	27.9	20.6	7.37	73.83	9.31	36	20
43	39.25	31.1	8.15	79.23	13.1	43	48-55
51	32.18	25.56	6.62	79.42	10.72	40	46-50
54	16.5	12	4.5	72.72	16.5	28	47
59	23.3	17.2	6	73.8	23.3	31	60
63	51.3	30.1	15.2	70.37	51.3	45	60
65	57.7	32	25.7	55.45	57.7	42	61-63
68	Net deformed , unsucceed						
70	175.3	131.3	44	74.9	175.3	73	50
72	42.6	34.9	7.7	81.92	42.6	46	54-56
74	40.8	24.6	16.2	60.3	40.8	49	66-67
76	133.86	15.25	118.6	11.4	133.86	42	24-25

* Fishes : includes economic cephalopods and crabs

Table 6. Catch composition by weight (kg) of major species trawled (Cruise I).

Species	Station																					
	2	5	9	16	17	23	25	32	39	40	43	51	54	58	61	63	65	68	72	74	78	80
Saurida undosquamis	3.70	0.45	0.80	1.35	0.30		2.00	0.80		1.80	0.80	0.50		*		*	*	*	*	*		*
Priacanthus tayenus		3.95	1.62	0.90	1.20			1.00			1.10	5.50	*	*	*	*	4.50	*	*	2.50	*	
Siganus canaliculatus			2.46	0.55				0.50		4.00	0.90	2.00	*		*	*	*		*	*	*	
Priacanthus macracanthus								0.70			1.15	1.70			*	*	7.00	*	*	4.00	*	*
Trichiurus spp.		0.82		1.15	1.28		0.50	8.20	0.80				*	*		*				*		
Saurida micropectooralis			0.80					1.70	1.20	0.20	0.90			*		*	*		*	*		
Nemipterus mesoprion			0.80	0.20				0.80			0.90	2.80	*			*	*			*	*	
Selar cruemenophthalmus				0.20	0.40		1.50	0.90					*		*	*		*	*		*	
Nemipterus hexodon					0.50				0.50	0.70	0.50	0.40			*	*	*	*				
Scolopsis taeniopterus		1.30						0.40		1.80	1.20	0.50		*		*	*					*
Chirocenthus dorab					0.20	0.25	0.70	19.8	2.00								*	*	*			
Sardinella frimbriata			1.20					0.60				0.60	*		*		*					
Rastelliger kanagurta		0.30		0.80	0.45	1.70	0.70				0.35											
Nemipterus furcosus															*	*	1.60	*				
Alute mate	0.23	0.90					1.20	0.40														
Rastelliger brachysoma					0.30	0.60	0.60															
Alutera monoceros								4.70				0.20										
Nemipterus nemurus					0.40														9.50			
cephalopods & shellfishes	3.95	9.44	7.30	1.05	0.82	6.90	3.32	1.98	4.06	7.1	2.45	1.14										
Mixed fishes	1.81	14.34	0.44	3.92	1.82	9.97	7.84	14.60	5.22	10.26	6.40	4.22										

Table 7. Catch composition by weight (kg) of major species trawled (Cruise II)

* = included in mixed fishes

Species	Station																						
	2	5	8	12	14/15	18/19	23	29	31/32	33	37	40	43	51	54	59	63	65	70	72	74	76	80
Mixed carangids	*	*	*	*	1.30	0.7	*	*	1.10	*	*	*	1.60	0.48	*	*	*	*	*	*	*	*	*
Priacanthus tayenus	*	0.78	15.5	2.73	4.50	*	*	*	*	1.34	*	2.00	1.17	0.66	*	0.56	1.60		3.70	*	2.50		
Saurida undosquamis	*	0.45	*	7.00	3.40			*	*	6.56		1.23	0.65	5.53	0.53	1.80	*	2.80	4.86	3.80		*	*
Scolopsis taeniopterus	2.00	1.70			*			*	*	*	*	1.22		*	*	*	*		*	*	*	0.45	*
Nemipterus mesoprion	*	*	0.75	*	*	*		*	*	*	*	*	0.90	*	*						*		*
Siganus canaliculatus	0.97	0.50	0.30	0.75	0.45		*	*	*		*	0.80	*	*					*	*			*
Alutera monoceros	0.55	1.40	*	*	*				*	*	*					1.10	*	*	*	*	*	*	
Priacanthus macracanthus				0.67	*	*	*	*	*	1.90	1.52	0.80	2.80	0.85		*		*		*	*		
Saurida micropectoralis			0.80	*	*	*				3.50	3.05		5.80	1.90	*	*	*	*	*	*			
Epinephelus spp.		2.45		1.80	1.34	*		*	*		*		0.75			0.76		5.20			*	*	
Rastelliger kanagurta		*		*		*	*	*	0.80	0.77	*	*	*	0.33	*								
Nemipterus nemurus			*													4.30	8.60	7.40	3.90	6.32	6.10	4.60	
Lutjanids	2.90	0.80			*							*	*	*	*						2.30	*	*
Chirocenthus dorab		*				2.00	*	*			0.82	0.64	*	*	*								
Parupeneus cinnabaricus		*															*	1.30	*	*	*	*	*
Sphyraena spp.		1.00			4.20				1.20			*	*						*		*		
Scomberomorusspp.	0.52					0.70				1.75	5.00		3.30	0.55									
Pristipomoides multidens				*						*						*	*	6.55			*		
Nemipterus hexodon			1.58	*		10			*														
Nemipterus nematophorus			*	13	11	*				*			*								*		
Selaroides leptolepis												1.30			7.50	3.30		0.60					
Trachinocephalus myops																						3.50	1.8
Shellfishes and Cephalopods	5.70	6.80	2.42	6.70	3.52	*	1.50		9.10	6.60	4.30	9.20	10.8	*	*	*	*	4.50	*	7.72	3.10	1.80	13
Mixed fishes	5.86	5.25	18.20	16.38	9.89	2.10	9.90	11.30	5.60	8.08	3.31	7.86	7.65	21.95	4.50	7.74	21.50	6.45	127.4	20.86	13.10	5.33	80.10

Acknowledgments

This research is successed by the cooperations of many organizations and people, with very appreciated gratitutes, I would like to extend to; Mr Saramise Uraiwan and Mr. Lertchai Podapon including their staff of the Marine Fisheries Division and crews of the R.V. Pramong 4, and the crew staff K. K. Manchong, K. K. Mersuji for their good assistant and operation of the trawling surveys, data collecting and hospitalities during on board, including to Mr. Rooney Biusing, Mr.Benjimin Martin (Fishery Research Center, Sabah) and Mr. Richard Rumpet, Mr Shung Jet Tin (Fishery Research Institute, Sarawak). The identifications of the fish was consulted and well facilitated by Dr. K. K. P. Ng and P.K.L. Ng of Zoological Reference Collection, National University of Singapore. Several valuable comment and suggestions of species identification were provided by; L. Compagno (South African Museum), B. Mabel Manjaji (Univ. Malaysia, Sabah) and Peter Last (CSIRO, Australia) for elasmobranches; Gerald Allen (Western Aust. Meseum) and John E. Randall (Hawaii) for some bony fish.

References

Annandale, N. 1916. Preliminary report on the fauna of the Tale Sap, or inland sea of Singora. J. Nat. Hist. Siam Soc., 2(2):96-102.

Anonymous 1968. Results of the exploratory trawling surveys in the outer part o the Gulf of Thailand and in the South China Sea by R. V. Fisheries research No. 2 cruise No 1/2511. Exploratory Fishing Unit, Dept. Fisheries, Bangkok, Thailand, Spacial Publ. SR 011, 79p (Thai).

Anonymous 1969. Eatable marine animal for Thais. Fishery exploratory Division, Dept.Fisheries, Bangkok, Thailand, 179p (Thai).

Anonymous 1969. Results of fisheries and oceanographic surveys on Sunda continental Shelf and South China Sea by R.V. Fisheries reserch No. 2. cruise No. 1/2511. Exploratory Fishing Unit; Department of Fisheries, Bangkok; Spec. Publ. SR. 011, 79 pp. (in Thailand).

Allen, G.R. 1985. FAO species catalogue Vol.6. Snappers of the world. An annotated and illustrated catalogue of Lutjanid species known to date. FAO. Fish. Synop.,(125) Vol.6 : 208 pp.

Allen, G.R. and Swainston, R. 1993. Reef fishes of New Guinea. Publication No. 8 Christensen Research Institute Papua new Guinea. 132 p.

__________.1988. The marine fishes of North-western Australia. Western Australian Museum, Perth:201 pp.

Allen , G.R. and Talbot , F.H. 1985. Review of the snappers of the genus *Lutjanus* (Pisces : Lutjanidae) from the Indo-Pacific, with the description of a new species. Indo-Pacific Fishes. No.11: 87 p.

Carpenter, K.E. 1987. Revision of the Indo-Pacific fish family Caesionidae (Lutjanoidea) , with descriptions of five new species. Indo-Pacific Fishes. No.15: 56 p.

__________1988. FAO species catalogue. Vol.8. Fusilier Fishes of the world. An Annotated and Illustrated Catalogue of Caesionid Species Known to Date. FAO. Fish. Synop.,(125) Vol.8 : 75 p.

Carpenter K.E. and Allen, G.R. 1989. FAO species catalogue. Vol.9 Emperor fishes and large-eye breams of the world (Family Lethrinidae). An Annotated and illustrated catalogue of lethrinidae species known to date. FAO. Fish. Synop.(125) Vol.9:118 p.

Castle, P.H.J. 1984. Muraenesocidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol.3. FAO,Rome. pag. var.

Chen, S.C. (eds.), 1993. Fishes of taiwan. National University of Taiwan, Dept. Zool. xx+960 (Chinese).

Collette, B.B. 1984. Belonidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol.1. FAO,Rome.pag. var.

Collette, B.B. 1984. Hemiramphidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol.2. FAO,Rome. pag. var.

Collette, B.B. and Nauen, C. 1983. FAO. species catalogue. Vol.2. Scombrids of the world. An annotated and illustrated catalogue of tunas , mackerels, bonitos and related species known to date. FAO. Fish. Synop. (125) Vol.2 : 137 p.

Compagno, L.J.V. 1984. FAO. species catalogue. Vol.4,Part 1. Sharks of the world : Hexanchiformes to Lamniformes. An annotated and illustrated catalogue of shark species known to date. FAO. Fish. Synop. (125) Vol.4,Part 1 : 249 p.

_________ 1984. FAO. species catalogue. Vol.4,Part 2. Sharks of the world :Carcharhiniformes. An annotated and illustrated catalogue of shark species known to date. FAO. Fish. Synop.(125) Vol.4,Part 2 : 655 p.

_________ 1996. Dasyatidae. Stingrays.p. 1-25. In K.E. Carpenter ans V. Niem (eds.) FAO Identification Guide for Fishery Purposes. The Western Central Pacific.

De Bruin, G.H.P. , Russell, B.C. and Bogusch, A. 1994. The marine fishery resources of Sri Lanka. FAO. species identification field guide for fishery purposes. FAO. Rome. 400 p.

Debelius, H. 1993. Indian Ocean tropical fish guide. Ziethen Farbdruckmedien, Cologne. 321 p.

Eschmeyer, W.N., Hallacher and L.E. Rama-Rao, K.V. 1979. The Scorpionfish genus *Minous* (Scorpaenidae , Minoinae) including a new species from the Indian Ocean. Proceedings of the California Academy of Sciences (20) Vol. XLI, pp. 453-473.

Eschmeyer, W.N. , Rama-Rao, K.V. and Hallacher, L.E. 1979. Fishes of the Scorpionfish subfamily Choridactylinae from the Western Pacific and the Indian Ocean. Proceedings of the California Academy of Sciences (21) Vol.XLI, pp. 475-500.

Fischer, W. and P.J.P. Whitehead. 1974. (eds). FAO species identification sheets for fisheries purpose, 4 vols. FAO of the United Nation, Rome, no pagination.

Fraser, T.H. and Lachner, E.A. 1985. A Revision of the cardinalfish subgenera *Pristiapogon* and *Zoramia* (Genus *Apogon*) of the Indo-Pacific Region (Teleostei : Apogonidae). Smithsonian Contribution to Zoology. 47 p.

Gloerfelt-Tarp, T. and Kailola, P.J. 1984. Trawled fishes of Southern Indonesia and Northwestern Australia. The Australian Development Assistance Bureau; DirectorateGeneral of Fisheries, Indonesia; German Agency for Technical Cooperation, 406 pp.

Gomon, J.R., 1983. Plotosidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol. 1. FAO,Rome. pag. var.

Gushiken, S. 1983. Revision of the Carangid Fishes of Japan. Galaxea 2:135-264.

Heemstra, P.C. and Randall, J.E. 1993. FAO species catalogue.Vol.16. Groupers of the world. (Family Serranidae , Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO. Fish. Synop. (125) Vol.16 :382 p.

Hora, S.L. 1924.a. Zoological result of tour in far east , Fishes of Talesap, Peninsular Siam. Mem. Asiatic Soc. Bengal, 6 (pt. 1): 463-476.

Hora, SL. 1924b. Zoological result of tour in far east , Fishes of Talesap, Peninsular Siam. Mem. Asiatic Soc. Bengal, 6 (pt. 2): 479-500.

Isarankura, A.P. and G. Kuhtmorgen-Hill. 1966. Demersal fishes resources investigation in the Gulf of Thailand. Mar. Fisher. Lab. Bangkok, 15pp.

Jayaram, K.C. 1984. Ariidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol. 1. FAO,Rome. pag. Var.

Johnstone, J. 1903. Report on the marine fishes. Fasciuli Malayenses-Zoology, 1: 294-302.

Kuiter, R.H. 1992. Tropical reff-fishes of the Western Pacific Indonesia and adjacent waters. Percetakan PT Gramedia, Jakarta. 314 p.

Kuiter, R.H. and Debelius,H. 1994. Southeast Asia tropical fish guide. IKAN-Unterwarrearchiv, Germany. 321 p.

Kuhlmorgen-Hille, G. 1968. An illustrated field key to the family Leiognathidae in the Gulf of Thailand. Contribution No. 12, Marine Fish. Lab., Dept. Fisheries, Bangkok: 7pp.

Kuhlmorgen-Hille, G. and S. Ritragsa. 1972. Result of the comparative fishing between the Thai R.V. " Pramong 2" and the Malaysian R.V. " PenyelidexI" in May 1971. In: 3rd Symposium on Marine fisheries, Mar. Fiisher. Lab. Bangkok, 26-27 January 1972, 7pp.

Kumchirtchuchai, P. 1985. Taxonomy of the puffers found in the waters of Thailand. Master Thesis Department of Marine Sciences, Chulalongkorn University. 163p. (Thai).

Lal-Mohan, R.S., 1983. Sciaenidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol. 1. FAO,Rome. pag. var.

Last, P.R. and Stevens, J.D. 1994. Skarks and rays of Australia CSIRO. Australia. 513 p.

Masuda, H.; Amaoka, K.; Araga, C. and Yoshino, Y.(eds.) 1984. The fishes of the Japanese Archipelago. Tokai Univ. Press. 456p.

Mckay, R.J. 1992. FAO species catalogue Vol.14. Sillaginid Fishes of the World (Family Sillaginidae). An Annotated and Illustrated Catalogue of the Sillago, smelt or Indo-Pacific Whiting species known to date. FAO. Fish. Synop.,(125) Vol.14:87 p.

Menon, A.G.K. 1977. A Systematic Monograph of the Tongue Soles of the Genus *Cynoglossus* Hamilton-Bochanan. (Pisces : Cynoglossidae). Smithsonian Contribution to Zoology No 238:129 p.

Michael, S.W. 1993. Reef sharks and ray of the world. Sea Challengers. Monterey, California.107 p.

Monkolprasit, S.P. 1967. Addenda additions to the Pleuronectiformes fauna of the Gulf of Thailand. Kasetsart University Museum of Fisheries.

Nakamura, I. and Parin, N.V. 1993. FAO species catalogue. Vol. 15. Snake mackerels and cutlassfishes of the world. (Family Gempylidae and Trichiuridae). An annotated and illustrated catalogue of the snake mackerels, snoeks, escolars, gemfishes, sackfishes, domine, oilfish, cutlassfishes, scabbardfishes, hairtails and frostfishes known to date. FAO. Fish. Synop. (125) Vol.15 : 136 p.

Palsson , W.A. and Pietsch , T.W. 1989. Revision of the Acanthopterygian fish family Pegasidae (order Gastrosteiformes). Indo-Pacific Fishes. 18:38 p.

Petchsathit, B. 1992. Taxonomy of halfbeak and needdlefish (Pisces:Hemiramphidae, Belonidae) in Thai waters. Master Thesis Department of Biology, Chulalongkorn University (Thai).

Poreeyanond, D. and W. Pokapunt, 1980. The trawl survey in the Gulf of Thailand by M.V. Nagasaki-Maru. In: Report of the Thai-Japanese-SEAFDEC joint oceanographic and trawling survey in the Gulf of Thailand on board Nagasaki-Maru, 15-28 May 1980, Southeast Asia Fisheries Development Center, Samutprakarn, Thailand, pp. 41-56.

Premcharoen, S. 1993. Toxonomy of Ponyfishes and Silver-Biddles (Pisces: Leiognathidae and Gerreidae) in Thai waters. Master Thesis Department of Marine Sciences, Chulalongkorn University. 176 pp.

Punpoka, S. 1964. A review of The Flatfishes (Pleuronectiformes = Heterosomata) of the Gulf of Thailand and its tributaries in Thailand. Bull. of Kasetsart Univ. 86 p.

Randall, J.E. 1995. Coastal fishes of Oman. Hawaii Univ. Press., 438 p.

Randall , J.E. and Heemstra , P.C. 1991. Revision of Indo-Pacific Groupers (Percifomes : Serranidae: Epinephelinae), with Descriptions of Five New Species. Indo-Pacific Fishes. No.20. Hawaii. 338 p.

Randall , J.E. and Hoese , D.F. 1986. Revision of the groupers of the Indo-Pacific genus *Plectopomus* (Perciformes: Serranidae: Epinephelidae), with descriptions of five new species. Indo-Pacific Fishes. No.13:31 p.

Randall, J.E.; Ida, H.; Kato, K.; Pyle, R.L. and Earle, J.L. 1997. Annotated checklist of the inshore fishes of the Ogasawara Islands. Nat. Sci. Mus. Monographs No 11, Tokyo.

Ritragsa, S. et al. 1968. An analysis of de mersal catches taken from the otterboard trawling survey in the Gulf of Thailand, 1966. Mar. Fisher. Lab., Bangkok, Contr., 11:1-104 (in Thai).

_________ 1969. An analysis of de mersal fish catches taken from the otterboard trawling survey in the Gulf of Thailand, 1967. *Mar. Fisher. Lab., Bangkok, Contr*., 15:1-79 (in Thai).

Rofen, R.R. 1963. Handbook of the food fishes of the Gulf of Thailand. The George Vanderbilt Foundation and the University of California, Scripps Institute of Oceanography, La Jolla, California, 236 pp.

Russell, B.C. 1990. FAO species catalogue. Vol.12. Nemipterid fishes of the world (Threadfin breams, whiptail breams , monocle breams , dwarf monocle breams, and coral breams) family Nemipteridae. An annotated and illustrated catalogue of nemipterid species known to date. FAO. Fish. Synop. (125) Vol.12 : 149 p.

__________ 1991. Description of a new species of *Nemipterus* (Pisces: Perciformes: Nemipteridae) from the Western Pacific, with redescription of *Nemipterus maginatus* (Valenciennes), *N. mesoprion* (Bleeker) and *N. nematophorus* (Bleeker). J.Nat. Hist. 25:1379-1389.

__________ 1993. A review of the threadfin breams of the genus *Nemipterus* (Nemipteridae) from Japan and Taiwan, with description of a new species. Jap. J. Ichthyol. 39(4): 295-310.

Sasaki, K. 1996. Sciaenidae. Croakers, drums. p. 1-55. In K.E. Carpenter and V. Niem (eds.) FAO Identification Guide for Fishery Purposes. The Western Central Pacific. (In press).

Sirimontaporn, P. 1984. Fishes of Songkhla Lake. (Vol.1), the fishes collected in the year 1981-1983. National. Institute of Coastal Aquaculture Department of Fisheries, Thailand. JICA, 91P.

__________ 1987. Description of the fishes family Gerreidae and Sciaenidae occuring in the Gulf of Thailand. National. Institute of Coastal Aquaculture Department of Fisheries,Thailand. 46 p.

__________ 1990. Fishes of Songkhla Lake. (Vol.2), Tech. Pap. No.3. National. Institute of Coastal Aquaculture Department of Fisheries, Thailand, 101p.

Smith-Vaniz, W.F. 1984. Carangidae. In W. Fischer and G. Bianchi(eds.) FAO species identification sheets for fishery purposes. Western Indian Ocean fishing area 51. Vol. 1. [pag. var.]. FAO,Rome.

Tiews, K. 1965. Bottom fish resources investigation in the Gulf of Thailand and an outlook on further possibilities to develope the marine fisheries in Southeast Asia. *Arch. Fishereiwiss. Hamburg*, 16(1):67-108.

Tiews, K. et al. 1967. On the changes in the abundance of demersal fish stocks in the Gulf of Thailand from 1963-1964 to 1966 as consequence of the trawl fisheries development. Mar. Fisher. Lab. Bangkok, Contr. 8:1-39 (with Thai translation).

Trewavas , E. 1977. The Sciaenid Fishes of the Indo-West-Pacific. Trans. Zool. Soc. 33. London. 253-541 p.

Tyler, J.C. 1968. A monograph on Plectognath fish of the superfamily Triacanthoidea. Monograph No. 16, The Academy of Natural Sciences of philadelphia. 344 p.

Vari, R. 1978. The terapon perches (Percoidei; Teraponidae). A cladistic analysis and taxonomic revision. Bull. Am. Mus. Nat. Hist. 159(5):179-340.

Whitehead, P.J.P. 1985. FAO species catalogue. Vol.1,Part 1. Clupeoid fishes of the world (Suborder Clupeoidei) : Chirocentridae, Clupeidae and Pristigasteridae. An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO. Fish. Synop. (125) Vol.7,Part 1:303 p.

Whitehead, P.J.P., Nelson, G.J. and Wongratana, T. 1988. FAO species catalogue. Vol.1,Part 2. Clupeoid fishes of the world (Suborder Clupeoidei):Engraulididae. An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO. Fish. Synop. (125) Vol.7,Part 2 : 579 p.

Wongratana, T. 1968. A checklist of fishes caught during the trawl surveys in the Gulf of Thailand and off The East coast of the Malay Peninsula. Department of Fisheries. Bangkok. Thailand. 96 p.

_______. 1975. A record of a flatheadfish. *Thysanophrys papillolabium* Schulty, in the Andaman Sea, with a key to fourteen species of the Platycephalidae from Thai waters (Pisces :Platycephalidae) Phuket Mar. Biol. Cent. Res. Bull. No.7:9 pp.

_______. 1982. Ichthyological observations made during the Andaman cruise of the "Nagasaki-Maru", 1-14 November 1981. Nat. Hist. Bull. Siam Soc. 30(2):105-124.

_______ .1985. Ichthyological result of the otter-board bottom trawl operated by M.V.Nagasaki-Maru at off shore Songkhla and Nakorn Si Thamarat , Gulf of Thailand , 28-29 Oct. 1982 with count of ecology of the region . Proc. of Aquatic Resource Research Institute. Chulalongkorn Univ. 365-390.

_______ . 1989. Record of a rare stingray, *Himantura jenkinsii* (Annandale) (Pisces:Dasyatidae) in the Andaman sea. Nat. Hist. Bull. Siam Soc. 37(1):25-30.

Woodland , D.J. 1990. Review of the fish family Siganidae with descriptions of two new species and comments on distribution and biology. Indo-Pacific Fishes. No.19. 136 p.

Kinds, Abundance and Distribution of the Fish Larvae in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia.

Apichart Termvidchakorn

Museum and Aquarium Institute, Department of Fisheries
Phaholyotin Rd., Chatuchak, Bangkok 10900, Thailand

ABSTRACT

Fish larvae samples were obtained from 81 stations in the Gulf of Thailand and the east coast of (Peninsular) Malaysia during the pre-northeast monsoon season (4 Sept - 4 Oct 1995) and the post-northeast monsoon (23 Apr - 23 May 1996). About 30 minutes were needed to obtain the samples from the surface layer and an obligue haul at each station. Around 73 families and 97 species of fish larvae were found among these pre and post-northeast monsoon specimens. For the pre-northeast monsoon sampling, there were 10,422 individuals from 66 families and 91 species in the surface horizontal hauls and 34,779 individuals from 63 families and 84 species in the obligue hauls. The post-northeast monsoon collection showed 11,875 individuals from 54 families and 74 species in the surface horizontal hauls and 32,541 individuals from 53 families and 73 species in the oblique hauls. From the surface layer, the most abundant larvae were *Stolephorus* sp., *Sardinella* sp., Gobiidae and *Upeneus* sp. *respectively*. Specimens from the oblique hauls showed Gobiidae, *Stolephorus* sp., *Bregmaceres rarisquamosus* and *Nemipterus* sp. to be most abundant in the collection.

Introduction

Fish resources in the South China Sea is an important subject of consideration by the countries bordering this area. The Gulf of Thailand and the east coast of Peninsular Malaysia are exsamples of the coastal areas of the South China Sea. The maximum depth within these areas is less than 100 metres and there are many islands and oil platforms able to provide shelter to the fishes and other marine organisms. Knowledge on fish larvae in terms of biology, morphology, spawning period, spawning peak, spawning ground and rearing ground for this area is needed for proper fishery management. Due to the limitation of such knowledge for this area, a collaborative research project between SEAFDEC member countries that included the participation of the Department of Fisheries, Thailand was carried out using M.V.SEAFDEC to investigate the available fish resources as well as the biological and physical oceanographic conditions.

Fish larvae were investigated for their kinds, abundance and distribution. The objectives of this study being to identify the composition of the fish larvae found, as well as the spawning grounds, spawning periods, spawning peaks, rearing grounds and periods, the information of which may then be used to formulate a fisheries management program.

Study on fish larvae in Southeast Asia were first conducted by Delsman from 1922-1938. He described and illustrated the larvae of *Chirocentrus dorab*, *Dussumieria hasseltii*, *Clupea* sp., *Engraulis* sp., *Setipinna* sp. and Myctophoidae sp. from the Java Sea.

Previous important studies on fisheries resources in the Gulf of Thailand were conducted by the Department of Fisheries. As for example, Sidthichokpan (1972) found 2 spawning peaks for the anchovy on the west coast of the Gulf of Thailand from March to April and July to September. Vatanachai (1972) showed that there were at least 107 families of fish larvae in the South China Sea, and around 51 families of them in the upper Gulf of Thailand (Vatanachai 1978). Chamchang (1986) found 47 families of fish larvae in the waters of the west coast of the Gulf of Thailand from Surat Thani to Narathivas with Gobiidae and Engraulidae being the most abundant. Termvidchakorn (1987) showed there were about 54 families of fish larvae in the central part of the Gulf of Thailand where

Carangidae was the most abundant.

Material and Methods

Sampling for fish larvae was carried out using M.V.SEAFDEC from 4 September - 4 October 1995 during the pre-northeast monsoon period, while the post-northeast monsoon period was between 23 April and 23 May 1996, at 81 sampling stations in the Gulf of Thailand and on the east coast of Peninsular Malaysia. Two types of fish larvae sampling method were employed. The surface horizontal haul represents a study on the diurnal migration and the economically important pelagic families. The standard larvae net, 1.30 metre in diameter with a 5-mm mesh size at the mouth part and 330 micron at the cod end, was used in the surface sampling.

The oblique haul catches all the species which occur in the area. The bongo net, 60 cm. in diameter with mesh size 500 micron at the mounth part and 330 micron at the cod end, was employed for this haul.

A flow meter was attached to the mouth part of the net. The sampling period was for about 30 minutes with the speed of haul at about 2 knots. For the oblique haul, the net went down to a depth of about 5 metres above the bottom (as measured by a depth sensor).

Specimens were preserved in 10% seawater/formalin immediately after each haul. Sorting and identification was done at the laboratory. After sorting, the fish larvae were preserved in 4% seawater formalin. Their identification and illustration was done using the stereomicroscope and a camera lucida attached to the stereomicroscope. Specimens were identified to the genera or species level. Their abundance and distribution were estimated in terms of number of individuals per 1000 cubic metres (No./1000 m^3) of sea water. The keys used in this identification were taken from Delsman (1922-1938), Leis and Rennis (1983), Leis and Trnski (1989), Mito (1966), Moser *et al.*(ed)(1984), and Okiyama (1988).

Data on temperature, salinity and dissolved oxygen at the surface and mid- depth of each station were also used to relate the abundance, distribution and migration of the fish larvae.

Results

There were 10,422 and 34,779 individuals of fish larvae obtained from the surface and oblique hauls of the pre-northeast monsoon cruise. The post-northeast monsoon cruise provided 11,875 and 32,541 individuals from the surface and oblique hauls. The specimens were identified to comprise of 73 families and 97 species of fish larvae from the pre-northeast and post-northeast monsoon. The pre-northeast monsoon specimens showed 66 families and 91 species from the surface horizontal hauls and 63 families and 84 species from the oblique hauls. The post-northeast monsoon collection provided 54 families and 74 species from the surface sampling and 53 families and 73 species from the oblique hauls.

The most abundant fish larvae from the surface layer in order of importance in both cruises were *Stolephorus* sp., *Sardinella* sp. Gobiidae and *Upeneus* sp., respectively. For specimens from the oblique hauls in both cruises, the abundant larvae were Gobiidae, *Stolephorus* sp., *Bregmaceros rarisquamosus* and *Nemipterus* sp., respectively.

The most abundant fish larvae from the surface hauls of the pre-northeast monsoon were *Stolephorus* sp. (20.678%), *Sardinella* sp. (14.988%), Gobiidae 12.608% and *Upeneus* sp. (9.713%), respectively. Those from the oblique hauls were Gobiidae (24.087%), *Stolephorus* sp. (12.787%), *Bregmaceros rarisquamosus* (7.542%) and *Nemipterus* sp. (5.070%), respectively. The post-northeast monsoon showed the abundant fish larvae at the surface as *Stolephorus* sp. (33.154%), *Sardinella* sp. (27.192%), Gobiidae (10.165%) and *Upeneus* sp. (4.421%), respectively. Those from the oblique hauls were Gobiidae (26.591%), *Stolephorus* sp. (13.340%), *Bregmaceros rarisquamosus* (6.411%) and *Nemipterus* sp. (6.168%), respectively.

The abundance and distribution of the fish larvae in the Gulf of Thailand and the East Cooast of

Peninsular Malaysia .

Family Clupeidae

Clupeidae larvae which occurred in both the surface and oblique samples were *Sardinella* sp. which formed the second most abundant fish larvae from the surface specimens. There were 1,562 individuals or 14.988% from 40 stations of the surface hauls in the pre- monsoon cruise, while for post-monsoon 3,229 individuals or 27.192% from 42 stations. Larvae were collected in abundance in the early morning, at night and during cloudy conditions. *Sardinella* sp. was the most abundant in the surface layer at densities 489.71 and 244.01 individuals per 1000 cubic metres in the post-monsoon and pre-monsoon samples. It was also the most abundant in the oblique samples at densities of 1544.84 and 512.53 individuals per 1000 cubic metres in the pre-monsoon and post-monsoon samples.

Dussumieria sp. larvae occurred in both the surface and oblique samples in pre- and post-monsoon collection. There were 80 and 19 individuals from 17 and 4 stations in the surface sampling from the pre- and post-monsoon cruises, respectively. The oblique sampling showed 34 and 31 individuals from 17 and 14 stations pre- and post-monsoon cruises, respectively with most of the samples collected at night.

Family Engraulidae

Engraulidae larvae occurred in both the surface and oblique samples with *Stolephorus* sp. showing the most abundant in the surface samples in both pre- and post- monsoon sampling. There were 2155 individuals from 51 stations of the surface hauls in the pre-monsoon cruise. The most abundant station provided a density of 125.55 individuals per 1000 cubic metres. In the surface sampling of the post-monsoon, there were 3,937 individuals from 54 stations with the most abundant station recording 206.05 individuals per 1000 cubic metres. Amounts of this larvae in the oblique hauls were 4,447 and 4,341 individuals from 73 and 64 stations in the pre- and post-monsoon cruise, respectively. The most abudant station for *Stolephorus* sp. provided 2,080.16 and 1,022.47 individuals per 1000 cubic metres in the post- and pre-monsoon. Light intensity affected their abundance because of Phototaxis but there was no difference between the pre- and post-monsoon collection, the difference being only among the surface and oblique specimens.

Family Chirocentridae

Chirocentrus sp. occurred in both pre- and post-monsoon cruises and from the surface and oblique specimens, with most abundance in the oblique samples of the pre-monsoon period. There were 111.60 individuals per 1000 cubic metres at station number 22 of the pre-monsoon oblique hauls, this being the lighest figure.

Family Chanidae

Chanos chanos occurred at some stations, with only few specimens obtained from the night stations. Only 8 specimens were obtained from 7 stations.

Family Synodontidae

Four species of this family occurred during these research cruises. These were *Saurida elongata*, *Saurida undosquamis*, *Synodus variegatus* and *Trachinocephalus myops*.

Saurida elongata showed 13 and 138 individuals from 2 and 24 stations of the surface and oblique hauls in the pre-monsoon and 3 individuals from 1 station of in the oblique hauls of the post-monsoon cruises.

Saurida undosquamis showed 4 and 203 individuals from 3 and 35 stations in the surface and oblique hauls from the pre-monsoon cruise and 126 individuals from 24 stations in the oblique hauls from the post-monsoon cruise. *Saurida undosquamis* was the most abundant among the 4 species especially in the oblique haul specimens. The most abundant station showed 83.95 individuals per 1000 cubic metres at station number 33 in the pre- monsoon oblique hauls.

Synodus variegatus showed 6 and 52 individuals from 2 and 22 stations in the surface and oblique hauls from the pre-monsoon cruise and 94 individuals from 24 stations in the oblique hauls from the post-monsoon cruise.

Trachinocephalus myops showed 22 and 105 individuals from 9 and 27 stations in the surface and oblique hauls from the pre-monsoon cruise. The post-monsoon provided 3 and 62 individuals from 3 and 20 stations in the surface and oblique hauls.

Family Belonidae

Only 4 individuals of *Tylosaurus coccodylus* occurred in the surface and oblique hauls during the post-monsoon cruise.

Family Hemiramphidae

Hemiramphus sp. occurred in these research cruises in both the surface and oblique hauls but for the oblique hauls, *Hermiramphus* sp. were obtained in the night stations or on cloudy days. Very few specimens were collected in these research cruises. There were 11 and 5 individuals from 8 and 3 stations in the surface and oblique hauls from the pre- monsoon cruise. The post-monsoon showed 36 and 10 individuals from 16 and 5 stations in the surface and oblique specimens.

Family Exocoetidae

There were 2 genus of exocoetid larvae in these samples. *Exocoetus* sp. and *Cypselurus* sp. are true pelagic species which occurred mostly in the surface specimens, collected at night and on cloudy days. There were very few specimens collected at each station but *Exocoetus* sp. had a wider distribution and was collected at more stations.

Exocoetus sp. showed 7 and 3 individuals from 6 and 1 stations in the surface and oblique hauls during the pre-monsoon cruise. There were 32 individuals from 19 stations of the surface specimens in the post-monsoon cruise.

Cypselurus sp. showed 4 and 1 individuals from 4 and 1 stations in the surface and oblique hauls in the pre-monsoon cruise and 15 individuals from 10 stations in the surface hauls of the post-monsoon cruise.

Family Antennariidae

Antennarius sp. occurred mostly in the oblique hauls of the pre-monsoon and the post-monsoon cruises. They showed 53 and 38 individuals of larvae from 27 and 20 stations of the oblique hauls in the pre- and post-monsoon cruises. But for the surface sampling, there were only 2 specimens in station 2 during the pre-monsoon cruise.

Family Pegasidae

Pegasius sp. is a small group of larvae which showed 1 and 10 individuals in 1 and 5 stations occurred in both the surface and oblique hauls of the pre-monsoon, but only 2 specimens from 2 stations in the oblique hauls of the post-monsoon cruise.

Family Bregmacerotidae

Bregmaceros rarisquamosus occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 178 individuals from 20 stations of the surface pre-monsoon cruise and 170 individuals of 9 stations in the surface post-monsoon cruise. They also showed third abundance in the oblique collection in both the pre- and post-monsoon. There were 2,623 individuals of larvae from 72 stations in the oblique hauls during the pre-monsoon cruise and 2,086 individuals of larvae from 60 stations in the obliques of the post-monsoon cruise. The most abundant in the obliques during the pre-monsoon cruise was 577.16 individuals per 1000 cubic metres and for the obliques in the post-monsoon cruise 2,029.82 individuals per 1000 cubic metres. The bregmaceros larvae occurred in the surface sampling when light intensity was limited as in the early morning, on cloudy days or during the night time.

Family Fistulariidae

The larvae of *Fistularia* sp. occurred in both the surface and oblique samples of the pre- and post-monsoon. There were 14 and 119 individuals from 9 and 45 stations in the surface and oblique samples in the pre-monsoon, while the post-monsoon period showed 6 and 93 individuals from 3 and 33 stations of the surface and oblique samples. They have the possibility to be a sub-surface or demersal species.

Family Syngnathidae

There were 2 genus of *Syngnathus* sp. and *Hippocampus* sp. occurring in the samples but only 1 specimen of *Hippocampus* sp. was obtained from station number 49 in the oblique hauls of the post-monsoon. The *Syngnathus* sp. occurred in both the surface and oblique samplings of the pre- and post-monsoon. There were 2 and 13 individuals from stations 2 and 11 of the surface and oblique hauls in the pre-monsoon. There were 33 individuals from 17 stations in the oblique hauls during the post-monsoon cruise.

Family Centriscidae

Only one species of *Centriscus scutatus* occurred in the oblique collection. There were 13 and 4 individuals from 13 and 4 stations of the pre- and post-monsoon cruise.

Family Holocentridae

The two genus of Holocentrid larvae occurring in the samples were *Holocentrus* sp. and *Myripristis* sp.

Holocentrus sp. showed 5 and 1 individuals from 4 and 1 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise provided 10 and 2 individuals from 8 and 1 stations in the surface and oblique hauls.

Myripristis sp. showed 3 and 2 individuals from 2 stations each from the surface and oblique hauls during the pre-monsoon cruise. The post-monsoon provided 4 and 1 individuals from 3 and 1 stations in the surface and oblique hauls.

Family Sphyraenidae

Only one genus of *Sphyraena* sp. occurred in the sampling from both the surface and oblique hauls in the pre- and post-monsoon cruise. There were 74 and 86 individuals of larvae from 27 and 26 stations in the surface and oblique hauls from the pre-monsoon cruise. The post-monsoon cruise showed 63 and 41 individuals from 15 and 19 stations in the surface and oblique samples.

Family Mugillidae

Eleven larvae of *Valamugil* sp. were collected from 6 stations of the surface hauls during the pre-monsoon cruise. They were observed to occur mostly at the coastal stations.

Family Ambassidae

larvae of *Ambassis* sp. occurred only in the surface hauls of both pre- and post- monsoon cruises. There were 45 and 33 individuals from 6 and 1 stations in the pre- and post-monsoon cruises.

Family Serranidae

There were 2 genus of serranid larvae occurring in the samples from both the surface and oblique hauls with the numbers in the oblique haul samples higher than surface hauls in both the pre- and post-monsoon cruise. For the surface hauls, *Epinephelus* sp. showed 5 and 1 individuals from 5 and 1 stations of the pre- and post-monsoon cruises. There were 16 and 2 individuals of *Serranus* sp. from 3 and 1 stations in the pre- and post-monsoon cruises. For the oblique samples, there were 72 and 48 individuals of *Epinephelus* sp. from 27 and 25 stations in the pre- and post-monsoon cruises, and for the *Serranus* sp. 36 and 12 individuals from 13 and 4 stations in the pre- and post-monsoon cruises.

Family Theraponidae

Only one species of *Therapon jarbua* occurred in both the surface and oblique specimens in the pre- and post-monsoon cruises. There were 330 and 52 individuals from 29 and 19 stations in the surface and oblique specimens in the pre-monsoon cruise. The post-monsoon provided 464 and 71 individuals from 44 and 11 stations for the surface and oblique specimens most of the larvae were collected from surface hauls.

Family Priacanthidae

There were 42 and 449 individuals of *Priacanthus tayenus* from 13 and 55 stations of the surface and oblique specimens from the pre-monsoon cruise. The post-monsoon sampling showed 13 and 212 individuals from 6 and 49 stations in the surface and oblique samples.

Family Apogonidae

There were at least 3 species of apogonid larvae occurring in the sampling of both surface and oblique hauls from the pre- and post-monsoon cruises. These were *Apogon lineatus*, *Apogon nigrofasciatus*, *Apogon* sp. and *Gymnopogon* sp. The occurrence of the *Apogon lineatus* on the pre-monsoon cruise was 19 and 634 individuals from and 65 stations in the surface and oblique specimens and the post-monsoon cruise showed 55 and 339 individuals from 10 and 54 stations in the surface and oblique samples. The *Apogon nigrofasciatus* showed 5 and 712 individuals from 4 and 36 stations of the surface and oblique hauls from the pre-monsoon cruise. The post-monsoon cruise showed 43 and 162 individuals from 5 and 21 stations in the surface and oblique hauls *Apogon* sp. and *Gymnopogon* sp. showed the same pattern of abundance and distribution, while the oblique specimens showed a wider distribution and more abundance than the surface specimens.

Family Sillaginidae

Sillago sp. occurred in the oblique sampling of both pre and post-monsoon but were collected only in the surface haul in the post-monsoon . There were 35 and 17 individuals from 4 and 5 stations of the oblique samples from the pre- and post-monsoon cruises while there were 52 individuals from station number 1 in the surface sampling from the post-monsoon.

Family Coryphaenidae

The specimens were *Coryphaena hippurus*. There were 3 and 2 individuals from 5 stations occurring in both surface and oblique collection of the pre- and post-monsoon cruises.

Family Carangidae

Carangid is a large group of larvae comprising the *Decapterus* sp., *Selar crumenophthalmus*, *Caranx leptolepis*, *Caranx mate*, *Caranx speciosus*, *Caranx* sp., *Scomberoides lysan* and *Zonichthys nigrofasciata.*

Decapterus sp. were obtained from both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 257 and 765 individuals from 31 and 53 stations in the surface and oblique specimens of the pre-monsoon cruise. The post-monsoon cruise showed 341 and 629 individuals from 38 and 54 stations in the surface and oblique specimens from the post-monsoon cruise.

Selar crumenophthalmus occurred in both the surface and oblique specimens of the pre and post-monsoon cruises. There were 4 and 171 individuals from 2 and 18 stations inthe surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 1 and 65 individuals from 1 and 7 stations in the surface and oblique samples.

Caranx leptolepis showed 87 and 415 individuals from 15 and 39 stations of the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 64 and 213 individuals from 4 and 18 stations of the surface and oblique collection from the post-monsoon cruise.

Caranx mate was collected in both the surface and oblique sampling of the pre- and post-monsoon cruises. There were 574 and 191 individuals from 19 and 28 stations in the surface and oblique hauls of the pre-monsoon cruise. For the post-monsoon cruise, there were 16 and 10 individuals from 6 and 5 stations in the surface and oblique specimens.

Caranx speciosus showed 21 and 89 individuals from 15 and 21 stations of the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise provided 23 and 38 individuals from 16 and 12 stations in the surface and oblique specimens.

Caranx sp. showed 94 and 923 individuals from 33 and 45 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 33 and 234 individuals from 13 and 12 stations in the surface and oblique hauls.

Scomberoides lysan showed 20 and 3 individuals from 9 and 7 stations of the surface and oblique hauls in the pre-monsoon cruise. The post-monsoon cruise provided 34 and 1 individuals from 12 and 1 stations in the surface and oblique specimens.

Zonichthys nigrofasciata showed 9 and 10 individuals from 7 and 6 stations in the surface and oblique specimens in the pre-monsoon cruise. The post-monsoon cruise provided 29 individuals from 18 stations in the surface collection.

Family Meneidae

There is only one species of moon fish in the world. *Mene maculata* which occurred in both the pre- and post-monsoon. There were 13 and 38 individuals from 1 and 10 stations in the surface and oblique hauls in the pre-monsoon. The post-monsoon showed only 1 individual from 1 station in the oblique hauls.

Family Lutjanidae

Lutjanus sp. occurred in both the surface and oblique samples in the pre- and post-monsoon cruises. There were 60 and 561 individuals from 16 and 54 stations in the surface and oblique specimens of the pre-monsoon. For the post-monsoon, there were 52 and 330 individuals from 12 and 60 stations in the surface and oblique specimens occurring in the samples.

Family Nemipteridae

Nemipterus sp. was the fourth most abundant fish larvae in the oblique sampling. There were 213 and 1763 individuals from 28 and 73 stations in the surface and oblique sampling in the pre-monsoon cruise. The post-monsoon cruise showed 129 and 2,007 individuals from 20 and 58 stations in the surface and oblique sampling.

Family Gerreidae

Gerres sp. occurred in both the surface and oblique hauls of the pre- and post- monsoon cruises. There were 333 and 221 individuals from 32 and 23 stations of the surface and oblique hauls of the pre-monsoon. The post-monsoon showed 281 and 186 individuals from 27 and 24 stations in the surface and oblique sampling.

Family Lobotidae

Lobotes surinamensis is of only one species in the world and there was only one specimen occurring at one station in the surface collection of the post-monsoon cruise.

Family Leiognathidae

Leiognathus sp. occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 186 and 1,660 individuals from 22 and 66 stations of the surface and oblique hauls of the pre-monsoon. The post-monsoon showed 26 and 609 individuals from 10 and 62 stations in the surface and oblique collection.

Family Pomadasyidae

The genus *Plectorhynchus* occurred in both surface and oblique hauls of the pre- and post-monsoon. There were 4 and 283 individuals from 2 and 41 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 36 and 52 individuals from 3 and 24 stations in the surface and oblique specimens.

Family Lethrinidae

Lethrinus sp. showed 7 and 36 individuals from 5 and 21 stations of the surface and oblique hauls of the pre-monsoon cruise. For the post-monsoon cruise, 11 and 14 individuals from 5 and 8 stations in the surface and oblique collection.

Family Sparidae

Acanthopagrus sp. was identified from the family Sparidae. There were 47 and 218 individuals from 4 and 21 stations in the surface and oblique collection of the pre- monsoon cruise. For the post-monsoon cruise, 2 individuals from 1 station in the oblique collection were identified.

Family Sciaenidae

The larvae of *Sciaena* sp. were obtained from the surface and oblique hauls of the pre- and post-monsoon cruises. There were 1 and 22 individuals from 1 and 11 stations of the surface and oblique hauls in the pre-monsoon cruise. There were 5 and 22 individuals from 3 and 7 stations of the surface and oblique hauls in the post-monsoon cruise.

Family Mullidae

The larvae in this family, *Upeneus* sp., was the fourth most abundant in the surface collection for the pre- and post-monsoon cruises. There were 956 and 648 individuals from 54 and 35 stations of the surface and oblique hauls in the pre-monsoon cruise. For the post- monsoon cruise, 525 and 139 individuals from 56 and 18 stations in the surface and oblique hauls.

Family Ephippidae

Platax tiara was identified from the surface and oblique hauls of the pre- monsoon cruise. There were 10 and 12 individuals from 2 and 6 stations in the surface and oblique collections.

Family Depranidae

Depane sp. was obtained from the surface and oblique hauls of the pre- monsoon cruise, but for the post-monsoon cruise it was obtained only from the oblique hauls. There were 2 and 14 individuals from 1 and 5 stations of the surface and oblique hauls of the pre-monsoon. There were 26 individuals from 9 stations of the oblique hauls in the post- monsoon cruise.

Family Kryphosidae

Kryphosus sp. was obtained only from the surface hauls of the pre- and post- monsoon cruises. There were 14 and 1 individuals from 3 and 1 stations in the surface hauls of the pre- and post-monsoon cruise.

Family Chaetodontidae

Chaetodon sp. was obtained from the surface hauls of the pre- and post- monsoon cruises. There were 1 and 2 individuals from 1 station each in the surface collection of pre and post-monsoon cruises.

Family Cepolidae

Acanthocepola sp. was obtained from both surface and oblique hauls of the pre and post-monsoon cruises but the oblique hauls showed more abundance than the surface hauls. There were 2 and

58 individuals from 2 and 23 stations in the surface and oblique hauls of the pre-monsoon cruise. For the post-monsoon cruise, there were 3 and 37 individuals from 2 and 14 stations in the surface and oblique hauls.

Family Pomacentridae

There were 3 genera of pomacentrid larvae occurring among these specimens. These were *Pomacentrus* , *Chromis and Abudefduf. Pomacentrus* larvae were obtained only from the surface hauls of the pre-monsoon cruise. There were 29 individuals from 7 stations. *Chromis* larvae occurred in both surface and oblique hauls of the pre-monsoon , there were 20 and 8 individuals from 7 and 4 stations in the samples. *Abudefduf* larvae were obtained only from the surface hauls of the pre-monsoon cruise, there were 3 specimens from 3 stations.

Family Plesiopidae

Plesiops sp. occurred only in the surface hauls of the pre-monsoon cruise. There were 4 individuals from only 1 station.

Family Labridae

Halichores larvae occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 66 and 318 individuals from 7 and 53 stations in the surface and oblique hauls of the pre-monsoon cruise. For the post-monsoon cruise, there were 6 and 186 individuals from 1 and 52 stations in the surface and oblique hauls.

Family Uranoscopidae

Uranoscopus sp. occurred only in the oblique hauls of the pre- and post- monsoon. There were 26 and 4 individuals from 10 and 2 stations of the pre- and post-monsoon cruises.

Family Champsodontidae

The larvae were *Champsodon* sp. There were 7 and 136 individuals from 3 and 40 stations in the surface and oblique hauls of the pre-monsoon cruise. There were 31 and 66 individuals from 11 and 19 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon showed 7 and 21 individuals from 7 and 14 stations in the surface and oblique haul samples.

Family Blenniidae

Blenneus sp. larvae occurred in both the surface and oblique hauls of pre- and post-monsoon cruises. There were 31 and 66 individuals from 11 and 19 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon showed 7 and 21 individuals from 7 and 14 stations in the surface and oblique haul samples.

Family Brotulidae

Brotulus sp. occurred in both the surface and oblique hauls of the pre-monsoon cruise but for the post-monsoon cruise, the occurrence was only in the oblique haul samples. There were 7 and 47 individuals from 2 and 20 stations in the surface and oblique hauls of the pre-monsoon cruise. The oblique hauls of the post-monsoon showed 11 individuals from 5 stations.

Family Carapidae

Carapus sp. larvae occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 3 and 6 individuals from 2 and 5 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon showed 5 and 7 individuals from 5 and 7 stations in the surface and oblique haul samples.

Family Callionymidae

Callionymus sp. was the fifth most abundant larvae of the oblique haul samples and occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 46 and 665 individuals from 18 and 58 stations in the surface and oblique hauls of pre- monsoon cruise. The post-monsoon showed 73 and 1,141 individuals from 9 and 67 stations in the surface and oblique sampling.

Family Siganidae

Siganus sp. showed only 1 individual from 1 station in the surface hauls of the pre-monsoon and 22 individuals from 7 stations in the oblique hauls of the post-monsoon cruise.

Family Histiophoridae

Histiophorus sp. larvae were obtained only from the surface hauls of both the pre-and post-monsoon cruises. There was 1 individual from 1 station in the pre-monsoon cruise and 13 individuals from 6 stations in the post-monsoon cruise

Family Scombridae

There were 3 genera of Scombrid larvae occurring in this area. These were *Rastrelliger*, *Scomberomorus* and *Euthynus*. *Rastrelliger* sp. occurred in both the surface and oblique hauls of the pre-monsoon cruise.

Rastrelliger sp. showed 163 and 365 individuals from 10 and 22 stations of the surface and oblique hauls of the pre-monsoon. For the post-monsoon cruise, there were 109 individuals from 8 stations in the oblique hauls.

Scomberomorus sp. occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 141 and 96 individuals from 26 and 20 stations of the surface and oblique hauls of the pre-monsoon cruise. For the post-monsoon cruise, there were 39 and 5 individuals from 14 and 3 stations in the surface oblique haul samples.

Euthymus sp. occurred only in the pre-monsoon cruise in both the surface and oblique hauls. There were 1 and 246 individuals from 1 and 27 stations occurring in the samples.

Family Trichiuridae

Trichiurus lepterus occurred in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 6 and 115 individuals from 5 and 34 stations of surface and oblique hauls in the pre-monsoon cruise, The post-monsoon cruise showed 1 and 40 individuals from 1 and 17 stations in the surface and oblique haul samples.

Family Schneideriidae

Schneideria sp. occurred in both the surface and oblique hauls of the pre- and post- monsoon cruises. There were 18 and 98 individuals from 4 and 9 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 9 and 121 individuals from 1 and 17 stations in the surface and oblique haul samples.

Family Typaucheniidae

Typanchen sp. occurred in both the surface and oblique hauls of the pre- and post- monsoon cruises. There were 220 and 71 individuals from 21 and 22 stations of the surface and oblique hauls during the pre-monsoon cruise. The post-monsoon cruise showed 19 and 53 individuals from 9 and 8 stations in the surface and oblique haul samples.

Family Gobiidae

Gobiidae was the only family identified to the family level, being the most abundant larvae in the oblique hauls of both the pre- and post-monsoon cruises. There were 1314 and 8377 individuals from 42 and 74 stations in the surface and oblique hauls of the pre -monsoon. The post-monsoon showed 1207 and 8653 individuals from 49 and 76 stations in the surface and oblique haul samples.

Family Platycephalidae

Platycephalus sp. was obtained from the surface and oblique hauls of the pre- monsoon. There were 5 and 141 individuals from 5 and 19 stations. For the post-monsoon cruise, there were 61 individuals from 15 stations in the oblique haul samples.

Family Scorpaenidae

There were 2 genera of scorpaenid larvae occurring in both the surface and oblique hauls of the pre- and post-monsoon cruise. These were the *Minous* sp. and *Scorpaenoides* sp.

Minous sp. showed 14 and 117 individuals from 5 and 49 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 9 and 92 individuals from 4 and 31 stations in the surface and oblique samples.

Scorpanoides sp. showed 17 and 45 individuals from 11 and 24 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 1 and 20 individuals from 1 and 13 stations in the surface and oblique haul samples.

Family Triglidae

Lepidotrigla sp. was identified as from the family Triglidae. There were 4 and 54 individuals from 3 and 24 stations in the surface and oblique hauls in the pre-monsoon cruise. The post-monsoon cruise showed only 1 individual from 1 station oblique haul.

Family Dactylopteridae

Dactylopterus sp. was identified from the family Dactylopteridae. There were 1 and 3 individuals from 1 and 3 stations in the surface and oblique hauls in the pre-monsoon cruise. The post-monsoon cruise showed 14 individuals from 6 stations in the surface samples.

Family Psettodidae

Psettodes erumei was obtained from the oblique hauls of the pre-monsoon cruise. There were 15 individuals from 4 stations.

Family Paralichthyidae

Pseudorhombus sp. was obtained from both the surface and oblique hauls of pre- and post-monsoon cruises. There were 4 and 75 individuals from 1 and 18 stations in the surface and oblique hauls of pre-monsoon cruise. The post-monsoon cruise showed1 and 51 individuals from 1 and 16 stations in the surface and oblique haul samples.

Family Soleidae

Aserraggodes sp. were identified from solea larvae. There were 2 and 44 individuals from 2 and 17 stations in the surface and oblique hauls of the pre-monsoon cruise.The post-monsoon showed 3 and 22 individuals from 3 and 8 stations in the surface and oblique hauls.

Family Bothidae

There were 3 genera of bothid larvae occurring in both the surface and oblique hauls of the pre- and post-monsoon cruises. These 3 genera were *Bothus*, *Engyprosopon* and *Arnoglossus.*

Bothus sp. showed 106 and 275 individuals from 22 and 35 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 2 and 70 individuals from 2 and 4 stations in the surface and oblique haul samples.

Engyprosopon sp. was the seventh in abundance of the oblique haul of the post- monsoon cruise. There were 10 and 753 individuals from 3 and 63 stations in the surface and oblique hauls in the pre-monsoon cruise. The post-monsoon cruise showed 73 and 1,020 individuals from 17 and 75 stations in the surface and oblique haul samples.

Arnoglossus sp. was 1 and 135 individuals from 1 and 37 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 6 and 32 individuals from 1 and 12 stations in the surface and oblique haul samples.

Family Cynoglossidae

Cynoglossus was obtained from both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 28 and 249 individuals from 16 and 59 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 19 and 177 individuals from 13 and 49 stations in the surface and oblique haul samples.

Family Cithacidae

Brachypleura novaezeelandiae was the only species identified from the family Cithacidae. There were 4 and 97 individuals from 3 and 27 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed only 1 individual from 1 station in the oblique haul.

Family Echeneidae

Echeneus sp. was obtained from the surface and oblique hauls of the pre-monsoon cruise. Threr were 2 and 30 individuals from 2 and 6 stations in the surface and oblique haul samples.

Family Tetraodontidae

Tetraodon sp. was obtained in both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 1 and 158 individuals from 1 and 45 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 2 and 188 individuals from 2 and 56 stations in the surface and oblique haul samples.

Family Diodontidae

Diodon sp. was obtained from both the surface and oblique haul in the pre- and post-monsoon cruises. There were 11 and 4 individuals from 7 and 1 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 4 and 2 individuals from 2 and 1 stations in the surface and oblique haul samples.

Family Balistidae

Balistes sp. was obtained from both the surface and oblique hauls of the pre- and post-monsoon cruises. There were 28 and 6 individuals from 8 and 6 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise were 1 station each of the surface and oblique haul samples.

Family Monacanthidae

There were 2 genera occurring in these samples.

Monacanthus sp. was obtained from both the surface and oblique hauls in the pre- and post-monsoon cruises. It was the sixth in abundance of the oblique haul samples in the pre-monsoon cruise. There were 63 and 1,122 individuals from 15 and 58 stations in the surface and oblique hauls of the pre-monsoon cruise. The post-monsoon cruise showed 13 and 263 individuals from 10 and 37 stations in the surface and oblique haul samples.

Aluterus sp. showed 14 individuals from 6 stations in the surface hauls of the pre-monsoon cruise and 2 individuals from 1 station in the oblique hauls of the post-monsoon cruise.

Leptocephalus sp. The eel larvae were sorted out from the sample but were not identified to the family or genus because of time constraints.

Discussion

Fish larvae in The Gulf of Thailand and on the east coast of Peninsular Malaysia were studied for their kinds, abundance and distribution in the surface and oblique sampling. There were 73 families and 97 species of fish larvae occurring in the Gulf of Thailand and on the east coast of Peninsular Malaysia. This showed more families than the study of Vatanachai (1972) conducted in the South China Sea, and it is also greater than those in the studies of Chamchang (1986), Songchitsawat (1989), Chansakul (1988) and Termvidchakon (1985) conducted in the Gulf of Thailand. *Stolephorus* sp. was the most abundant larvae in the surface sampling and the second most abundant in the oblique sampling similar to the study of Vatanachai (1972), Chamchang (1986), Songchitsawat (1989) showed Engraulidae as the most economically abundant family and Clupeidae as the second most abundant. Gobiidae was the most abundant in the oblique sampling. Vatanachai (1972), Chamchang (1986), Songchitsawat (1989), Chansakul (1988), Termvidchakorn (1985) showed Gobiidae as the most abundant larvae in their studies in the Gulf of Thailand in both the coastal and deeper areas. There were some larvae that showed occurrence or abundance in the oblique sampling of the early morning, night time or cloudy days and some of these larvae also occurred, and were more abundant, in the surface sampling due to phototaxis activities.

There was no difference between the species composition of larvae in the Gulf of Thailand and on the east coast of Peninsular Malaysia. Similar types of larvae were obtained on the east coast of Peninsular Malaysia. Coastal areas near islands showed more abundance than the offshore stations.

The pelagic and demersal characters of larvae were shown from their abundance and distribution in the surface and oblique sampling.

Larvae which showed pelagic characteristics were *Sardinella* sp., *Dussumieria* sp., *Stolephorus* sp., *Hemiramphus* sp., *Exocoetus* sp., *Cypselurus* sp., *Sphyraena* sp., *Ambassis* sp., *Therapon jarbua*, *Caranx mate*, *Gerres* sp., *Histiophorus* sp. *and Scomberomorus* sp.

The demersal of larvae observed were *Saurida elongata*, *Saurida emdosquamis*, *Synodus variegatus*, *Trachinocephalus myops*, *Antennarius* sp., *Bregmaceros rarisquamosus*, *Fistularia* sp., *Holocentrus* sp., *Myripristis* sp., *Epinephelus* sp., *Serranus* sp., *Priacanthus* sp., Apogonidae, *Lutjanus* sp., *Nemipterus* sp., *Leiognathus* sp., *Acanthocepola* sp., *Upeneus* sp., *Blenneus* sp., *Callionymus* sp., *Rastrelliger* sp., *Euthynus* sp., *Trichiurus lepturus*, Gobiidae, *Pseudorhombus* sp., *Aserraggodes* sp., *Bothus* sp., *Engyprosopon* sp., *Arnoglossus* sp., *Cynoglossus* sp., *Tetraodon* sp., *Balistes* sp., and *Monacanthus* sp.

The abundance of *Sardinella* sp., *Stolephorus* sp., etc. (Table 10) between the pre- and post-monsoon showed spawning peaks in the post-monsoon period.

There were differences in the abundance of fish larvae in the surface and oblique haul samples. The early morning, night and "cloudy" stations showed that larvae from the surface hauls were more abundant than the oblique hauls due to positive phototaxis activity and larvae from the day time, the oblique haul specimens were more abundant due to negative phototaxis and their demersal characteristics.

Histiophorus sp. showed true pelagic characteristics from its occurrence only in the surface hauls while species that showed demersal characteristics from their occurrence in the oblique specimens were *Lutjanus* sp., *Nemipterus* sp., *Acanthocepola* sp. and *Engyprosopon* sp.

This study showed the occurrence and abundance of the fish larvae the coastal areas or around the islands are greater than those in the deeper or open sea.

Conclusion

1) Species composition of fish larvae in the Gulf of Thailand and East Coast of Pen insular Malaysia was the same.
2) Fish larvae found in abundance from the surface hauls of the pre- and post-mon

soon were *Stolephorus* sp., *Sardinella* sp., Gobiidae and *Upeneus* sp., respectively. For the oblique hauls these were Gobiidae, *Stolephorus* sp., *Bregmaceros risquamosus* and *Nemipterus* sp., respectively.

3) The difference in the abundance of larvae between the pre and post northeast mon soon period indicates the spawning period and spawning peak.

4) The day - night catch of larvae was different because of phototaxis and their other living characters.

5) In the shallow or coastal areas around the island, the larvae were more abundant than the deeper waters or open sea.

Acknowledgements

I am grateful to Dr. Maitree Duangsawasdi, for his encoragement and valuable suggestions. Sincere appreciation is expressed to the Captain, crew and scientists on M.V. SEAFDEC for their cooperation at sea. Many thanks are due to the SEAFDEC staff who have supported this work.

References

Chamchang, c. 1986. Kinds and distribution of the economic important pelagic fish larvae in the west coast of the Gulf of Thailand from Surat thani to Narathivas. Master thesis Department of Marine Science. Faculty of Science. Chulalongkorn University 165 p.

Chansakul, V. 1988. Kinds and distribution of the fish larvae in Rayong Bay, Rayong Province. Master Thesis Department of Marine Science, Faculty of Science, Chulalongkorn University 148 p.

Delsman, H.C. 1922. Fish eggs and larvae from the Java sea. 2. *Chirocentrus dorab* (Forsk). *Treubia*, 3: 38-46.

Delsman, H.C. 1925. Fish eggs and larvae from the Java sea. 4. *Dussumieria hasseltii*, Blkr. *Treubia*, 6: 297-307.

Delsman, H.C. 1926. Fish eggs and larvae from the Java sea. 7. The genus *Clupia. Treubia*, 8: 218-239.

Delsman, H.C. 1930. Fish eggs and larvae from the Java sea. 12. The genus *Engraulis*. *Treubia*, 11: 275-281.

Delsman, H.C. 1932. Fish eggs and larvae from the Java sea. 19. The genus *Setipinna.Treubia*, 14: 109-114.

Delsman, H.C. 1933. Fish eggs and larvae from the Java sea. 23. A few more *Clupea* eggs. *Treubia*, 14: 249-254.

Delsman, H.C. 1938. Fish eggs and larvae from the Java sea. 24. *Myctophoidea*. *Treubia*, 16: 415-420.

Leis, J.M. and D.S. Renms. 1983. The larvae of Indo-Pacific coral reef fishes. New South Wales. Univ. Press Australia 2691 p.

Leis, J.M. and T. Transki. 1989. The larvae of Indo-Pacific shore fishes. New South Wales. Univ. Press Australia 371 p.

Moser, H.G. (ed). 1983. Ontogeny and systematics of fishes special Publication Number 1. American Society of Ichthyologists and Herpetologists. Allen Press Inc. KS. USA. 760 p.

Okiyama, M. 1988. An atlas of the early life stage fishes in Japan. Tokai Univ. Press. 1154 p.

Sidthichokpan, S. 1972. Studied on the spawning season and area of the Anchovy (Stolephorus sp.) in the west coast of the Gulf of Thailand between 1978 and 1979. Report of the pelagic fisheries Marine Fisheries Research Laboratory Division p.47- 93.

Songcitsawat, A. 1898. Identification, abundance and distribution of fish larvae of the Chang Island, Trat Province. Master Thesis, Chulalongkorn University, Bangkok Thailand.

Termvidchakorn., A. 1987. Kinds and abundance of the fish larvae in the Andaman Sea. Exploratory Division Report 28 p.

Vatanachai, S. 1972. The identification of fish eggs and fish larvae obtained from the servery cruise in the South China Sea. Third symeposium on marine fisheries, Marine Laboratory. M.F 272-10 p. 1-27.

Vatanachai, S. 1978. The abundance and distribution of the fish larvae in the upper part of the Gulf of Thailand in the year 1975-1976. Marine Laboratory Report No. 15. 40 p.

Distribution, Abundance and Composition of Zooplankton in the South China Sea, Area I :Gulf of Thailand and East Coast of Peninsular Malaysia

Jutamas Jivaluk

Department of Fisheries, Chatuchak, Bangkok 10900, Thailand

ABSTRACT

The sample of 81 stations in the Gulf of Thailand and the East Coast of Peninsular Malaysia were collected by M.V.SEAFDEC on 4 September - 4 October 1995 for the pre northeast monsoon period and on 23 April - 23 May 1996 for the post-northeast monsoon period. 34 groups of zooplankton were found in this study. Copepod was the most abundant in both period followed by Chaetognatha in pre-monsoon and Ostracod in post-monsoon. Biomass and abundance vary from 0.069 - 20.172 ml/m^3 and 36 - 3,413 no/m^3 in pre-monsoon and 0.18 - 2.589 ml/m^3 and 91-1,514 no/m^3 in post-monsoon respectively. There was significant difference for abundance between pre and post-monsoon period (at 95 % level). But there was no significant difference between biomass for both period.

Key words: zooplankton, the Gulf of Thailand, Peninsular Malaysia

Introduction

Marine zooplankton serve a key role in the food chains of the sea as they transfer energy from the phytoplankton to higher tropic levels. In the context of fisheries biology, the transfer of energy to the fish stocks is of particular interest, especially during the first weeks in the life of the fish, as the survival of the larvae. Previous investigations of zooplankton in the Gulf of Thailand have been done since 1926. Many papers concerned the seasonal abundance and distribution of zooplankton in the Gulf of Thailand were based on the results of the NAGA Expedition during 1959-1961 (Brinton 1963, Suvapepun, 1977: Suwanrumpha, 1980[a] and Suvapepun, 1980). Few studies have been made on copepod (Suvapepun and Suwanrumpha, 1969: Suwanrumpha, 1980[b]), salps (Suwanrumpha, 1995), fish larvae (Chayakul, 1990), shrimp larvae (Tubtimsang, 1981[a]) and invertebrate larvae (Tubtimsang, 1981[b]). However, at least 238 species of zooplankton have been record in this region (Suvapepun, 1981).

The propose of the present investigation is to describe the zooplankton community in the gulf of Thailand and Malaysia, and provide an estimation of abundance, composition, biomass and their distribution.

Methods

The sample of 81 stations in the Gulf of Thailand and the East Coast of Peninsular Malaysia were collected by M.V.SEAFDEC on 4 September - 4 October 1995 for the pre monsoon period and on 23 April - 23 May 1996 for the post-monsoon period. Station no. 27 was omitted (Table 1 and Figure 1). The oblique tow was made from the surface to ~5 m above the bottom with 0.03 mm bongo net fitted with the mouth flow-meter. The sampling time was approximately 30 minutes with the ship speed was about 2 knots. The samples were preserved in 10 % buffered formalin-seawater immediately. In the laboratory, the displacement volume of total zooplankton was measured after large gelatinous zooplankton had been removed. The samples were sub-sampled with Folsom Plankton Splitter and then counted to taxon. Data on biomass and abundance were standardized per cubic meter.

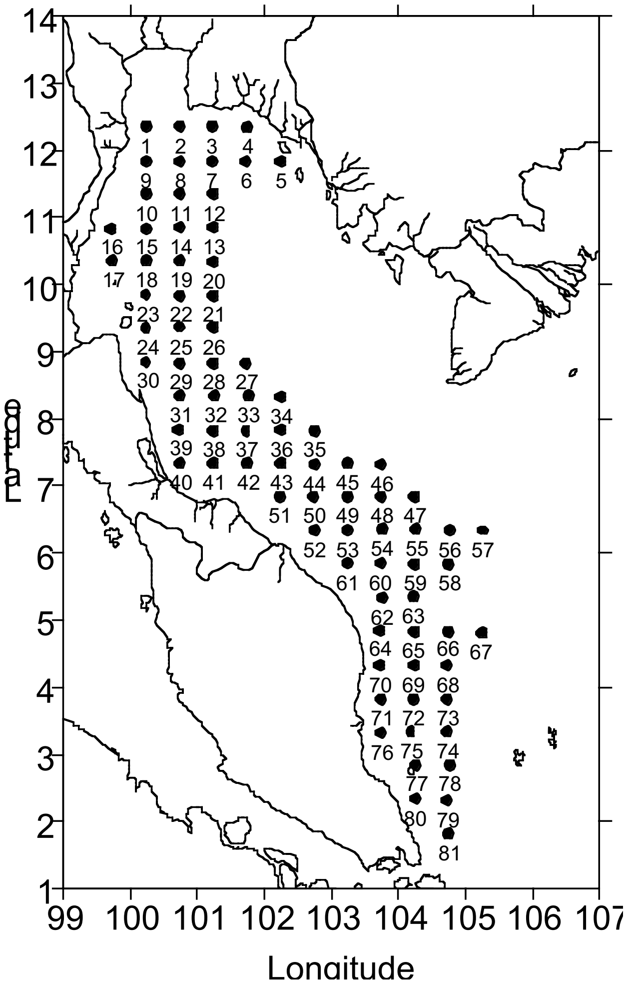


Fig. 1. Area and stations of collaborative research survey in the Gulf of Thailand and the east coast of Peninsular Malaysia

Results

Biomass and abundance of total zooplankton

Pre-monsoon period

Biomass and abundance of total zooplankton were showed in Fig. 2 and 4. Biomass vary from 0.069-20.172 ml/m^3 which station 42 (near Pattani bay) has the highest biomass. Abundance vary from 36 - 3,413 no/m^3 which station 42 (near Pattani bay) has the highest abundance.

Post-monsoon period

Biomass and abundance of total zooplankton were showed in Fig. 3 and 5. Biomass vary from 0.18 - 2.589 ml/m^3 which station 24 (near Ko Samui) has the highest biomass. Abundance vary from 91 - 1514 no/m^3 which station 2 (near Amphor Sattahip) has the highest abundance. It is obvious that the abundance was high in the upper part of the Gulf of Thailand, near Ko Samui and the lower part of Peninsular Malaysia.

In post-monsoon period, there were 49 stations (61.25 %) which increase in biomass while 29 stations (36.25 %) were decrease and 2 stations (2.5 %) were constant (Table 2 and 4). For abundance, in post-monsoon period, there were 60 stations (75 %) which increase in abundance while 11 stations (13.75 %) were decrease and 9 stations (11.25 %) were constant (Table 3 and 4).

T-test (Table 5) shows the significant difference for abundance between pre and post-monsoon

Table 1. Information of the stations in the study areas.

Stn. No.	Pre-NE monsoon		Post-NE monsoon		Position		Depth (m)
	Date	Time	Date	Time	Latitude	Longitude	
1	5/9/95	0609-0617	24/4/96	0810-0823	12-20 N	100-15 E	31
2	5/9/95	1048-1055	24/4/96	1149-1210	12-20 N	100-45 E	29
3	5/9/95	1511-1526	24/4/96	1616-1628	12-20 N	101-15 E	31
4	5/9/95	1912-1228	24/4/96	2100-2125	12-20 N	101-45 E	27
5	6/9/95	0559-0617	25/4/96	0600-0628	11-50 N	102-15 E	30
6	6/9/95	1026-1047	25/4/96	1023-1052	11-50 N	101-45 E	47
7	6/9/95	1436-1458	25/4/96	1507-1538	11-50 N	101-15 E	45
8	6/9/95	1840-1859	25/4/96	1933-2000	11-50 N	100-45 E	40
9	7/9/95	0606-0627	26/4/96	0557-0622	11-50 N	100-15 E	37
10	7/9/95	1022-1043	26/4/96	1026-1056	11-20 N	100-15 E	50
11	7/9/95	1425-1453	26/4/96	1456-1524	11-20 N	100-45 E	52
12	7/9/95	1837-1858	26/4/96	1926-1955	11-20 N	101-15 E	60
13	8/9/95	0559-0632	27/4/96	0623-0632	10-50 N	101-15 E	65
14	8/9/95	1228-1157	27/4/96	1042-1112	10-50 N	100-45 E	60
15	8/9/95	1631-1700	27/4/96	1532-1603	10-50 N	100-15 E	55
16	8/9/95	2051-2118	27/4/96	2002-2032	10-50 N	099-45 E	50
17	9/9/95	0555-0628	28/4/96	0557-0626	10-20 N	099-45 E	48
18	9/9/95	1116-1143	28/4/96	1010-1040	10-20 N	100-15 E	55
19	9/9/95	1557-1620	28/4/96	1439-1507	10-20 N	100-45 E	60
20	9/9/95	2015-2042	28/4/96	1853-1922	10-20 N	101-15 E	65
21	10/9/95	0557-0625	29/4/96	0557-0628	09-50 N	101-15 E	70
22	10/9/95	1010-1038	29/4/96	1021-1050	09-50 N	100-45 E	60
23	10/9/95	1431-1455	29/4/96	1436-1504	09-50 N	100-15 E	35
24	10/9/95	1847-1909	29/4/96	1842-1913	09-20 N	100-15 E	30
25	12/9/95	0600-0625	1/5/96	0555-0623	09-20 N	100-45 E	37
26	12/9/95	1036-1110	1/5/96	1028-1057	09-20 N	101-15 E	65
27	-	-	2/5/96	2145-2215	08-50 N	101-45 E	75
28	12/09/95	1517-1550	1/5/96	1508-1532	08-50 N	101-15 E	59
29	12/09/95	1950-2015	1/5/96	2027-2057	08-50 N	100-45 E	32
30	13/9/95	0557-0613	2/5/96	0555-0624	08-50 N	100-15 E	25
31	13/9/95	1139-1201	2/5/96	1116-1145	08-20 N	100-45 E	29
32	13/9/95	1539-1604	2/5/95	1519-1547	08-20 N	101-15 E	55
33	13/9/95	2002-2027	3/5/96	0551-0622	08-20 N	101-45 E	70
34	14/9/95	0548-0622	3/5/96	1014-1043	08-20 N	102-15 E	78
35	14/9/95	1207-1240	3/5/96	1558-1625	07-50 N	102-45 E	72
36	14/9/95	1651-1717	3/5/96	2006-2035	07-50 N	102-15 E	73
37	14/9/95	2116-2143	4/5/96	0553-0622	07-50 N	101-45 E	57
38	15/9/95	0600-0626	4/5/96	1017-1046	07-50 N	101-15 E	50
39	15/9/95	1022-1034	4/5/96	1427-1451	07-50 N	100-45 E	28
40	15/9/95	1419-1438	4/5/96	1835-1853	07-20 N	100-45 E	22
41	15/9/95	1823-1852	6/5/96	0542-0611	07-20 N	101-15 E	42
42	17/9/95	0903-0930	6/5/96	1001-1030	07-20 N	101-45 E	50
43	17/9/95	1329-1357	6/5/96	1423-1441	07-20 N	102-15 E	52
44	17/9/95	1744-1816	6/5/96	1835-1905	07-20 N	102-45 E	55
45	18/9/95	0600-0625	7/5/96	0541-0611	07-20 N	103-15 E	56
46	18/9/95	1046-1113	7/5/96	1010-1039	07-20 N	103-15 E	53
47	18/9/95	1622-1648	7/5/96	1530-1600	06-50 N	104-15 E	58
48	18/9/95	2249-2318	7/5/96	1952-2020	06-50 N	103-45 E	57
49	19/9/95	0554-0623	8/5/96	0540-0608	06-50 N	103-15 E	55
50	19/9/95	1047-1109	8/5/96	1030-1100	06-50 N	102-45 E	51
51	19/9/95	1502-1528	8/5/96	1451-1521	06-50 N	102-15 E	49
52	19/9/95	2044-2107	8/5/96	2025-2055	06-20 N	102-45 E	39
53	20/9/95	0558-0625	9/5/96	0540-0610	06-20 N	103-15 E	35
54	20/9/95	1028-1056	9/5/96	0959-1027	06-20 N	103-45 E	62
55	20/9/95	1458-1528	9/5/96	1417-1446	06-20 N	104-15 E	62
56	20/9/95	1925-1958	9/5/96	1836-1904	06-20 N	104-45 E	61
57	21/9/95	0545-0613	10/5/96	0529-0600	06-20 N	105-15 E	60
58	21/9/95	1119-1147	10/5/96	1107-1135	05-50 N	104-45 E	62
59	21/9/95	1543-1611	10/5/96	1523-1551	05-50 N	104-15 E	66
60	21/9/95	2016-2043	10/5/96	1953-2022	05-50 N	103-45 E	57
61	23/9/95	0552-0617	12/5/96	0607-0637	05-50 N	103-15 E	50
62	23/9/95	1208-1234	12/5/96	1142-1211	05-20 N	103-45 E	61
63	23/9/95	1627-1654	12/5/96	1609-1638	05-20 N	104-15 E	65
64	23/9/95	2221-2245	12/5/96	2152-2222	04-50 N	103-45 E	60
65	24/9/95	0849-0918	13/5/96	0925-0955	04-50 N	104-15 E	65
66	24/9/95	1314-1444	13/5/96	1338-1408	04-50 N	104-45 E	72
67	24/9/95	1742-1813	13/5/96	1752-1822	04-50 N	105-15 E	76
68	25/9/95	0548-0618	14/5/96	0544-0612	04-20 N	104-45 E	73
69	25/9/95	1019-1046	14/5/96	1025-1053	04-20 N	104-15 E	67
70	25/9/95	1436-1501	14/5/96	1445-1513	04-20 N	103-45 E	40
71	25/9/95	1915-1930	14/5/96	1904-1932	03-50 N	103-45 E	34
72	26/9/95	0544-0611	15/5/96	0539-0609	03-50 N	104-15 E	53
73	26/9/95	1014-1044	15/5/96	0952-1021	03-50 N	104-45 E	73
74	26/9/95	1433-1502	15/5/96	1416-1444	03-20 N	104-45 E	68
75	26/9/95	1849-1915	15/5/96	1827-1854	03-20 N	104-15 E	53
76	27/9/95	0545-0602	16/5/96	0541-0603	03-20 N	103-45 E	27
77	27/9/95	1054-1120	16/5/96	1139-1209	02-50 N	104-15 E	46
78	27/9/95	1511-1534	16/5/96	1557-1627	02-50 N	104-45 E	65
79	27/9/95	1934-2000	16/5/96	2018-2047	02-20 N	104-45 E	60
80	28/9/95	0515-0542	17/5/96	0535-0604	02-20 N	104-15 E	34
81	28/9/95	1043-1104	17/5/96	1123-1151	01-50 N	104-45 E	54

Table 2. Biomass of zooplankton (ml./m^3) in the Gulf of Thailand and the East Coast of Peninsular Malaysia: pre = pre-monsoon post = post-monsoon

Station	pre	post	Station	pre	post	Station	pre	post
1	0.58	0.89	29	1.31	0.88	56	0.43	0.79
2	0.56	2.08	30	1.46	1.63	57	0.21	0.61
3	0.52	1.16	31	0.51	0.90	58	0.35	0.66
4	0.27	1.17	32	0.59	0.37	59	0.36	0.92
5	0.36	0.43	33	1.56	0.60	60	0.42	0.19
6	0.83	1.13	34	1.63	0.65	61	1.21	0.27
7	0.27	1.03	35	2.60	0.46	62	0.53	0.63
8	0.26	0.98	36	1.17	0.34	63	0.50	0.79
9	0.60	0.82	37	0.70	0.61	64	0.78	0.46
10	0.32	1.16	38	0.18	0.44	65	0.24	0.61
11	2.12	0.87	39	0.82	0.69	66	0.09	0.18
12	0.35	0.72	40	0.83	0.74	67	0.23	0.41
13	0.07	0.42	41	0.68	0.49	68	0.18	0.45
14	0.16	0.33	42	20.17	0.45	69	0.15	0.64
15	0.16	0.70	43	1.71	0.48	70	0.60	0.79
16	0.47	1.06	44	1.89	0.5	71	0.52	0.8
17	0.41	1.10	45	0.66	0.42	72	0.49	0.86
18	0.90	0.66	46	0.27	1.71	73	0.37	0.53
19	0.51	0.37	47	0.21	0.19	74	0.2	0.58
20	0.64	0.34	48	0.36	0.38	75	0.28	0.49
21	0.22	0.31	49	0.38	0.57	76	1.76	0.67
22	0.29	0.41	50	0.47	0.33	77	0.35	1.07
23	0.87	0.81	51	0.80	0.31	78	0.31	0.77
24	0.95	2.59	52	1.23	0.61	79	0.45	0.84
25	0.86	0.99	53	0.78	0.40	80	0.92	0.65
26	0.11	0.50	54	0.53	0.48	81	0.79	0.44
28	0.37	0.21	55	0.21	0.54			

Table 3. Total abundance of zooplankton (ml./m^3) in the Gulf of Thailand and the East Coast of Peninsular Malaysia: pre = pre-NE monsoon, post = post-NE monsoon

Station	pre	post	Station	pre	post	Station	pre	post
1	253	924	29	735	242	56	153	367
2	272	1,514	30	752	509	57	110	343
3	186	828	31	284	833	58	108	301
4	256	568	32	157	779	59	170	219
5	168	290	33	483	497	60	188	351
6	530	942	34	201	657	61	188	134
7	275	766	35	477	561	62	195	209
8	193	663	36	298	379	63	161	433
9	594	561	37	230	275	64	319	240
10	210	769	38	91	603	65	159	453
11	834	1,361	39	489	481	66	70	288
12	153	528	40	1,036	528	67	95	91
13	73	352	41	693	506	68	111	178
14	69	234	42	3,413	361	69	98	135
15	61	536	43	1,390	458	70	328	563
16	252	756	44	296	353	71	328	742
17	333	909	45	223	429	72	212	620
18	377	518	46	134	199	73	159	860
19	237	410	47	83	466	74	90	427
20	196	372	48	36	213	75	167	410
21	155	369	49	192	214	76	1,624	456
22	134	310	50	278	334	77	588	851
23	453	856	51	762	352	78	250	565
24	709	1,234	52	837	438	79	227	724
25	621	780	53	495	646	80	974	842
26	63	452	54	142	224	81	296	961
28	170	428	55	105	228			

Table 4. Differences of total abundance and biomass of zooplankton from the Gulf of Thailand and the East Coast of Peninsular Malaysia in the pre- and post-northeast monsoon periods.

	Abundance		**Biomass**	
	No. of station	Percentage	No. of station	Percentage
Increase	60	75	49	61.25
Decrease	11	13.75	29	36.25
Constant	9	11.25	2	2.5

Table 5. Probability (p) of null hypothesis (significant $p < 0.05$) from t-test for comparing biomass and abundance at pre- and post-northeast monsoon period.

	P
Biomass	0.9189
Abundance	0.0080

Table 6. Taxonomic list of zooplankton found in the Gulf of Thailand and the East Coast of Peninsular Malaysia. The average abundance of zooplankton:

+++ = very commom (>10 no./m^3)
++ = common (6-10 no./m^3)
+ = rare (0-5 no./m^3).
pre = pre-NE monsoon period (4 September - 4 October 1995)
post = post-NE monsoon period (23 April - 23 May 1996)

Taxon	**Abundance**		**Taxon**	**Abundance**	
	pre	**post**		**pre**	**post**
Medusae	+	+	Phyllosoma larvae	+	+
Siphonophora	+++	+++	Shrimp larvae	++	++
Ctenophora	+	+	Anomura larvae	+	+++
Nemertinea	+	+	Brachyura larvae	+	+
Cyphonautes larvae	+	+	Stomatopod larvae	+	+
Actinotroch larvae	+	+	Heteropoda	+	+
Chaetognatha	+++	+++	Pteropoda	++	+++
Polychaeta	+	+	Cephalopoda	+	+
Cladocera	+	++	Gastropod larvae	+++	+++
Ostracoda	+++	+++	Bivalve larvae	++	++
Copepoda	+++	+++	Echinodermata larvae	+	+
Cirripedia larvae	-	+	Larvacean	+++	+++
Amphipoda	+	+++	Thaliacea	+	++
Isopoda	+	-	Brachiopod larvae	+	+
Mysidacea	+	+	Crustacean nauplii	+	+
Cumacea	+	+	Fish eggs	+	+
Euphausiacea	+	-	Fish larvae	+	+
Lucifer spp.	+++	+			

period (at 95 % level). But there is no significant difference between biomass for both period.

Taxonomic composition

34 groups of zooplankton were found in this study (Table 6 and 7). Copepod dominated the zooplankton community with average 208 and 229 no/m^3 (55.99 % and 43.9 % composition) in the pre-monsoon and the post-monsoon respectively. Followed by Chaetognatha (average 30 no/m^3 with 8.02 % composition) in pre-monsoon and Ostracod (average 93 no/m^3 with 17.8 % composition) in post-monsoon (Table 8).

Distribution of individual taxa

Medusae

In pre-monsoon period, the medusae were found to be very common. Large number were observed in station 53 and 80 (13 and 10 no/m^3 respectively) which were in the east coast of Peninsular Malaysia. But in post-monsoon period, Large number were observed in station 8 (77 no/m^3) which were in the Gulf of Thailand. Furthermore, the number of individual of medusae was higher in post-monsoon period than in pre monsoon period in the great number of the stations. However, most of medusae distributed near shore rather than offshore (Fig. 6 and 7).

Siphonophora

Siphonophora were observed to be very common in both area. The amount of siphonophora was increase in post-monsoon period for 1.5 - 100 times in every stations (except station no. 42). Nevertheless, there were more abundant in nearshore samples for both period (Fig. 8 and 9).

Ctenophora

Ctenophora found to be rare in this investigation. The percent occurrence was 26.25 % in pre-monsoon and 23.75 % in post-monsoon. The greatest number were 4 no/m^3 at station no. 24 (near Ko Samui) in pre-monsoon period and 4 no/m^3 at station 2 (near Amphor Sattahip). Most of them were found in the Gulf of Thailand. However, there were more abundant in nearshore samples for both period (Fig. 10 and 11).

Nemertinea

Nemertinea were rare in pre-monsoon period (8.75 % occurrence) but quite common in post-monsoon period (73.75 % occurrence). The abundance was high in post-monsoon period and the distribution were similar in patterns for both of samples taken at nearshore and offshore(Fig. 12 and 13).

Cyphonautes larvae

Cyphonautes larvae were common in pre-monsoon period (70% occurrence) but rare in post-monsoon period (10% occurrence). The abundance was high in pre-monsoon period (Fig. 14 and 15).

Actinotroch larvae

For both period, Actinotroch larvae were quite rare and abundance were occurrence (Fig. 16).

Chaetognatha

Chaetognatha were the second most abundant component in pre-monsoon period but were the forth abundant component in post-monsoon period. Station 42 (near Pattani Bay) and station 11 (near Prachuap Khiri Khan) had the highest abundance in pre-monsoon period. While station 2 had the highest abundance in post-monsoon period. The patterns of distribution were similar for the near

Table 7. Taxonomic list of zooplankton found in the Gulf of Thailand and the East Coast of Peninsular Malaysia. Frequency of occurrence is shown as;
R = Rare
C = Common
VC = Very Common.
pre = pre-NE monsoon period (4 September - 4 October 1995)
post = post-NE monsoon period (23 April - 23 May 1996)

Taxon	Frequency		Taxon	Frequency	
	pre	post		pre	post
Medusae	VC	VC	Phyllosoma larvae	C	C
Siphonophora	VC	VC	Shrimp larvae	VC	VC
Ctenophora	R	R	Anomura larvae	VC	VC
Nemertinea	R	VC	Brachyura larvae	VC	VC
Cyphonautes larvae	VC	R	Stomatopod larvae	VC	VC
Actinotroch larvae	R	R	Heteropoda	VC	VC
Chaetognatha	VC	VC	Pteropoda	VC	VC
Polychaeta	VC	VC	Cephalopoda	C	C
Cladocera	VC	VC	Gastropod larvae	VC	VC
Ostracoda	VC	VC	Bivalve larvae	VC	VC
Copepoda	VC	VC	Echinodermata larvae	VC	VC
Cirripedia larvae	-	R	Larvacean	VC	VC
Amphipoda	VC	VC	Thaliacea	VC	VC
Isopoda	R	-	Brachiopod larvae	R	R
Mysidacea	VC	VC	Crustacean nauplii	VC	VC
Cumacea	R	R	Fish eggs	VC	VC
Euphausiacea	R	-	Fish larvae	VC	VC
Lucifer spp.	VC	VC			

Table 8. Percent composition of some zooplankton in the Gulf of Thailand and the East coast of Peninsular Malaysia in the pre-and post-northeast monsoon periods.

Rank	Pre-monsoon		Post-monsoon	
	Taxon	Per cent composition	Taxon	Per cent composition
1	Copepoda	55.99	Copepoda	43.9
2	Chaetognatha	8.02	Ostracoda	17.8
3	Ostracoda	5.47	Siphonophora	6.3
4	Siphonophora	3.61	Chaetognatha	5.4
5	Gastropod larvae	3.17	Gastropod larvae	4.4
6	Lucifer spp.	3.17	Amphipoda	3.2
7	Laevacean	2.78	Pteropod	3.0
8	Shrimp larvae	2.67	Laevacean	2.1
9	Pteropod	2.57	Shrimp larvae	1.9
10	Bivalve larvae	2.25	Anomura larvae	1.8

shore and offshore stations in post-monsoon period. But in pre-monsoon period, the number of chaetognatha taken from the near shore stations were higher than the offshore stations (Fig. 17 and 18).

Polychaeta

Polychaet larvae were observed to be fairly common even though the number of them were not so high. However, the number of organisms were higher in pre-monsoon than post-monsoon period. Higher abundance occurred near shore than offshore for both period. In the post-monsoon period, polychaet were absent in the east coast of Peninsular Malaysia (Fig. 19 and 20).

Cladocera

Cladocera were the regular component in the samples in this investigation. Station 17 (near Chumphon) had the highest abundance in pre-monsoon period. While station 1 and station 17 had the highest abundance in post-monsoon period. Higher abundance occurred near shore than offshore for both period especially in the Gulf of Thailand (Fig. 21 and 22).

Ostracoda

Ostracoda were the third most abundant in pre-monsoon period and the second most abundant in post-monsoon period. They were observed to be common in this study area. In post-monsoon showed higher abundance than in pre-monsoon period. However, in pre-monsoon period the ostracoda distributed near shore rather than off shore while in the post-monsoon period the patterns of distribution were similar (Fig. 23 and 24).

Copepoda

Copepoda dominated the zooplankton in this investigation in both season. They consisted 55.4% and 43.9% of zooplankton population in pre and post-monsoon respectively. Number of copepod were increase in post-monsoon period in most of the stations. There were higher abundance at near shore than offshore stations in both period (Fig. 25 and 26).

Cirripedia larvae

Cirripedia larvae were very rare in this study. They found only 0-5 no./m^3 during post-monsoon and none in pre-monsoon (Fig. 27)

Amphipoda

Amphipoda were very common. High number of abundance occurred near shore in both period. There are no differences in number between pre and post-monsoon period (Fig. 28 and 29).

Isopoda

Isopoda were very rare in this study. The percentage of occurrence was 10 in pre-monsoon and 0 in post-monsoon period (Fig. 12).

Mysidacea

The per cent occurrence of mysidacea was quite high for both period. They were abundant from the lower part of the Gulf of Thailand along the east coast of Peninsular Malaysia. Most of them distributed off shore rather than near shore. However, the abundance in post-monsoon was higher than in pre-monsoon (Fig. 30 and 31).

Cumacea

Cumacea were occasionally present in zooplankton samples especially along the east coast of

Peninsular Malaysia. The average abundance in both period were not difference. Cumacea number were high at near shore stations in pre-monsoon period but there were similar in post-monsoon period (Fig. 32 and 33).

Euphausiacea

Euphausiacea were very rare in this study. They found only 10 per cent occurrence in pre-monsoon period and none in post-monsoon period (Fig. 12).

***Lucifer* spp.**

Lucifer spp. were very common. They were abundant in the upper part of Gulf of Thailand, Pattani Bay and near shore along the east coast of Peninsular Malaysia in pre-monsoon period. Although they found to be most abundant in the upper part of Gulf of Thailand, near Ko Samui and the lower part of Peninsular Malaysia in post-monsoon period. The distribution pattern were similar for both nearshore and offshore stations (Fig. 34 and 35).

Phyllosoma larvae

Phyllosoma larvae were found to be irregular in this area. The largest number in post-monsoon was found near Ko Samui. However, The average abundance showed no differences between both period (Fig. 36 and 37).

Shrimp larvae

Shrimp larvae were the regular component in the zooplankton population. The great number were found near shore in both season especially at Pattani Bay in pre-monsoon period (81 no/m^3) and in the upper part of the Gulf of Thailand in post-monsoon period (126 no/m^3). The average abundance showed no differences between both period(Fig.38 and 39).

Anomura larvae

Anomura larvae were common organisms. The average abundance was higher in post-monsoon period (10 no/m^3) than in pre-monsoon period (1 no/m^3). The distribution was dispersed nearshore and offshore (Fig. 40 and 41).

Brachyura larvae

Brachyura larvae occurred regularly in the zooplankton samples. They found most abundant at Pattani Bay and nearshore stations in pre-monsoon period. The post-monsoon period showed the same pattern of distribution but the great number was 27 no/m^3 near Ko Samui (station 24). The average abundance of brachyura larvae was higher in pre-monsoon (4 no/m^3) than in post-monsoon period (2 no/m^3) (Fig. 42 and 43).

Stomatopod larvae

Stomatopod larvae were very common. The average abundant in both season showed no differences. The distribution was scattered throughout the study area (Fig. 44 and 45).

Heteropoda

Heteropoda were very common. In pre-monsoon period, the abundance was high near shore along the east coast of Peninsular Malaysia whereas in post-monsoon they were scattered throughout the study areas. However the average abundance in both season showed no differences (Fig. 46 and 47).

Pteropoda

Pteropoda were very common. The average abundant of them was a little bit higher in post-monsoon (15.6 no/m^3 than in pre-monsoon period (9.57 no/m^3). Pteropods number were high at nearshore stations (Fig. 48 and 49).

Cephalopoda larvae

Cephalopoda larvae were quite seldom in this study. The average number for both period was no differences. Anyway, they dispersed throughout the study area (Fig. 50 and 51).

Gastropod larvae

Gastropod larvae were very common. They occurred in considerable number during pre and post monsoon period. However, the abundance of gastropod in post-monsoon was a little bit higher than in pre-monsoon. They found high number near Pattani Bay and along the lower part of Peninsular Malaysia in pre-monsoon while along the middle through the lower part part of the Gulf of Thailand in post-monsoon period (Fig. 52 and 53).

Bivalve larvae

Bivalve larvae were observed to be very common but not in large number. There was no differences in both period. The distribution was scattered (Fig. 54 and 55).

Echinodermata larvae

Echinodermata larvae consisted of asteroidea (star fish larvae), holothuroidea (sea cucumber larvae), echinoidea (sea urchin larvae), ophiuroidea (brittle star larvae) and crinoidea (feather star larvae). They were the regular component in the plankton samples in this study but not in large number. The result showed no differences between both period. Most of the echinodermata larvae dispersed nearshore in pre-monsoon and scattered in post-monsoon period (Fig. 56 and 57).

Larvacean

Larvacean were very common but found in small number. The number increased in post-monsoon period. The abundance of larvacean occurred nearshore. The highest number was station 42 (near Pattani Bay) and station 80 in Peninsular Malaysia in pre-monsoon while the upper part of the Gulf of Thailand and near Ko Samui were rich in Lavacean number in post-monsoon period (Fig. 58 and 59).

Thaliacea

Thaliacea (tunicates or salps) were observed to be very common. The number of thaliacea was increased in post-monsoon period in most of the stations. Thaliacea number were high at nearshore stations especially in the middle part of the Gulf of Thailand in post-monsoon (Fig. 60 and 61).

Brachiopod larvae

Brachiopod larvae were occasionally present in low number. In pre-monsoon the abundance were found at around Battani Bay and the end of Peninsular Malaysia but in post-monsoon there were found at the upper gulf of Thailand and the end of Peninsular Malaysia. There were no differences in number in both period (Fig. 62 and 63).

Crustacean Nauplii

Crustacean Nauplii occurred regularly in the plankton samples but not in high number. The number were increased in post-monsoon period. However, the abundance occurred in the nearshore stations in both period (Fig. 64 and 65).

Fish eggs and Fish larvae

This important component of the meroplankton appeared in considerable number during pre and post monsoon period. The abundance of fish larvae and fish eggs in pre-monsoon occurred near Ko Samui, Battani Bay and station 80. In post-monsoon period, the abundant of fish larvae was near Ko Samui but fish eggs was around Prachuap Khiri Khan Bay. The number of fish larvae and fish eggs increased in post-monsoon period in some area (Fig. 66 - 69).

Discussion

The biomass of zooplankton in the Gulf of Thailand in this study was higher than the pass which had range from 14.28 to 33.14 ml/100 m^3 in 1979 (Suvapepan, 1980). In general, the plankton biomass off the east coast of the Gulf of Thailand was lower than that in the Inner Gulf and Upper western coast. Highest plankton density in the Inner Gulf was 155.3 ml/100m^3 in December (Suvapepan, 1977). The mean abundance of zooplankton in the Gulf of Thailand was slightly increased from 1976-1994 and the patterns of zooplankton distribution were unchanged (Sribyatta, 1996). The present observation showed that zooplankton collected comprises a great variety of organisms and copepod was the main group. The result agree with various workers who reported that copepod was the most important groups and wildly distributed in the Inner Gulf and the western coast of the Gulf of Thailand (Suvapepan, 1979: Suwanrumpha, 1980: Sudara and Udomkit, 1984 and Temiyavanich, 1984).

It is obvious that the monsoon affect the zooplankton abundance and their distribution. In post-monsoon period , many organisms were increased in number such as Siphonophora, Cladocera, Ostracoda, Amphipoda, Mysidacea, Anomura larvae Pteropoda and Gastropod larvae. Some organisms were decreased such as Polychaet and *Lucifer* spp. Sribyatta (1996) also found higher number of zooplankton in the northeast monsoon and southwest monsoon. According to Suvapepan (1980) and Suwanrumpha (1980) they concluded that in the Inner Gulf of Thailand periods of high and low zooplankton number coincided with the periods of the two monsoons: with minimum density occurred during the intermonsoons in April and October and that seasonal distribution of different zooplanktonic groups and the species composition are effected by prevailing hydrographical condition induced by the monsoons.

Overall on the shelf, nutrients, phytoplankton and zooplankton show significant positive covariance (Hopcroft and Roff, 1990). This is true also in the Inner Gulf of Thailand whereas Sudara and Udomkit (1984) found that major factor influencing the distribution of zooplankton seems to be the amount of nutrients available. Besides, Tamiyavanich (1984) found the zooplankton abundance had significant correlation to the phytoplankton. Salinity also acts as the major factor determining the variability of zooplankton abundance (Sribyatta, 1996) while temperature is the minor factor (Suwanrumpha, 1978).

Acknowledgements

Appreciation is extended to the Southeast Asian Fisheries Developement Center for supporting this research. Thanks are extened to Captain, crews and scientists on the M.V. SEAFDEC for their help in the sampling. Ms. Penjan Rochana-anawat, Ms. Suvimon Sae-Koe and Ms. Siriporn Seurungreong are thanked for preparing the manuscrips. Finally, I wish to thank Mr. Boonlert Phasuk for constructive criticism of the manuscript.

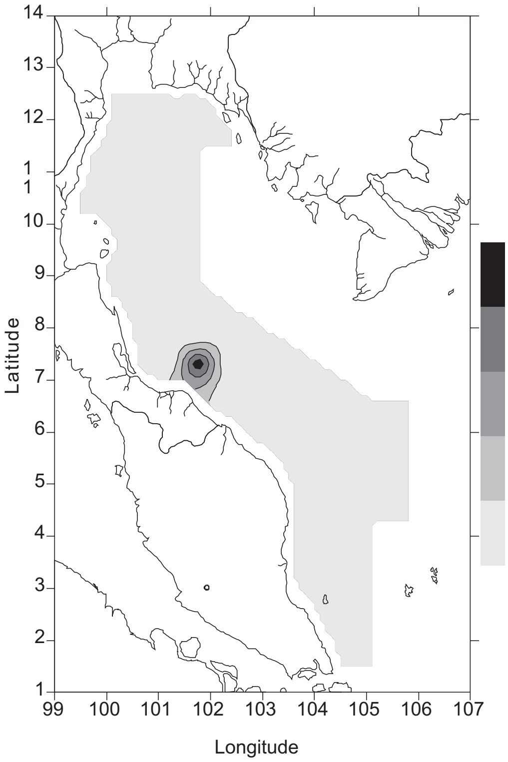


Fig. 2. Biomass of total zooplankton (ml/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

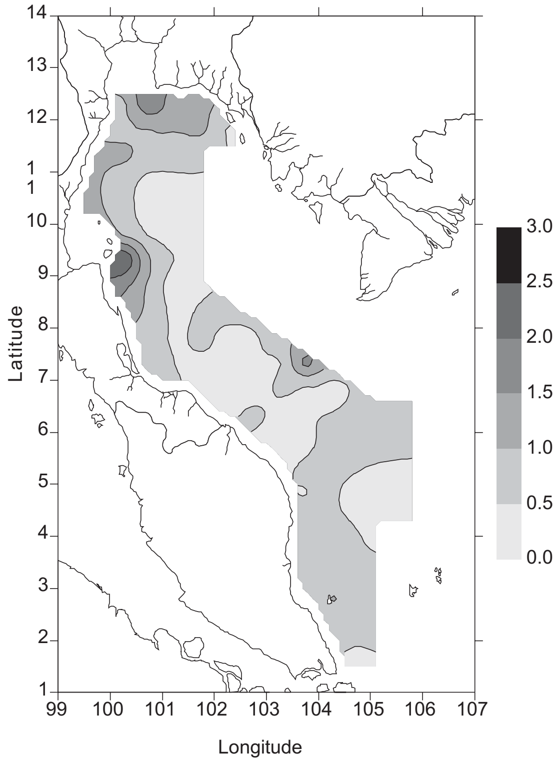


Fig. 3. Biomass of total zooplankton (ml/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

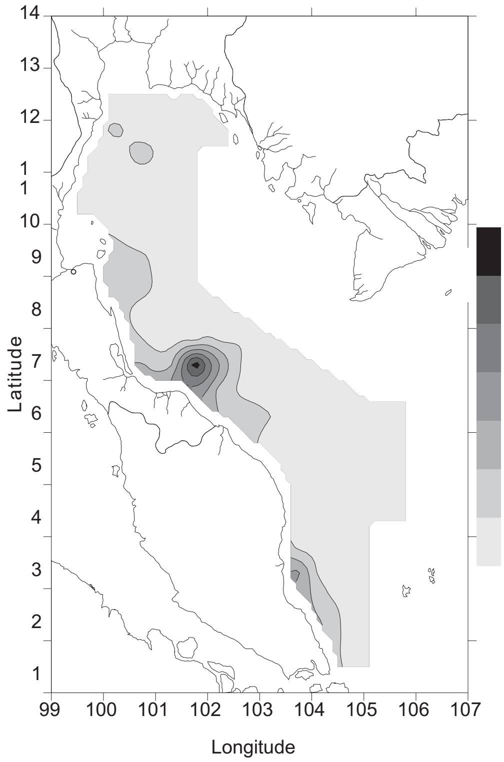


Fig. 4. Abundance of total zooplankton (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

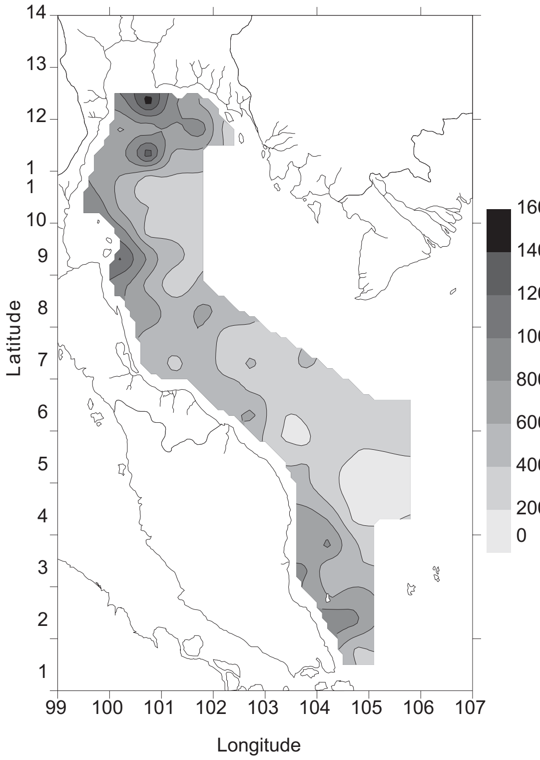


Fig. 5. Abundance of total zooplankton (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

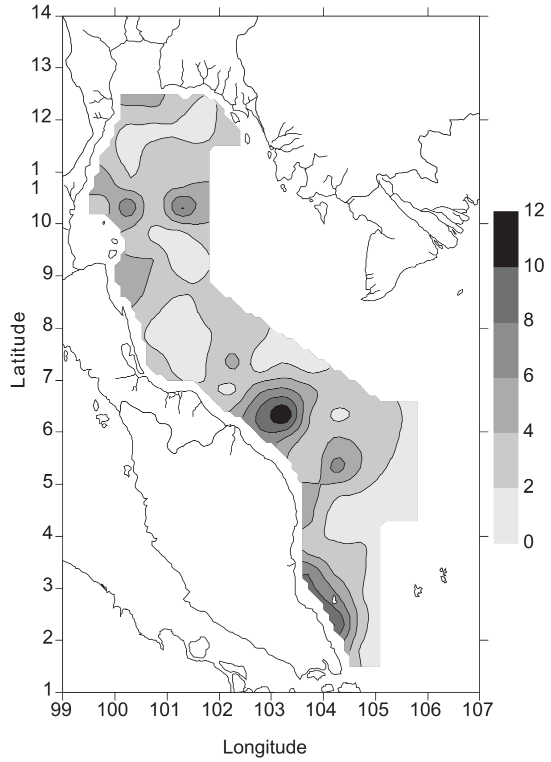


Fig. 6. Distribution of Medusae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

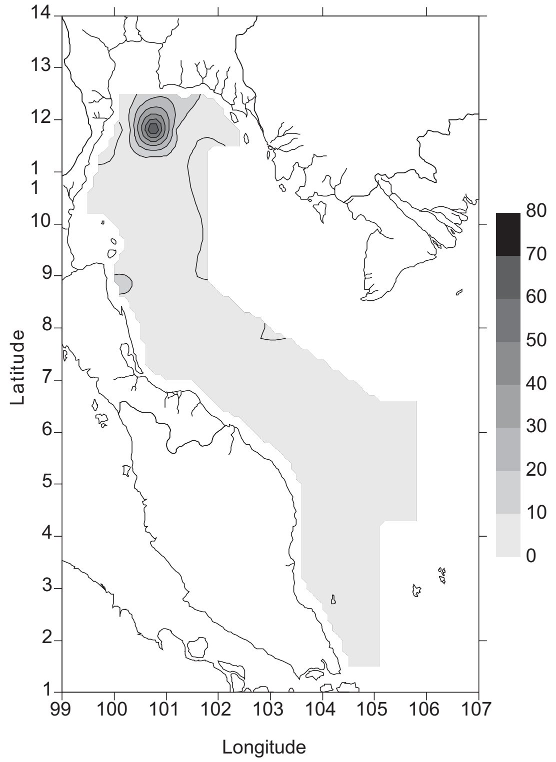


Fig. 7. Distribution of Medusae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

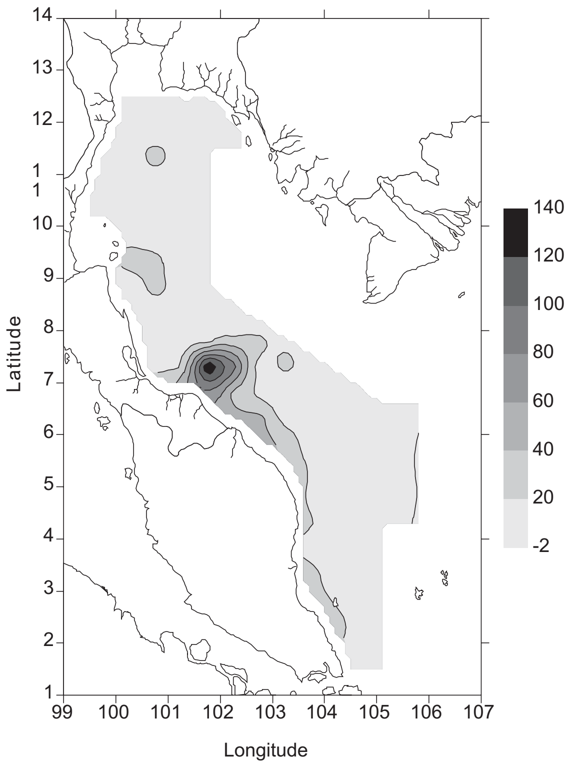


Fig. 8. Distribution of Siphonophora (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

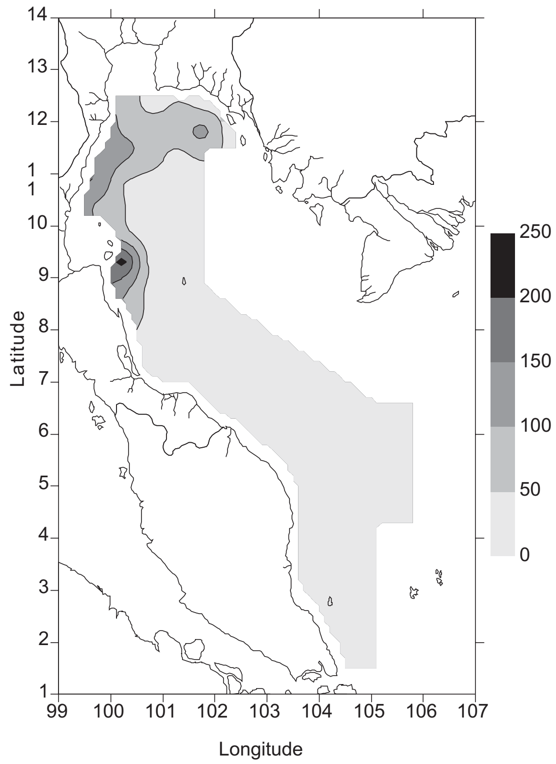


Fig. 9. Distribution of Siphonophora (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

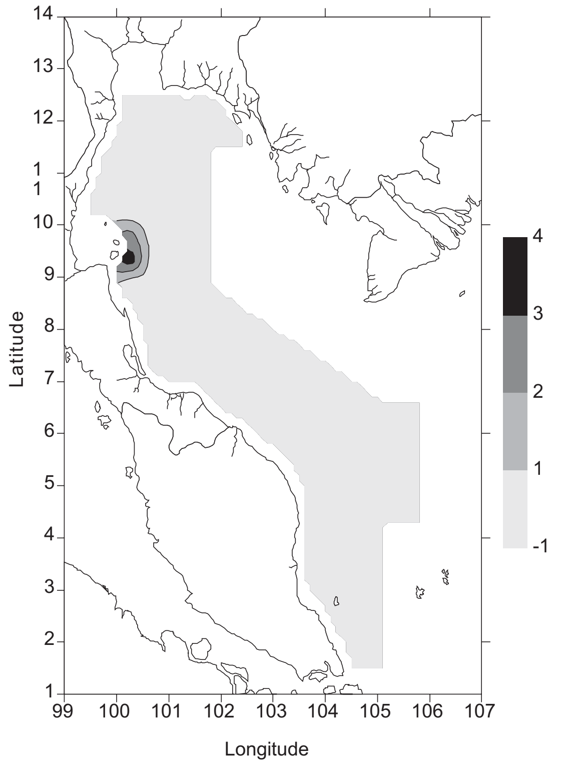


Fig. 10. Distribution of Ctenophora (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

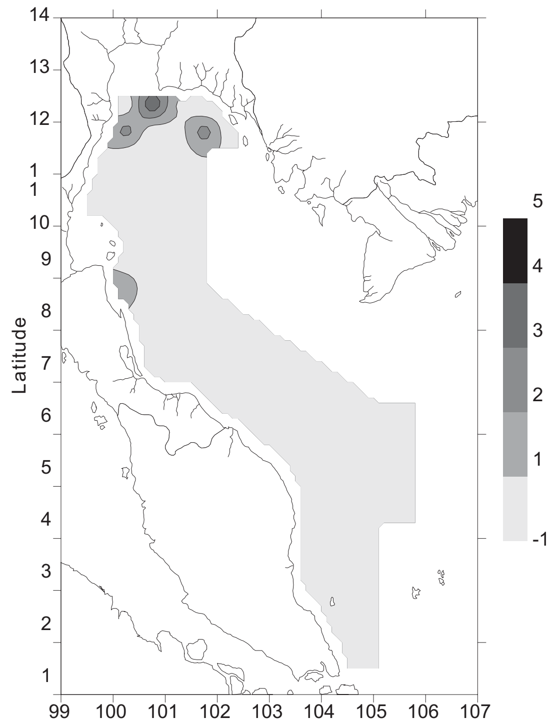


Fig. 11. Distribution of Ctenophora (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

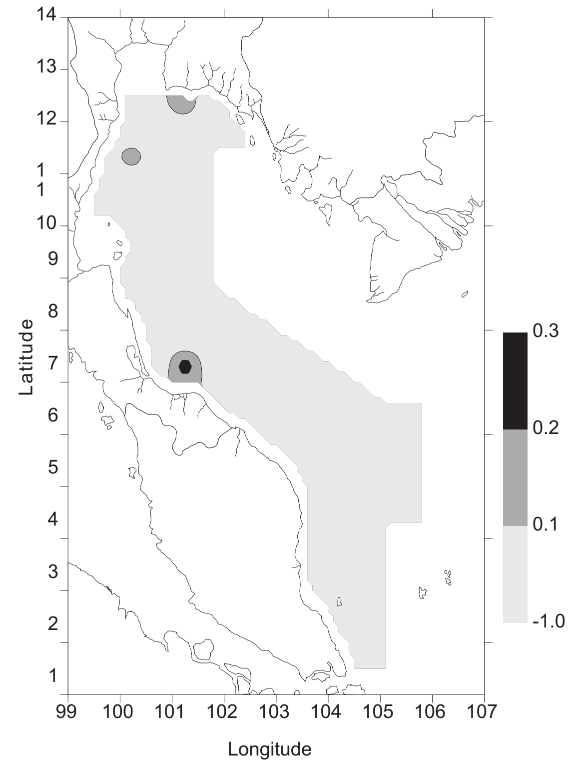


Fig. 12. Distribution of Nemertinea (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

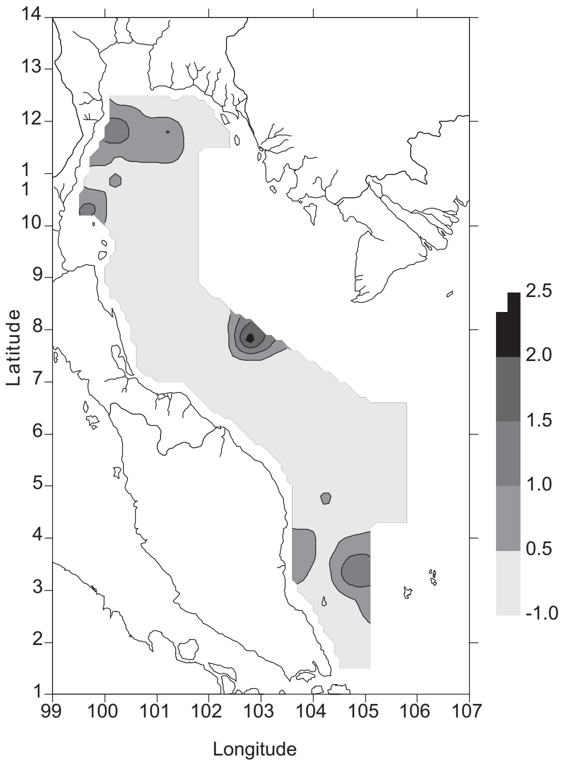


Fig. 13. Distribution of Nemertinea (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

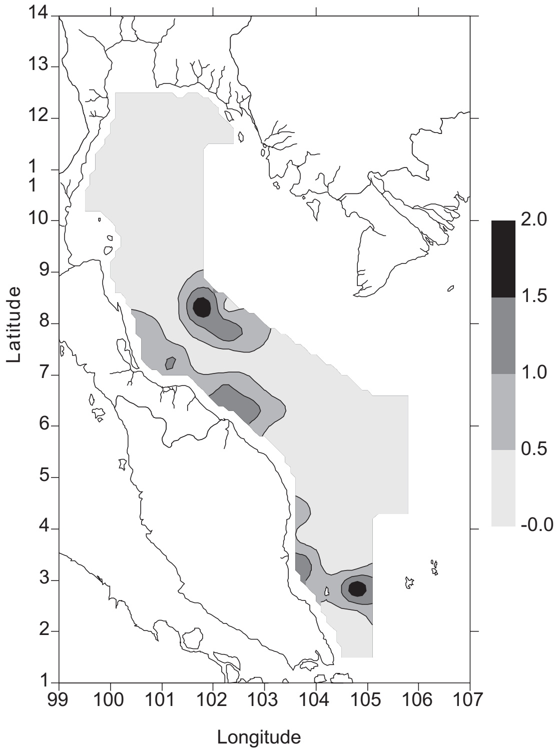


Fig. 14. Distribution of Cyphonautes lavae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

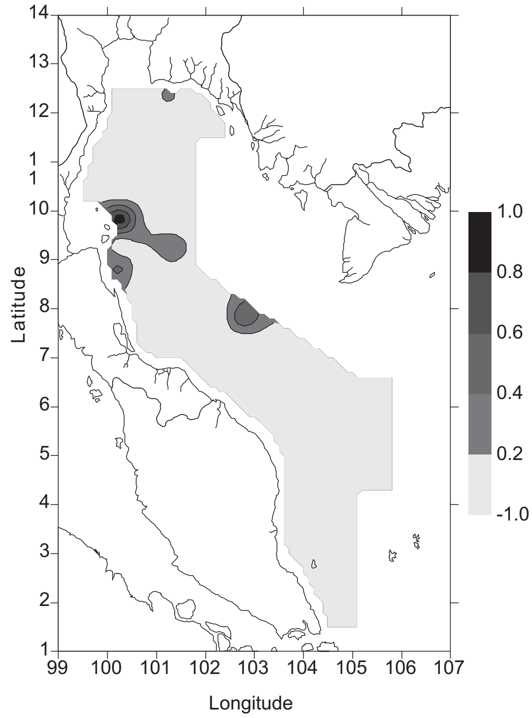


Fig. 15. Distribution of Cyphonautes larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

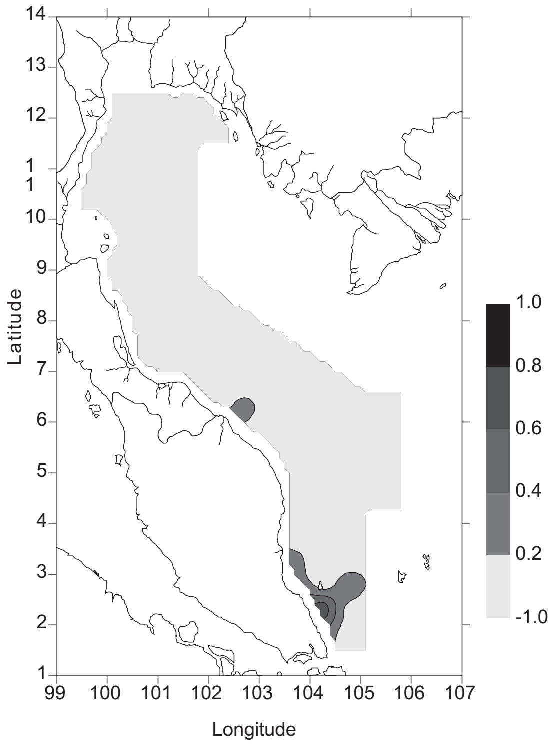


Fig. 16. Distribution of Actinotrocha (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

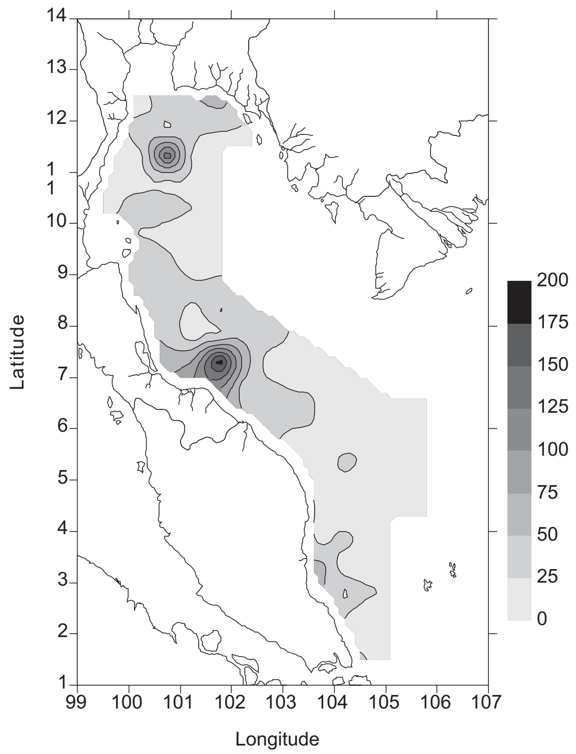


Fig. 17. Distribution of Chaetognatha (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

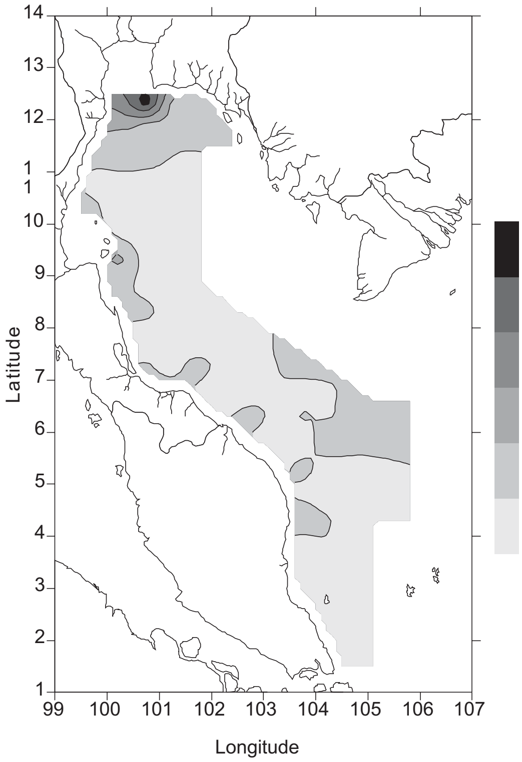


Fig. 18. Distribution of Chaetognatha (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

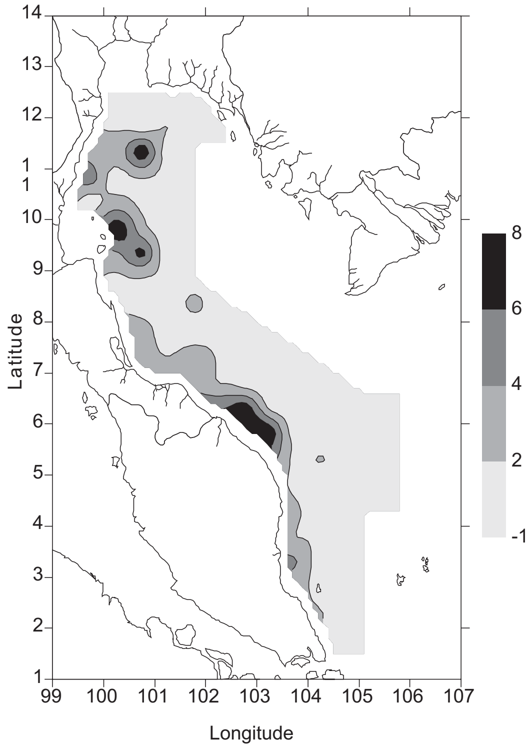


Fig. 19. Distribution of Polychaeta (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

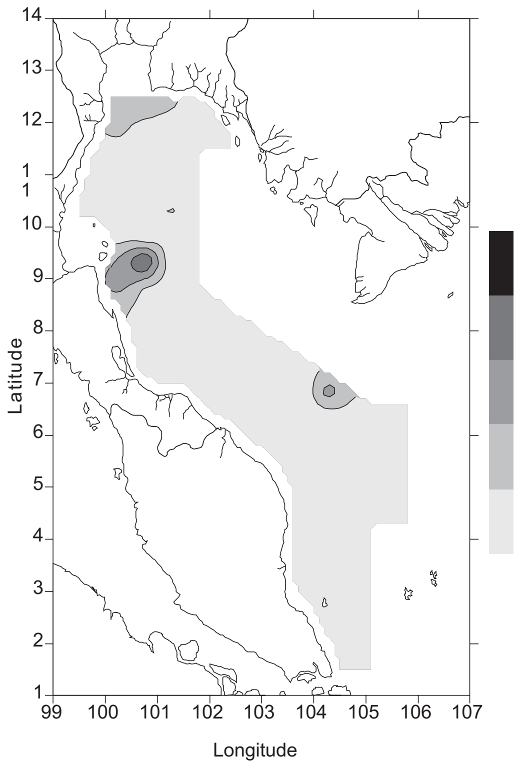


Fig. 20. Distribution of Polychaeta (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

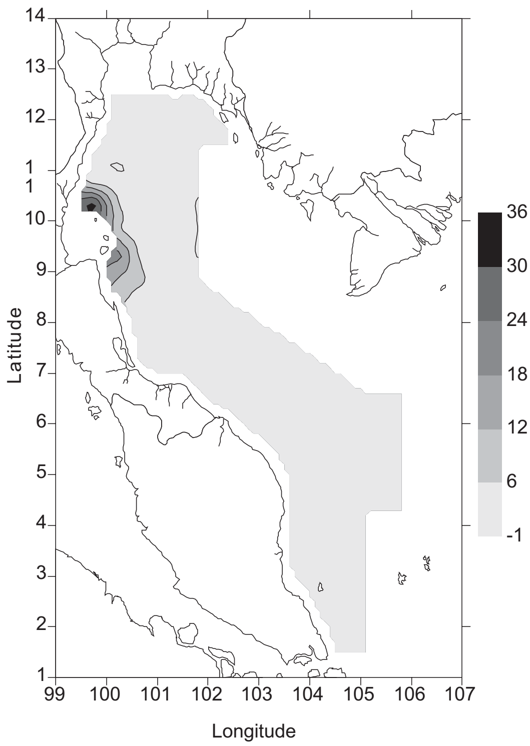


Fig. 21. Distribution of Cladocera (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

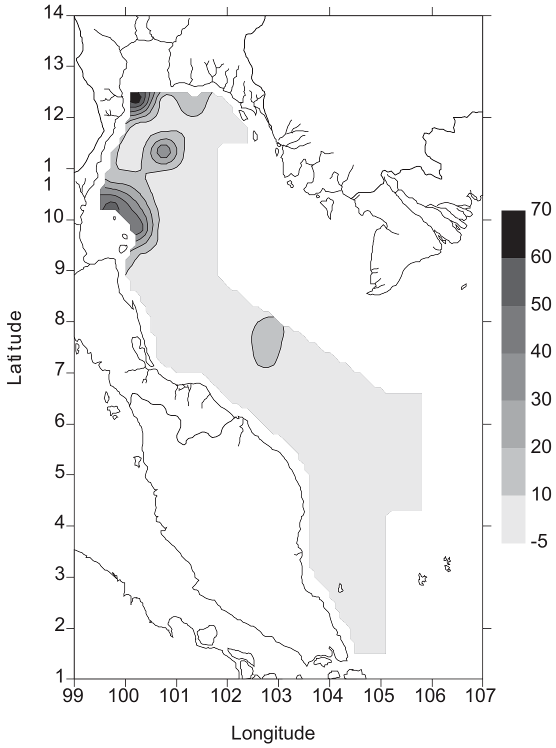


Fig. 22. Distribution of Cladocera (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

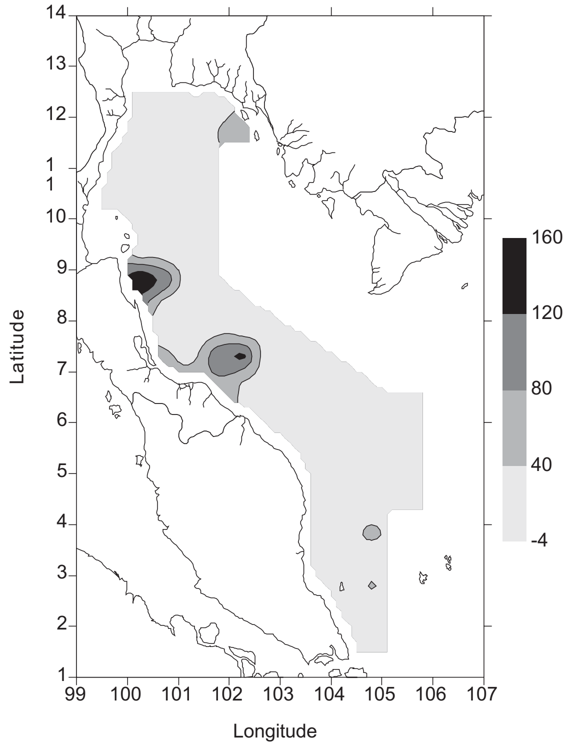


Fig. 23. Distribution of Ostracoda (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

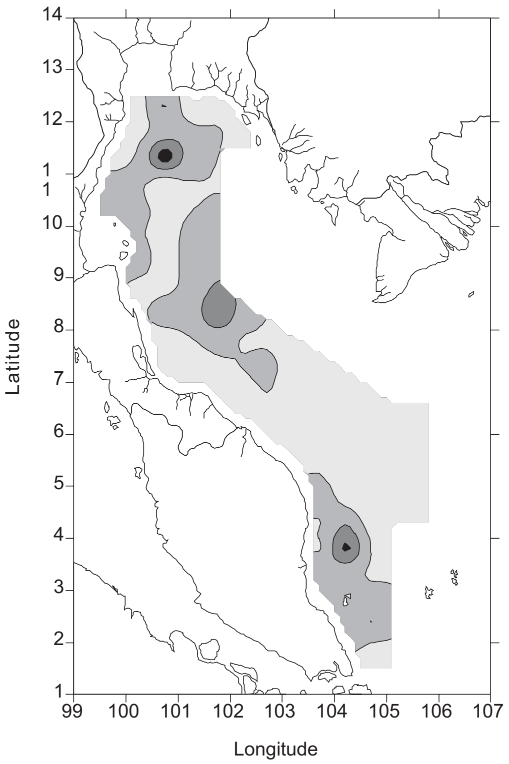


Fig. 24. Distribution of Ostracoda (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

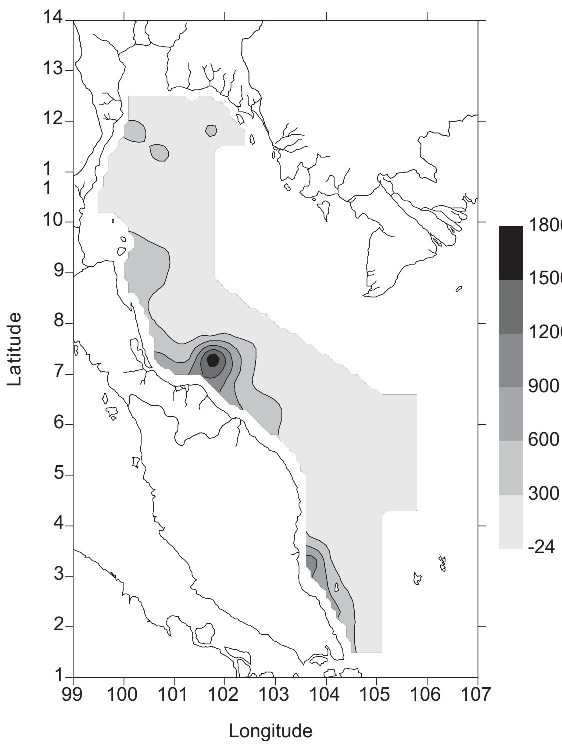


Fig. 25. Distribution of Copepoda (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

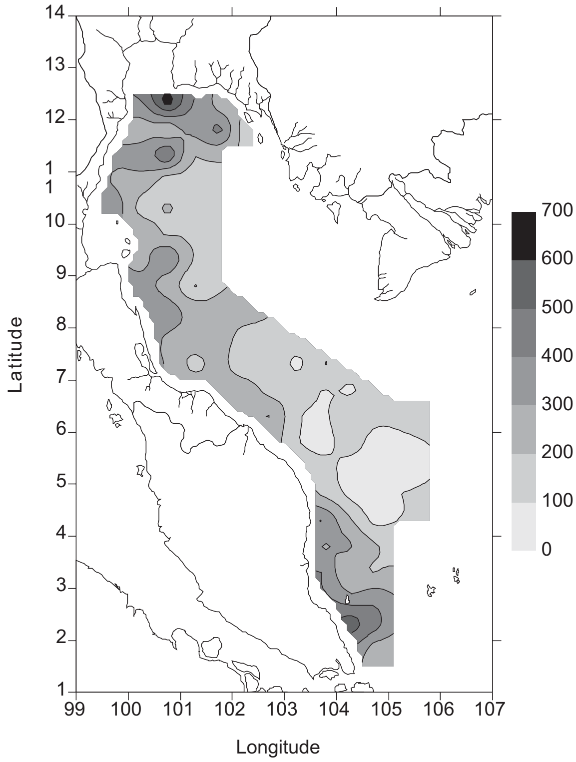


Fig. 26. Distribution of Copepoda (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

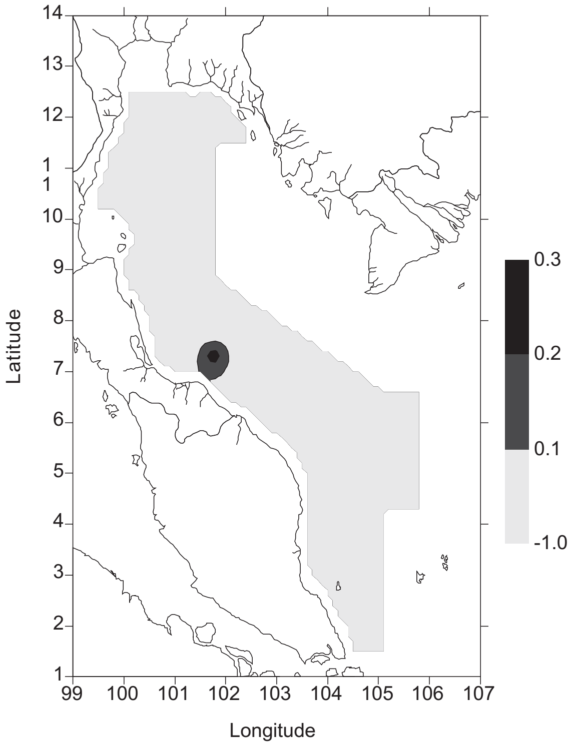


Fig. 27. Distribution of Cirripedia Larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

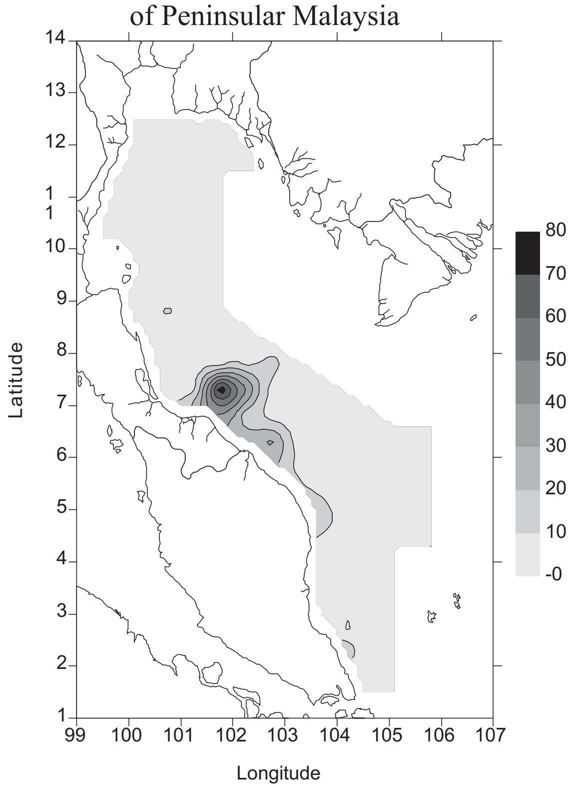


Fig. 28. Distribution of Amphipoda (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

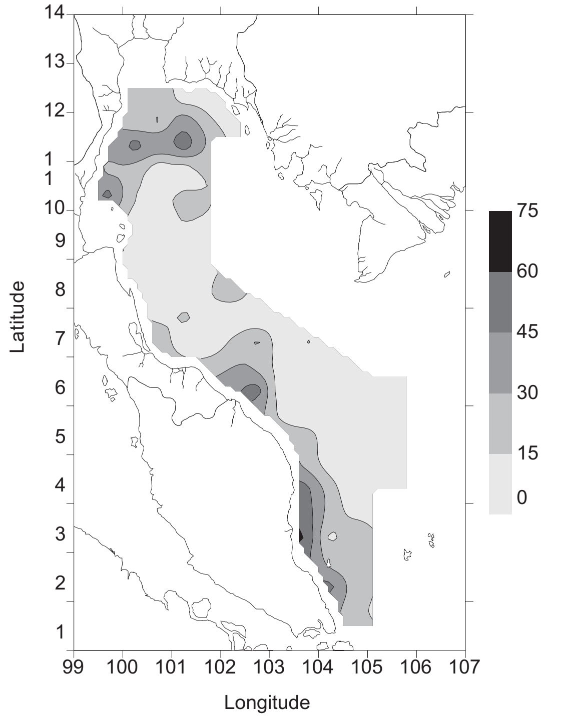


Fig. 29. Distribution of Amphipoda (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

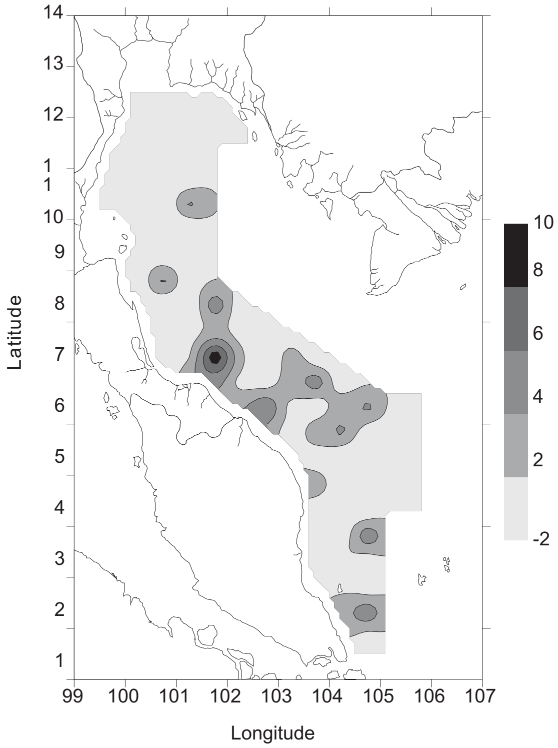


Fig. 30. Distribution of Mysidacea (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

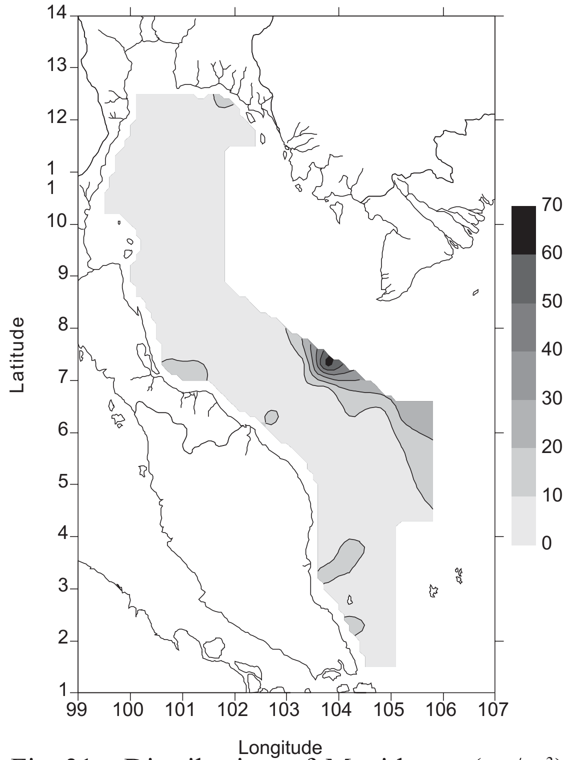


Fig. 31. Distribution of Mysidacea (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

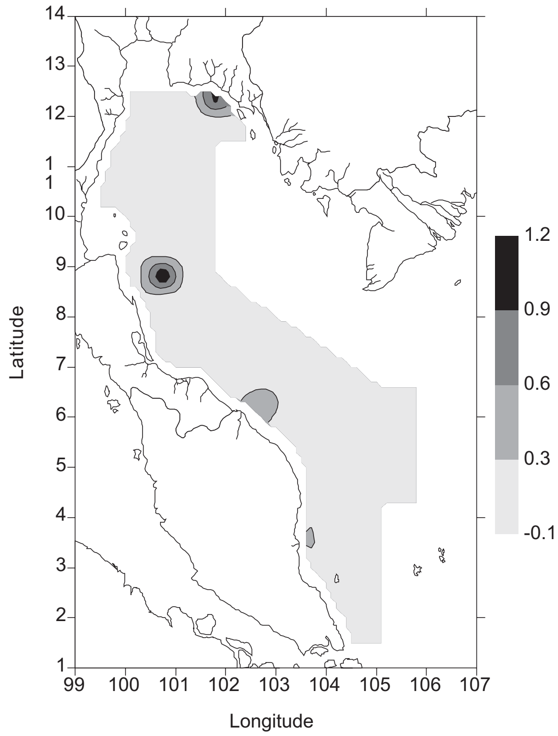


Fig. 32. Distribution of Cumercea (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

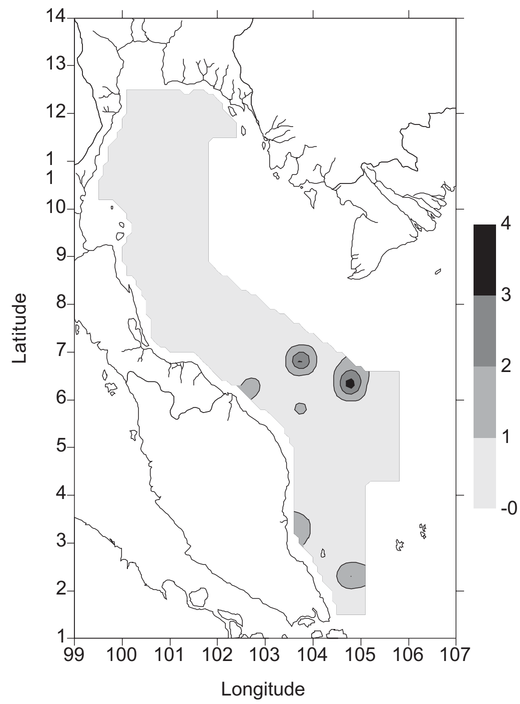


Fig. 33. Distribution of Cumacea (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

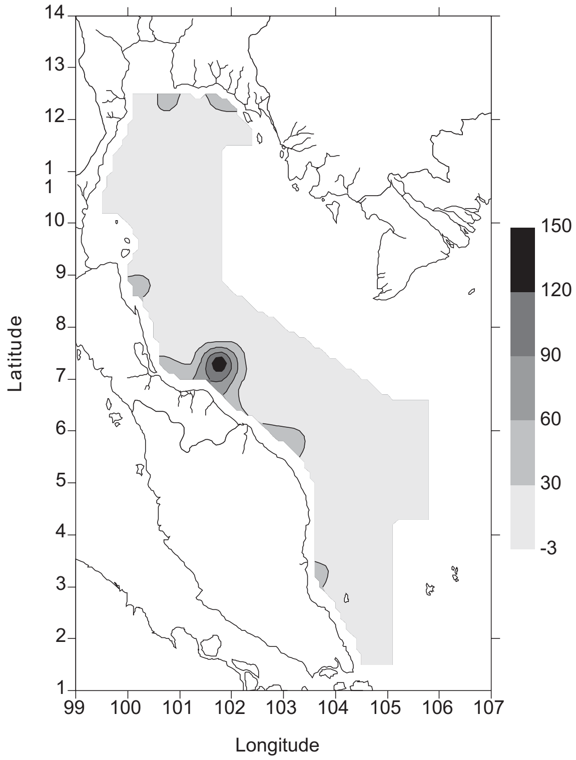


Fig. 34. Distribution of Lucifer spp. (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

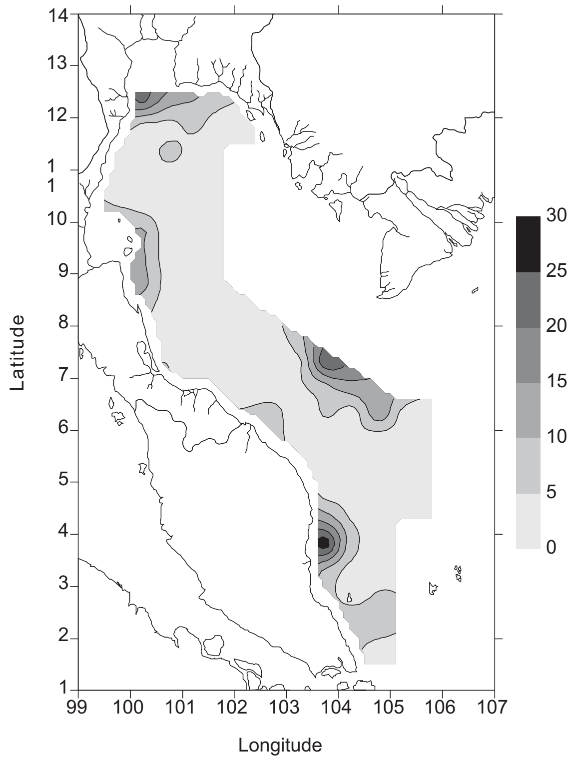


Fig. 35. Distribution of Lucifer spp. (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

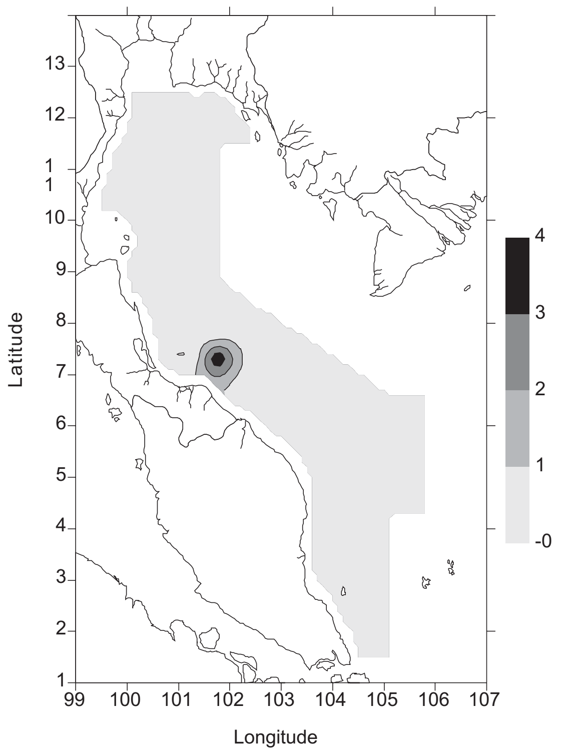


Fig. 36. Distribution of Phyllosoma larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

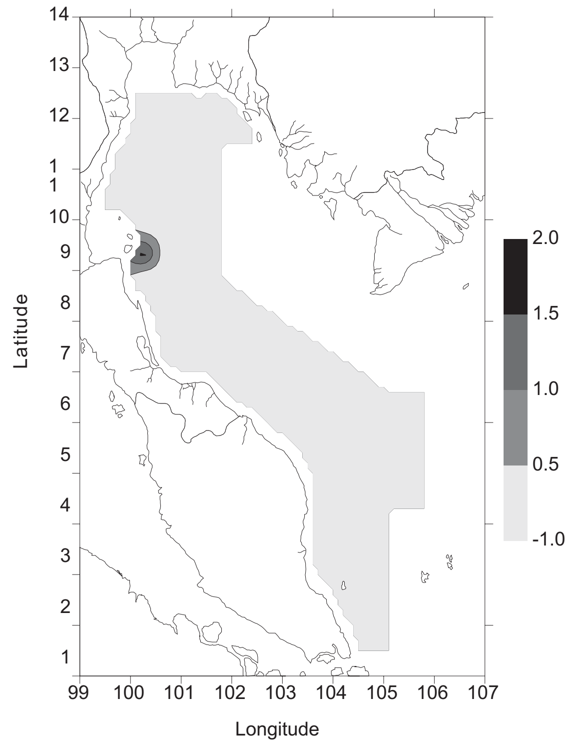


Fig. 37. Distribution of Phyllosoma larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

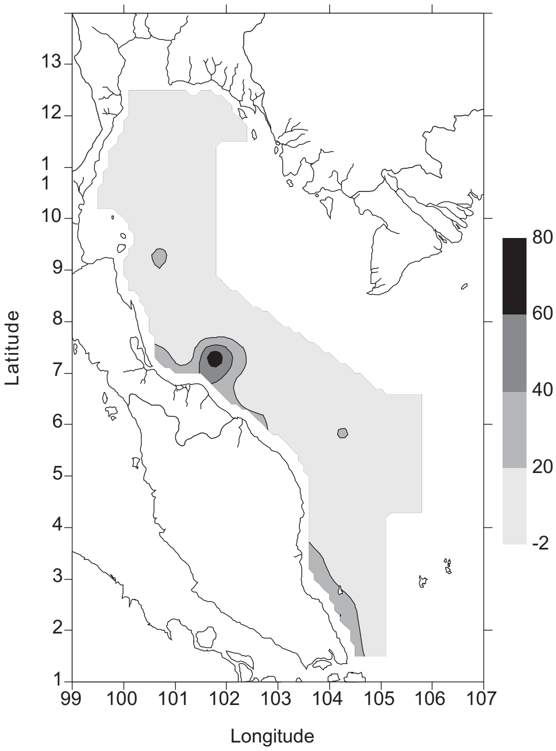


Fig. 38.Distribution of Shrimp larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

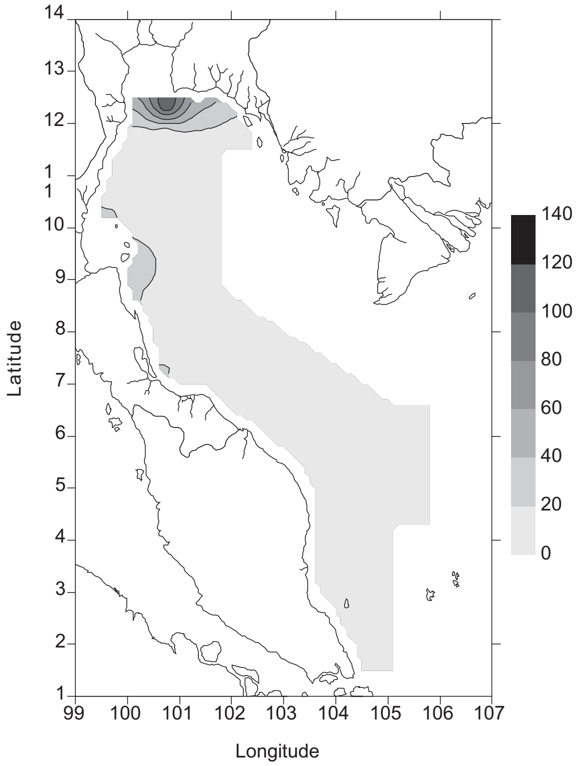


Fig. 39.Distribution of Shrimp larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

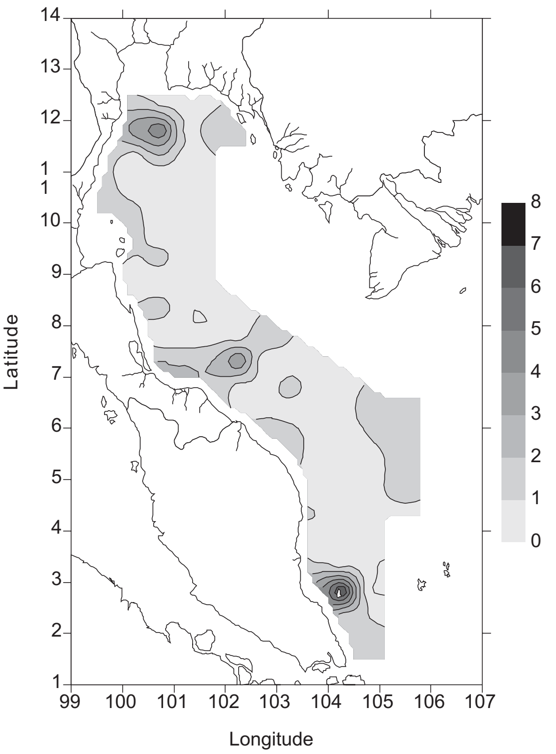


Fig. 40.Distribution of Anomura larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

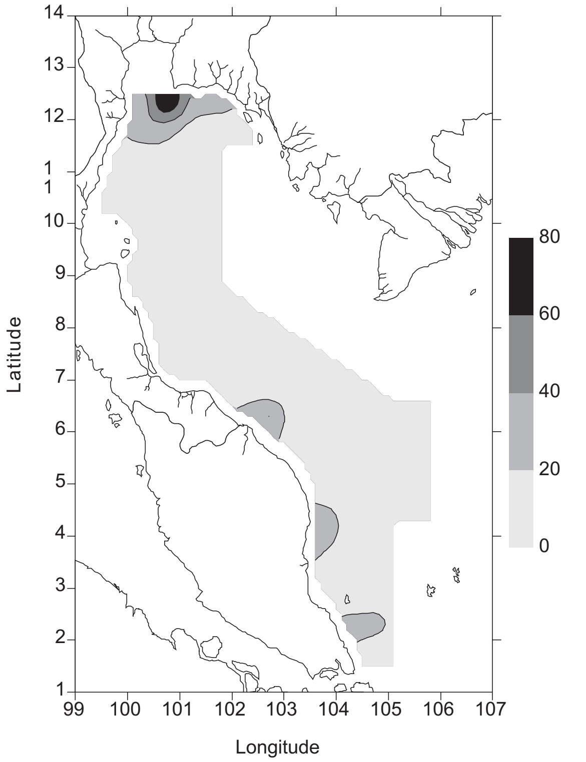


Fig. 41.Distribution of Anomura larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

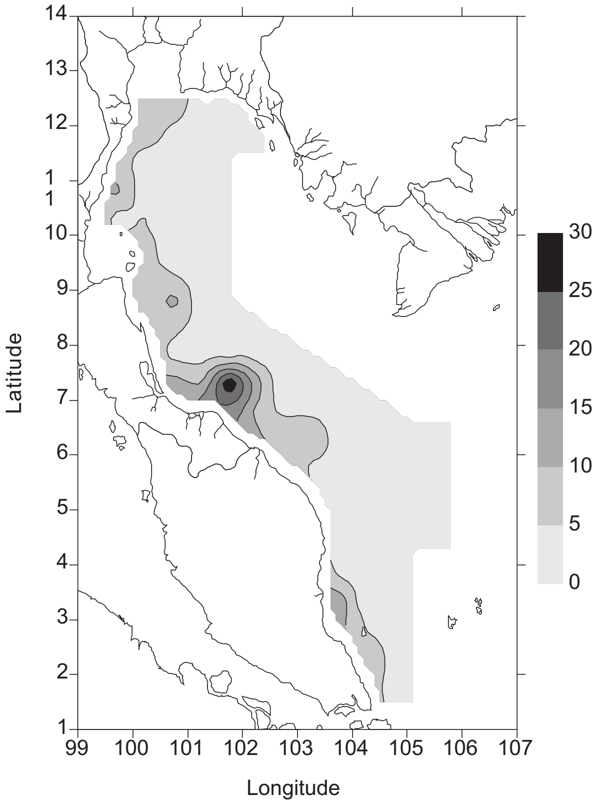


Fig. 42. Distribution of Brachyura larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

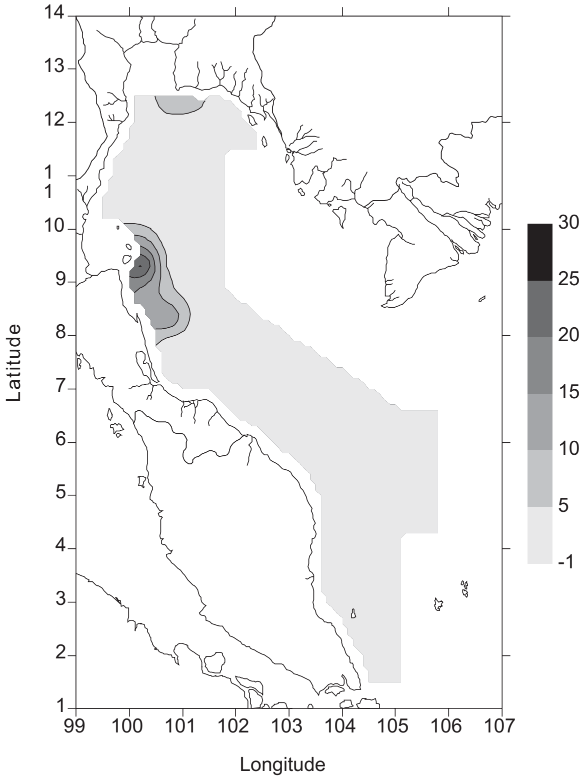


Fig. 43. Distribution of Brachyura larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

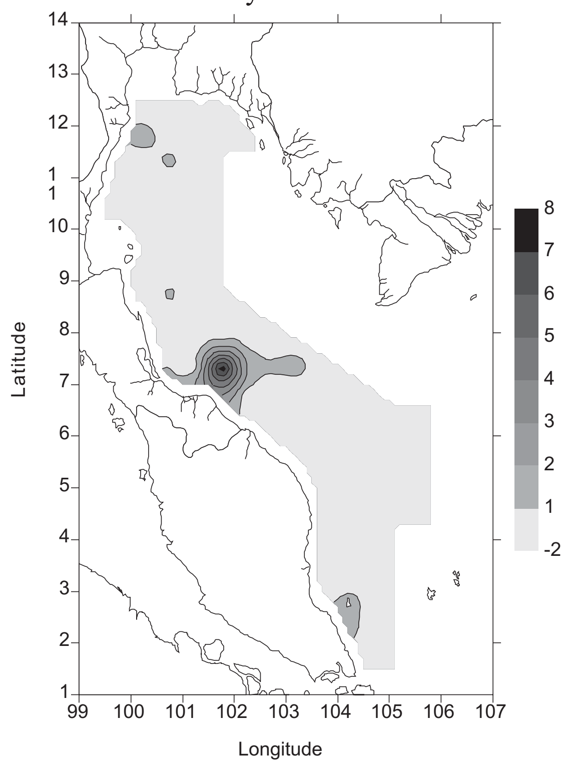


Fig. 44. Distribution of Stomatopod larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

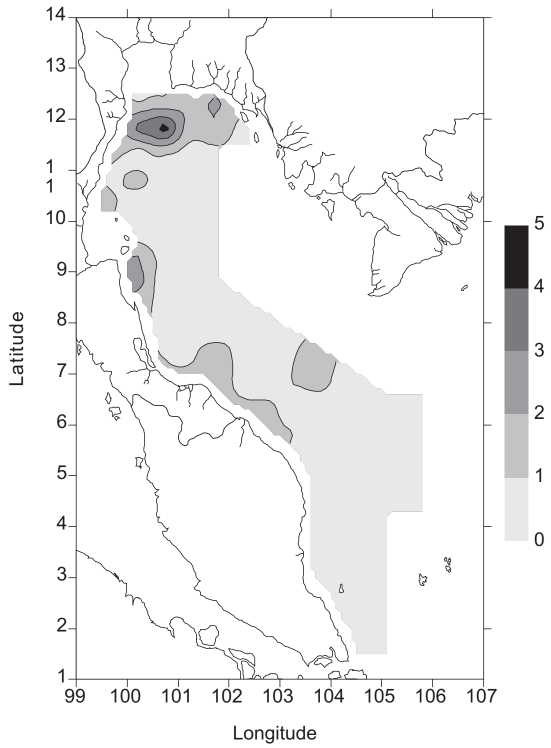


Fig. 45. Distribution of Stomatopod larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

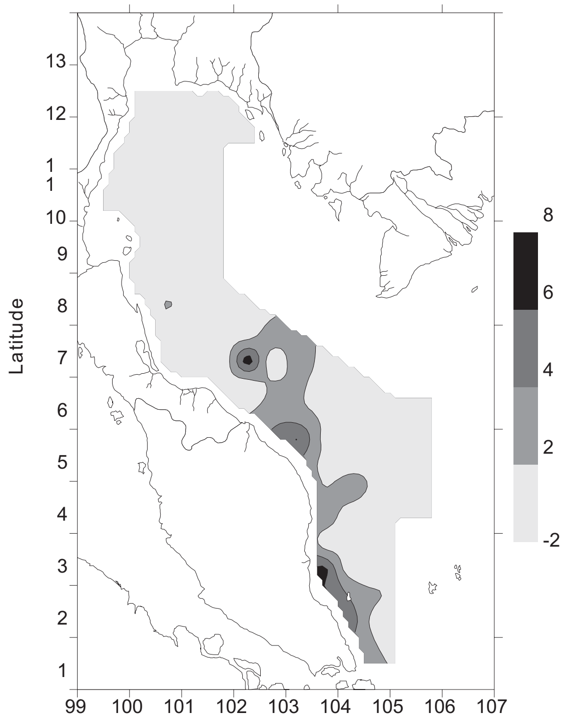


Fig. 46. Distribution of Heteropoda (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

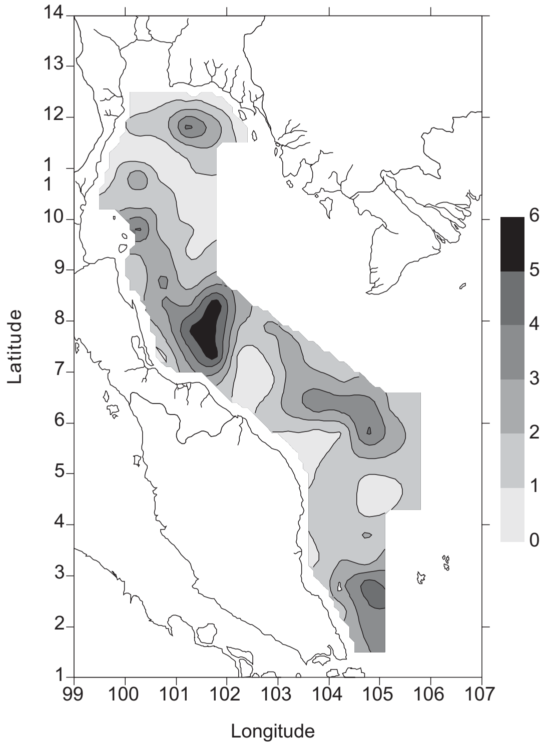


Fig. 47. Distribution of Heteropoda (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

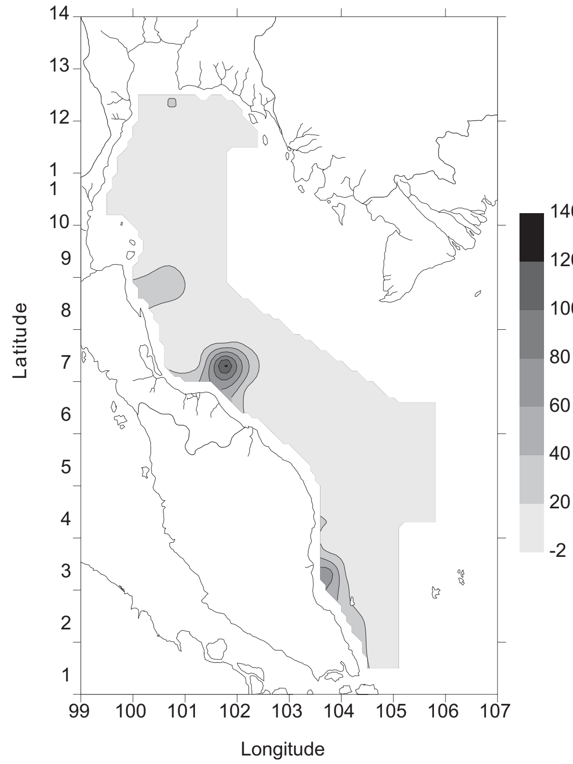


Fig. 48. Distribution of Pteropoda (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

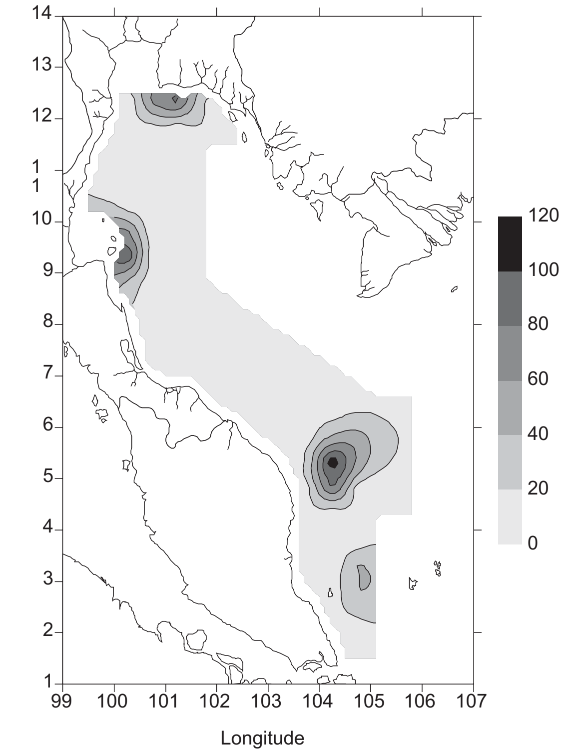


Fig. 49. Distribution of Pteropoda (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

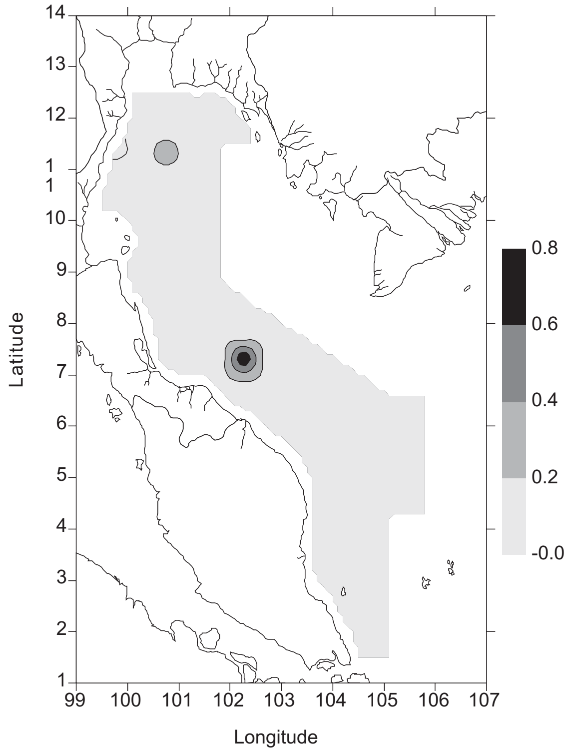


Fig. 50.Distribution of Cephalopoda (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

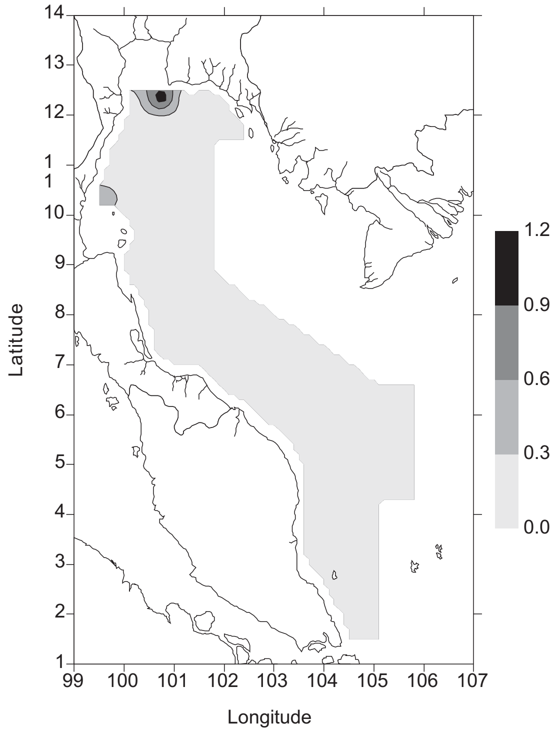


Fig. 51.Distribution of Cephalopoda (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

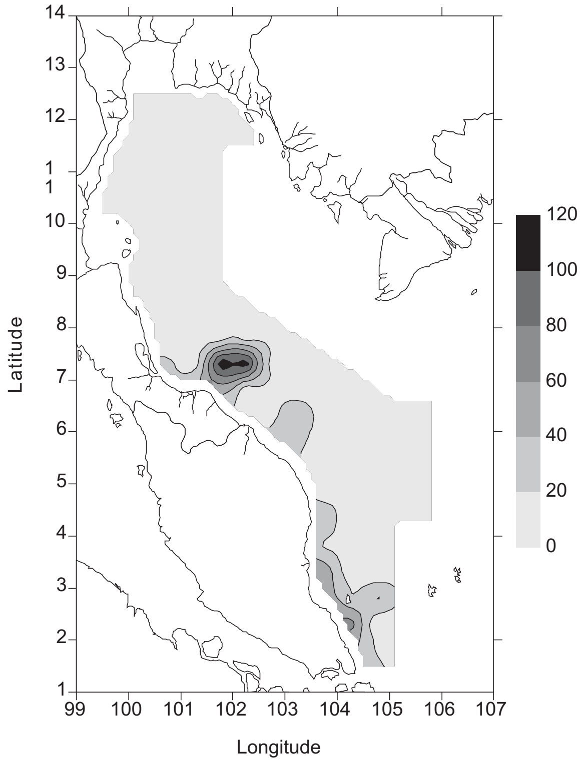


Fig. 52.Distribution of Gastropod larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

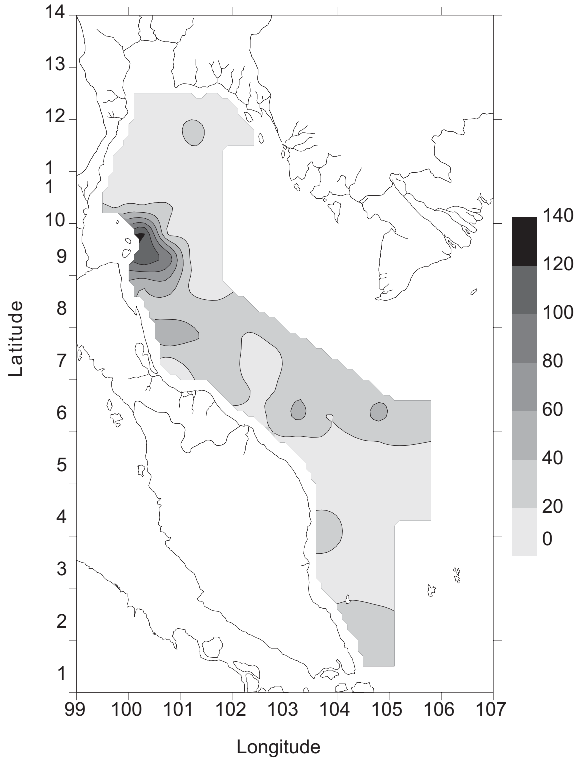


Fig. 53.Distribution of Gastropod larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

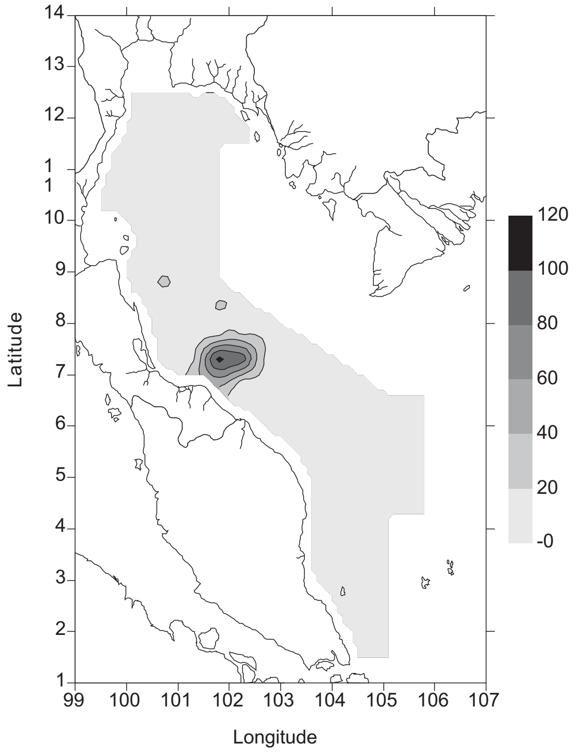


Fig. 54. Distribution of Bivalve larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

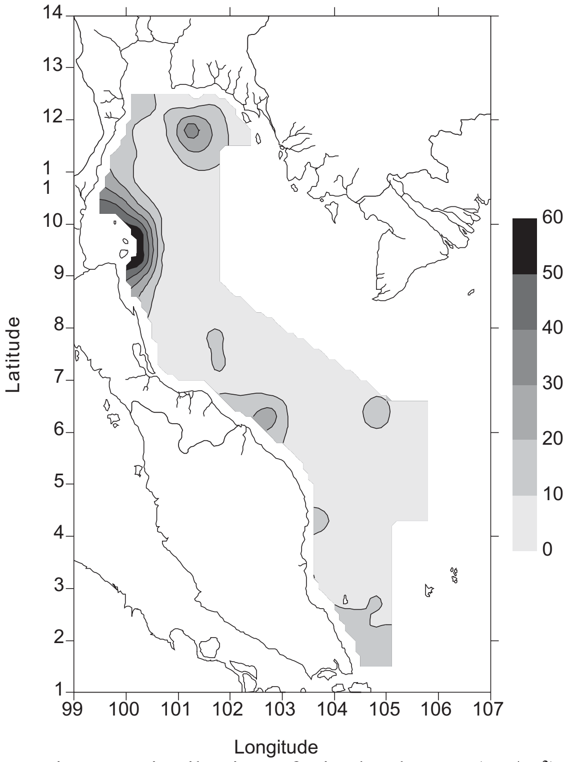


Fig. 55. Distribution of Bivalve larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

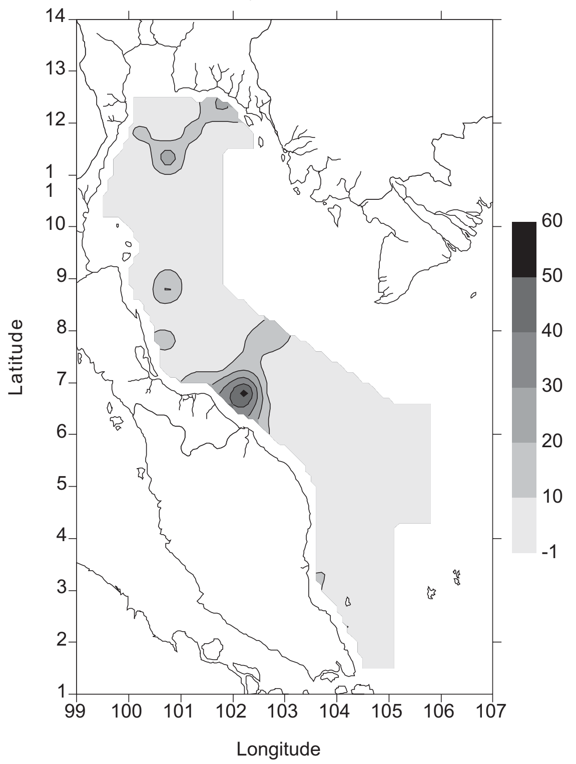


Fig. 56. Distribution of Echinodermata larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

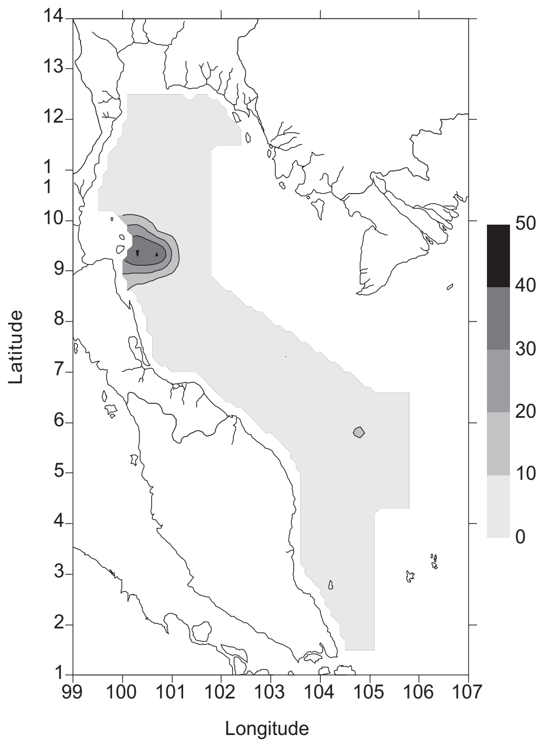


Fig. 57. Distribution of Echinodermata larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

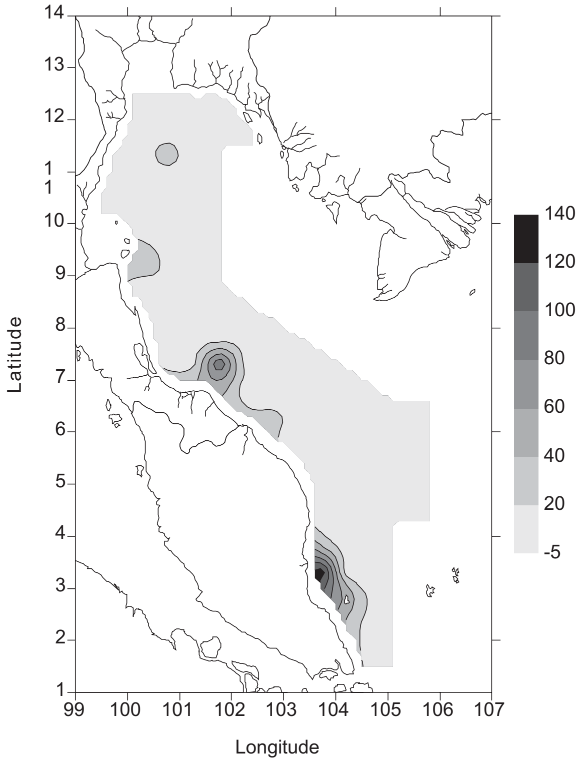


Fig. 58. Distribution of Larvacean (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

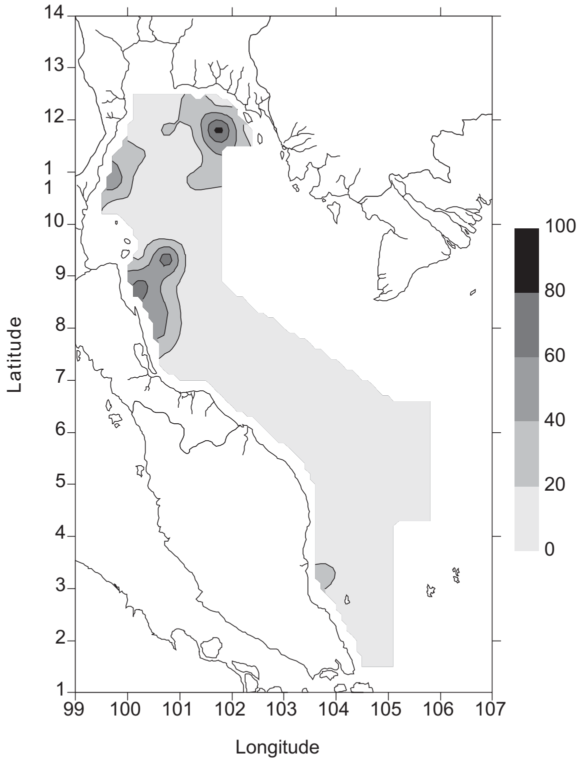


Fig. 59. Distribution of Larvacean (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

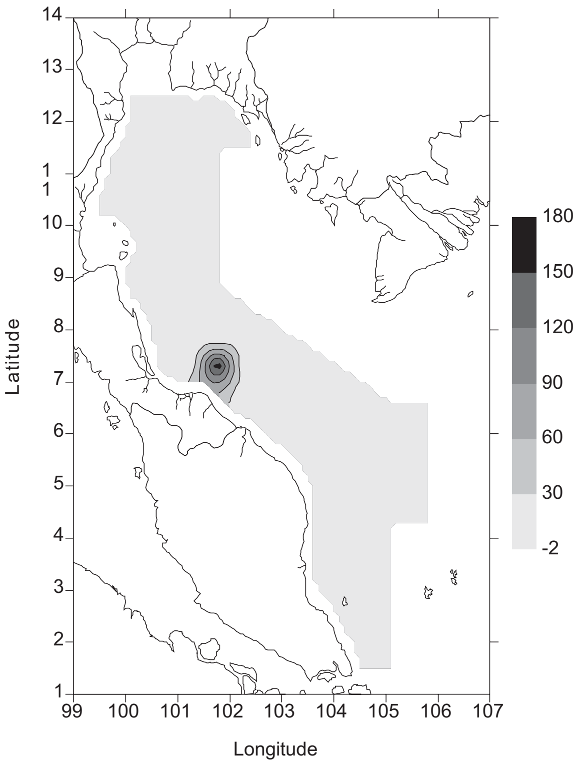


Fig. 60. Distribution of Thaliacea (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

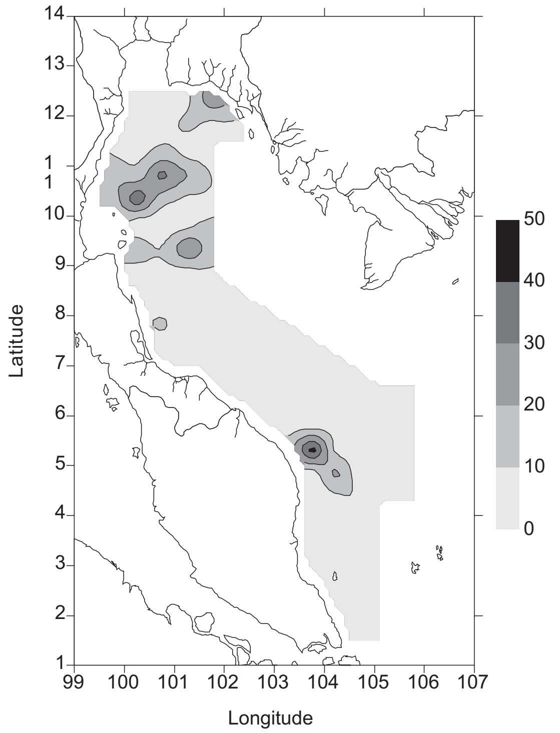


Fig. 61. Distribution of Thaliacea (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

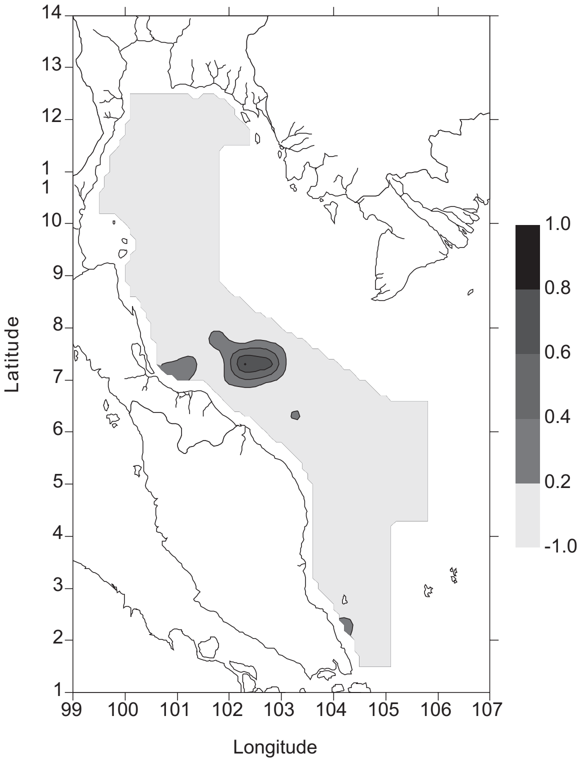


Fig. 62. Distribution of Brachiopoda larvae (no/m³) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

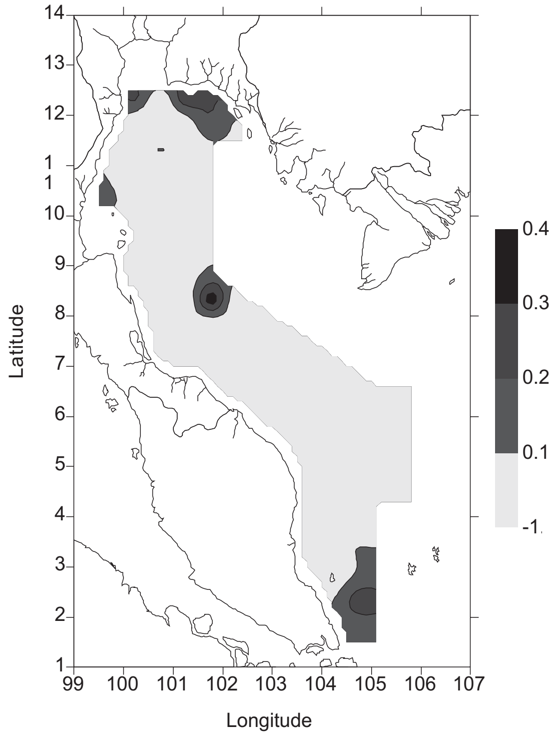


Fig. 63. Distribution of Brachiopoda larvae (no/m³) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

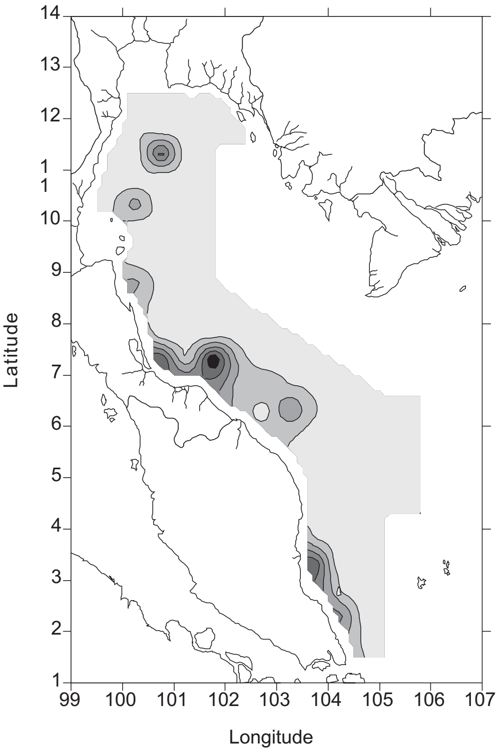


Fig. 64. Distribution of Crustacean Nauplii (no/m³) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

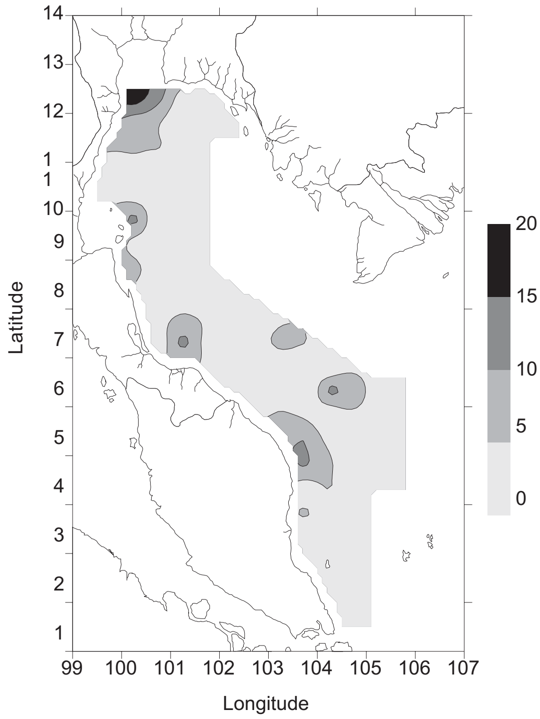


Fig. 65. Distribution of Crustacean Nauplii (no/m³) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

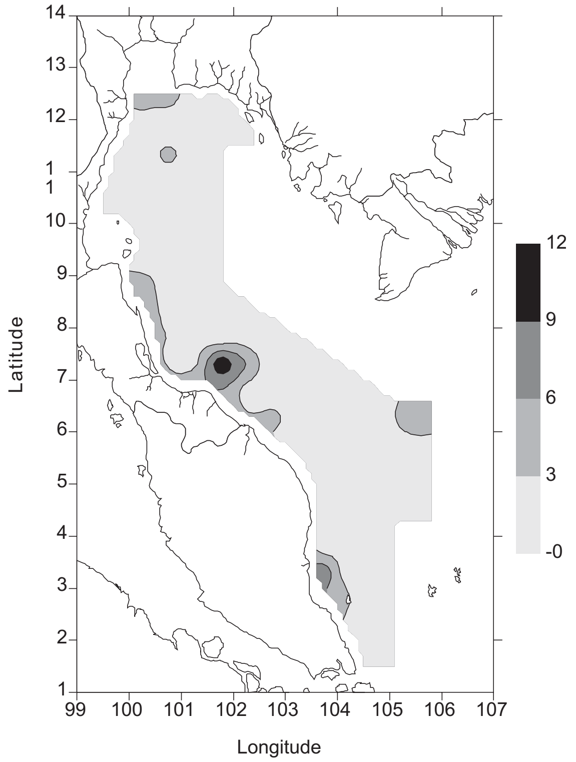


Fig. 66. Distribution of Fish eggs (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

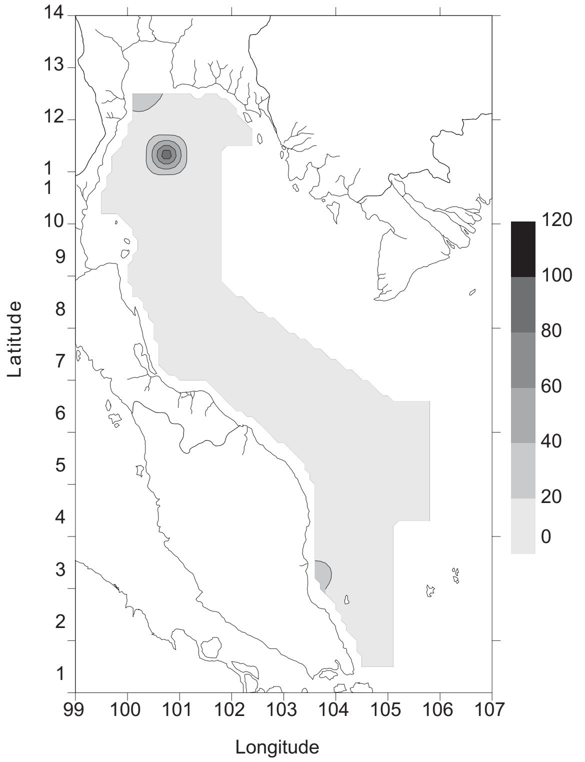


Fig. 67. Distribution of Fish eggs (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

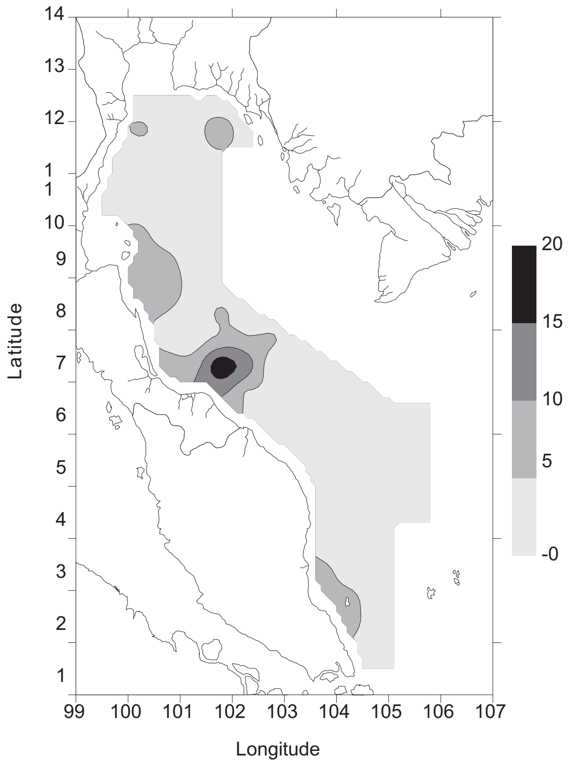


Fig. 68. Distribution of Fish larvae (no/m^3) during pre-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

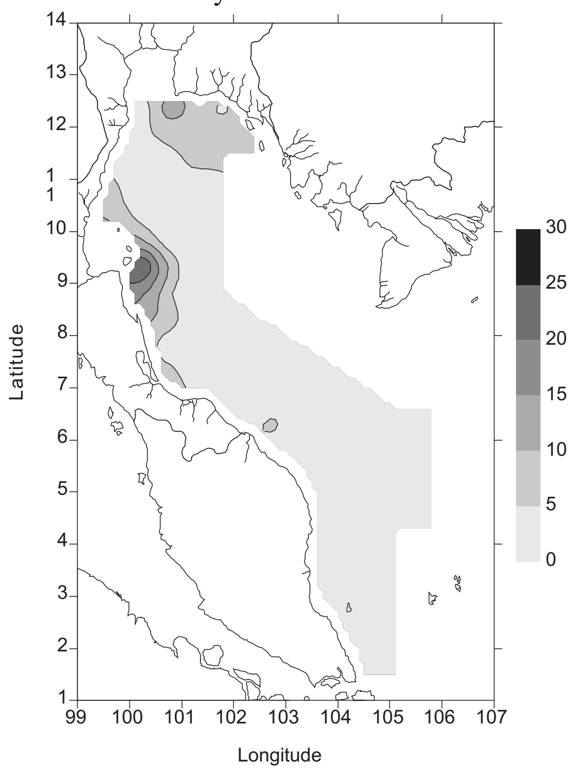


Fig. 69. Distribution of Fish larvae (no/m^3) during post-monsoon period in the Gulf of Thailand and the east coast of Peninsular Malaysia

References

Brinton, E. 1963. Zooplankton abundance in the Gulf of Thailand and South China Sea. Scripps Inst. Oceanogr., SIO-Ref. (63-6):53-58

Chayakul, R. 1990. Larvae and juveniles fishes occurring in the Gulf of Thailand. Tech. Paper of Mar. Res. Sur. Team, No. 4/1990. 98 p.

Hopcroft, R. R. and J. C. Roff. 1990. Phytoplankton size fractions in a tropical neretic ecosystem near Kingston, Jamica. J. Plank. Res. 12: 1069-1088.

Sribyatta, P. 1996. Variation of zooplankton abundance in the Gulf of Thailand 1976-1994. Tech. Paper No 4/2539. Mar. Fish. Envir. Group, Mar. Fish.Div., Dept. of Fish.58 p.

Sudara, S. and A, Udomkit. 1984. Distribution of Important Zooplankton in the Inner Part of the Gulf of Thailand. Proceedings of the third seminar on 'The Water Quality and the Quality of Living Resources in Thai Waters'. 10 p.

Suvapepun, S. and W. Suwanrumpha, 1969. Distribution of copepod in the Inner Gulf and the Western Coast of the Gulf of Thailand. Proc. Indo-Pacific Fish. Coun.,13(II): 1-9

Suvapepun, S. 1977. Variability of plankton quantity in the Inner Gulf of Thailand. Mar. Fish. Lab., Tech. Paper No 7/1977. 12 pp.

Suvapepun, S. 1980. Variability of plankton quantity off the east coast of the Gulf of Thailand. Tech. Paper No 23/3. Mar. Fish. Envir. Group, Mar. Fish. Div., Dept of Fish.. 16p.

Suvapepun, S. 1981. Zooplankton in the Gulf of Thailand. Thai Fish. Gaz.. 34 (2): p. 201-214.

Suwanrumpha, W. 1978. The seasonal abundance of plankton in the Inner Gulf of Thailand in relation to the ichthyoplankton, salinity and temperature. Mar. Fish. Lab.,Tech. Paper No. 7/1978. 25p.

Suwanrumpha, W. 1980[a]. Zooplankton in the Inner Gulf of Thailand. I. Seasonal abundance and distribution of zooplankton 1975-1976. Tech. Paper No 22/6. Mar. Fish. Envir. Group, Mar. Fish. Div., Dept. of Fish. 23p.

Suwanrumpha, W. 1980[b]. Zooplankton in the Inner Gulf of Thailand. II. Species group and seasonal variation in the copepod 1975-1976. Tech. Paper No 22/7. Mar. Fish. Envir. Group, Mar. Fish. Div., Dept. of Fish.. 89 p.

Suwanrumpha, W. 1995. Distribution of salps species in the Gulf of Thailand. Marine Fish. Envir. Group, Mar. Fish. Div., Dept of Fish. 34 p.

Temiyavanich, S. 1984. Distribution and abundances of zooplankton along the Eastern Coastline of the Inner Gulf of Thailand. Proceedings of the third seminar on 'The Water Quality and the Quality of Living Resources in Thai Waters'. 4 p.

Tubtimsang, w. 1981[a]. Distribution of some invertebrate larvae in the Gulf of Thailand. Tech. Paper No 21/27. Aquatic animal Group, Mar. Fish. Div, Dept. of Fish. 42 p.

Tubtimsang, w. 1981[b]. Observation on the distribution of shrimp larvae in the Gulf of Thailand. Tech. Paper No 21/28. Aquatic animal Group, Mar. Fish. Div., Dept. of Fish. 35 p.

Distribution of Macrobenthos in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia.

Abdul Hamid Yasin and Solahuddin A. Razak

Marine Fishery Resources Development and Management Department
(MFRDMD)/SEAFDEC Fishery Garden, Chendering
21080 K. Terengganu, Malaysia.

ABSTRACT

A study on the macrobenthos profile was conducted using the research vessel MV SEAFDEC in almost all parts of the Gulf of Thailand and the East Coast of Peninsular Malaysia. A total of 44 stations were located within the Gulf of Thailand and 37 within that of East Coast of Peninsular Malaysia. Two cruises were carried out during the pre-and post-north-east monsoon. Macrobenthos showed greater density in Malaysian waters during the pre-monsoon period with 2500 individuals (at an average 67.6 individuals/m^2) compared to the Gulf of Thailand which showed 860 individuals (average 19.5 individuals/m^2). However, sampling after the monsoon has indicated quite the reverse, with 2680 individuals (60.9 individuals/m^2) found in the Gulf of Thailand compared to 620 individuals (16.8 individuals/m^2) in the East Coast of Peninsular Malaysia. All samples from both cruises were dominated by polychaete worms, followed by crustacea. Other groups such as echinoderms, molluscs, nemertians and sipunculids were also observed in lesser quantities. In terms of diversity, the Gulf of Thailand showed less families/taxa before the monsoon (with 20 families) than after the monsoon (with 35 families). The reverse holds true for the east coast of Peninsular Malaysia when 33 families were uncovered before the monsoon compared to 26 families after the monsoon. Among the dominant families/taxa were the polychaetes Cirratulidae, Orbiniidae, Eunicidae and Maldanidae; caridean shrimps and ophiuroids (brittle star).

Introduction

The role and importance of macrobenthos in the marine ecosystem has long been known and discussed. These organisms, mostly comprising the marine invertebrates, are greatly diversed biologically especially those found on the continental shelf. They form a major food item for the bottom feeders like demersal fish. Moreover, certain macrobenthic species are themselves of commercial importance as, for example, the prawns, crabs and cockles.

These benthic organisms have a normally limited movement, and as such are easily exposed to threats from pollution. A number of assessment and monitoring studies have made use of these organisms as an important element of measurement to indicate the quality of the marine ecosystem within the areas to be developed.

Comprehensive surveys on the macrobenthic profile found within the waters of Malaysia and Thailand are rarely conducted due to the various logistic problems and high costs incurred. Some previous studies worth mentioning, although these were conducted on a much smaller scale, are those by Chua *et al.* (1980), Othman *et al*. (1989) and Lotfi *et al*. (1994) in the waters of Malaysia, and Aryuthaka *et al.* (1991) and Sanguansin (1986) in the Gulf of Thailand.

Such surveys are gaining in importance due to man-made activities which exert undue and adverse pressures on the marine habitat have greatly increased. Some examples of these activities are those related to petroleum/gas drilling, shipping, commercial fishing and recreational fishing. Alongi (1990) believed that such benthic studies are greatly needed in the tropics to provide the required basic data for comparison to any critical disorders that might arise in future. This paper outlines the preliminary results on the macrobenthic profile within the studied area obtained during the collaborative research survey between the SEAFDEC departments of Thailand and Malaysia.

Materials and Methods

The study area covered almost all parts of the Gulf of Thailand and the East Coast of Peninsular Malaysia. A total of 81 stations were selected in this survey using the research vessel MV SEAFDEC (Figure 1). Two cruises were carried out for the pre-monsoon and post-monsoon period. The first cruise started from September 4th to October 4th 1995 (pre-monsoon), while the second was from 23rd April to 23rd May 1996 (post-monsoon).

Bottom sediment was taken using a Smith-Mclntyre grab with an estimated opening of $0.05m^2$. Due to the limited time, only one grab sample was collected at each station. Sediment samples were washed and sieved through two types of sieve of mesh size 2.00 mm and 0.5mm. The animals were hand picked using a pair of forceps. All specimens were preserved with 10% formalin in sea water and subsequently transferred in 70% ethanol back to the MFRDMD laboratory. Samples were identified under the dissecting microscope to the family level.

The Shannon-Wiener Index (1949) is used to calculate the Diversity Index (H) and Eveness Index (J). The formula is as follows:-

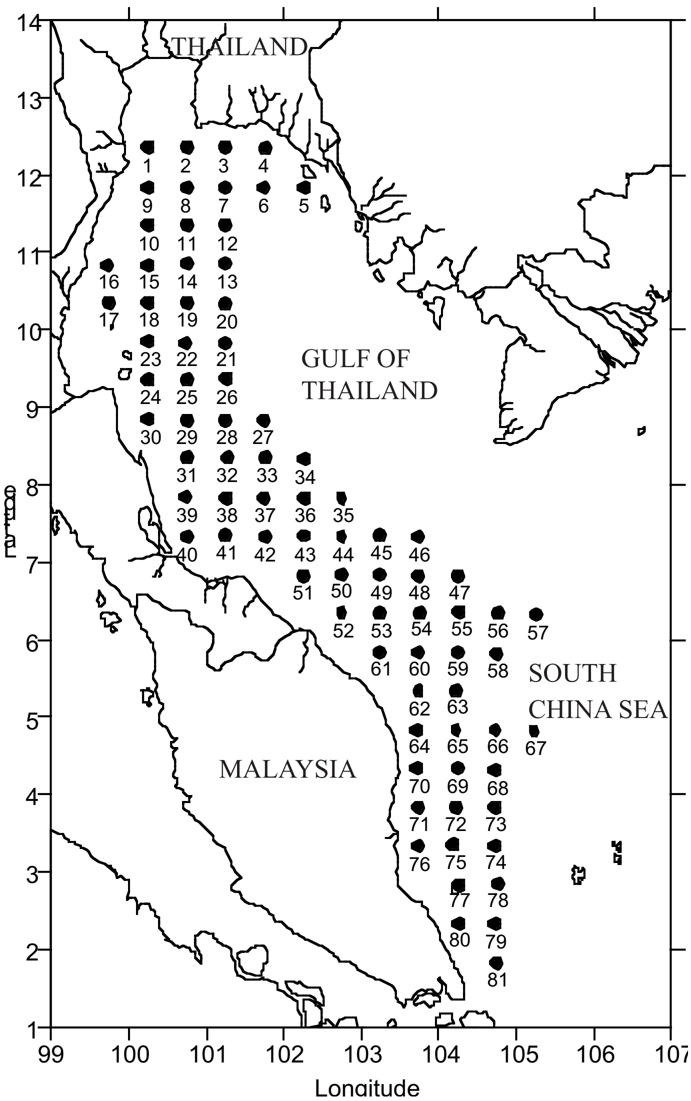


Fig. 1. Survey area and sampling locations in the Gulf of Thailand and South China Sea.

$$H = -S\, P_i \log_2 P_i \text{ ....(i)}$$

where $P_i = n_i/N$

n_i = the number of individuals of the species

N = the total number of individuals

The diversity index can measure species richness (H) and species eveness (J)

$J = H/\log_2 S$ .... (ii) where S = number of species

Results and Discussion

From the 81 stations examined, a total of 44 stations were located within the Gulf of Thailand and 37 off the East Coast of Peninsular Malaysia. This paper compares the results obtained from the two areas during the pre- and post-monsoon cruises. In this study, polychaetes were identified up to the family level, while the other benthic specimens were identified according to their relevant taxa.

Individual macrobenthic organisms showed greater density in Malaysian waters during the pre-monsoon period with 2500 individuals (at an average 67.6 individuals/m^2) compared to the Gulf of Thailand which showed 860 individuals (average 19.5 individuals/m^2) (see Table 1).

A similar sampling after the monsoon indicated quite the reverse, with 2680 individuals (60.9 individuals/m^2) found in the Gulf of Thailand compared to 620 individuals (16.8 individuals/m^2) on the East Coast of Peninsular Malaysia. In general, the macrobenthic abundance in this study is considerably less than those obtained by Othman *et al.* (1987) and Lotfi *et al.* (1994) in Terengganu waters, and Menasveta & Hongskul (1988) in the Gulf of Thailand. Each group of polychaetes, crustacea and others also showed a similar pattern in abundance.

All the obtained samples were dominated by the polychaete worms, with Crustacea second in abundance. Other groups of organisms observed in lesser quantities are the Echinoderms, Molluscs, Nemertians and Sipunculids. The percentage of contribution by the polychaete is large in both waters during the pre- and post-monsoon period, ranging from 53-72% (Table 1). Domination by the polychaete is a natural phenomenon in soft bottom substrates as shown in the studied area (Fauchald, 1997). Its dominance in the waters of the East Coast of Peninsular Malaysia is slightly greater before the monsoon (at 72%) than after (at 71%). In the Gulf of Thailand, the difference is more pronounced with its percentage before the monsoon at 67.4%, which declines to 53% after the monsoon. Crustacea showed a greater percentage (20.9 - 35 %) in the Gulf of Thailand compared to those in the East Coast of Peninsular Malaysia (of 13.6 - 16.1 %)

In terms of diversity, the Gulf of Thailand showed less families/taxa before the monsoon (with 20 families) than after (with 35 families). The reverse holds true for the East Coast of Peninsular Malaysia where 33 families were observed before the monsoon as opposed to 26 families afterward. Shannon's Index of diversity for all samples in all areas is rather high, ranging from 4.04-4.62, while the Evennes Index showed a range from 0.9 - 0.96 (Table 1). This indicates non-domination within the area by any specific family. A clear domination by any species would indicate non-stability in the benthic habitat.

The less species richness obtained is, however, indicative of the low number of families observed throughout the study. This could perhaps be attributed to the single replicate taken at each of the stations, this being unavoidable due to the tight time schedule followed during the sampling.

The number of families recorded at each station is considerably lower compared to previous studies within the same area. Tables 2 and 3 show the relative abundance andnumber of families of macrobenthos, as well as the other groups at each station. In the Gulf of Thailand, the greatest numbers werelocated at stations 4 and 13 during the post-monsoon cruises where 580 and 340 individuals/m^2 were recorded from 11 and 10 families, respectively. For the study areas off Malaysia, station 52 was identified as providing the highest number on the pre-monsoon cruise (6 families, 180 individuals/m^2), and station 77 on the post-monsoon (7 families, 160 individuals/m^2).

Figure 2 shows the abundance of each family of macrobenthos in the Gulf of Thailand. In

Table 1. Summary of distribution analyses of macrobenthos in the Gulf of Thailand and the East Coast of Peninsular Malaysia.

Gulf of Thailand

	Polychaete		Crustacea		Others		Total	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Total	580	1420	180	960	100	300	860	2680
Average	13.2	32.3	4.1	21.8	2.3	6.8	19.5	60.9
Percentage	67.4	53	20.9	35.8	11.6	11.2	100	100
No. of family	15	25	3	5	2	5	20	35
Diversity index							4.04	4.59
Evenness index							0.93	0.9

East Coast of Peninsular Malaysia

	Polychaete		Crustacea		Others		Total	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Total	1800	440	340	100	360	80	2500	620
Average	48.6	11.9	9.2	2.7	9.7	2.2	67.6	16.8
Percentage	72	71	13.6	16.1	14.4	12.9	100	100
No. of family	24	20	5	4	4	2	33	26
Diversity index							4.62	4.22
Evenness index							0.92	0.96

general, almost every family recorded lower numbers during the pre-monsoon comprising the polychaete families i.e. Cirratullidae, Maldanidae and Eunicidae, and the Thallassinoids crustacean. These families were dominant in both of the cruises. On the other hand, all families of macrobenthos generally accord higher individuals during the pre-monsoon cruise compared to post-monsoon (Figure 4). Among the dominant families are the polychaetes Orbiniidae, Eunicidae and Maldanidae; caridean shrimp and ophiuroids (brittle star).

Generally, the different environmental changes that are known to occur before and after the monsoon in both areas are rather significant and more detailed investigation pertaining to its influences is needed. More so, when the study area is actually located far from shore. The influence of the monsoon has been numerously recorded in the coastal areas and estuaries. Alongi (1990) concluded that the effects of the monsoon are greatly felt in coastal areas that receive some form of sedimentation from the land (eg. river run-offs) during and after the monsoon. These shallow areas would normally experience greater disturbance from the turbulent ocean currents compared to offshore areas with greater depths.

Acknowledgements

The authors wish to thank Mr. Wan Mohd Lotfi b. Wan Muda of the Faculty of Natural Resource Science, University Kebangsaan Malaysia for his expert advice and Dr. Mohd Taupek b. Mohd Nasir for reviewing the manuscript.

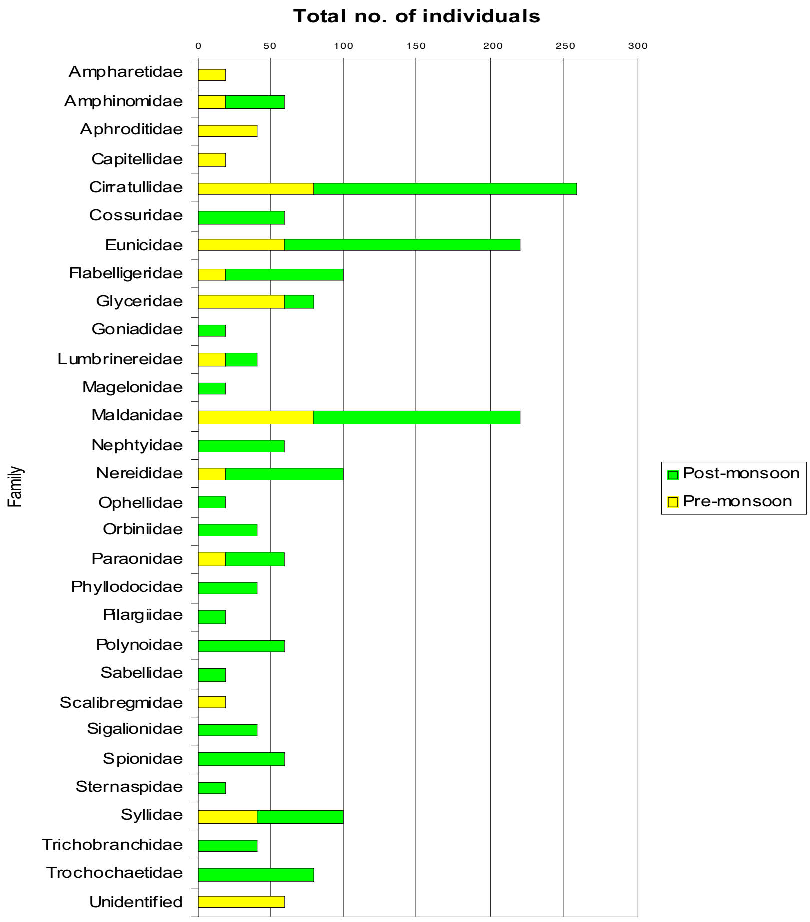


Fig. 2a. Total number of individuals contributed by each polychaete families in the Gulf of Thailand

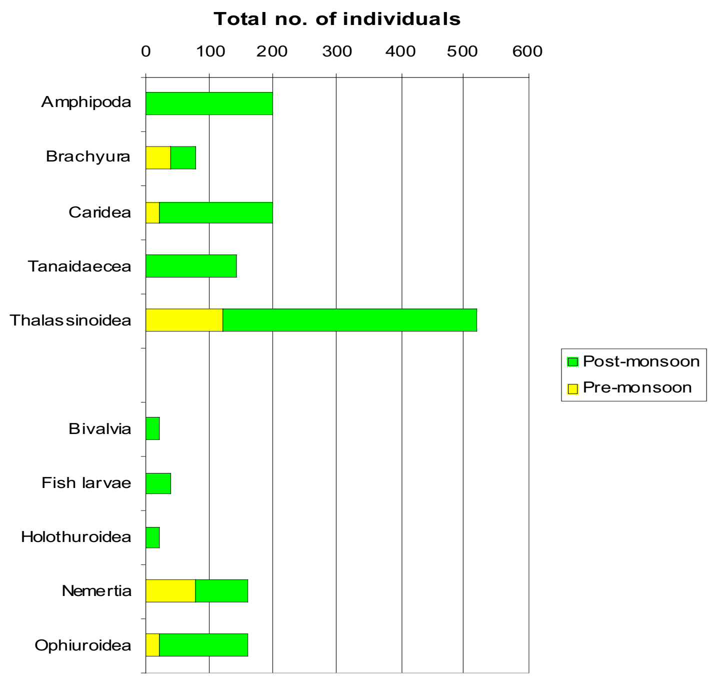


Fig. 2b. Total number of individuals contributed by crustacean and other taxa (families) in the Gulf of Thailand.

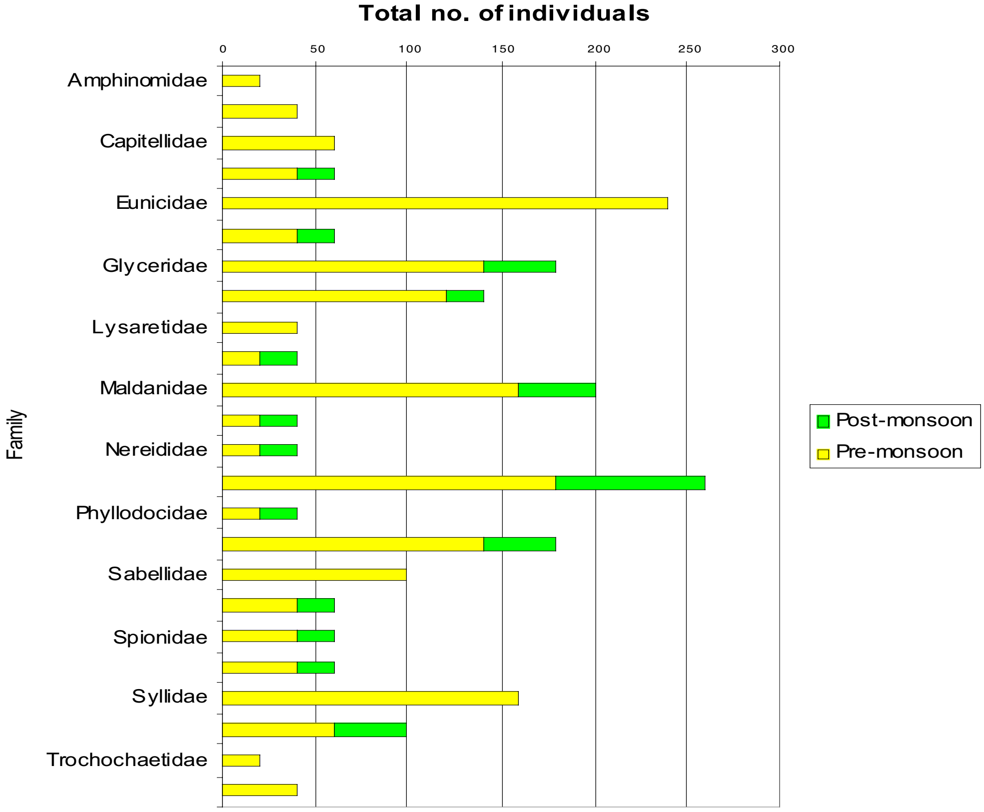


Fig. 3a. Total number of individuals contributed by polychaete families in the East Coast of Peninsular Malaysia.

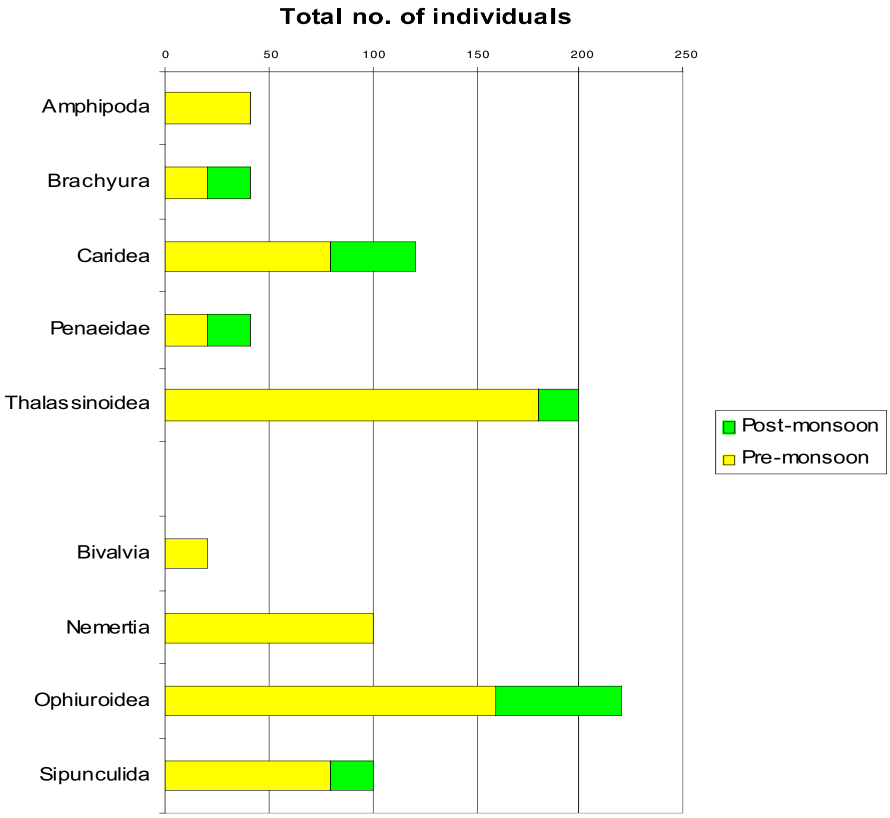


Fig. 3b. Total number of individuals contributed by crustaceans and other families (texa) in theEast Coast of Peninsular Malaysia.

Table 2. Abundance of macrobenthos at stations located in the Gulf of Thailand.

Pre-monsoon				
Stations	Abundance (no. of family)			
	Polychaete	Crustacea	Others	Total
8	80 (3)	-	-	80 (3)
14	20 (1)	-	-	20 (1)
19	20 (1)	-	-	20 (1)
25	80 (3)	-	-	80 (3)
27	60 (3)	80 (1)	-	140 (4)
28	40 (2)	-	-	40 (2)
29	40 (2)	-	-	40 (2)
30	20 (1)	-	-	20 (1)
31	60 (3)	40 (2)	-	100 (5)
32	20 (1)	20 (1)	-	40 (2)
35	-	-	40 (1)	40 (1)
38	20 (1)	-	-	20 (1)
39	-	40 (2)	40 (1)	80 (3)
40	20 (1)	-	-	20 (1)
41	60 (3)	-	-	60 (3)
42	20 (1)	-	20 (1)	40 (2)
51	20 (1)	-	-	20 (1)
Post-monsoon				
Stations	Abundance (no. of family)			
	Polychaete	Crustacea	Others	Total
2	60 (3)	-	20 (1)	80 (4)
4	360 (8)	180 (2)	40 (1)	580 (11)
6	20 (1)	20 (1)	-	40 (2)
7	40 (2)	20 (1)	40 (2)	100 (5)
8	20 (1)	40 (2)	-	60 (3)
11	140 (6)	60 (1)	-	200 (7)
13	180 (5)	120 (3)	40 (2)	340 (10)
14	80 (3)	40 (2)	20 (1)	140 (6)
18	100 (4)	160 (2)	60 (3)	320 (9)
19	60 (2)	140 (2)	40 (2)	240 (6)
21	120 (6)	20 (1)	20 (1)	160 (8)
23	80 (3)	-	-	80 (3)
24	40 (2)	160 (1)	-	200 (3)
26	20 (1)	-	20 (1)	40 (2)
38	20 (1)	-	-	20 (1)
41	60 (3)	-	-	60 (3)
51	20 (1)	-	-	20 (1)

Table 3. Abundance of macrobenthos at stations located in the East Coast of Peninsular Malaysia.

Pre-monsoon				
Stations	Abundance (no. of family)			
	Polychaete	Crustacea	Others	Total
45	40 (2)	-	-	40 (2)
47	80 (4)	-	-	80 (4)
48	20 (1)	-	-	20 (1)
49	40 (2)	-	-	40 (2)
50	20 (1)	20 (1)	-	40 (2)
52	180 (6)	-	-	180 (6)
53	20 (1)	-	-	20 (1)
54	40 (2)	20 (1)	20 (1)	80 (4)
55	20 (1)	20 (1)	20 (1)	60 (3)
57	-	40 (2)	-	40 (2)
58	60 (2)	-	40 (1)	100 (3)
59	80 (4)	20 (1)	40 (2)	140 (7)
61	20 (1)	-	40 (2)	60 (3)
62	40 (2)	20 (1)	-	60 (3)
63	40 (2)	-	40 (1)	80 (3)
64	40 (2)	20 (1)	-	60 (3)
65	40 (1)	-	20 (1)	60 (2)
66	40 (2)	-	20 (1)	60 (3)
67	60 (3)	-	40 (1)	100 (4)
68	20 (1)	-	-	20 (1)
69	100 (5)	20 (1)	20 (1)	140 (7)
70	80 (2)	-	-	80 (2)
71	40 (1)	-	-	40 (1)
72	60 (3)	20 (1)	20 (1)	100 (5)
73	60 (3)	60 (2)	-	120 (5)
74	40 (2)	-	-	40 (2)
75	160 (5)	-	-	160 (5)
76	20 (1)	20 (1)	-	40 (2)
77	140 (6)	20 (1)	-	160 (7)
78	20 (1)	20 (1)	-	40 (2)
79	40 (2)	-	40 (2)	80 (4)
80	140 (4)	20 (1)	-	160 (5)
Post-monsoon				
Stations	Abundance (no. of family)			
	Polychaete	Crustacea	Others	Total
45	40 (2)	-	-	40 (2)
48	20 (1)	-	-	20 (1)
53	20 (1)	-	-	20 (1)
54	40 (2)	20 (1)	20 (1)	80 (4)
58	60 (2)	20 (1)	40 (1)	120 (4)
62	40 (2)	20 (1)	-	60 (3)
68	20 (1)	-	-	20 (1)
72	60 (3)	20 (1)	20 (1)	100 (5)
77	140 (6)	20 (1)	-	160 (7)

References

Alongi, D.M., 1990. The ecology of the tropical soft bottom benthic ecosystem. *Ocean.Mar, Biol. Rev*., **28**, 381-496.

Aryuthaka, C., N. Paphavasit and J. Chivalak. 1991. Soft Bottom Brachyura (Crustacea: Decapoda) in the middle portion of the west coast of the gulf of

Thailand. **In** Alcala, A.C.(ed.). *Proceedings of the Regional Symposium on Living Resources in Coastal Areas* pp.581-587. Manila, Philippines.

Chua, T.E. and Charels, J.K. 1980. *Coastal Resources of East Coast Peninsular Malaysia: An assessment in relation to potential oil spills*. USM, Pulau Pinang, Malaysia.

Fauchald, C. 1997. *Polychaetes Worms. Definition and key to the Order, Family and Genera.* Los Angeles County Museum of Natural History Science Series **28**: 1-190.

Lotfi, W.M., B.H.R. Othman, M. Zamry & A. Aziz. 1994. Composition and temporal changes in abundance of macrobenthos at two opposite locations of Pulau Redang, Malaysia. **In** Sudara, S., C.R. Wilkinson, L.M. Chou (eds.). *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources*, **Vol 2**: 581-587. Bangkok, Thailand.

Menasveta, D. & V. Hongskul. 1988. The gulf of Thailand. *In* Postma, H. and J.J. Zilstra. (Eds.). *Ecosystem of the World: Continental Shelves*. 363-383. Elsvier. Amsterdam.

Othman, B.H.R., Nor M. Mahadi, Basir Jasin & M.A. Badri. 1987. *The Marine Environment of Dulang Oilfield. A baseline Study of Selected Aspect*. A final Report for PETRONAS Carigali Sdn. Bhd.

Sanguansin, J. 1986. Benthic fauna in the central gulf of Thailand. *SEAFDEC Res. Pap. Ser*. **8**:37-64.

Distribution of Dinoflagellate Cysts in the Surface Sediment of the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Thaithaworn Lirdwitayaprasit

Department of Marine Science, Chulalongkorn University, Bangkok 10330, Thailand

ABSTRACT

To obtain more information on the distribution of dinoflagellate cysts in Thai and Malaysian waters, the surface sediment samples of 48 stations in the Gulf of Thailand and the east coast of Peninsular Malaysia were collected by M.V. SEAFDEC during the research cruise in September 1995 and repeated again in April 1996. Cysts of 20 species belonging to Goniolacoid, Tuberculodinioid and Peridinioid were found in the surface sediments collected from both cruises. ***Spiniferites*** spp. (= *Gonyaulax* spp.) were the dominant cyst in Thai and Malaysian waters. No cysts of harmful species were observed during this study.

Introduction

Marine dinoflagellates have been known to alternate between vegetative (motile cell) and resting stage (non-motile cell) in their life history. The resting cysts are produced during a sexual phase in its life cycle. A recent review by Anderson (1984) showed cysts have a variety of potential functions in the overall ecology of the dinoflagellates such as:

1) seed population to initiate red tides
2) a survival mechanism through environmental extremes
3) agents for species dispersal
4) means for genetic recombination
5) direct sources of toxicity
6) a factor in bloom termination

The potential importance of benthic dinoflagellate cysts, *Gonyaulax tamarensis* (=*Alexandrium tamarense*) and *G. excavata* (= *A. catenella*), in initiating toxic shellfish was pointed out by Anderson and Wall (1978). The importance of life cycle events in the population dynamics of *G. tamarensis* demonstrated that the blooms of this species were initiated by excystment and terminated mainly by encystment (Anderson *et al*. 1983). Cysts of *Chattonella* spp. also seem to play an important role in the Seto Inland Sea, Japan (Imai and Itoh, 1987). However, this important role of dinoflagellate cysts in Thai and East Coast of Peninsular Malaysia have not been studied.

Concerning shellfish intoxication, it has been proposed that shellfish toxicity in the deep water might be due to the ingestion of cysts of toxic species (Bourne, 1965). Dale *et al*. (1978) found natural samples of *Gonyaulax excavata* cysts were ten times more toxic than the vegetative cells. The study of Lirdwitayaprasit *et al*. (1990) showed the cyst production of *Alexandrium catenella* under laboratory conditions was more toxic than the vegetative cells. However, very few studies have been carried out on the distribution of benthic dinoflagellate cysts in the surface sediments of ASEAN waters. For example, the distribution of cyst of toxic dinoflagellate *Pyrodinium bahamense* is little known in the waters of Thailand and the east coast of Peninsular Malaysia. The blooms of this species were found for the first time in the northwestern coast of Borneo (Brunei and Sabah waters), the Philippines and Eastern Indonesia in 1976, 1983 and 1994, respectively (Maclean, 1989 and Wiadnyana *et al*., 1996). The blooms reoccurred again some years later in some other places, but it has been almost an annual feature in Manila Bay since 1991 (Bajarias and Relox, 1996). There is a possibility that the vegetative cells and cysts of this toxic species could be dispersed into the Gulf of Thailand and the east coast of Peninsular Malaysia by the discharge of water and sediments from ships' ballast tank, translocation of shellfish and water current.

To provide baseline information on dinoflagellate ecology and also for the preparation of a red tide management programme, investigation of benthic cysts in these areas was carried out.

Materials and Methods

The surface sediment samples of 48 stations were collected using the gravity core sampler during the collaborative research cruises from September 3 - October 3, 1995 and repeated again during April 23 - May 23, 1996 by M.V. SEAFDEC. The study area is shown in Fig. 1.

Surface sediment samples of about 1 cm in thickness each were cut and kept in plastic bottles with a small amount of seawater above the sediment. The sample preparation for identification and quantitative analysis of the benthic cysts was performed using the method described by Matsuoka *et al.* (1989) while the main references used in this study for identification purposes were Matsuoka and Fukuyo (1995), Matsuoka (1985 a, b, c) and Matsuoka (1987). Both empty cysts and living were identified and counted.

Results and Discussion

Environmental Conditions

Some physical parameters during the surveys were recorded and shown in Table1. These parameters from the two cruises are almost identical and show no clear relationship with the average total cyst densities.

Abundance and Distribution

A total of 20 species of the modern dinoflagellate cysts belonging to Goniolacoid, Tuberculodinioid and Peridinioid were found in this study and shown in Table 2. The abundance and distribution of cysts in both cruises was almost the same with the average cyst densities shown in Fig. 2-21. All cysts were found in small densities in the surface sediment samples of both Thai and Malaysian waters and most of them were found at depths of more than 30 metres. There are two possible reasons to explain this observation, one probably due to fishing activities, especially trawl fishing which stirs the surface sediment and resuspended the cysts into the water column, while the other could possibly be at depths of 0-30 metres, cysts were exposed to the optimal conditions for germination including high temperature and high light intensity.

Cysts of *Spiniferites* spp. were the dominant species in both the upper and lower parts of the Gulf whereas cysts of *Protoperidinium* spp. were found almost entirely in the upper part of the Gulf (Stations 4 to 16). In Malaysian waters only cysts of *Spiniferites* spp. were the dominant group throughout the east coast of Peninsular Malaysia. Bujak (1984) pointed out that protoperidiniacean dinoflagellate abundance is associated with high diatom productivity and closely related to the rich dissolved nutrients such as those present in the upwelling areas. Matsuoka (1987) suggested that the areas dominated by protoperidiniacean cysts could be divided into two categories. One is related to the upwelling areas such as the regions be off Pisca, Peru, off West Africa and off Western South Africa. Another could probably be related to the enrichment of nutrients by rivers such as the Gulf of Main, Dover Strait, Gulf of Mexico, etc. The appearance of protoperidiniacean cysts in the upper part

Table 1. Physical parameters and average total dinoflagellate cysts in the surface sediment samples from the Gulf of Thailand and East Coast of Peninsular Malaysia; 1 = first cruise; 2 = second cruise

Station	Depth(m)		Temperature (oC)		Surface Sediment Characteristic	Total
	1	2	1	2		cysts/cm3
1	27	27	29.4	29.9	Brownish coarse sandy mud	NO
2	30	30	29.0	30.1	Brownish coarse sandy mud	NO
3	31	31	28.9	30.4	Brownish coarse sandy mud	NO
4	23	23	28.9	30.4	Brownish coarse sandy with shell fragments	36
5	34	34	29.1	30.0	Brownish coarse sandy with shell fragments	12
6	51	53	28.9	28.3	Brownish coarse sandy with shell fragments	84
7	54	53	28.9	29.7	Brownish fine sandy mud with shell fragments	NO
8	40	40	28.8	29.7	Brownish fine sandy mud with shell fragments	12
9	36	37	28.7	28.5	Brownish fine sandy mud with shell fragments	36
10	48	48	28.6	28.5	Brownish fine sandy mud with shell fragments	24
11	54	53	28.6	28.5	Brownish fine sandy mud with shell fragments	36
15	56	58	28.8	28.2	Brownish fine sandy mud with shell fragments	24
16	50	50	28.8	27.5	Brownish fine sandy mud with shell fragments	72
17	46	46	28.9	27.5	Brownish fine sandy mud with shell fragments	60
18	61	61	28.1	28.0	Brownish fine sandy mud with shell fragments	60
22	59	58	27.5	28.4	Brownish fine sandy mud with shell fragments	72
23	34	34	28.7	28.5	Black silt clay with shell fragments	12
24	29	29	29.2	29.2	Brown fine sandy mud with shell fragments	NO
25	40	40	27.9	29.1	Brown fine sandy mud with shell fragments	24
29	32	33	28.8	29.2	Brown fine sandy mud with shell fragments	12
30	24	24	29.2	29.8	Brown-yellowish silt clay with shell fragments	24
31	29	29	29.3	29.3	Brown-yellowish silt clay with shell fragments	NO
32	55	55	27.7	28.3	Brown-yellowish silt clay with shell fragments	NO
38	49	50	27.9	28.1	Brown fine sandy mud with shell fragments	NO
39	28	28	29.4	29.5	Brown coarse sandy mud with shell fragments	12
40	22	22	29.4	30.1	Brown coarse sandy mud with shell fragments	12
41	41	42	28.1	28.9	Brown fine sandy mud with shell fragments	12
42	49	49	27.1	27.4	Brown fine sandy mud with shell fragments	NO
50	51	51	28.6	26.5	Brown fine sandy mud with shell fragments	NO
51	48	50	27.7	27.2	Brown fine sandy mud with shell fragments	NO
52	39	39	27.7	27.4	Brown coarse sandy mud with shell fragments	36
53	53	53	28.8	27.1	Brown coarse sandy mud with shell fragments	24
60	57	57	27.5	26.4	Brown coarse sandy mud with shell fragments	36
61	52	52	27.2	26.9	Brown coarse sandy mud with shell fragments	60
62	61	61	26.5	26.4	Brown coarse sandy mud with shell fragments	48
63	64	64	25.5	26.1	Brown coarse sandy mud with shell fragments	96
64	59	59	25.2	26.2	Brown coarse sandy mud with shell fragments	96
65	66	66	24.2	26.0	Brown coarse sandy mud with shell fragments	48
69	67	67	24.0	26.0	Brown coarse sandy mud with shell fragments	24
70	39	39	27.2	26.9	Brown coarse sandy mud with shell fragments	NO
71	35	35	28.3	27.2	Brown coarse sandy mud with shell fragments	NO
72	55	54	25.7	26.2	Brown coarse sandy mud with shell fragments	24
75	50	50	26.5	26.3	Brown coarse sandy mud with shell fragments	12
76	25	26	28.4	28.0	Brown coarse sandy mud with shell fragments	24
77	48	48	27.2	26.4	Brown coarse sandy mud with shell fragments	12
78	65	66	24.2	26.0	Brown coarse sandy mud with shell fragments	36
79	59	59	25.8	26.4	Brown coarse sandy mud with shell fragments	84
80	34	34	28.5	27.0	Brown coarse sandy mud with shell fragments	12
81	51	52	27.3	26.9	Brown coarse sandy mud with shell fragments	72

NO = no cyst was observed

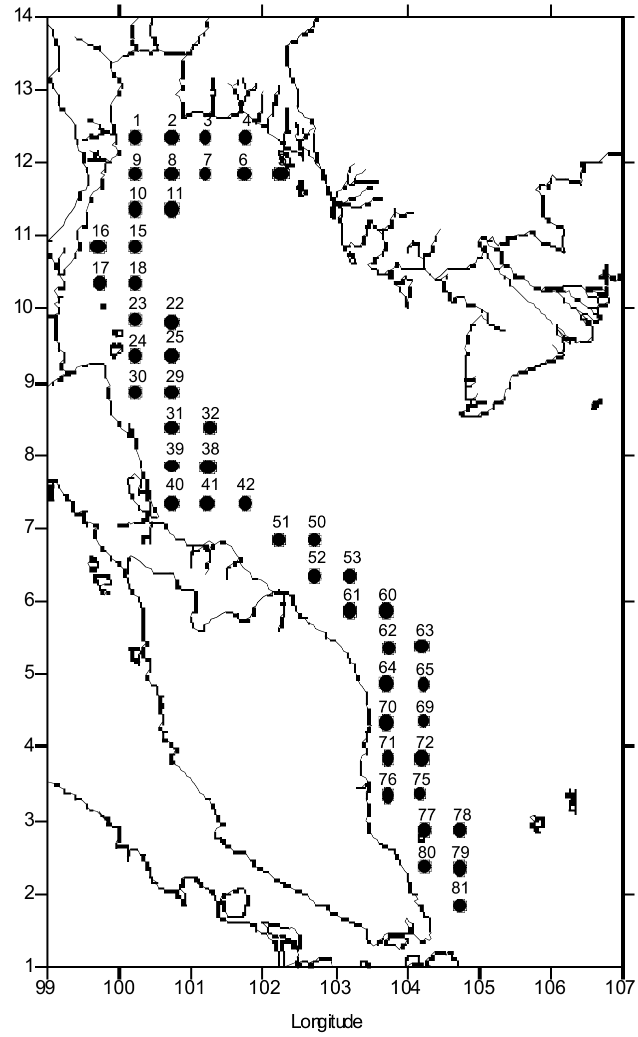


Fig. 1. Area and Stations of Dinoflagellate Cyst Sampling in the Gulf of Thailand and the East Coast of Peninsular Malaysia

of the Gulf of Thailand, where nutrient concentrations and productivity of diatoms are high, as shown in this study, is consistent with the discussion above.

Although cysts of harmful species have not been observed in this study, dinoflagellate cysts type E found at station 76 (Fig. 17), type F found at stations 5 and 39 (Fig. 18) and type H found at station 65 (Fig. 20) were similar to cysts of the *Alexandrium* group. This area has a possibility of being contaminated by motile cells and cysts of toxic species from the discharge of water and sediment from ships ballast tank during transportation into Thai and Malaysian waters.

Conclusions and Recommendations

1) This study provided more information on the distribution of dinoflagellate cysts in Thai and East Coast of Peninsular Malaysia waters useful for a cyst and/or red tide monitoring programme.
2) It is important to note that although cysts of toxic species have not been found in this study some observed cysts were similar to the cyst from the genus *Alexandrium*, some species of which were reported as the PSP (Paralytic Shellfish Poisoning) toxin producing organisms.
3) Further investigation should be conducted on germination experiments to clarify the roles of benthic cysts in this area.

Table 2. Checklist of dinoflagellate cysts found in the surface sediment samples from the Gulf of Thailand (T) and the East Coast of Peninsular Malaysia (M)

Peleontological name for cyst	Biological name for motile cell	T	M
	Goniolacoid		
1. *Spiniferites cf. bulloideus*	*Gonyaulax scrippsae*	/	/
2. *Spiniferites cf. ramosus*	*Gonyaulax spinifera complex*	/	/
3. *Spiniferites sp. 1*	*Gonyaulax sp. 1*	/	
4. *Operculodinium centrocarpum*	*Protoceratium reticulatum*	/	/
5. *Lingulodinium machaerophorum*	*Gonyaulax polyedra*	/	/
	Tuberculodinioid		
6. *Tuberculodinium vancampoae*	*Pyrophacus steinii*	/	/
	Peridinioid		
7. *Trinoventedinium cf. capitatum*	*Protoperidinium pentagonum*		/
8.	*Protoperidinium sp. 1*	/	/
9.	*Protoperidinium sp. 2*	/	
10. *Stelladinium sp.*	*Protoperidinium sp. 3*	/	
11.	*Scrippsiella sp.*	/	
	Unknown		
12. *Dinoflagellate Cyst Type A*		/	/
13. *Dinoflagellate Cyst Type B*		/	
14. *Dinoflagellate Cyst Type C*		/	
15. *Dinoflagellate Cyst Type D*		/	
16. *Dinoflagellate Cyst Type E*			/
17. *Dinoflagellate Cyst Type F*		/	
18. *Dinoflagellate Cyst Type G*		/	
19. *Dinoflagellate Cyst Type H*			/
20. *Dinoflagellate Cyst Type I*			/

Acknowledgements

The author would like to thank the staff of M.V. SEAFDEC, Miss Montira Piamphipmanus, Mrs. Jutamas Jivaluk and Dr. Charumas Chareonpanich for their assistance in collecting the 35 surface-sediment samples. This study was supported by South East Asian Fisheries Development Center (SEAFDEC) through the Collaborative Research Programme between the SEAFDEC Training Department, Thailand and the Marine Fisheries Resources Development and Management Department, Malaysia.

References

Anderson, D. M. and Wall, D. 1978. Potential importance of benthic cysts of *Gonyaulax tamarensis* and *Gonyaulax excavata* in initiating toxic dinoflagellate bloom. J. Phycol., 14: 224-234.

Anderson, D. M., Chisholm, S. W. and Watras, C. J. 1983. Important of life cycle events in the population dynamics of *Gonyaulax tamarensis*. Mar. Biol. 76: 179-189.

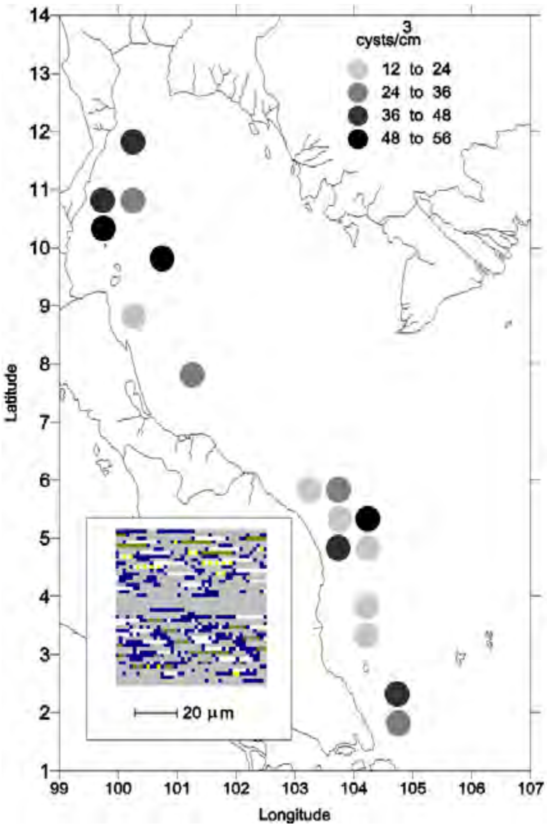


Fig. 2. Distribution and abundance of Spinferites cf. bulloideus

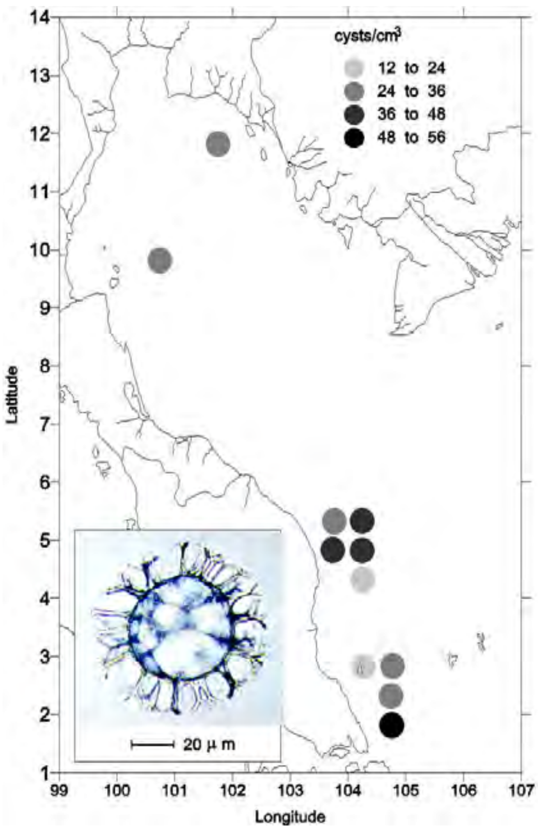


Fig. 3. Distribution and abundance of Spinferites cf. ramosus

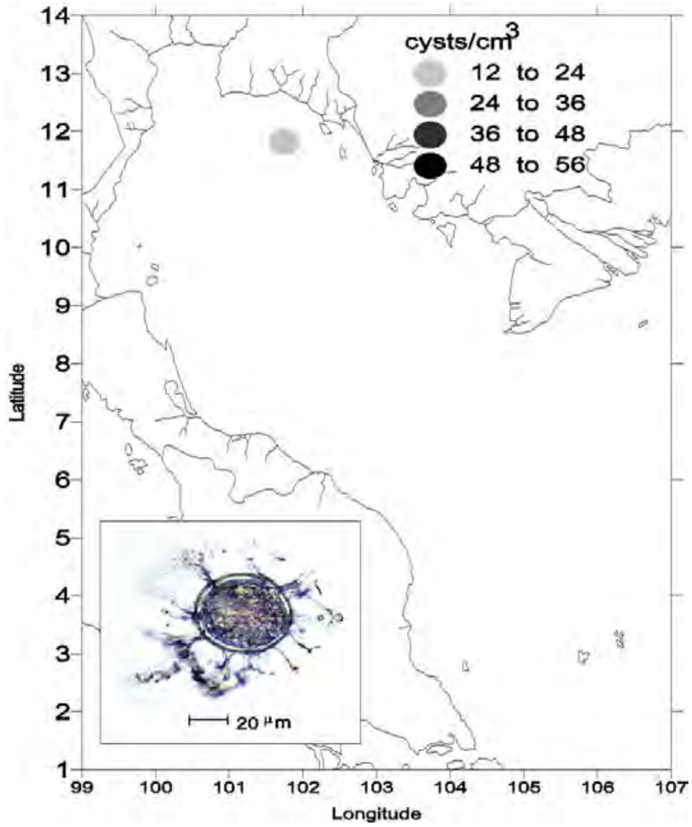


Fig. 4. Distribution and abundance of *Spinferites* sp. 1

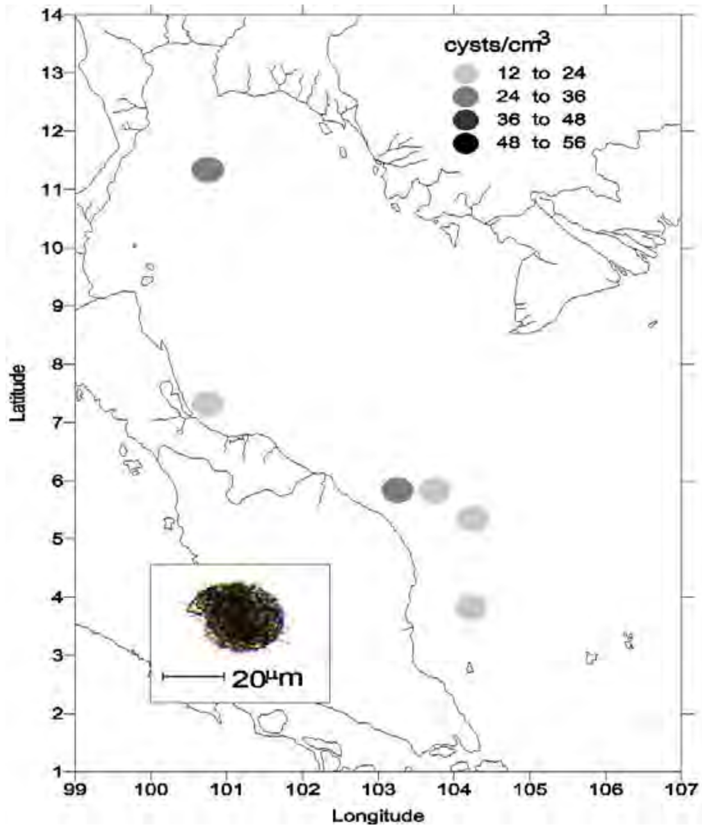


Fig. 5. Distribution and abundance of *Operculodinium centrocarpum*

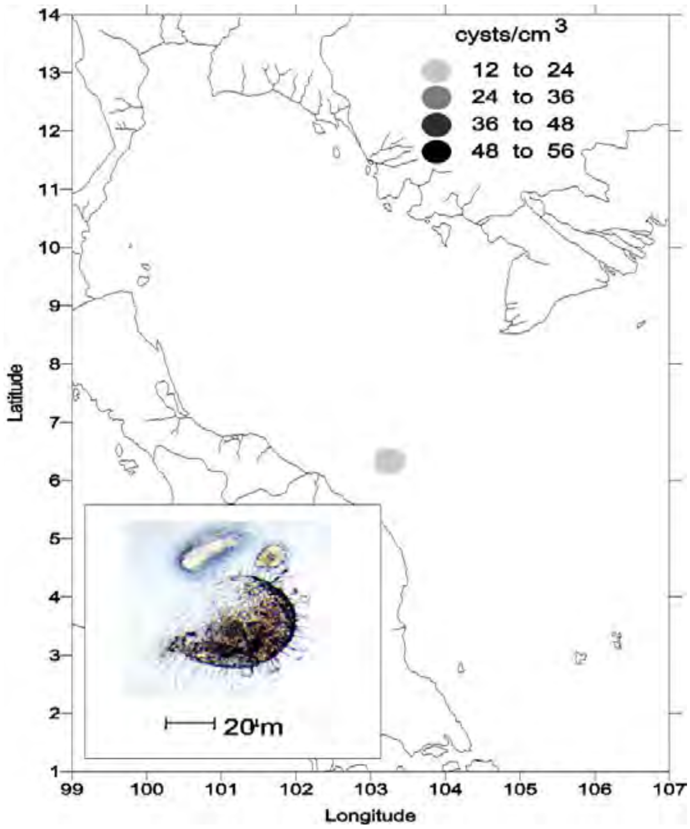


Fig. 6. Distribution and abundance of Lingulodinium machaerophorum

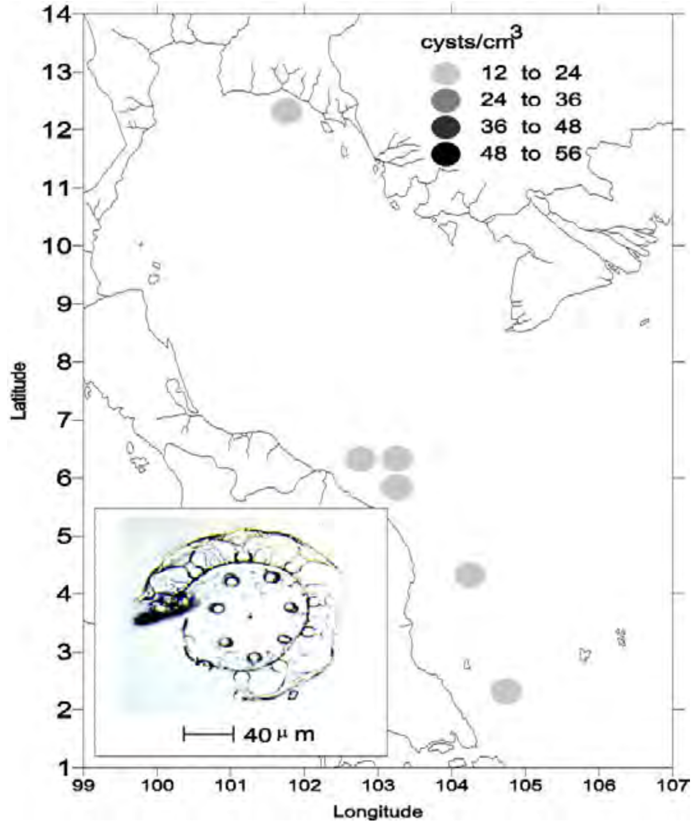


Fig. 7. Distribution and abundance of Tuberculodinium vancampoae

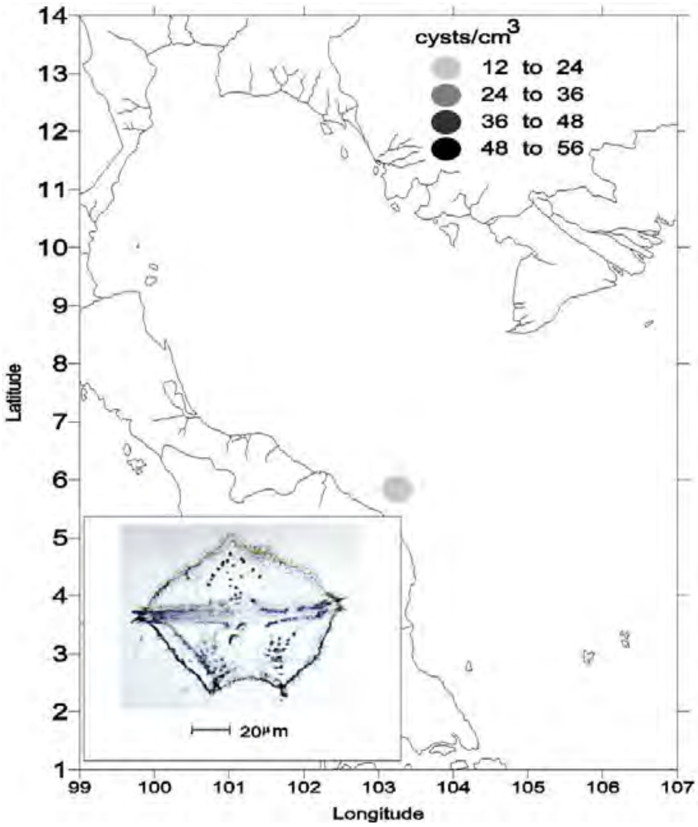


Fig. 8. Distribution and abundance of *Trinovantedinium cf. capitatum*

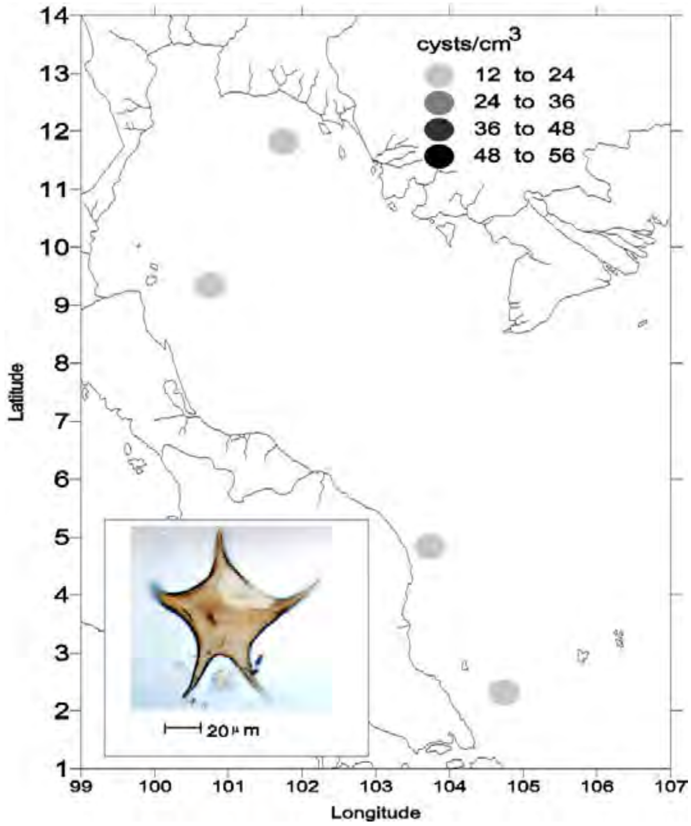


Fig. 9. Distribution and abundance of *Protoperidinium* sp. 1

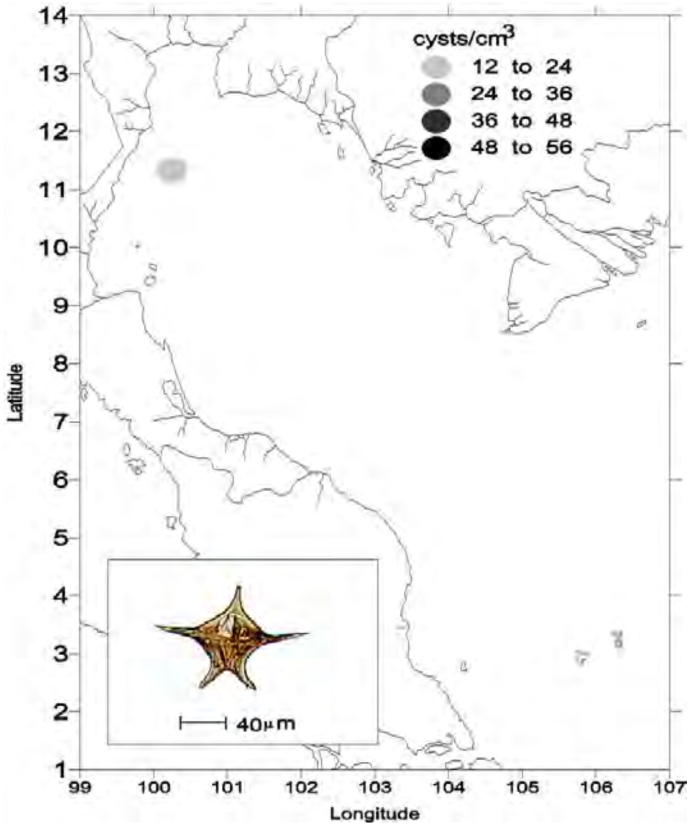


Fig. 10. Distribution and abundance of *Protoperidinium* sp. 2

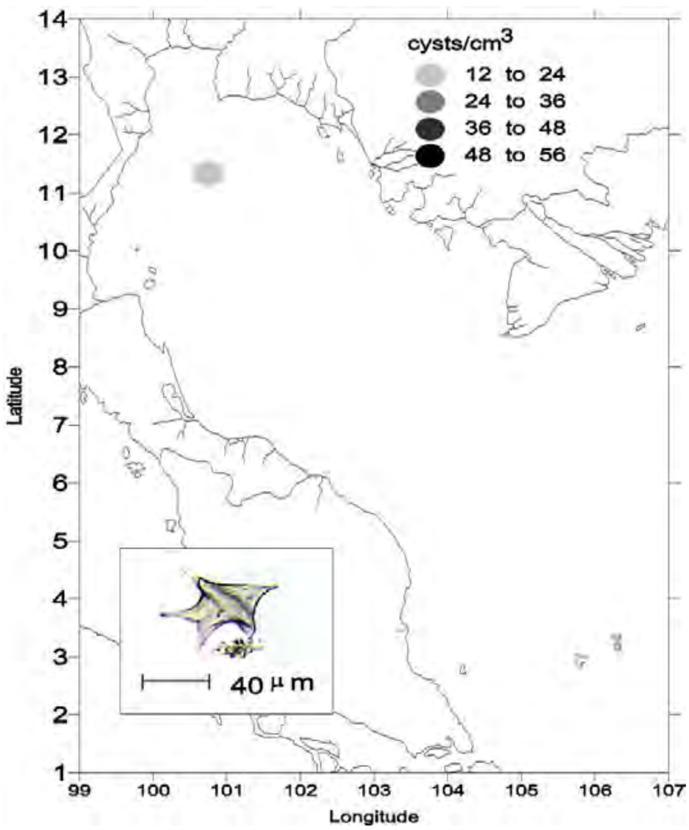


Fig. 11. Distribution and abundance of *Protoperidinium* sp. 3

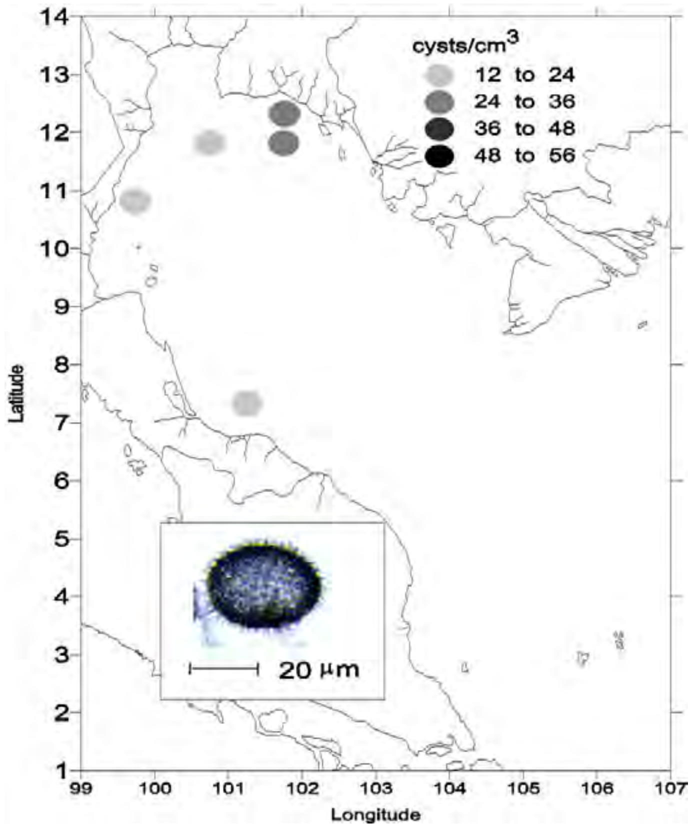


Fig. 12. Distribution and abundance of *Scrippsiella* sp.

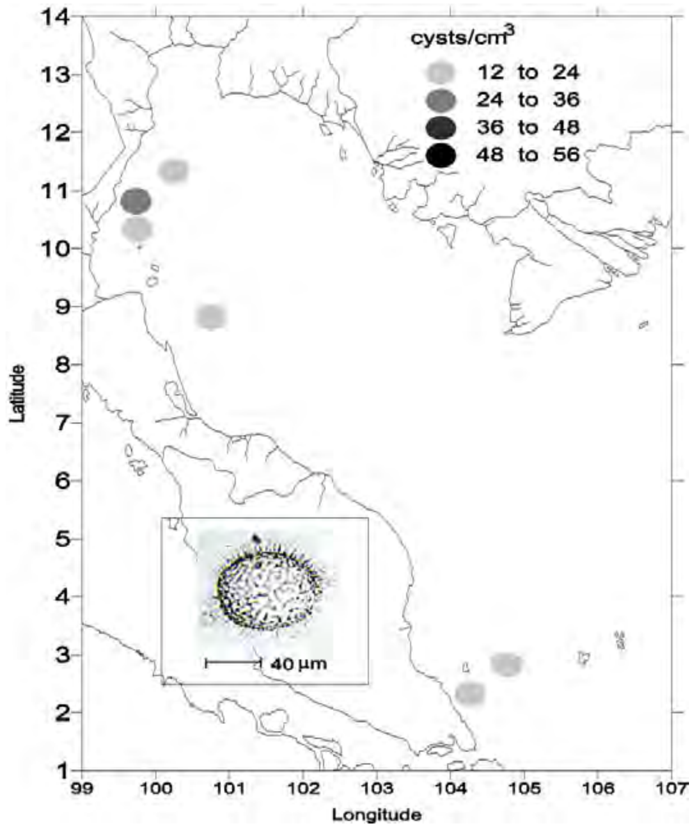


Fig. 13. Distribution and abundance of Dinoflagellate Cyst Type A

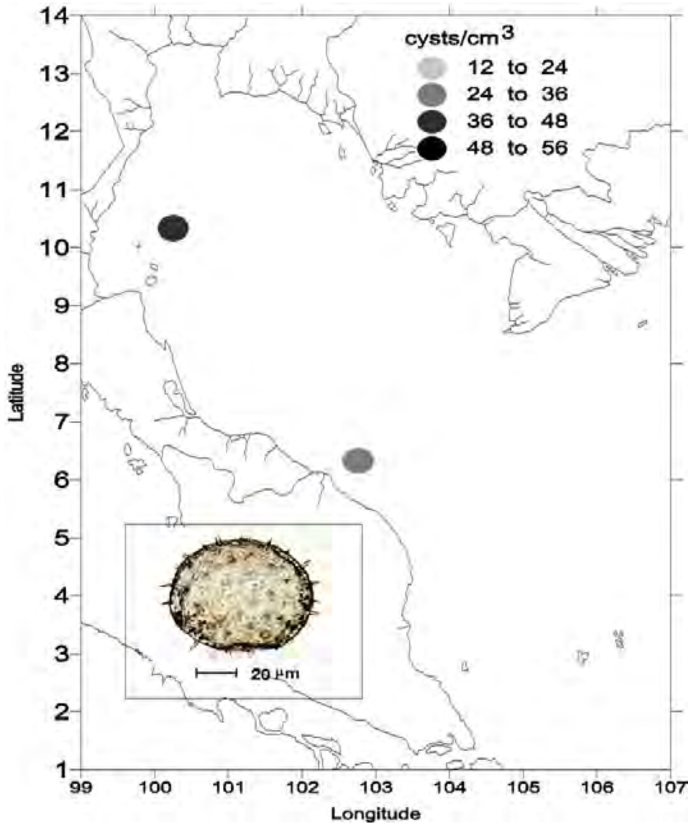


Fig. 14. Distribution and abundance of Dinoflagellate Cyst Type B

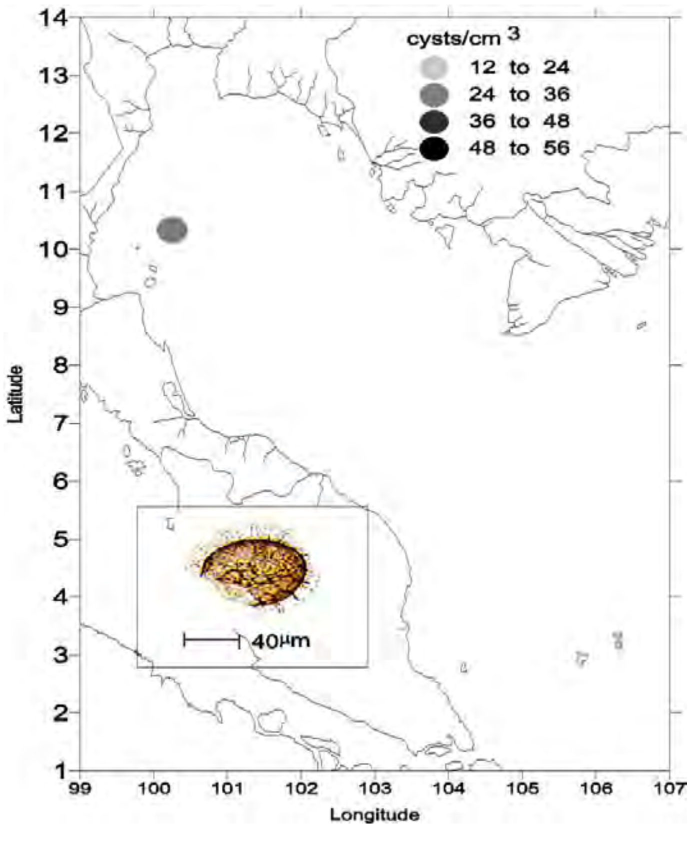


Fig. 15. Distribution and abundance of Dinoflagellate Cyst Type C

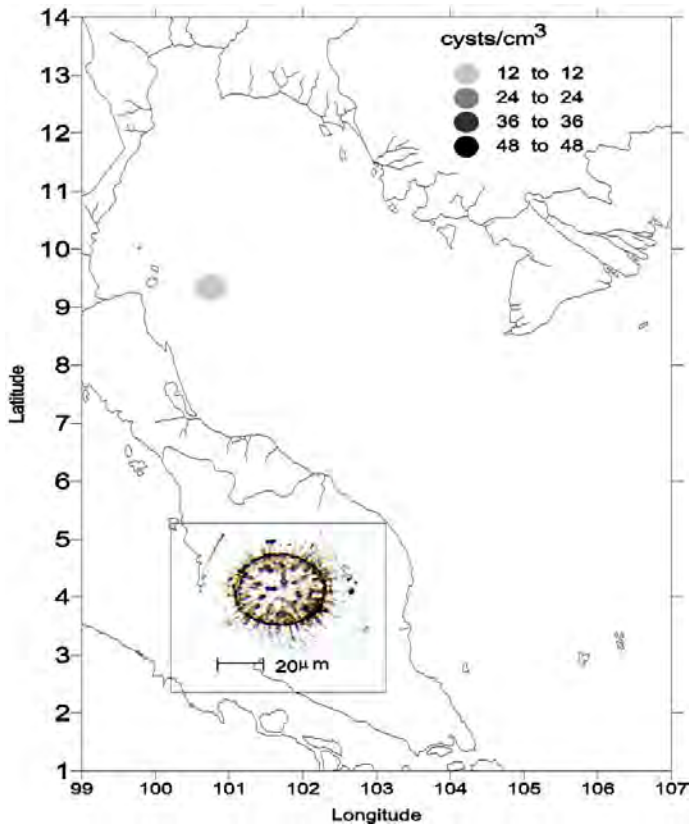


Fig. 16. Distribution and abundance of Dinoflagellate Cyst Type D

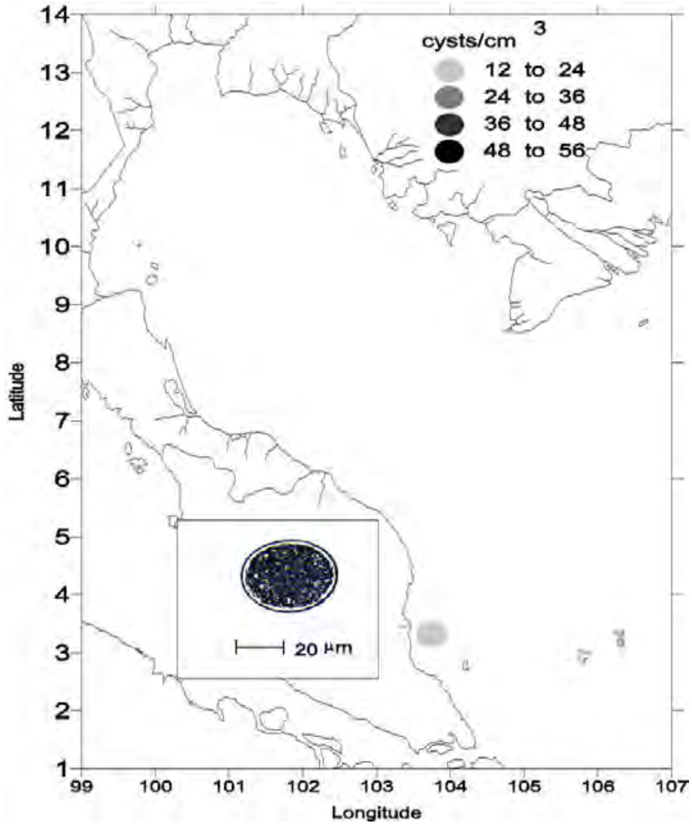


Fig. 17. Distribution and abundance of Dinoflagellate Cyst Type E

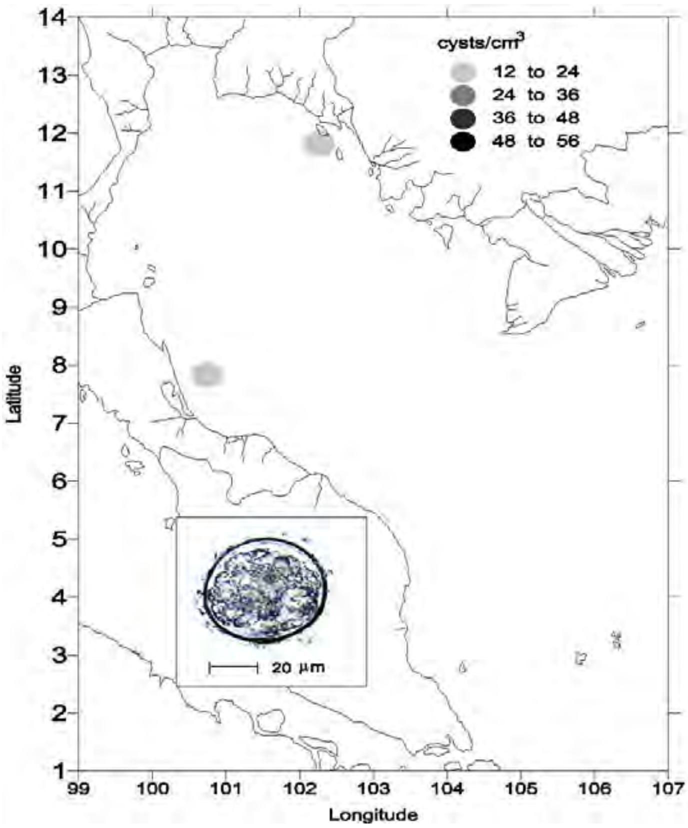


Fig. 18. Distribution and abundance of Dinoflagellate Cyst Type F

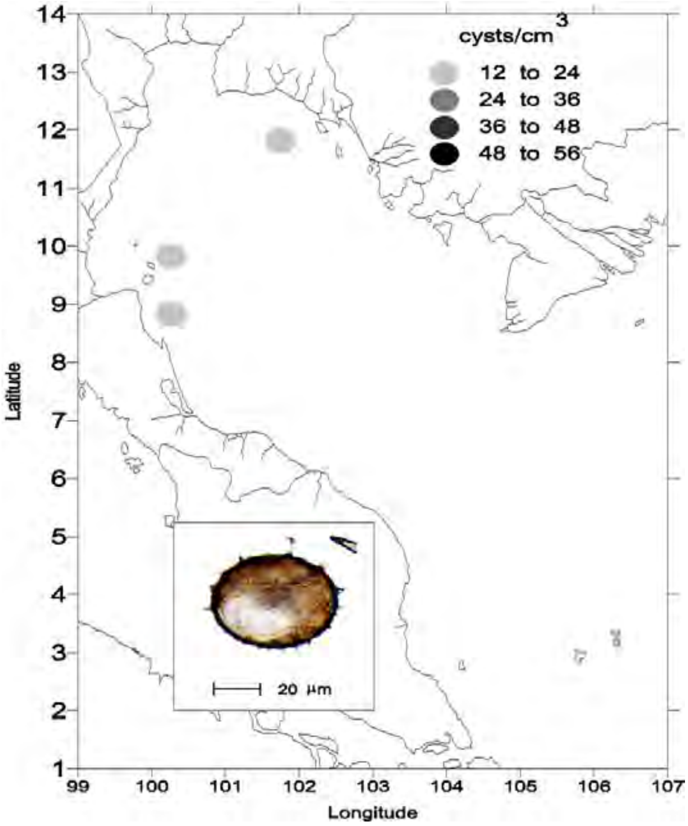


Fig. 19. Distribution and abundance of Dinoflagellate Cyst Type G

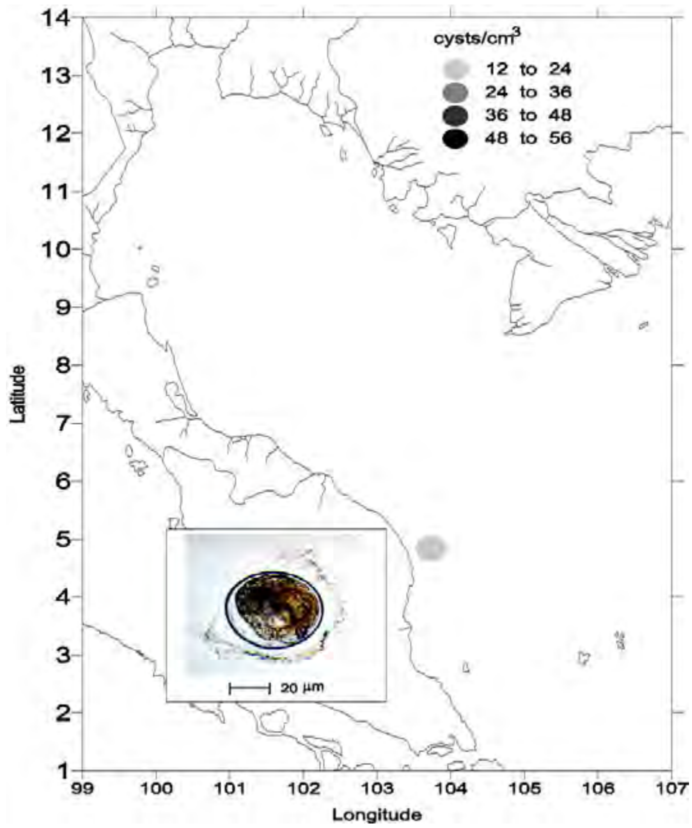


Fig. 20. Distribution and abundance of Dinoflagellate Cyst Type H

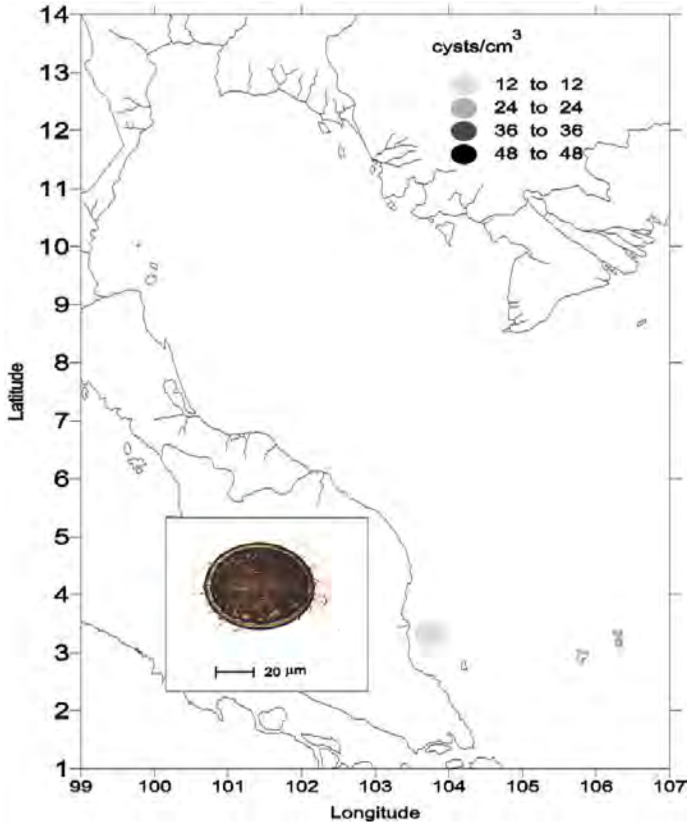


Fig. 21. Distribution and abundance of Dinoflagellate Cyst Type I

Anderson, D. M. 1984. Shellfish toxicity and dormant cysts in toxic dinoflagellate blooms. Seafood Toxins. American Chemical Society, Washington, D. C. pp: 125-138.

Bajarias, F. F. A and Relox, Jr. J. R. 1996. Hydrological and Climatological parameters associated with the *Pyrodinium* blooms in Manila Bay, Philippines. In Harmful and Toxic Algal Blooms. Yasumoto, T., Oshima, Y. and Fukuyo, Y. (eds.) Intergovernmental Oceanographic Commission of UNESCO, Paris. pp: 49-52.

Bourne, N. 1965. Paralytic shellfish poison in the sea scallops, *Placopeten magellanicus*, Gmelin, J. Fish. Res. Bd. Can. 22: 1137-1149.

Bujak, J. P. 1980. Dinoflagellate cysts and acritarchs from the Ecocene Barton Beds of Southern Enland: In Dinoflagellate cysts and acritarchs from the Ecocene Southern England, Bujak, J. P. (ed), Palaeontology (Special paper), 24: 36-91.

Dale, B., Yentsch, C.M., Hurst, J. W. 1978. Toxicity in resting cysts of the red tide dinoflagellate *Gonyaulax excavata* from deeper water coastal sediments. Science 201: 1223-1224.

Imai, I. and Itoh, K. 1987. Annual life cycle of *Chattonella* spp., causative flagellates of noxious red tides in the Inland Sea of Japan. Mar. Biol. 94: 287-292.

Lirdwitayaprasit, T., Nishio, S., Montain, S. and Okaichi, T. 1990. The biochemical processes during cyst formation in *Alexandrium catenella*. In Toxic Marine Phytoplankton Granili, E., Sandstrom, B., Edler, L. and Anderson, D. M. (eds.). Elsevier, New York pp: 294-299.

Maclean, J. L. 1989. An overview of *Pyrodinium* red tides in the western Pacific, In Biology, Epidemiology and management of *Pyrodinium* red tides, Hallegraeff, G. M. and Maclean, J.L. (eds.). ICLARM Contribution No. 585 pp: 1-7.

Matsuoka, K. 1985 a. Archeopyle structure in modern gymnodinialean dinoflagellate cysts. Review of Palaeobatany and Palynology, 44: 217-231.

Matsuoka, K. 1985 b. Organic-walled dinoflagellate cysts from surface sediments of Nagasaki Bay and Senzaki Bay, West Japan Buil. Fac. Lib. Art. Nagasaki Univ., Nat. Sci. Vol. 25, No. 2, pp: 21-115.

Matsuoka, K. 1985 c. Cyst and thecate forms of *Pyrophacus steinii* (Sehiller) Wall et Dale, 1971. Trans. Proc. Palaeont. Soc. Japan, N. S. No. 140, pp: 240-262.

Matsuoka, K. and Fukuyo, Y. 1986. Cyst and motile morphology of a colonial dinoflagellate *Pheopolykrikos hartmannii* (Zimmermann) comb. Nov. J. Plank. Res. 8(4): 811.

Matsuoka, K. 1987. Organic-walled dinoflagellate cysts from surface sediments of Akkeshi Bay and Lake Soroma, North Japan. Bull. Fac. Lib. Art. Nagasaki Univ. Nat. Sci. Vol. 28, No. 1, pp: 123.

Matsuoka, K., Fukuyo, Y. and Anderson, D. M. 1989. Methods for dinoflagellate cysts studies. In Biology, Epidemilogy and Management of *Pyrodinium* Red tides. Hallegraeff, G.M. and Maclean, J. L. (eds.) ICLARM Contribution No. 585 pp: 231-234.

Matsuoka and Fukuyo, Y. 1995. Manual for modern dinoflagella cyst study. IOC-DANIDA Training course on the taxonomy and biology of harmful marine microalgae, University of Copenhagen, Botanical Institute 31 July - 11 August 1995. 59 pp.

Wiadnyana, N. N., Sidabutar, T., Matsuoka, K., Ochi, T., Kodama, M. and Fukuyo, Y. 1996. Note on the occurrence of *Pyrodinium bahamense* in eastern Indonesian waters. In Harmful and Toxic Algal Blooms, Yasumoto, T., Oshima. Y. and Fukuyo, Y. (eds.), Intergovernmental Oceanographic Commission of UNESCO, Paris. pp: 53-56.

Microplankton (Including Dinoflagellate And Foraminifera) in the South China Sea, Area I : Gulf of Thailand and Peninsular Malaysia

Lokman Shamsudin [1]
Abdul Hamid Yasin [2]
Solahudin Abdul Razak [2]
Mohd Shukri Yusoff [2]

[1] Faculty Applied Science and Technology, Universiti Putra Malaysia Terengganu, (UPMT)
21030 Kuala Terengganu, Malaysia.
[2] Marine Fishery Research Development and Management Dept. SEAFDEC
Kuala Terengganu, Malaysia

ABSTRACT

Joint collaborative research surveys in the Gulf of Thailand and the South China Sea around the east coast of Peninsular Malaysia during the pre northeast monsoon (4 September - 4 October, 1995) and the post northeast monsoon (24 April - 17 May, 1996) periods were carried out on board the MV SEAFDEC. The microplankton from the sampling stations consisted of more than 205 taxa consisting predominantly of blue green algae (2 species), diatoms (> 120 species), dinoflagellates (> 80 species) and microzooplankton (> 30 groups). The dominant diatom species comprised of *Chaetoceros lorenzianum,C. coastatum, Thalassionema frauenfeldii, Skeletonema costatum, Pleurosigma elongatum, Bacteriastrum comosun, Bacillaria paxillifera, Coscinodiscus jonesianus* and *Rhizosolenia calcar-avis*. The genera *Chaetoceros, Rhizosolenia, Coscinodiscus, Bacteriastrum* and *Ceratium* were found to contain a wide range of species. *Skeletonema* bloom (1.12 x $10^6/m^3$; 47% of the total cell count) occurred around the Johore waters of the South China Sea. Dinoflagellate was also present during the premonsoon period, especially in offshore waters of the Gulf of Thailand and Terengganu nearshore waters of the South China Sea. The microzooplankton consisted of more than 30 species dominated by copepod nauplii while the foraminifera consisted mainly of the *Globigerina* species. The diversity index (H) and evenness index (J) values were usually high at stations near to the coast.

Key words: Plankton, Tropic, Northeast Monsoon, Dinoflagellate, Algae, South China Sea.

Introduction

This study is complementary to the other related oceanographic data and fishery resource studies being conducted on joint collaborative research surveys in the Gulf of Thailand and the South China Sea adjoining the east coast of peninsular Malaysia in 1995/96. The aim of this survey is to compare the distribution, composition, species abundance and their contribution to production processes at various study sectors of the South China Sea during the pre and post northeast monsoon seasons. Studies on microplankton (Shamsudin 1987, Shamsudin & Baker 1987, Shamsudin *et al.* 1987, Chua & Chong 1973) 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.

Published works on microplankton, especially diatoms, blue greens, dinoflagellates and other related organisms of the Gulf of Thailand and Malaysian waters in the South China Sea are scanty. Qualitative studies of plankton in 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 composition, distribution and abundance of microplankton in such waters had been lacking. Studies by Shamsudin *et al.* (1984) in the South China Sea around coasts of Johore, Terengganu and Kelantan found the majority of the phytoplankton found were diatoms which comprised of *Bacteriastrum, Chaetoceros, Rhizosolenia* and *Pleurosigma*. Studies by Chua and Chong (1973) in the Malacca Straits showed that the distribution and abundance of pelagic species especially the small tuna (*Euthynnus affinis*), chub makerel (*Rastrelliger* sp.) and anchovies (*Stolephorus* sp.) were related to the density of phytoplankton.

In the present study the composition of the microplankton community has been analysed during the pre and postmonsoon periods in 1995/96 in the Gulf of Thailand and the South China Sea around the east coast of peninsular Malaysia. The distribution, composition and species abundance at various study sectors of the South China Sea during the two seasons were determined.

Methods

Study Area

The study area covered an area which extends from the Gulf of Thailand in the North east (Lat. 12^{o} 31.4 E; Long. 100^{o} 10.5'N) to the southern tip of peninsular Malaysia covering the Johore waters (1^{o} 37.4'E; 105^{o} 12'2 N) of the South China Sea (Fig. 1). The estimated study area is ca 15910 nautical square miles (ca 51600 sq. km) covering the economic exclusive zone (EEZ) of Thailand and Malaysia seas of the South China Sea. The cruise track followed a zig-zag manner starting from the northern tip of the Gulf of Thailand and ended up at the southern tip of Johore waters covering a total of 80 sampling stations.

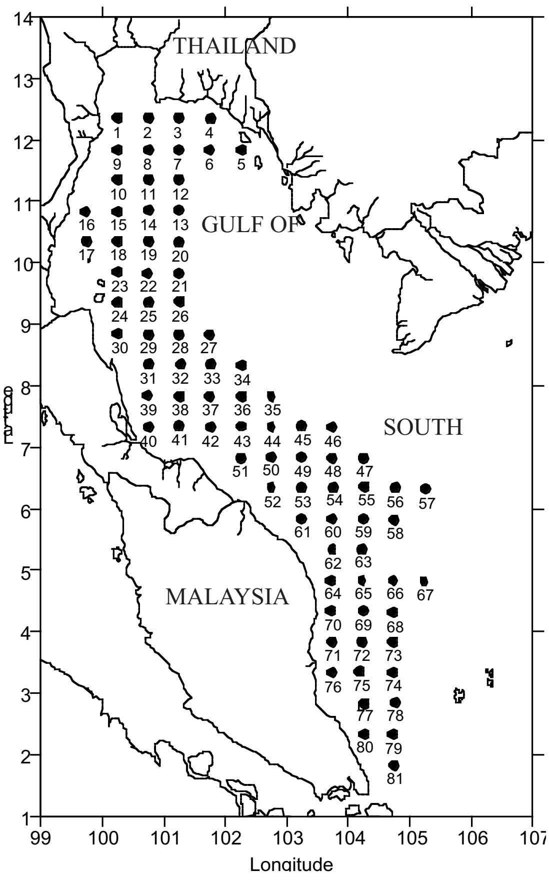


Fig. 1. Map showing various sampling stations in the Gulf of Thailand and the South China around the east coast of Peninsular Malaysia.

Sampling Method & Preparation

The research survey were carried out at eighty stations in October 1996 and June 1997 during the surveys. A vertical plankton net (mesh size 56 ?m, dia. 45 cm, length 92 cm) was hauled at a speed of 1 m/s from 40 m (twice the depth of the 1% surface illumination) to the surface. Samples at various depths using Van Dorn water sampler (20 litres) were also taken to quantify the microplankton population which also include some of the microzooplankton. This was to compensate the error which might arise from plankton escaping the net. The samples were preserved in 10% formalin. The microplankton fractions of the samples were examined for species composition and abundance.

The microplankton cells were routinely examined with a Nikon microscope using a x 10 eyepiece and a x 40 bright field objective. Difficult specimens were examined under a x 100 oil immersion objective. Where it was necessary for detailed identification, samples were treated by boiling and washing in 10% HCI (Tippett, 1970) to clean diatom frustules in order to show up their ultra fine structure for identification purposes, employing the scanning electron microscope (SEM) technique. The samples which had been fixed and preserved in absolute alcohol, were then mounted on (SEM) stubs with double-sided cellotape. The stubs with adhering samples were then coated with an alloy (gold with pelladium) before being observed under the scanning electron microscope (Barber & Haworth, 1981). Microplankton were identified with reference to Palmer & Keely (1900), Cleve (1901, 1904), Gran (1912), Pascher (1914, 1915 & 1925), Hustedt (1930), Sewell (1933), Handey (1933, 1964), Fritsch (1935), Cummins & Mulryan (1937), Cupp (1943), Cleve-Euler (1944), Crossby & Wood (1959), Winstead (1961), Banse (1964), Patrick & Reimer (1968), Shirota (1966), Newell & Newell (1973), Taylor (1976), Taylor & Seliger (1979) and Barber & Haworth (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 (1949) index. The formula for calculating Shannon-Wiener (diversity) index (H) is :

$$\mathbf{H = P_i \log_2 P_i},$$

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)
$J = H/\log_2 S$ - (ii), S is the number of species

Statistical Analysis

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. 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).

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).

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 index (Pielou, 1984; Ludwig & Reyholds, 1988).

Results

The microplankton from the sampling stations during the pre and post monsoon survey cruises consisted of more than 205 taxa consisting predominantly of blue green algae (2 species), diatom (> 120 species) and dinoflagellates (> 80 species) (Tables 1 & 2). One species of blue green (*Trichodesmium erythraeum*) and 12 species of diatom were dominant. The dominant diatom species comprised of *Chaetoceros lorenzianum, C. compressum, C. coastatum, C. pseudocurvisetum, C. didynum, Thalassionema* (*Thalassiothrix* ?) *frauenfeldii, Skeletonema costatum, Pleurosigma elongatum, Bacteriastrum comosun, Bacallaria paxillifera, Coscinodiscus jonesianus* and *Rhizosolenia calcar-avis*; while those of dinoflagellates consisted of *Ceratium fusus, C. pentagonum, C. arietinum, Protoperidinium* sp., *Protoceratium* sp., *Ceratocorys* sp. and *Alexandrium* sp.(Table 3 and 4). The genera *Chaetoceros, Rhizosolenia, Coscinodiscus, Bacteriastrum* and *Ceratium* were found to contain a wide range of species. The total microplankton densities ranged from 11.2 to 85.7 x 10^6 cells/m^3 and from 0.24 to 1.76 x 10^6 cells/m^3 during the premonsoon (more stable water column) and postmonsoon periods (less stable mixing water column) respectively (Fig. 1.1). There was an increase of ca 50 times in magnitude in the total cell population during the premonsoon as compared to the post monsoon season. The diversity index H values ranged from 1.7 to 4.8 with usually high values in the coastal stations during both seasons (Fig. 2.). The J evenness index values were usually directly proportional to the H values.

The results from Figs. 3.1 and 3.2 show the distribution of dominant species at various stations during the pre and postmonsoon seasons in the South China Sea. During the premonsoon period, various species of *Chaetoceros, Bacteriastrum, Rhizosolenia, Trichodesmium, Coscinodiscus, Thalassionema, Ceratium, Hemiaulus,* Copepod nauplii, *Tintinnopsis* and *Protoperidinium* in the order of dominance were encountered. The first six dominant species ranged in cell density from 6.3 to 19.9 x 10^4/m^3 while the *Protoperidinium* ranged from 5.3 to 39.8 x 10^3/m^3. However, during the postmonsoon, the dominant species arranged in the order of importance were *Trichodesmium, Bacteriastrum, Chaeroceros, Coscinodiscus, Rhizosolenia, Thalassionema, Ceratium, Hemiaulus,* Copepod nauplii, *Tintinnopsis* and *Protoperidinium*. The first four dominant species ranged in cell density from 3 to 13.1 x 10^4/m^3 while *Protoperidinium* ranged from 2.1 to 11.4 x 10^3/m^3.

Microplankton population at various sectors

The sampling stations during the study period can be categorised into at least 6 sectors with respect to their similarities in species composition using cluster analyses on 80 stations by mean of the unweighted pair group average (UPGA) Pearson index analyses (Fig. 4). The identified sectors in the South China Sea comprised of a) Chao Phraya bay, b) Pattany bay, c) Terengganu nearshore waters, d) Johore waters, e) Thailand offshore waters and f) Malaysian offshore waters. The mean cell densities of various stations of the 6 sectors (data from various stations from each sector were pooled) were high during the premonsoon with values of 1.79 x 10^7, 2.16 x 10^7, 2.39 x 10^7, 1.28 x 10^7, 4.25 x 10^6 and 6.54 x 10^6 cells/m^3 respectively.

The major microplankton species at the Chao Phraya bay sector during pre monsoon comprised of *Rhizosolenia calcar-avis, Chaetoceros lorenzianus, Coscinodiscus jonesianus, Trichodesmium*

Table 1. Taxonomic list of microplankton identified from the Gulf of Thailand and the South China Sea of the east coast of Peninsular Malaysia (* dominant)

	Continue >>	**Continue >>**
1. Class, Cyanophyceae; Order	*C. messanensis* Castracane	*H. membranacea* Cleve
Hormogoneae; Family Osciliatoriaceae;	*C. paradoxum* Cleve	*H. sinensis* Greville
* *Trichodesmium erytheraeum Ehrenberg*	*C. pendulus* Karsten	*** *Hemidiscus cuneiformis* Wallich**
T. thiebautii Gom.	* *C. peruvianum* Brightwell	**(Indicator sp.)**
2. Pylum Bacillariphyceae (Diatom)	* *C. pseudocurvisetum* Mangin	*H. hardmanianus*
***Actinophychus undulatus* Ralfs**	*C. setaceum* Jorg	***Lauderia annulata* Gran**
***Actinocyclus* Ehrenberg**	*C. siamense* Ostenfeld	*L. borealis*
***Asterolampra marylandica* Ehrenberg**	*C. sumatranum* Karsten	***Leptocylindrus danicus* Cleve**
***Asteromphalus elegans* Greville**	*C. tetrastichon* Cleve	*L. mediterraneus* (H. Peragallo) Hasle
A. heptactis Ralfs	*C. tripos* Nitsch	*Lithodesmium undulatum* **Ehrenberg**
A. flabellatus Greville	*C. weissflogii* Schutt	*Navicula* sp.
Bacillaria paxillifera (O.F. Muller)	***Climacodium biconcavum* Cleve**	*** *Nitzschia closterium* W. Smith**
Bacteriastrum comossum Pavillard	*C. frauenfeldianum* Grunow	*N. closterium* W. Smith
* *B. delicatulum* Cleve	*Corethron hystrix* Henden	*N. hungarica* Grun
B. elegans Pavillard	*C. pelagicum* Brun	*N. lanceolata* W. Smith
B. elongatum Cleve	***Coscinodiscus asteromphalus* Ehrenberg**	*N. longissima* Gran
* *B. hyalinum* Lauder	* *C. concinus* W. Smith	*N. longissima* var. *reversa*
B. mediaterraneum	* *centralis*	*N. paradoxa* Gmelin
B. minus	* *C. curvatulus* Grunow	*N. pacifica* Cupp
* *B. varians* Lauder	* *debilis*	*N. plana* W. Smith
Biddulphia dubai	* *C. gigas* Ehrenberg	*N. pungens* Cleve
B. longicrucia	*C. granii* Gough	*N. seriata* Cleve
* *B. mobilensis*	*C. janischii* Schmidt	*N. sigma* W. Smith
B. regia	* *C. jonesianus* (Greville) Ostenfeld	*N. sigma* var intercedens
B. sinensis	*C. lineatus* Ehrenberg	*N. spectavilis* Ralfs
***Campylodiscus biangulatus* Hantsch**	*C. marginatus* Ehrenberg	*N. vitrea* Norman
C. daemelianus Grun	*C. nitidus* Gregory	*N. bicapitata* Cleve
C. echeneis Ehrenberg	*C. nobilis* Grunow	***Odentella mobiliensis* (Bailey) Grunow**
C. orratus Grun	*C. nodulifer* Schmidt	*O. sinensis* (Greville) Grunow
C. undulatus sp.	*C. occulus rividis* Ehrenberg	***Planktoniella blanda* A. Schmidt**
Cerataulina Bergonii	*C. perforatus* Ehrenberg	*P. sol* (Wallich) Schutt
C. Compacta	*C. radiatus* Ehrenberg	***Pleurosigma affine* Gran**
C. pelagica (Cleve) Hendey	*C. Rothii* Grunow	*P. angulatum* W. Smith
C. coarctatum Lauder	*C. stellaris* Roper	*P. coompactum* Grew
***Chaetoceros affinis* Lauder**	*C. subtilis* Ehrenberg	* *P. elongatum* W. Smith
C. brevis Schutt	*C. weilesii* Gran & Angst	*P. fasciola* W. Smith
C. compressum Lauder	***Cylindrotheca closterium* Ehrenberg**	*P. intermedium* W. Smith
C. constrictum Gran	***Dactyliosolen blavyanus* H. Peragallo**	*P. nicobaricum* Gran
C. costatus Pavillard	*D. fragilissinum* (Bergon) Hasle	*P. Normanii* Ralfs
* *C. curvisetum* Cleve	***Detonula pumila* (Castracane) Gran**	*P. pelagicum* Perag
C. dadayi Pavillard	***Ditylum brightwelii* (West) Grunow**	*P. rectum* Donkim
C. debile Cleve	*D. sol* Grunow	*P. rigidum* Brun
* *C. decipiens* Cleve	***Eucampia cornuta* (Cleve) Grunow**	*P. salinarum* Gran

Table 1. (cont.)

Continue >>	**Continue >>**	**Continue >>**
R. delicatula Cleve	* *C. massiliense* (Gourret) Karsten	***Protoceratium spinulosum***
R. imbricata Brightwell	* *C. platycorne* Daday	***Protoperidinium conicum*** (Gran)
R. hesetata Gran	* *C. pentagonum* Gourret	* *P. brochii*
R. robusta Norman	*C. pulchellum* Schroder	*P. crassipes* (Kofoid) Balech
R. delicatula Cleve	*C. symmetricum* Paviilard	*P. depressum* (Bsiley) Balech
R. setigara Brightwell	* *C. teres* Kofoid	*P. diabolus* (Cleve) Balech
R. styliformis Brightwell	*C. trichoceros* (Ehrenberg) Kofoid	*P. divergents* (Ehrenberg) Balech
*** *Skeletonema costatum* (Greville) Cleve**	*C. tripos* (O.F. Muller) Nitzsen	*P. elegans* (Cleve) Balech
***Stephanopyxis palmeriana* Greville**	*C. vulture* Cleve	*P. globulum* (Stein) Balech
Striatella sp.	*Ceratocorys norrida* Stein	* *P. grande* (Kofoid) Balech
Surirella sp.	*C. horrida* Stein	*P. hirobis* (Abe') Balech
*** *Thalassionema frauenfeldii* Grunow**	*C. gourreti* Paulsen	*P. latispinum* (Mangin) Balech
T. nitzschioides (Grunow)	***Corythodinium resseratum*** Stein	*P. leonis* (Pavillard) Balech
***Thalassiosira bingensis* Takano**	Loebiich Jr. & Loebiien	*P. murrayi* (Kofoid) Balech
T. dipporocyclus Hasle	*Dinophysis homunculus* Stein	* *P. oceanicum* (Vanhoff) Balech
T. eccentrica (Ehrenberg) Hasle	*D. caudata* Sabille - Kent	*P. okamurai* (Abe') Balech
T. oestrupii (Ostenfeld) Hasle	*D. farus*	*P. ovum* (Schiller) Balech
* *T. subtilis* (Ostenfeld) Gran	*D. hastata* Stein	*P. pallidum* (Ostenfeld) Balech
***Triceratium favus* Ehrenberg**	*D. infundibula* Schiller	*P. paulseni* (Pavillard) Balech
3. Phylum Dinophyceae	*D. miles* Cleve	*P. Pellucidum* Bergn
(Dinoflagellate)	*D. ovum* Schutt	*P. puanerense* (Schreaser) Balech
Family : Peridiniidae	*D. schuettii* Murray & Whitting	*P. spinuiosum* (Schiller) Balech
***Alexandrium fraterculus* (Balech)**	*D. tripos*	*P. stenii* (Jorgensen)
A. tamiyavanichi Balech	***Diplopsalis lenticulata*** Berg	*P. thorianum* (Paulsen) Balech
***Amphidoma steini* Schill**	***Goniodoma polyedricum*** Pouchet	***Pyrophacus horologium*** Stein
***Amphisolenia bidentata* Schroder**	*G. spaericum*	*P. stein* (J. Schiller) Wall & Dale
A. thrinax Schutt	***Gonyaulax digitale*** (Pouchet) Kofoid	***Scripsiella trochoidea*** (Stein) Balech
A. globifera Stein	*G. gluptorhynchus* Murray & Whitting	**4. Family : *Dictyochaceae* (Phulum Protozoa)**
A. scnauinsianaii Lemmermann	*G. polygramma* Stein	Class : Mastogophora, Order :
***Ceratium axiale* Kofoid**	*G. spinifera* Clapareda & Lachmann	Chrysomonadina
C. arietinum Cleve	*Gynmodinium* sp.	*Dictyocha fibula* Ehrenberg
* *C. breve* Schroder	*Gyrodinium* sp.	*D. fibula var stapedia* Heack
C. biceps Gourret	*Kofoidinium* sp.	*D. fibula var major* Rampi
C. belone Cleve	***Noctiluca scintillans*** Macartney	**Family : Procentridae**
* *C. chrenbergii*	***Ornithocercus magnificus*** Stein	*Procentrum micans* Ehrenberg
C. condillans Jorgensen	*O. thumii* A. Schmidt	**Family : Phytodinidae**
C. candelabrium Ehrenberg Stein	*Pxytoxum scolopax* Stein	* *Pyrocystis elegans* Murray
C. contortum Gourret	*O. milneri*	**(Indicator sp.)**
C. carriense Gourret	*O. tesselatum*	*P. fusiformis* Murray
C. declinatum (Karsten) Jorgensen	***Phalacroma acutoides*** Balech	*P. hamulus var imacqualis* Schrober
* *C. deflexum* (Kofoid) Jorgensen	*P. doryphorum* Stein	*P. noctulica* Murray
C. dens Ostenfeld & Schmidt	*P. favus* Kofoid & Micherner	
C. falcatum (Kofoid) Jorgensen	*P. mitra* Schutt	
C. longissinum	*P. spinifera* Okamura	

Table 2. Taxonomic list of microzooplankton identified from the Gulf of Thailand and the South Sea of the east coast of peninsular Malaysia (*dominant)

Family : Globigerinidae	**Microzooplankton Larvae Abundance**	
Order : Foraminifera	**(* percentage total count)**	
Class : Sarcodina	**Copepoda nauplii (Calanoid,**	
Globigerina bulloides d'orb.	**cyclopoid, harpacticoid)**	***48%**
(Indicator sp.)	**Ostracoda**	**4**
Family : Acanthoplegmidae	**Siphonophora**	**2**
*** *Acanthocolla cruciata* Haeck**	**Gastropod**	**2**
Amoebophrya acanthometrae Koeppen	**Lucifer**	**2**
Family : Acanthometridae	**Laevacean**	**2**
***Acanthometron pellucidum* Mull**	**Shrimp**	**2**
A. elongata	**Pteropod**	**2**
Family : Amphilithidae	**Bivalve**	**2**
***Amphibelone hydrotomica* Haeck**	Modusae	
***Amphilithium clavarium* Haeck**	Ctenophora	
Family : Gigartaconidae	Nemertinea	
***Amphiacon denticulatus* Haeck**	Cyphonautes	
Family : Corticellidae	Actinotroch	
Order : Peritriches	Polychacta	
***Stichonlonche zanclea* Hertw**	Cladocera	
Family : Codonellidae	Amphipoda	
***Codonella aspera* Ion**	Isopoda	
*** *Tintinnopsis lobiancoi* Daday**	Mysidacea	
T. butschlii Daday	Cumacea	
T. mucula Fol	Euphausiacea	
T. radix Imhof	Phyllosoma	
Family : Ptychocylidae	Anomura	
***Favella adriatrica* Imhof**	Brachyura	
Family : Tintinnidae	Stomatopod	
***Tintinnus inquilinus* Muller**	Hetcropoda	
	Pteropoda	
	Cephalopoda	
	Gastropoda	
	Echinodermata	
	Thaliaceae	
	Brichiopoda	
	Crustacea	
	Fish eggs/larvae	

erythraceum, Ceratium fusus and copepod nauplii with mean values of 5.0 x 10^6, 3.9 x 10^6 and 2.5 x 10^6, 1.7 x 10^6, 0.5 x 10^6 and 0.47 x $10^6/m^3$ respectively (Fig. 5). Microplankton species during the premonsoon were present in higher concentrations than those during the postmonsoon.

The mean total cell densities in the Terengganu nearshore waters were 7.9 x 10^7 and 6.31 x $10^5/m^3$ during both monsoon seasons respectively (Fig. 6). During the premonsoon the blue green alga, *Trichodesmium erythraeum* reached its peak bloom at concentration of 7.15 x $10^7/m^3$ (> 90% of its total cell density); however, this species was not detected during the postmonsoon. *Rhizosolenium alata, Bacteriastrum cosmosum, Chaetoceros compressum, Thalassionema frauenfeldii* were dominant diatoms present during the premonsoon with values ranging from 2.51 x 10^5 to 15.8 x $10^5/m^3$. *Pleurosigma elongatum* were present only during the premonsoon. The dinoflagellate, *Ceratium fusus* and *Protoperidinium* sp. were also present with values ranging from 0.12 x 10^5 to 2.51 x $10^5/m^3$. *Tintinnopsis* sp. and Copepod nauplii were high during the premonsoon.

Table 3. The number of species in the genera of the microplankton polulation in the Gulf of Thailand and the South China Sea of the east coast of peninsular Malaysia (* Dominant)

Genus	Number of Species
1. Bacillariophyceae (Diatom)	
Asteromphalus	2
**** Bacillaria***	**1**
Compylodiscus	4
Cerataulina	3
Climacodium	2
Corethron	1
Dactyliosolen	2
Ditylum	2
** Eucampia*	2
** Fragilaria*	1
** Guinardia*	3
** Gyrosigma*	4
** Hemiaulus*	3
** Hemidiscus*	2
** Lauderia*	2
Leptocylindrus	2
** Nitzschia*	8
Odentella	2
** Planktoniella*	2
Pseudoguinardia	2
**** Skeletonema***	**1**
** Thalassiosira*	5
Triceratium	1
2. *Dinophyceae*	
Alexandrium	2
Amphisolenia	4
**** Ceratium***	**28**
**** Ceratocorys***	**2**
**Dinophysis*	5
Goniodoma	2
** Gonyaulax*	4
** Noctiluca*	1
**** Ornithocercus***	**5**
Palacroma	5
****Podolampas***	**4**
Prorocentrum	3
**** Protoperidinium***	**5**
Pyrophalus	2
3. *Cyanophyceae*	
Trichodesmium	**2**
4. *Dictyochaceae*	
Dictyocha	4
Procentrum	1
Pyrocystis	**3**
5. *Microzooplankton*	
Globigerina	1
Codonella	1
Tintinnopsis	**2**
Favella	**1**
Tintinnus	1
6 *Larvae/* nauplii	
Chaetognatha	-
Ostracoda	-
Siphonophora	-
Gastropod	-

Table 4. Dominant microplankton species in the Gulf of Thailand and the South China Sea of the east coast of peninsular Malaysia during the study period.

Genus	Species
1. Cyanophyceae (Blue greens)	
Trichodesmium	***T. erythraeum*** Ehrenberg
2. Bacillariophyceae (Diatoms)	
Bacillaria	***B. paxillifera*** O.F. Muller
Bacteriastrum	***Bac. comosum*** Pavillard
Chaetoceros	***C. coarctatum*** Lauder
	C. compressum Lauder
	C. curvisetum Cleve
	C. didynum Ehrenberg
	C. lorenzianum Grun
	C. lauderi Reefs
	C. messanensis Castracane
	C. siamense Ostenfeld
	C. tripos Nitsch
Coscinodiscus	*Cos. concinnus* W. Smith
	Cos. gigas Ehrenberg
	Cos. jonesianus Greville
	Cos. radiatus Ehrenberg
Ditylum	*D. sol* Grun
Eucampia	*E. cornuta* Cleve
Fragilaria	*F. intermedia* Grun
Guinardia	*G. cylindrus* Cleve
Hemiaulus	*H. hauckii* Grun
	H. indicus Karsten
Lauderia	*L. anmulata* Grun
Nitzschia	*N. closterium* W. Smith
	N. longissima Gran
Pleurosigma	***P. elongatum*** W. Smith
	P. fasciola W. Smith
Rhizosolenia	*R. alata* Brightwell
Skeletonema	***S. costatum*** (Greville) Cleve
Thalassionema	***T. frauenfeldii*** Grun
	T. nitzschioides Grun
3. Dinophyceae (Dinoflagellate)	
Alexandrium	*Alexandrium* sp.
Ceratium	*C. arietinum* Cleve
	C. furca Ehrenberg
	C. fusus Ehrenberg
	C. pentagonum Gourret
Noctiluca	*N. scintillans* Macartney
Ornithocercus	*O. magnificus* Stein
Podolampas	*P. bipes* Stein
Protoperidinium	*P. brochii* Gran
	P. grande Kofoid
	P. oceanicum Vanhoff
4. Phytodinidae	
Pyrocystis	*P. elegans* Murray

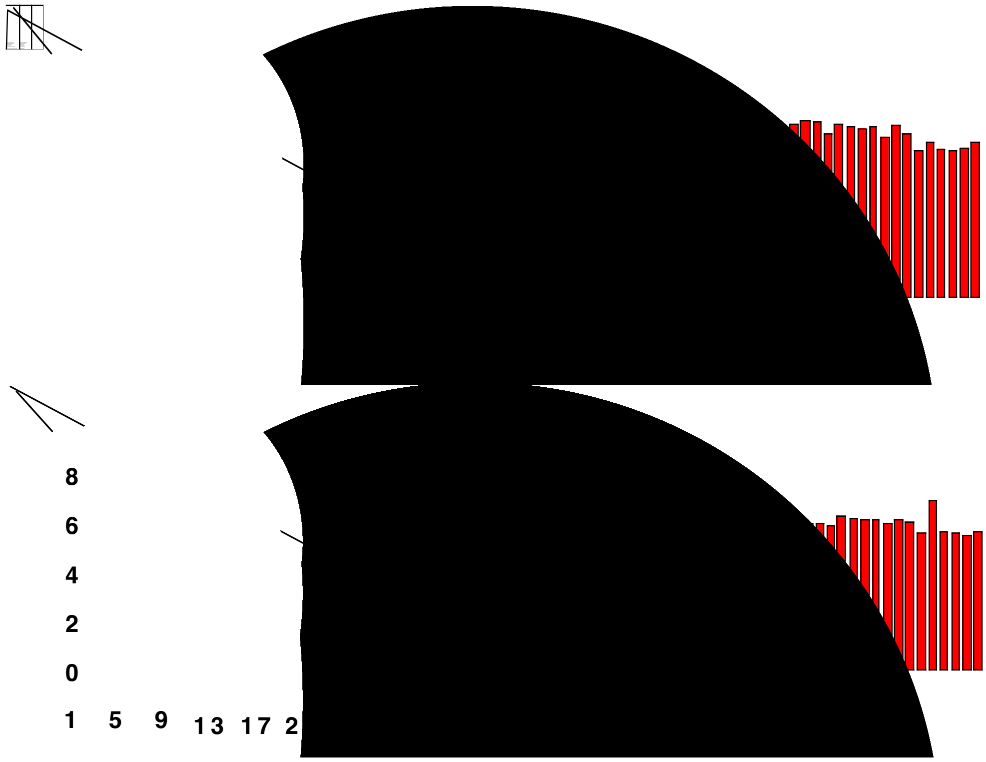


Fig. 1b. Total cell densities (log nos./m^3) at different stations during the pre and post - monsoon period (Oct. 1996 / June 1997 respectively) of the cruise surveys in the Gulf of Thailand and the South China Sea of the east coast of Peninsular Malaysia

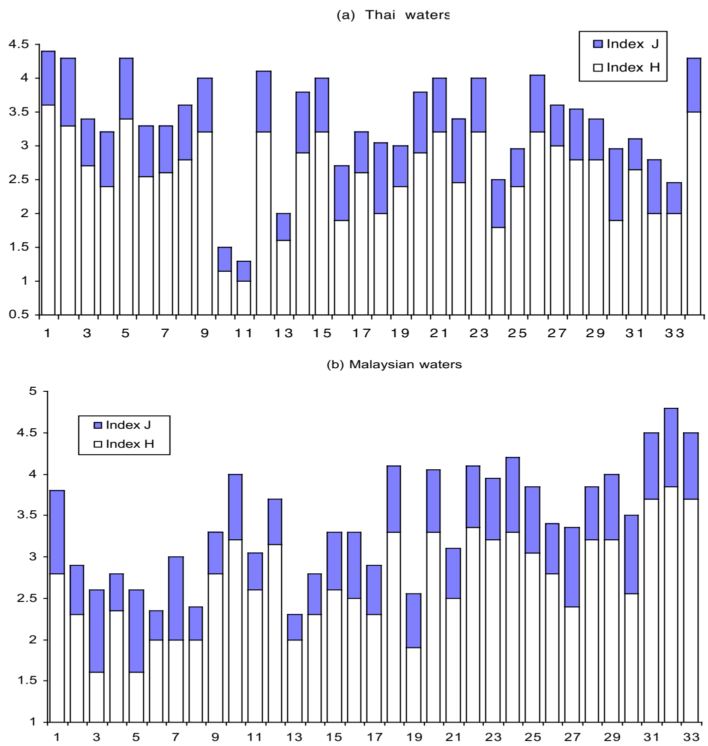


Fig. 2. The diversity (H) and evenness (J) indices of various stations in (a) the Gulf of Thailand and (b) waters of Peninsular Malaysia of the South China Sea during the post monsoon cruise (Apr.-May 1996).

Rhizosolenia sp. (mean density of 1.25 x $10^6/m^3$) and *Trichodesmium erythraeum* (mean density 7.94 x $10^5/m^3$) were dominant species in the Terengganu offshore waters, however both the species were present in lower concentrations during the postmonsoon(Fig. 7). *Bacillaria paxillifera, Planktonella sol, Pleurosigma elongatum* and *Thalassionema frauenfeldii* were present during the premonsoon; however *Chaetoceros compressum, Hemiaulus hauckii*., *Ceratium fusus* and copepod nauplii were found during both seasons. *Protoperidinium* sp. was present in considerable concentration during the post monsoon. The mean total cell densities in this sector were 5.01 x 10^6 and 2.51 x $10^5/m^3$ during the two seasons respectively.

Trichodesmium erythraeum bloom occurred in offshore waters of the Gulf of Thailand with its peak density value of 2.24 x $10^6/m^3$ (93.4% of total cell density)(Fig. 8). *Rhizosolenia alata, Pleurosigma elongatum, Lauderia annulata, Bacillaria paxillifera, Chaetoceros lorenzianum* and *Thalassionema frauenfeldii* were diatoms present during the premonsoon with values ranging from 6.31 x 10^4 to 7.76 x $10^5/m^3$. During the post monsoon, species of *Rhizosolenia, Thalassionema, Chaetoceros* and *Protoperidinium* were present in low concentrations ranging from 2.51 to 2.78 x $10^3/m^3$. The mean total cell density of the post monsoon was ca 63% that of the premonsoon.

The fifth sector was identified for those stations around the Pattany bay. During the premonsoon, the dinoflagellate *Ceratium* sp. (especially *C. fusus*); the diatoms (*Rhizosolenia calcar avis, Chaetoceros lorenzianum, Bacillaria paxillifera*) and the blue greens (*Trichodesmium erythraeum*) were dominant with values ranging from 1.14 x 10^3 to 6.3 x $10^3/m^3$ (Fig. 9). Many of these dominant species were either absent or negligible during the postmonsoon and being replaced by species of *Ceratium* and *Coscinodiscus*. Copepod nauplii were present during both seasons with values ranging from 150 to $1150/m^3$. The mean total cell densities were 2.45 x 10^6 and 4.07 x $10^5/m^3$ during the two seasons respectively.

Another interesting sector situated at the southern tip of peninsular Malaysia was identified as the Johore waters of the South China Sea. The striking phenomenon occurred in this sector was the occurrence of *Skeletonema costatum* bloom during the postmonsoon with a value of 6.5 x $10^5/m^3$ (54.2% of total cell density) (Fig. 10). The dominant diatom *Chaetoceros lorenzianum* (1.55 x $10^3/m^3$) was present in high concentration during the premonsoon. During the *Skeletonema* bloom, *Bacteriastrum comosum* and *Chaetoceros lorenzianum* were found to be associated with the bloom. Other species association that occurred during the bloom included those species of *Ceratium, Coscinodiscus* and *Hemiaulus*. The microzooplankton species of *Tintinnopsis* and copepod nauplii also present in small amount (> 0.1% of total density).

Diversity and evenness indices

The results from Fig. 11 show the diversity H index for the six sectors of stations studied. This index was effectively altered due to the occurrence of specific blooms, especially the offshore *Trichodesmium* bloom and the nearshore diatom as well as dinoflagellate blooms. The H diversity values were usually higher at nearshore sectors (ranging from 2.9 to 4.4) than those of offshore waters (ranging from 1.95 to 3.4).

Percentage microplankton abundance

The percentage abundance (expressed as the percentage of total cell density) of diatom, dinoflagellate, blue green and microzooplankton at the six identified sectors is as shown in Figs 12 a-d. Chao Phraya bay had high percentage of diatom during the two season with values ranging from 63 to 91%; however the value for Terengganu nearshore waters was high during the post monsoon. Thailand offshore sector had low percentage values (6 to 22%). High dinoflagellate percentage values were observed in certain sectors , especially Terengganu offshore waters (33%).

Pattaya bay (31%), Johore nearshore (24%) and Terengganu nearshore (23%) had high per-

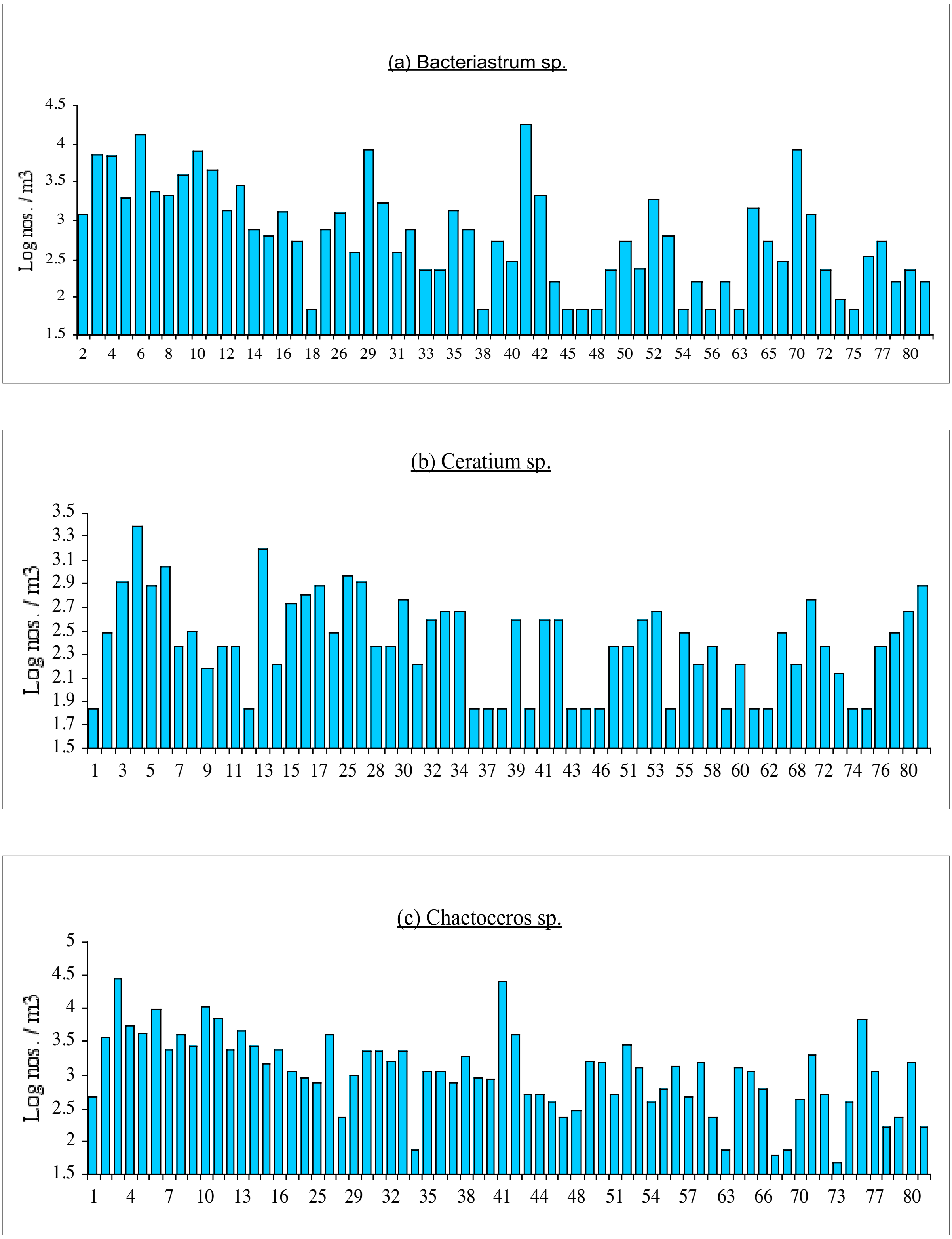
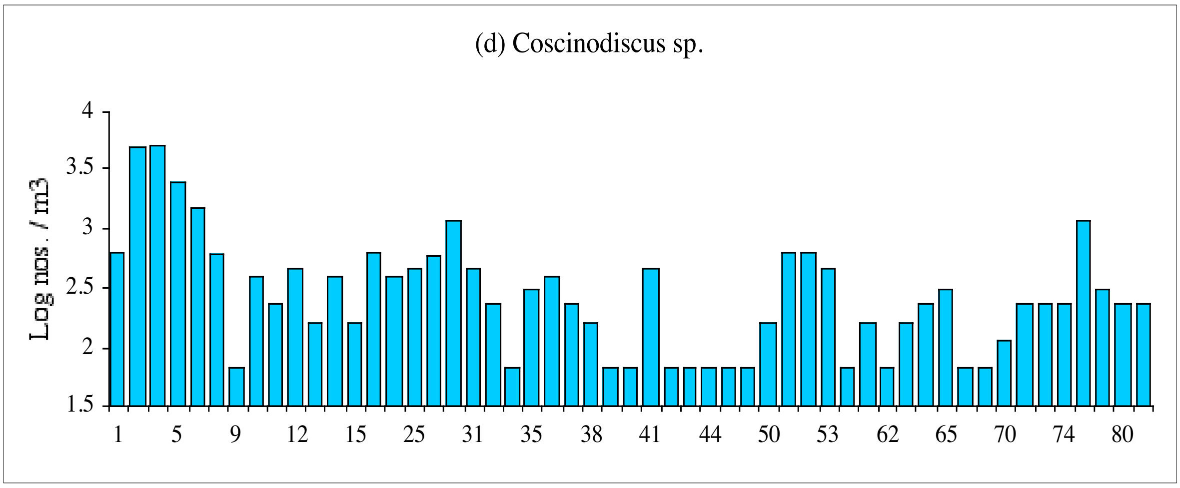
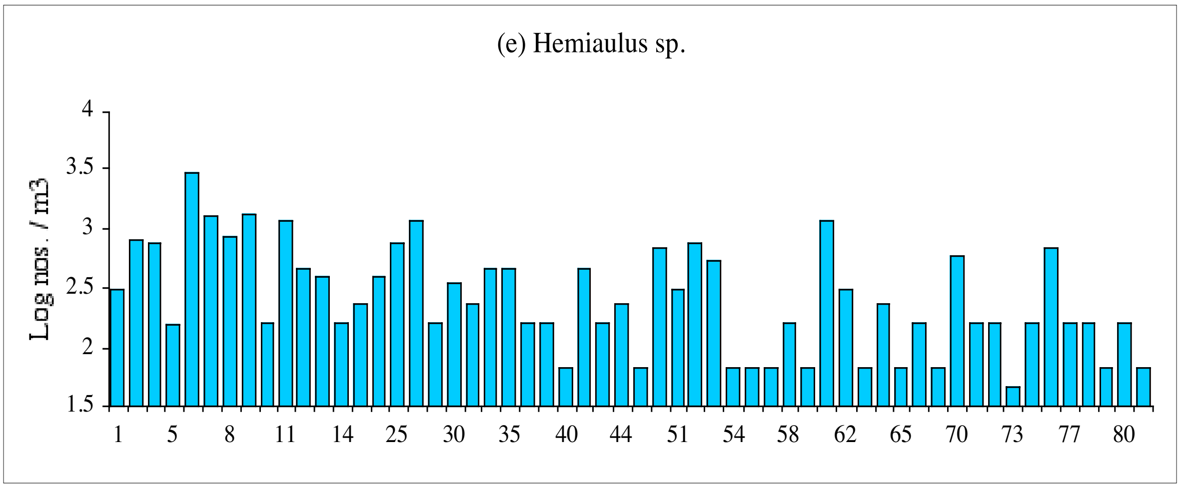


Fig. 3.1 Microplanktonic distribution of various dominant species at different stations during the premonsoon cruise (Sept/Oct 1995) in the Gulf of Thailand and waters of peninsular Malaysia of the South China Sea. (a) Bacteriastrum sp., (b) Ceratium sp., (c) Chaetoceros sp., (d) Coscinodiscus sp., (e) Hemiaulus sp., (f) Rhizosolenia sp., (g) Thalassionema sp., (h) Protoperidinium sp., (i) Trichodesmium sp., (j) Tintinnopsis sp. and (k) Copepod nauplii.





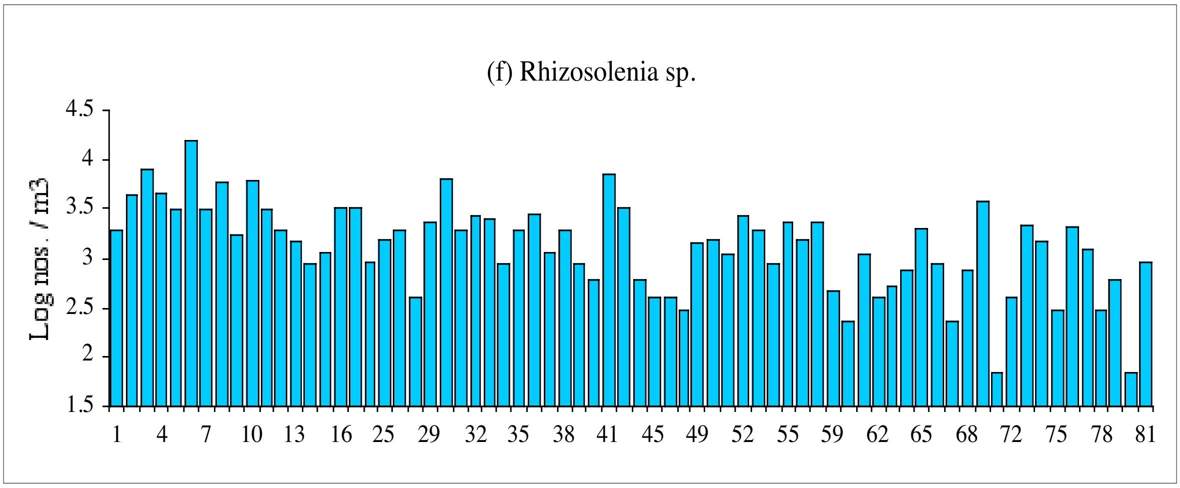
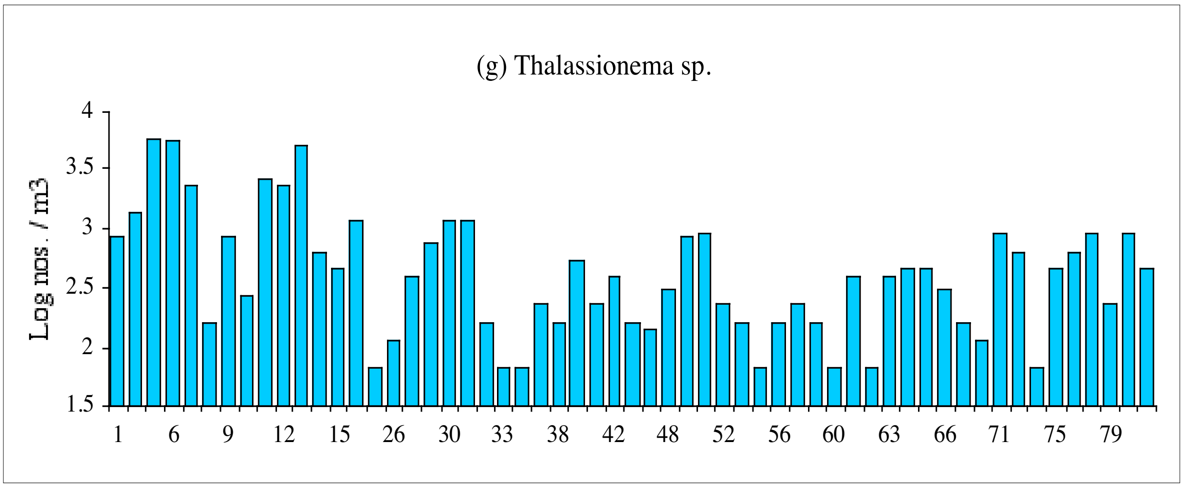
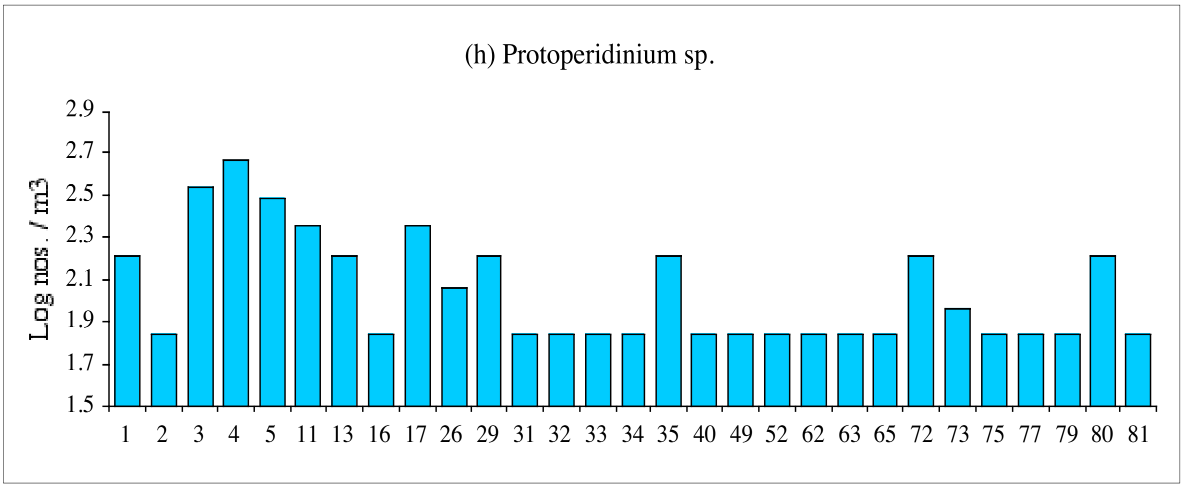


Fig. 3.1 Continue





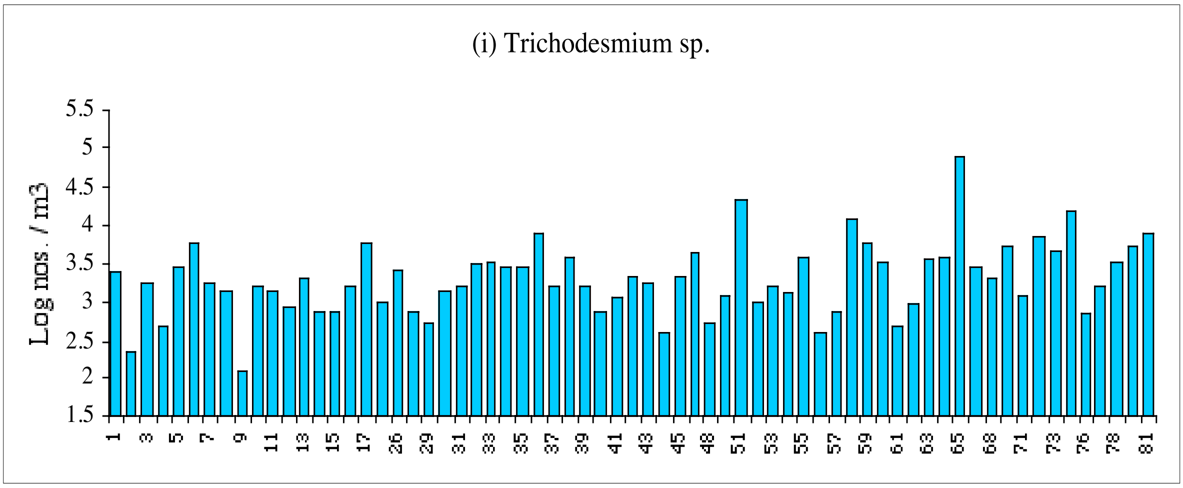


Fig. 3.1 Continue

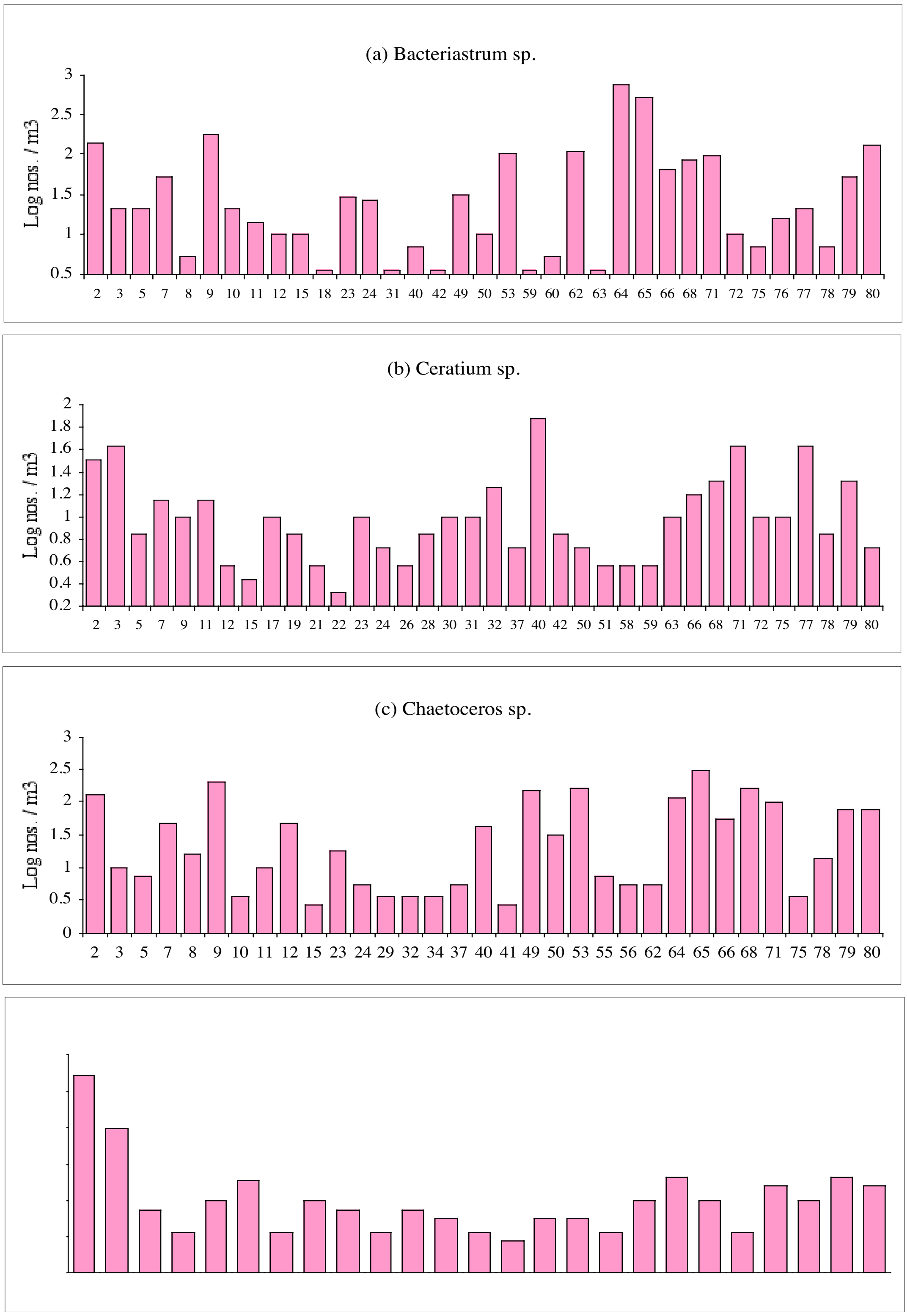


Fig. 3.2 Microplanktonic distribution of various dominant species at different stations during the post monsoon cruise (April/May 1996) in the Gulf of Thailand and waters of peninsular Malaysia of the South China Sea. (a) *Bacteriastrum* sp., (b) *Ceratium* sp., (c) *Chaetoceros* sp., (d) *Coscinodiscus* sp., (e) *Rhizosolenia* sp., (f) *Thalassionema* sp., (g) *Protoperidinium* sp., (h) *Trichodesmium* sp., (i) *Tintinnopsis* sp., (j) Copepod nauplii and (k) *Hemiaulus* sp.

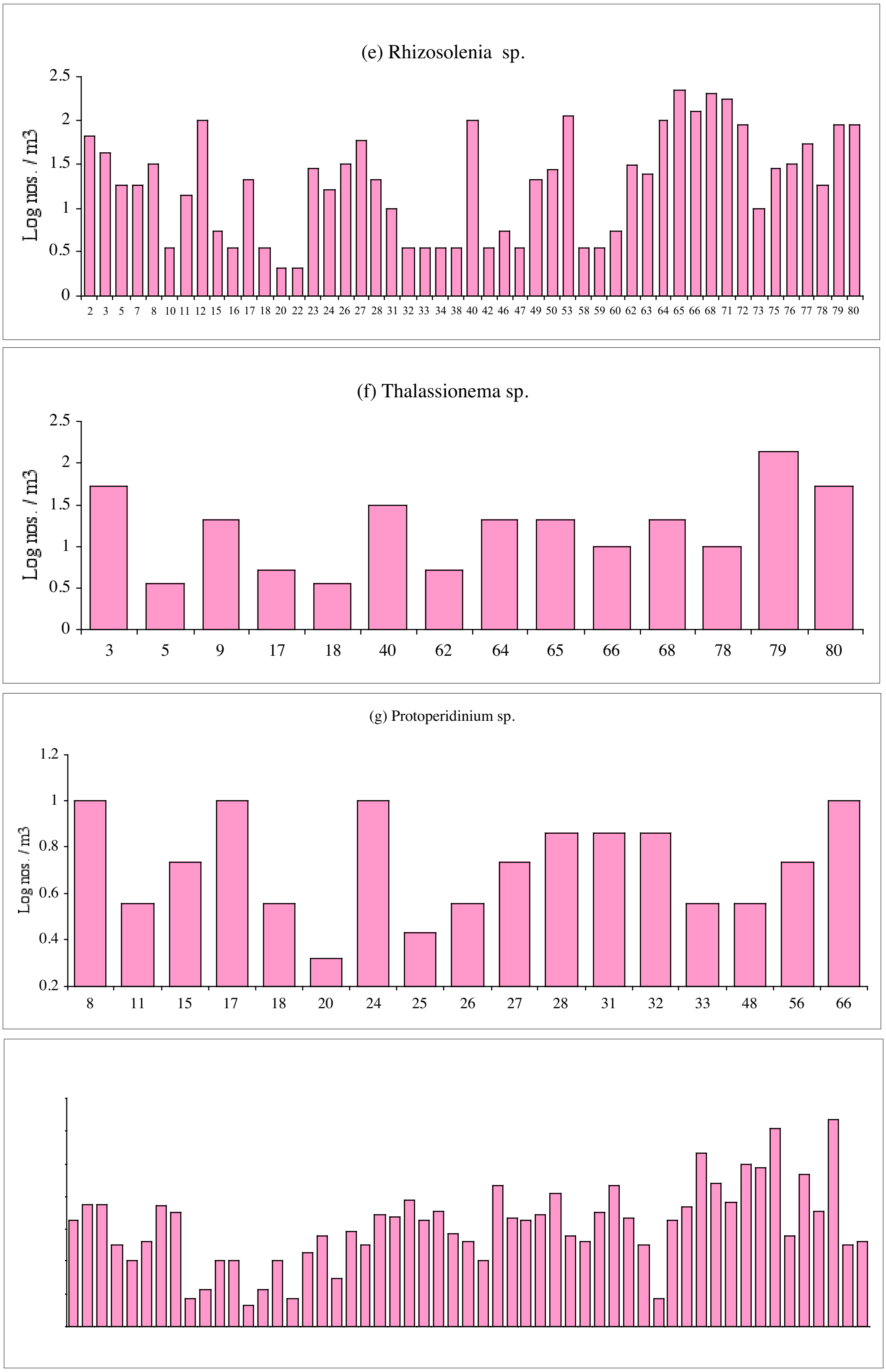


Fig. 3.2 Continue

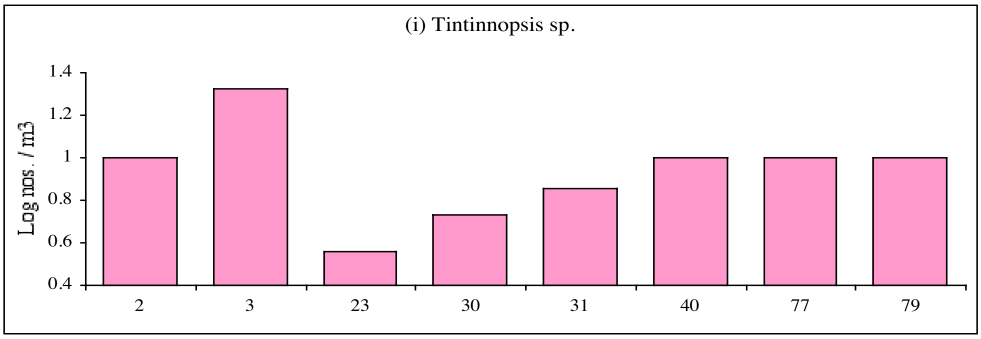


Fig. 3.2 Continue

centage concentrations of diatom. Bloom of dinoflagellate was detected from the Chao Phraya bay and Thailand offshore waters during the study period with values ranging from 51 to 76% abundance; similar bloom also occurred in Terengganu offshore waters during postmonsoon with a value of ca 66% abundance. Percentage abundance was low at Chao Phraya (3%) and Terengganu offshore waters (6%) during premonsoon. The value was low at Johore nearshore waters (2%) during postmonsoon. Microzooplankton were present in considerable concentrations in nearshore and offshore waters especially in premonsoon period.

Microplankton assemblages and associations

The results from Fig. 13 illustrate that the microplankton species comprise of at least seven species assemblages or associations in cluster analysis on 27 species sampled from the nearshore 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 (*Thalassionema, Dinophysis, Hemiaulus, Ceratium, Corethron*); group B (*Bacteriastrum, Chaetoceros, Thalassionema, Rhizosolenia*); group C (*Ditylum, Lauderia, Guirnadia*); group D (*Trichodesmium, Nitzschia*); group E (*Coscinodiscus, Fragilaria*); group F (*Pleurosigma, Tintinnus*); group G (*Protoperidinium, Tintinnopsis*).

Disussion

Earlier studies by Shamsudin *et al.* 1987 in the Malaysian waters of the South China Sea showed that the microphytoplankton from 16 oceanographic stations consisted predominantly of diatoms and blue green algae. The bulk of the diatom species consisted of *Chaetocerus, Rhizosolenia, Melosira, Thalassiothrix, Datyliosolen* and *Guinardia*. Another diatom species, *Planktoniella* was present only at stations further offshore from the coast. However, other diatom species which were also present included those of *Bacteriastrum, Asterionella, Fragilaria, Nitzschia, Skeletonema, Coscinodiscus* and *Pleurosigma*. More than 30 major species of diatom have been identified. The genera *Coscinodiscus, Chaetocerus* and *Rhizosolenia* were found to contain a wide range of species. The Cyanophyta comprised of only a few species among which *Trichodesmium thiebautii* and *T. erytheraeum* were abundant. The diversity index (H) and evenness index (J) values were high at stations near to the coast. In this study, the microplankton species from various stations of the South China Sea consisted of more than 205 taxa consisting predominantly of blue greens (2 species), diatoms (120 species) dinoflagellates (80 species) and microzooplankton (> 30 groups).

Other quantitative studies of microplankton in Malaysian waters including the Straits of Malacca had been conducted by Sewel (1933), Winstead (1961), Pathansali (1968), Chua & Chong (1973), Shamsudin (1987, 1993, 1994, 1997) and Shamsudin & Shazali (1991). Most of these studies were carried out at certain predetermined time and location; however, the present study was carried out

S4/FB8<SHAMSUDIN>

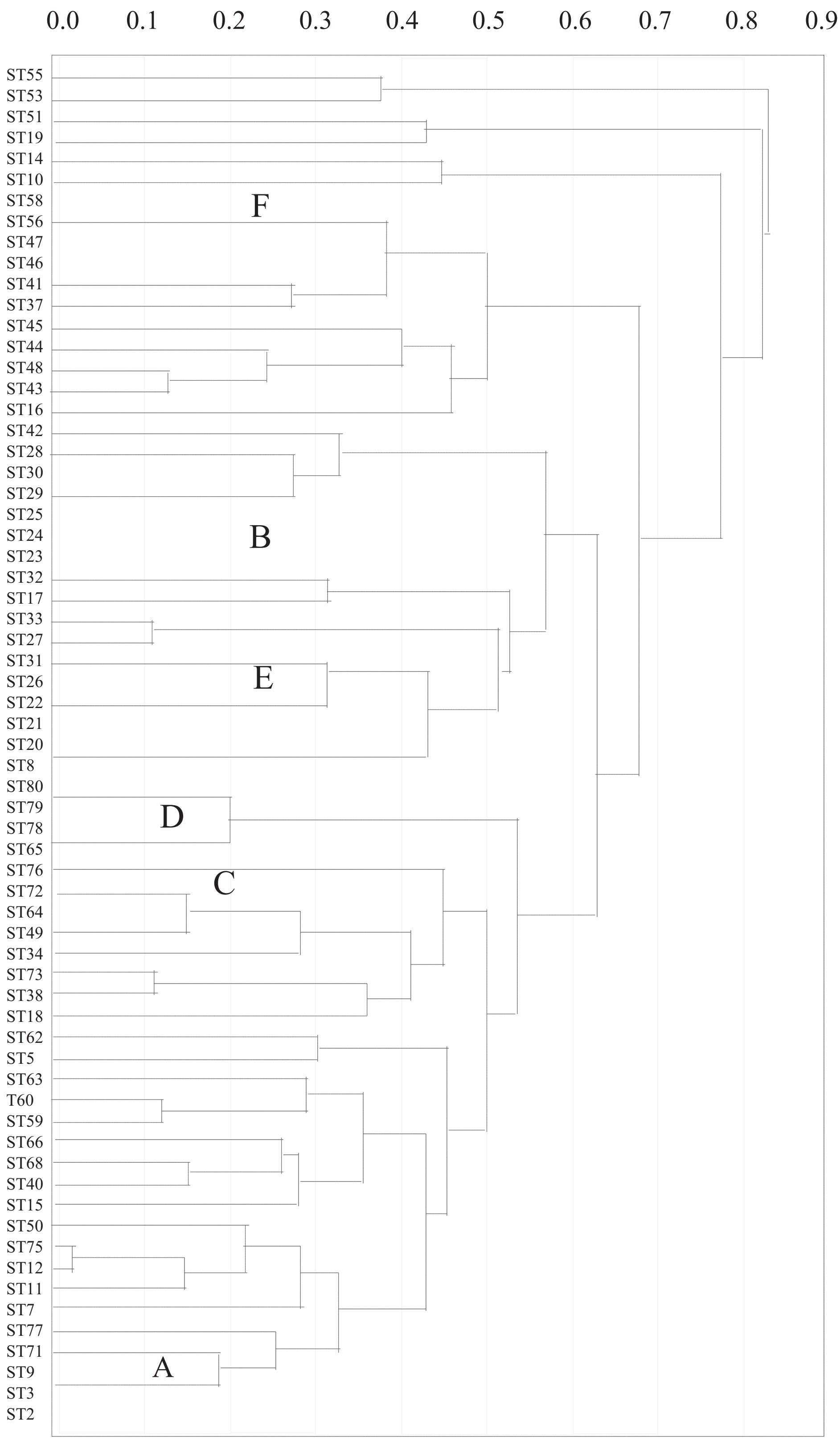


Fig. 4. Tree diagram for stations categorised intostudy sectors in the Gulf of Thailand and the south china Sea . (A- Chao phraya bay, C- Terengganu nearshore water, D- Johore water, E- Thailand offshore and F- Terengganu offshore waters)

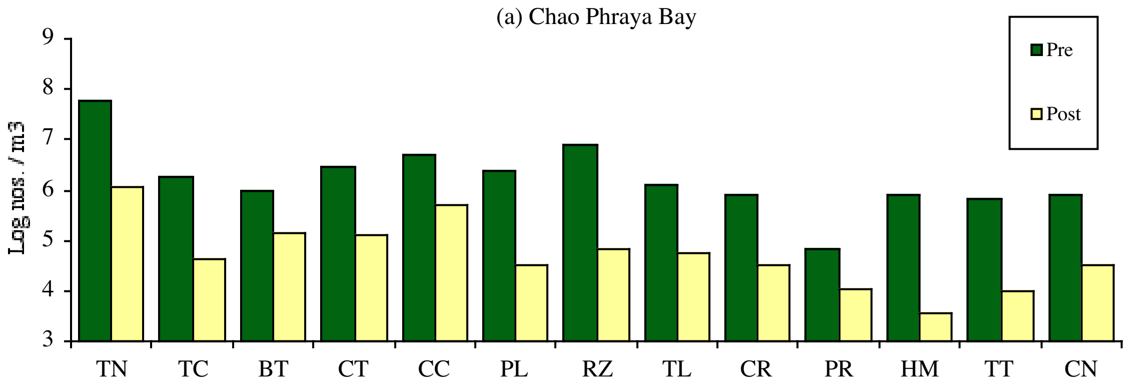


Fig. 5. Cell densities (log nos./m^3) of various microplankton species at stations nearby Chao Phraya Bay of the Gulf of Thailand during pre and post monsoon seasons. (TN-total cell, TC-Trichodesmium erythraeum, BT-Bacteriastrum cosmosum, CT-Chaetoceros lorenzianum, CC-Coscinodiscus jonesianus, PL-Pleurosigma elongatum, RZ-Rhizosolenia calcar-avis, TL-Thalassionema frauenfeldii, CR-Ceratium fusus, PR-Protoperidinium sp., HM-Hemiaulus hauckii, TT-Tintinnopsis sp., CN-Copepod nauplii).

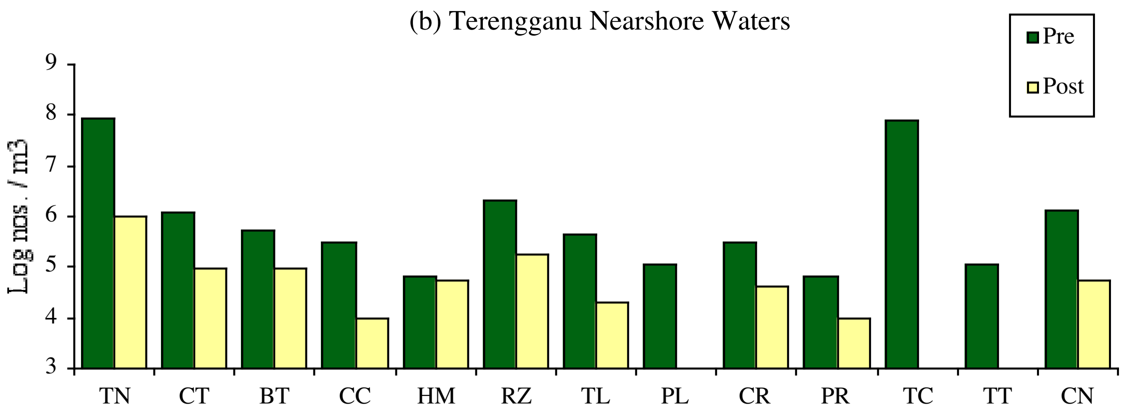


Fig. 6. Cell densities (log nos./m^3) of various microplankton species at stations in Terengganu nearshore waters of the South China Sea during pre and post monsoon seasons. (TN-total cell, CN-Chaetoceros lorenzianum, BT-Bacteriastrum comosum, CC-Coscinodiscus jonesianus, HM-Hemiaulus hauckii, RZ-Rhizosolenia calcar-avis, TL-Thalassionema frauenfeldii, PL-Pleurosigma elongatum, CR- Ceratium fusus, PR-Protoperidinium sp., TC-Trichodesmium erythraeum, TT-Tintinnopsis sp., CN- Copepod nauplii).

during the pre and post monsoon periods. Thus, the study will show the seasonal change and distribution of the microplankton species due to the monsoon season. Shamsudin *et al.* 1987 showed that the diversity (H) and evenness (J) indices were high in nearshore waters when compared to offshore waters. Similarly, the present study showed similar trend, however the occurrence of *Trichodesmium* and other diatom blooms would influence both the indices, indicating that there was a change in the planktonic community organisation in the water column, which could be represented by a number of species throughout the study period. An increase in the diversity value 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

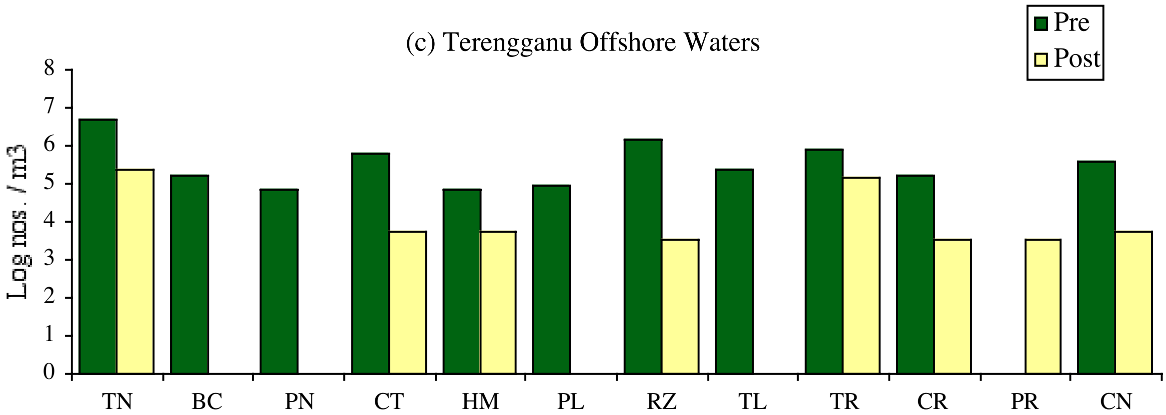


Fig. 7. Cell densities (log nos./m^3) of various microplankton species at stations in Terengganu offshore waters of the South China Sea during pre and post monsoon seasons. (TN. total cell, BT. *Bacillaria paxillifera*, PN. *Planktonella blanda* CT. *Chaetoceros compressum*, HM. *Hemiaulus hauckii*, PL. *Pleurosigma elongstum*, RZ. *Rhizosolenia calcar-avis*, TL. *Thallasionema frauenfeldii*, TR. *Trichodesmium erythraeum*, CR. *Ceratium* sp., PR. *Protoperidinium* sp., CN. Copepod nauplii)

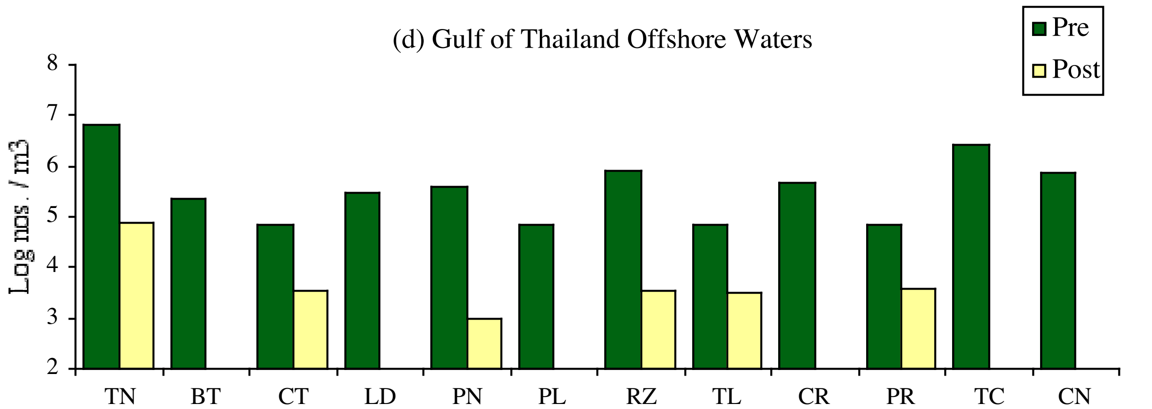


Fig. 8. Cell densities (log nos./m^3) of various microplankton species at stations in Thailand offshore waters of the South China Sea during pre and post monsoon seasons. (TN-total cell, BT-*Bacteriastrum cosmosum*, CT-*Chaetoceros lorenzianum*, LD-*Lauderia* sp., PN-*Planktonella* sp., PL-*Pleurosigma elongatum*, RZ-*Rhizosolenia calcar-avis*, TL-*Thallasionema frauenfeldii*, CR-*Ceratium fusus*, PR-*Protoperidinium* sp., TC-*Trichodesmium erythraeum*, CN-Copepod nauplii)

and thus effect or influence the number of species or the even distribution of individual species.

Premonsoon microplankton population

The present study also shows that the sampling stations can be categorised into 6 sectors in terms of similarities in species composition according to the two seasons (pre and postmonsoon periods) using cluster analyses . During the premonsoon, microplankton densities were high in the Chao Phraya bay, Pattany bay, Terengganu nearshore and the southern tip of peninsular Malaysia around Johore waters. There is a good correlation between the total microplankton and the diatom densities for both the seasons. The blue green (*Trichodesmium erythraeum*) developed bloom in Thailand offshore waters, Terengganu offshore waters as well as Johore waters. However, dinoflagellate species were dominant in the Chao Phraya bay and Johore waters. The offshore diatom species, *Bacillaria paxillifera* was dominant in the offshore waters of the South China Sea.

The chain forming diatom with long setae projection, *Bacteriastrum comosum* and *B. furcatum* were found in high concentrations in the nearshore waters of Malaysia and Thailand; similarly *Thalassionema frauenfeldii* was abundant in nearshore waters of the South China Sea. *Chaetoceros lorenzianus* was the dominant diatom in the Chao Phraya bay and the southern tip of peninsular Malaysia in Johore waters. Certain diatom species was dominant in certain study sectors; namely, *Chaetoceros pseudocurvisetum* with *Coscinodiscus jonesianus* in the Chao Phraya bay; *Chaetoceros compressum* in the Pattany bay and Malaysia nearshore waters; *Thalassionema nitzschioides* in nearshore waters of Thailand; *Trichodesmium erythraeum* occurred usually in offshore waters of the South China Sea. The two species of *Rhizosolenia* (*R. calcar-avis, R. alata*) occurred oceasionally in nearshore waters in high concentrations. *Thalassiosira subtilis* showed up in considerable concentrations in nearshore waters of Terengganu and Johore. The dinoflatellate species (especially *Ceratium fusus, Protoperidinium* sp.) were high in nearshore waters (Pattany bay, Terengganu nearshore, Johore waters) and Terengganu offshore waters with values ranging from 23 to 33% abundance out of the total cell count. The microzooplankton (comprising of copepods nauplii, *Tintinnopsis* sp., *Tintinnus* sp., crustacean larvae) were also present especially in nearshore waters.

The dominant species association available at the Chao Phraya bay comprised of *Chaetoceros lorenzianum, Thalassionema frauenfeldii, C. curvisetum* and *Coscinodiscus jonesianus* whereas at Pattany bay the species assemblage comprised of only three species (*Bacillaria, Trichodesmium erythraeum, Th. frauenfeldii*). Other species association occurred at various sectors namely, a) Terengganu nearshore waters (*Bacteriastrum comosum, Bacteriastrum furcatum, Th. frauenfeldii, T. erythraeum*); b) Johore waters had only 2 species (*Th. frauenfeldii, Thalassiosira subtilis*); c) Thailand offshore waters (*T. erythraeum, Th. frauenfeldii, Bacillaria paxillifera, C. lorenzianum*); d) Terengganu offshore waters (*Bacillaria paxillifera, Th. frauenfeldii, T. erythraeum, Pleurosigma* sp.).

Postmonsoon microplanton population

During the postmonsoon season, the diatom species (12 species) and 1 species of blue green (*Trichodesmium erythraeum*) were dominant. Diatom populations were high in nearshore waters (Chao Phraya bay, Pattany bay, Johore waters, Terengganu nearshore) with percentage abundance values ranging from 38 to 82% abundance. The dominant species encountered at Terengganu nearshore waters comprised of *Chaetoceros lorenzianus, C. compressum* and *Thalassionema frauenfeldii* ; whereas at the Pattany bay the species assemblages or association comprised of *Pleurosigma elongatum, Bacillaria paxillifera, Chaetoceros lorenzianum, C. didynum, Thalassionema frauenfeldii* and *Trichodesmium erythraeum*. Only two species association (*Skeletonema costatum, Chaetoceros lorenzianum*) was detected at the Johore waters while there was four species association (*Chaetoceros compressum, C. lorenzianum, C. pseudocurvisetum, Rhizosolenia alata*) at the Chao Phraya bay. Terengganu offshore waters had three species association (*Trichodesmium erythraeum, Chaetoceros compressum, Ceratium fusus*) while Thailand offshore waters had five species association (*T. erythraeum, Rhizosolenia calcar-avis, Chaetoceros coarctatum, Bacteriastrum cosmosum, Nitszchia closterium*).

Trichodesmium bloom occurred both at nearshore waters (Chao Phraya bay) and offshore waters (Terengganu and Thailand waters). Dinoflagellate (*Ceratium fusus, Protoperidinium* sp.) bloom occurred at Thailand offshore waters and nearshore waters (Terengganu and Johore waters).

Species assemblages by cluster analysis

Shamsudin (1987) showed that the diversity (H) and evennes (J) indices of microplankton population were high in Malaysian nearshore waters of the South China Sea during the study period

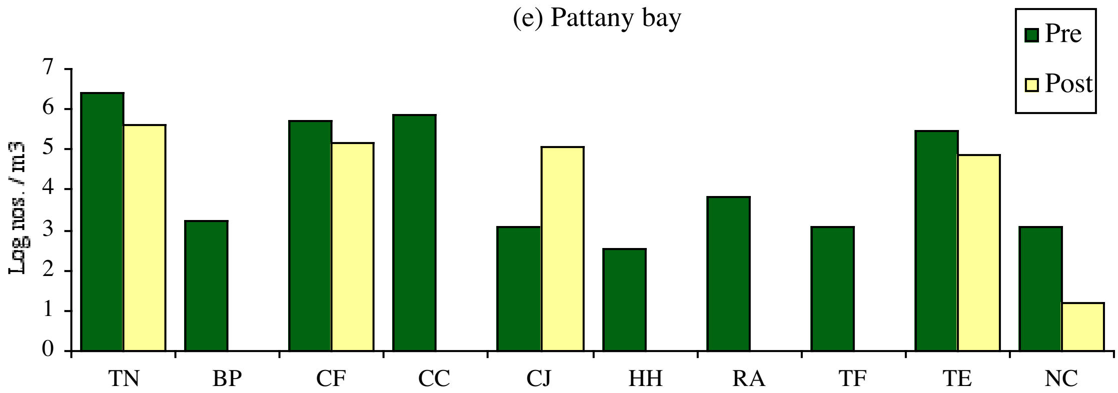


Fig. 9. Mean cell densities (log nos./m^3) of various species at Pattany bay sector during pre and post seasons (BP-*Bacillaria paxillifera*, CF-*Ceratium fusus*, CC-*Chaetoceros comosun*, CJ-*Coscinodiscus jonesianus*, HH-*Hemiaulus hauckii*, RA-*Rhizosolenia alata*, TF-*Thalassionema frauenfeldii*, TE-*Trichodesmium erythraeum*, NC- Copepod nauplii).

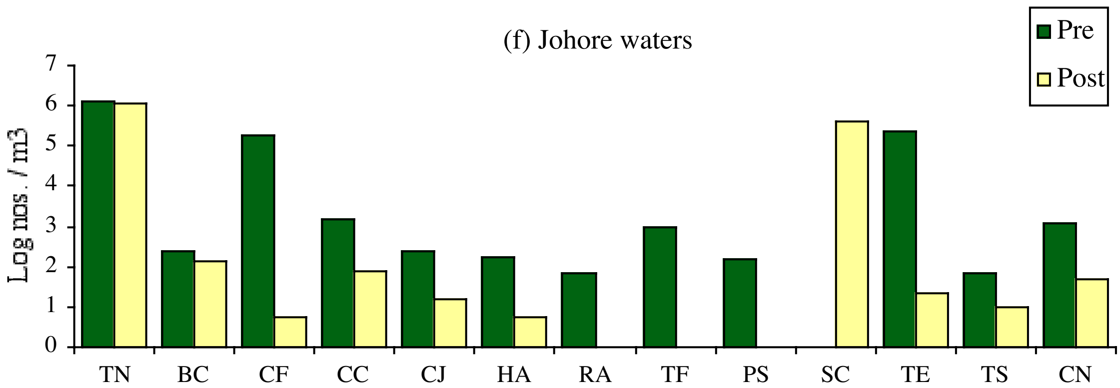


Fig. 10. Mean cell densities (log nos./m^3) of various species at Johore waters sector during pre and post seasons (PS-*Pleurosigma* sp., TS-*Thalassiosira subtilis*, SC-*Skeletonema costatum* the rest similar to Fig. 9).

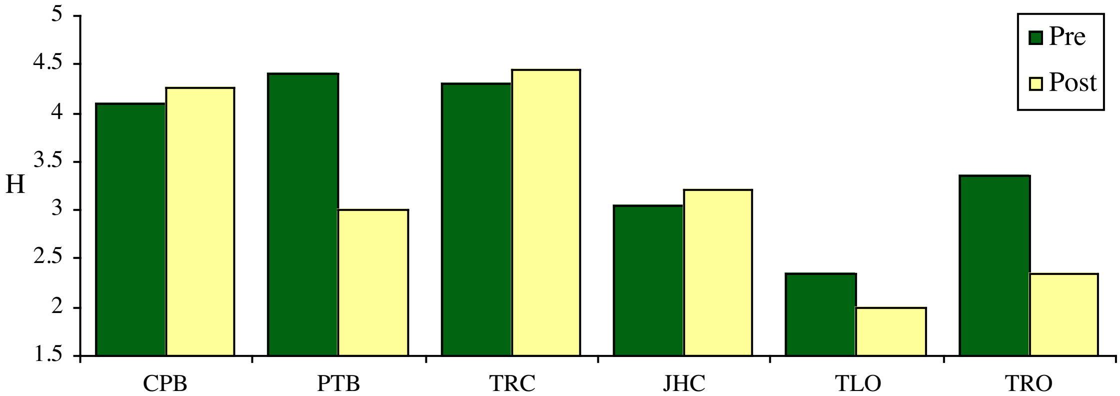


Fig. 11. The diversity (H) index at the six sectors (CPB - Chao Phraya Bay, PTB - Pattaya bay, TRC - Terengganu nearshore waters, JHC - Johore nearshore waters, TLO - Thailand offshore waters, TRO - Terengganu offshore waters

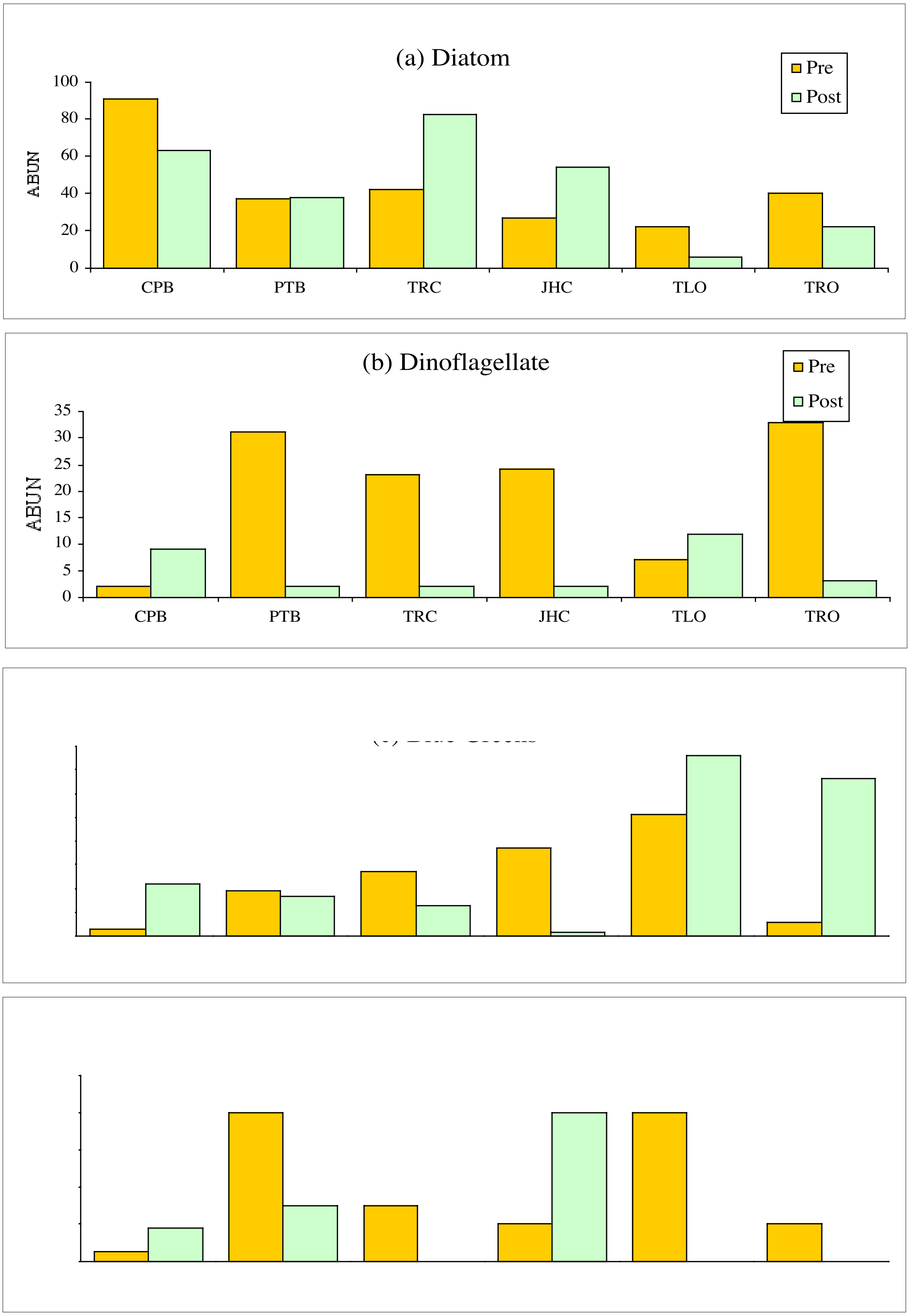


Fig. 12. The percentage abundance (expressed as percentage of total cell density) of diatom, dinoflagellate, blue green and microzooplankton at the six sectors (Name of sectors as shown in Fig. 11). (ABUN - abundance).

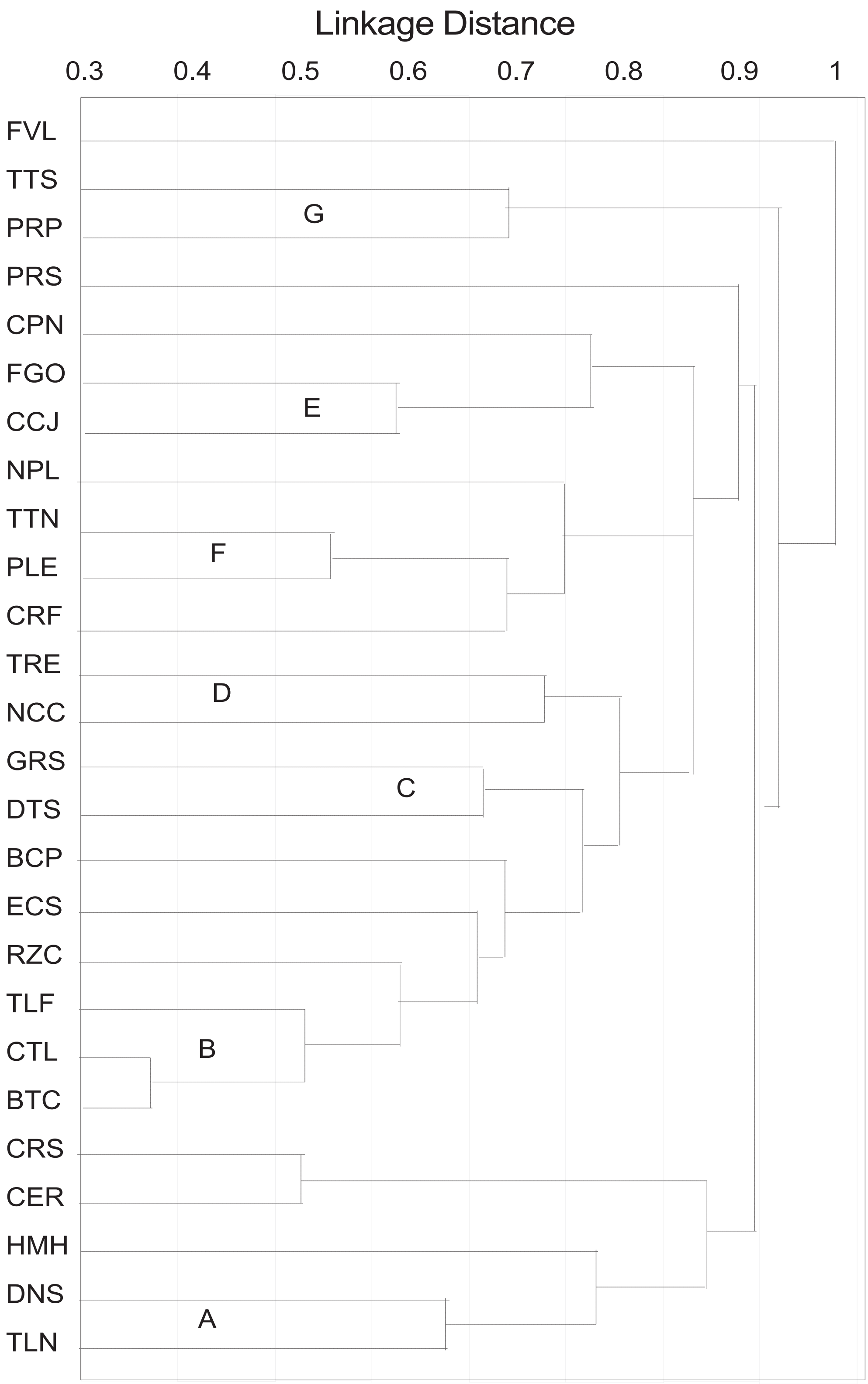


Fig. 13. Tree diagram for microplankton speciess associations using cluster analyses (unweighted pair group average - Pearson Index). Group A :Thalassionema nitzschioides, Dinophysis sp., Hemiaulus hauckii, Group B : Bacteriastrum comosum................

(March 1988 to April 1989); however, the sampling areas were not divided into sectors as a basis of comparison in species composition and association. The present study showed that the microplankton exhibited species associations or assemblages based on cluster analysis on species collected from 80 stations according to their preference on environmental conditions. These species can be classified into at least 7 groups using cluster analysis; namely group A (*Thalassionema nitzschioides, Hemiaulus hauckii, Dinophysis* sp.); group B (*Bacteriastrum comosum, Chaetoceros lorenzianus, Thalassionema frauenfeldii, Rhizosolenia calcar-avis, Eucampia* sp.); group C (*Ditylum sol, Lauderia borealis*); group D (*Nitzschia closterium, Trichodesmium erythraeum*); group E (*Coscinodiscus jonesianus, Fragilaria* sp., Copepod nauplii); group F (*Pleurosigma elongatum, Ceratium fusus, Tintinnus* sp.); group G (*Tintinnopsis* sp., *Protoperidinium* sp.). The species association between *Trichodesmium erythraeum* and *Nitzschia closterium* was obvious in offshore water of the Gulf of Thailand offshore waters. In a similar manner, the sampling stations containing various microplankton species composition and distribution can be classified into various sectors (at least six) according to species preference on environmental conditions. Markina (1972) reported that Peridinians around the tropical northern coast of Australia were represented less in species number than those of the diatoms which were mostly oceanic forms. *Ceratium deflexum* was found to occur in north Australian waters (Zernova, 1964; Semina, 1967) but the species was absent in the present study.

Microzooplankton population

The bulk of the microzooplankton species consisted of more than 30 different groups with several dominant species namely, copepod (> 50% of the total microzooplankton count); Chaetogratha (5%), Ostracod (3%), Siphonophora (2%), Cilliophora (4%) and Foraminifera (2-3%). The Ciliphora consisted of a few genera (*Tintinnopsis, Tintinnus, Favella, Codonellopsis*) while Foraminifera consisted mainly of the *Globigerina* species which is considered as an indicator tropical species. *Amphisolenia* (Fam.: Peridinidae) and *Ceratocorys* species were detected in considerable amount in nearshore stations. The dinoflagellate *Ceratium fusus* had intimate association with the blue green *Trichodesmium erythraeum* found especially around the Pattany bay. Only a few toxic species of *Protoperidinium* and *Alexanderium* were found around the Chao Phraya bay with a mean population of 2-19 x $10^3/m^3$.

The dominant copepod nauplii were abundant (ranging from 720-980 x $10^3/m^3$) in nearby Malaysian waters, especially Terengganu and Johore waters. *Chaetognatha* larvae had very similar distribution to that of copepod. Ostracod was abundant at nearshore waters of (Pattany bay, Terengganu). Siphonophora larvae was also encountered along Terengganu and Johore nearshore waters. Numerous larvae of shrimp, stomatopod, brachyura, gastropod, bivalve, lucifer, pteropod and larvacean were found especially in nearshore waters of the South China Sea.

Acknowledgement

The authors would like to thank the Captain and the crews of the MV SEAFDEC for collecting water samples during the cruise 1995/96 and Che Ku Haslinda for typing this manuscript.

References

Banse, K. 1964. On the vertical distribution of zooplankton in the sea. *Progress in Oceanography*. Vol. 2, p. 53-125.

Barber, H.G. & Haworth, E.Y. 1981. *A Guide to the morphology of the diatom Frustule. FSA Scient. Publ. no. 44.* Ambleside. Freshwater Biological Association, 35 p.

Chua, T.E., & Chong, B.J. 1973. Plankton distribution in the Straits of Malacca and its adjacent waters. *Special symposium on Marine Science, Dec. 1973*, Hong Kong.

Cleve, P.T. 1901. Plankon from the Indian Ocean and Malay Archipelago. *K. Sv. Vet. Ak. Handl*. Vol. 35 No. 5. 57 p.

Cleve, P.T. 1904. Plankton of the South African Seas. *Marine Inverstigation in South Africa,* Vol. III. 45 p.

Cleve-Euler, A. 1944. Die diatomeen als quartargeologische Indikatoren. *Geologiska Foreningens i Stockholm Forhandlingar*, 66(3) : 383-410.

Crosby, L.H. & Ferguson Wood 1959. Studies on Australian and New Zealand Diatoms. II. - Normally Epontic and Benthic Genera. *Trans. Roy. Soc. New Zealand* Vol. 86, part 1, 58 p.

Cummins, A.B. and H. Mulryan 1937. *Diatomite, Industrial minerals and rocks*. Published by the American Institute of Mining and Metallurgical Engineers, pp. 243-260.

Cupp, E.E. 1943. Marine Plankton Diatoms of the West coast of North America, Bykk, Scruoos Ubst. *Oceanography*, Vol. 5, No. 1, 237 p.

Doty, H.S., Soeriaatmadja, R. E. & Sogiarto, A. 1963. Observations on the primary marine productivity of northern Indonesian waters. *Marine Research in Indonesia* 5; 1-25.

Elliot, J.M. 1977. *Some methods for the Statistical analysis of benthos invertebrates.* Freshwater Biology Station Science Publication No. 25; 316 p.

Fritsch, F.E. 1935. *The structure and reproduction of the algae*. Vol. I. London and New York, Cambidge University Press, xvii + 791 pp.

Gran, H.H. 1912. Pelagic plant life. *In Depths of the Ocean*, J. Murray and J. Hjort. London, Macmillan and Co., Chapter 6, pp. 307-386.

Gray, J.S. 1981. The ecology of marine sediments. *An introduction to the structure and function of benthic communities.* Cambridge University Press 185 p.

Hendey, NI. 1964. *An introductory account of the smaller algae of British Coastal waters*. Post V Bacillariophyceae (Diatoms) Fishery Investigation Series IV 317 p.

Hustedt, F. 1930 Bacillariophyta (Diatom). In *Die Sasswasser-flora Mitteleuropas* 10 (Pascher, A., editor), 1-466. Jena. 122 p.

Ludowig, J.A. & Reynolds, J.F. 1988. Statistical ecology - *Primer on Methods and computing,* John Wiley new York 317 p.

Markina, N.O. 1972. Special features of plankton distribution around northern coasts of Australia during different seasons of 1968-1969, TINRO v. 81, 1-18.

Newell, G.E. & Newell, R.C. 1973 *Marine Plankton*. Hutchinson educational Ltd. 244 p.

Palmer, T.C. & Keeley, F.J. 1900. Structure of the diatom girdle. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 52: 465-479.

Pasher, A. 1914 Chlorophyceae 111. In *Die Sasswasser-flora Deutschlands, Osterreichs Und Der Schweiz 6.* 1-250. Jena. 120 p.

Pasher, A. 1915 Einzellige Chlorophyceengattungen unsicherer Stellung *Die Sasswasser-flora Deutschlands, Osterreichs Und Der Schweiz, Heft 5, 206 et seq.* 110 p.

Pasher, A. 1925 Cyanophyceae. In *Sasswasser-flora Deutschlands, Osterreichs Und Der Schweiz 12.* 1-481. Jena. 114 p.

Pathansali, D., 1968 Some observations on the distribution of Chaetognatha, west of Penang Island. *Publications of the Sato Marine biological laboratory,* Japan *15;* 391-397.

Patrick, R., & Reimer, CIW. 1968. *The diatom of the United States exlusively of Alaska and Hawaii*. Vol. I Philladelphia. 540 p.

Pielou, E.C. 1984. *The interpretation of ecological Data.* Wiley, NY, 125 p.

Semina, G.I. 1967. Phytoplankton, Pacific Ocean. *Biology of the Pacific Ocean*. B.I. plankton, M. 250 p.

Sewell, S.R., 1933. Marine copepoda from Malay States. *Bulletin of the Raffles Museum*, Singapore 8; 65 p.

Shannon, C.E. & Wiener, W. 1949. *The mathematical theory of communication*. Illinois Press, Urbana, III. 117 p.

Shamsudin L., M.I. Mansor Y Husin J. 1984. Primary productivity and mineral nutrient status of some estuaries and coastal waters along the east coast of Peninsular Malaysia during the off monsoon period. Pertanika 7(3): 79-87.

Shamsudin L. & Bakar M.G. 1987. The microzooplankton (including dinoflagellate and Foraminifera) of Sarawak waters of South China Sea In: *Matahari Expedition* 1987 (ed.) AKM. Mohsin *et al.*, FPSS, UPM : 109 - 114.

Shamsudin L. 1987. Microplankton distribution in the coastal waters of Port Dickson. *In : Proceedings of the 10th Seminar of the Malaysian Society of Marine Science*. Sasekumar, A. *et al.* (Eds) University Malaya special publication : 23-29.

Shamsudin L. & Shazili N.A.M 1991. Microplankton bloom in a brackish water lagoon of Terengganu. *Environmental Monitoring and Assessment* , 19: 287-294.

Shamsudin L. 1993. Biochemical composition and fatty acid content of zooplankton from tropical lagoon for larval rearing. *Journal Archives Internationales de Physiologie, de Biochemie et de Biophysique,* 1993, 101: 1-4.

Shamsudin L. & Sleigh, M.A. 1994. Seasonal changes in composition and biomass of epilithic algal floras of a chalk stream and a soft water stream with estimates of production. *Hydrobiologia* 273 (3): 131 - 146.

Shamsudin L. 1994. Food values of indigenous Zooplankton from the South China Sea on the East Coast of Peninsular Malaysia. *Journal of the World Aquaculture Society*. 25 (2) 208-231.

Shamsudin L. 1995. Lipid and fatty acid content in microplankton bloom from tropical fish ponds. *Archives Internationales de Physiologie, Biochemie et Biophysique* 103 (5) 21-27.

Shamsudin L. & Sleigh, M.A. 1995. Seasonal changes in composition and biomass of epiphytic algae on the macrophyte *Ranunculus penicillatus* is a chalk stream, with estimates of production and observation on the ephytes of *Cladophora glomerata. Hydrobiologia* 306: 85-95.

Shamsudin L., Yusof, M., Azis, A. & Shukri, Y. 1997. The potential of certain indigenous copepod species as live food for commercial fish larval rearing. *Aquaculture* 151: 351-356.

Shamsudin L., Kamal S. & Samo K. 1987. The microzooplankton of Sarawak waters of the South China Sea In : *Matahari Expedition* 1987 (ed.) AKM Mohsin *et al.*, FPSS, UPM : 99-108.

Shirota, A. 1966. *The Plankton of South Vietnam* - Fresh water and Marine Plankton. Oversea Technical Cooperation Agency, Japan, 464 p.

Southwood, T.R.E. 1978. *Ecological Methods,* Cambridge 210 p.

Taylor, F.J.R. 1976. *Dinoflagellates from the international Indian ocean expeditions*. A report on material collected by the R.V. Anton Brunei 1963-1964. Stuttgant 227 p.

Taylor, D.L. & Seliger, H.H. 1979. *Toxic dinoflagellate bloom In*: Proceedings of the 2nd International Conference on Toxic Dinoflagellate Blooms, Lewis M. Carrie (Ed.) Key Bicayre, Florida 31 Oct. - Nov. 1978, 497 p.

Tippett, R. 1970. Artificial surfaces as a method of studying populations of benthic micro-algae in freshwater. *Br. phycol. J. 5,* 189-199.

Vollenweider, R.A., Talling, J.F. & Westlake, D.F. 1974. *A manual on methods for measuring primary production in aquatic environments*, IBP Handbook No. 12. Blackwell, Oxford, 2nd. edn. 225 p.

Wickstead, J.H., 1961. A quantitative and qualitative study of some Indo-West Pacific Plankton. *Colonial Office Fisheries Publication. 16*, Her Majesty's Stationery Office, London. 47 p.

Zemova, V.U. 1964. Distribution of phytoplankton in the tropical parts of the western Pacific Ocean. Tr. ION USSK, 4. 65p.

Multi-Species Fish Stock Assessment by Acoustic Method in the South China Sea Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

Albert Chuan Gambang[1]
Hadil bin Rajali[1]
Raja Bidin bin Raja Hassan[2]
Rosidi bin Ali[2]
Kunimune Shiomi[2]
Shunji Fujiwara[2]
Shamusudin bin Basir[3]

[1]Fisheries Research Institute(Sarawak), P.O. Box 2243,
93744 Kuching, Sarawak, Malaysia
[2]SEAFDEC/MFRDMD, Fisheries Garden, Chendering,
21080 Kuala Terengganu, Malaysia
[3]Fisheries Research Institute, 11960 Batu Maung, Penang, Malaysia

ABSTRACT

Acoustic resource surveys were conducted by M/V SEAFDEC in the Gulf of Thailand and off the east coast of Peninsular Malaysia from September 5 to 28, 1995 for pre-NE monsoon season and from April 24 to May 17, 1996 for post-NE monsoon season, using the scientific echosounder FQ-70 (Furuno Electric Co.) .

Collected raw values of backscattering strength (SV) from the 200 kHz were carefully corrected and filtered to eliminate the influence of plankton. These corrected SV values were classified into pelagic and demersal fish, and were used to estimate the biomass of pelagic and demersal multi-species fish. Biomass of pelagic and demersal fish for each season was only estimated in the east coast of Peninsular Malaysia within Malaysian EEZ waters due to the availability of previous fisheries statistics and biological data. Dominant species were selected based on the fisheries statistics and landing place survey. Length (L) and weight were obtained from previous literatures. Target strength (TS) of these dominant species were calculated as TS =20 log (L) -66.

The distribution of the SV values for pelagic fish showed a distinct difference between pre- and post- monsoon seasons. Greater concentrations of SVs were observed from offshore compared to the nearshore waters in pre-monsoon season. The distribution for the demersal fish showed that there was no clear difference between pre- and post-monsoon. The estimated biomass of multi-species fish off the east coast of Peninsular Malaysia within Malaysian EEZ for the pre-and post-monsoon seasons was $4.4x10^5$ tonnes ($2.3x10^5$ tonnes of pelagic fish and $2.1x\ 10^5$ tonnes of demersal fish) and $3.1x\ 10^5$ tonnes ($1.9x10^5$ tonnes of pelagic fish and $1.2x\ 10^5$ tonnes of demersal fish), respectively.

Key words: Acoustic survey, Multi-species biomass estimation, East coast of Peninsular Malaysia

Introduction

Fish stock assessment in the South China Sea waters is a growing necessity in many countries in Southeast Asian countries. However, suitable multi-species fish stock assessment methods have not been facilitated in this region due to the complexity of biological characteristics, such as the multitude of fish species and spawning throughout the year. Furthermore, the inherent characteristics of fisheries in this region hinder the collection of reliable landing statistics. In such a situation, an acoustic method, which is independent of the fishery, is appropriate to grasp overall fish biomass in this region, although such a method may not be able to solve completely problems in tropical multi-species fish stock assessment. SEAFDEC has begun to make an effort to develop multi-species fish biomass estimation in South China Sea by means of acoustic method. This report presents one of the approaches to estimate tropical multi-species fish biomass estimation by acoustic method, and discusses the effect of Northeast monsoon season.

Materials and Methods

Two acoustic surveys, using FQ-70 (Furuno Electric Co.), were carried out simultaneously with oceanographic studies by M/V SEAFDEC in the Gulf of Thailand and off the east coast of Peninsular Malaysia. The first survey was conducted during the pre-Northeast(NE) monsoon season from September 5 to 28, 1995. The second survey was carried out during the post-NE monsoon season from April 24 to May 17, 1996. These timing of the surveys were primarily to examine whether the NE monsoon season (November to March) affects the abundance and distribution of fish in the survey area.

Calibration of FQ-70 was done prior to each survey near Luan Island (12 ° 57 ‘ N, 100 °37 ‘ E) on the upper coast of the Gulf of Thailand in September 4, 1995 for the first survey, and in April 23, 1996 for the second survey. The source level, receiving sensitivity, and the gain of amplifier were measured by means of a hydrophone. Parameter settings of the acoustic system were shown in Table 1.

Survey transect was set between oceanographic stations. Both surveys were conducted along the same transect as shown in Figure 1. The transects were accorded with grids of 30 ‘ in latitude by 30 ‘ in longitude throughout day- and night-time at a cruising speed of approximately 10 knots.

The acoustic system was set up to process echo and output of the volume backscattering strength (SV in dB/m^3) in real time from depth of 10m to 80m 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 from the surface, while layers 9 and 10 were set 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 the following forms:

1) Numeric data of integrated result of echo signals which were recorded in a floppy disk through data analyzer FQ-770
2) Print-out of the numeric data from the results of the integrated echoes (This output was also recorded simultaneously in a floppy disk).
3) Echo signals including echo of vertical distribution curve, which were traced on the recording paper through the recorder unit FQ-706.
4) Analog data for echo signals and log data which were recorded on a video tape.

Only the numeric data on a floppy disk and in printed form were used to process the SV values. The traced echo signals were only used as a reference. Analog data on the video tape were not utilized due to the absence of a post data analyzer.

Noise from other electric devices and unlocked echoes due to rough sea conditions may create errors to the collected raw SV values. Besides noise and unlocked echoes, the raw SV values may also be affected by plankton and other dense micronecton. Therefore, these raw SV values need to be corrected prior to further analysis.

The graphical method was used to correct erroneous SV values obtained by chance from noise of other electric devices and unlocked bottom echoes. The SV values were plotted against integration

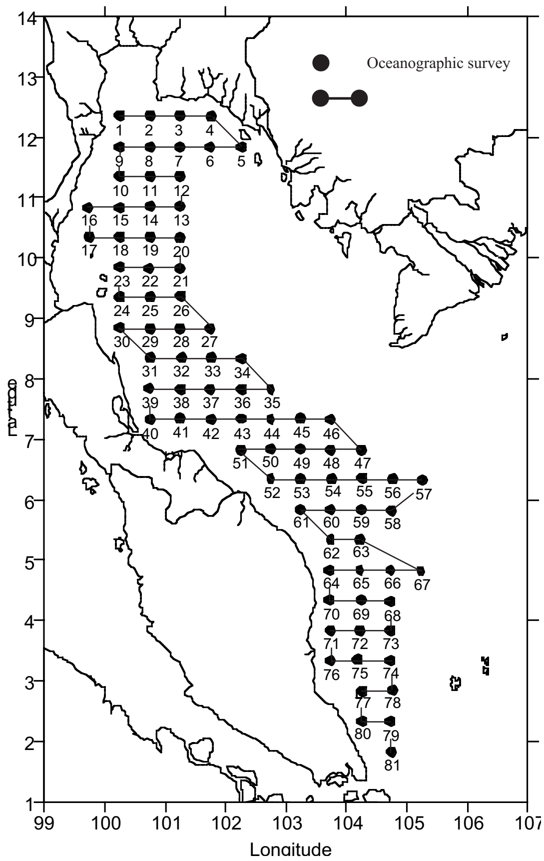


Fig. 1. Survey transects for the acoustic survey in the Gulf of Thailand and off the east coast of Peninsular Malaysia in September 1995 and April/May 1996. Number indicates the oceanographic survey station.

Table 1. Settings and calibration parameters of the acoustic system FQ-70.

Parameters	Sep. 1995		April/May 1996	
Frequency (kHz)	50	200	50	200
Source Level(dB)	215.3	219.5	212.5	218.8
Pulse Duration(ms)	1.2	1.2	1.2	1.2
Beam Width(dB)	-14.5	-16.1	-14.5	-16.1
Absorption Coefficient(dB)	9.9	92.7	9.9	92.7
Receiving Sensitivity(dB)	-186.0	-194.9	-185.6	-194.2
Amplifier Gain(dB)	49.0	50.1	49.0	50.2

Table 2. Depth layers and depth ranges of SV integration.

Depth Layer	Ranges (m)
1	10-80
2	10-20
3	20-30
4	30-40
5	40-50
6	50-60
7	60-70
8	70-80
9	10-5 (from Bottom)
10	5-1 (from Bottom)

number for each depth layer of 1 to 8 and average of layers 9 and 10. From the graphs, doubtful high echo traces were carefully corrected by referring to the recording paper. These were termed as the Corrected SV values.

The corrected SV values were further filtered to select the values from fish, using five-point moving average. These filtered SV values will be called the Calculated SV values.

The calculated SV values for each transect were averaged vertically from depth layer 2 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 of layers 9 and 10 were considered as demersal fish. The values remained from the subtraction of the SV values of layers 9 and 10, from the total SV values of layers 2 to 8, were considered as pelagic fish. The overall averaged calculated SV values throughout transects within the specified area for pelagic and demersal fish were used for fish biomass estimation.

The pelagic and demersal multi-species fish biomass off the east coast of Peninsular Malaysia within Malaysian EEZ was only estimated due to the availability of necessary information. For simplicity, the areas within the oceanographic station 45 to 81 was considered as Malaysian EEZ off the east coast of Peninsular Malaysia. The total survey areas was estimated by the method of Johnnesson and Mitson (1983). The following expression was applied to estimate fish biomass:

$$Q = (sv / ts)\ w\ a\ d$$

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 following equation from Furusawa (1990):

$$TS = 20 \log SL - 66$$

where TS : Target strength(dB)

SL : Fish Standard length(cm)

To determine single TS for biomass estimation, a representative species was used in this report. The representative species were determined in two steps. A representative fish group was selected based on the catch statistics of the major fishing gears operating in the survey area within Malaysian EEZ off the east coast of Peninsular Malaysia. Then the representative species was determined using the previous landing statistics and literatures. After determining the representative species, necessary information on standard length and average weight were extracted from the previous literatures.

Results

The distribution of the calculated SV values of pelagic and demersal fish for pre- and post-NE monsoon seasons for each transect were shown in Figures 2 to 5.

Distribution of SV values in Figures 2 and 3 for pelagic fish showed an apparent difference between seasons and area. There are higher SV values during pre-NE monsoon season than post-NE monsoon season. Higher SVs were observed especially in the shallower waters towards the upper part of Gulf of Thailand during pre-NE monsoon season. There is a tendency for higher SVs towards offshore waters during pre-NE monsoon season. In contrast, during the post-NE monsoon season, there is a relatively low SVs throughout the survey area and the concentration of SVs were rather towards the shore.

Distribution of SV values of demersal fish for the pre- and post NE monsoon season are shown

Table 3. Selected fishing gears operating in the survey area of Malaysian EEZ in the east coast of Peninsular Malaysia.

Fishing Gear	Size Class
Otter Board Trawl	40-69.9 ton over 70 ton
Purse Seine	40-69.9 ton

in Figures 4 and 5. There were no distinct difference between the seasons.

Major fishing gears operating off the east coast of Peninsular Malaysia within the survey area are listed in Table 3. The major fishing gears are otter board trawl and purse seine.

Table 4 showed the landings of both pelagic and demersal fish by the two gear groups off the east coast of Peninsular Malaysia for three years period between 1992-1994 (Department of Fisheries Malaysia,1993, 1994, and 1995). The major fish group landed in descending order were *Decapterus* spp., *Selaroides* sp., and *Rastrelliger* spp. for pelagic fish and *Nemipterus* spp, *Lutjanus* spp., and Marine catfish(*Tachysurus* spp., *Arius* spp., *Osteogenius* spp.) for demersal fish. Being the most dominant in landing (Mansor and Abdullah, 1995; Kimoto and Ibrahim, 1996), *Decapterus russelli* of the *Decapterus* spp. and *Nemipterus peronii* of the *Nemipterus* spp. were designated as the representative species for further analysis. Standard length and average weight for pelagic fish and demersal fish were obtained from Mansor and Abdullah (1995) and Kimoto and Ibrahim (1996) in Table 5, including estimated TS

Results of biomass estimation of pelagic and demersal fish off the east coast of Peninsular Malaysia within Malaysia EEZ between the two seasons were shown in Table 5. Total estimated survey area was 111, 129 km^2. The estimated density and biomass of pelagic fish for pre- and post NE monsoon seasons were 2.07 tonnes/km^2 and 230,000 tonnes, and 1.74 tonnes/km^2 and 190,000 tonnes, respectively, based on *Decapterus* r*usselli*. The estimated density and biomass of demersal fish for pre- and post NE monsoon were 1.88 tonnes/km^2 and 210,000 tonnes and 1.10 tonnes/km^2 and 120,000 tonnes, respectively, based on *Nemipterus peronii*. Total biomass of multi-species fish in the east coast of Peninsular Malaysia within Malaysian waters for the pre-and post-NE monsoon seasons were 430,000 tonnes and 310,000 tonnes, respectively.

Discussion

Distribution of SV in Figures 2 and 3 for pelagic fish showed apparent difference between seasons and areas. There is higher SV values during pre-NE monsoon season than post-NE monsoon season. This trend is similar to the monthly landing patterns from both Malaysia and Thai EEZ of the survey area as shown in Figures 6 and 7 (Department of Fisheries Malaysia, 1993, 1994, and 1995; Department of Fisheries Thailand, 1995). Higher fish landing occurred from June to October (pre-NE monsoon season) and landings started to decline in November until May (post-NE monsoon season). Mansor and Abdullah (1995) and Anon (1987) suggested that during pre-NE monsoon season, pelagic fish would move towards the east coast of Peninsular Malaysia and to the Gulf of Thailand and later disperse to the offshore waters of the South China Sea during post-NE monsoon season. Since a relative change of SV values seem to effect patterns in the availability of fish, the SV values could be used as an index to indicate the availability of fish resource, therefore fish abundance within survey area.

Off the east coast of Peninsular Malaysia within Malaysian EEZ, two acoustic surveys have been carried out. The survey results by R/V DR F. Nansen during off NE monsoon between June and August in 1980 showed that the density of pelagic fish in this area was 2.68 tonnes/km^2 (Aglen *et al*.,

Table 4a. Landing (tonnes) of pelagic fish from selected fisheries along the east coast of Peninsular within Malaysian EEZ from 1992 to 1994.

Fish Group	Year 1992	1993	1994	Average
Decapterus spp.	22,743	32,245	26,662	27,217
Selaroides leptolepis	9,533	10,738	9,860	10,044
Rastrelliger spp.	6,646	6,066	5,152	5,955
Thunnus tonggol/Euthynnus affinis/Auxis thazard	5,790	8,041	2,285	5,372
Sardinela spp.	4,703	5,124	5,202	5,010
Selar spp.	5,489	5,365	2,983	4,612
Scomberomorus spp.	3,954	3,321	577	2,617
Megalaspis cordyla	2,629	2,684	2,041	2,451
Alectis indica/Caranx spp.	1,338	1,091	650	1,026
Trichiurus lepturus	566	520	632	573
Carangoides spp.	552	823	342	572
Sphyraena jello/S. optusa	593	517	222	444
Rachycentrom canadus	373	414	149	312
Fomio niger/Pompus spp.	181	502	204	296
Chirocentrus dorab	247	169	208	208
Elagatis bipinnulatus	203	114	34	117
Istiophorus spp/Makaira spp.	72	55	2	43
Megalops cyprinoides	106	6	11	41
Stolephorus spp.	19	66	10	32
Scomberoides commersonianus	31	29	23	28
Polynemus spp./*Eleutheronema tetradactylum*	19	33	2	18
Liza spp./Valamugil spp.	1	2	1	1
Total	**65,788**	**77,925**	**57,252**	**66,988**

Table 4b. Landing (tonnes) of demersal fish from selected fisheries along the east coast of Peninsular within Malaysian EEZ from 1992 to 1994.

Fish Group	Year 1992	1993	1994	Average
Nemipterus spp.	9,950	10,063	4,604	8,206
Lutjanus spp.	4,191	2,811	1,575	2,759
Tachysurus spp./*Arius* spp./ *Osteogenius* spp.	2,039	3,100	821	1,987
Gymnura spp./*Dasyatis* spp.	1,664	1,908	1,219	1,597
Pristipomoides typus	1,355	1,130	644	1,043
Epinephelus spp./ *Plectropormus* spp.	1,174	1,193	582	983
Saurida spp.	571	891	1,098	853
Upeneus spp.	785	690	810	762
Galeorhinidae	876	648	428	651
Plectrorhinchus pictus	500	429	327	419
Scolopsis spp.	462	535	165	387
Sciaena spp./*Otolithoides* spp./ *Otolithus* spp./*Johnius* spp.	398	380	350	376
Siganus spp.	409	370	154	311
Sillago sihama/S. maculuta	263	186	178	209
Flatfish	214	207	184	202
Caesio spp.	154	81	125	120
Muraenesox spp.	114	109	62	95
Pomadasys spp.	36	54	113	68
Leiognathus spp./*Gazza* spp./ *Secutor* spp.	46	55	87	63
Callyodon spp./*Thalassoma* spp.	59	54	6	40
Tonguefish	49	39	30	39
Drepane punctata	26	33	25	28
Plotosus spp.	34	11	2	16
Lactarius lactarius	1	0	1	1
Total	**25,370**	**24,977**	**13,590**	**21,312**

Table 5. Estimated biomass with necessary information for pelagic and demersal fish along the east coast of the Peninsular Malaysia within Malaysian EEZ in pre and post Northeast monsoon seasons, using FQ-70.

	Northeast Monsoon	
	Pre (Sep, 1995)	**Post (Apr/May, 1996)**
Survey area (km2)	111,129	
Pelagic	*Decapterus russelli*	
Depth layer (m)	61	61
SV (dB)	-73.14	-74.07
SL (cm)	15.1	16.7
TS (dB)	-42.42	-41.55
Weight (g)	40	51
Density (tonnes/km2)	2.07	1.74
Biomass (1,000 tonnes)	230	190
Demersal	*Nemipterus peronii*	
Depth layer (m)	9	9
SV (dB)	-69.34	-70.83
SL (cm)	16.7	13.9
TS (dB)	-41.55	-43.14
Weight (g)	126	72
Density (tonnes/km2)	1.88	1.1
Biomass (1,000 tonnes)	210	120
Total biomass (1,000 tonnes)	440	310

1981). The other survey by R/V Rastrelliger during June and July in 1986 showed the density of pelagic fish in this waters was 1.02 tonnes/km^2 (Anon., 1987). From the present survey, the average of estimated fish density of pelagic fish in this waters during off NE monsoon season was 1.97 tonnes/km^2 (2.07 tonnes/km^2 and 1.74 tonnes/km^2 for the pre-NE monsoon season and the post-NE monsoon season respectively). The average of estimated biomass for pelagic fish was 210,000 tonnes. It could be speculated that the magnitude of biomass for pelagic fish in this waters may not exceed an order of 10^6.

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

Acknowledgements

We are gratefully to Dr. T. Sasakura, SASA LABO. Co., and Dr. T. Inagaki, Ocean Research Institute, University of Tokyo, for their helpful advice.

References

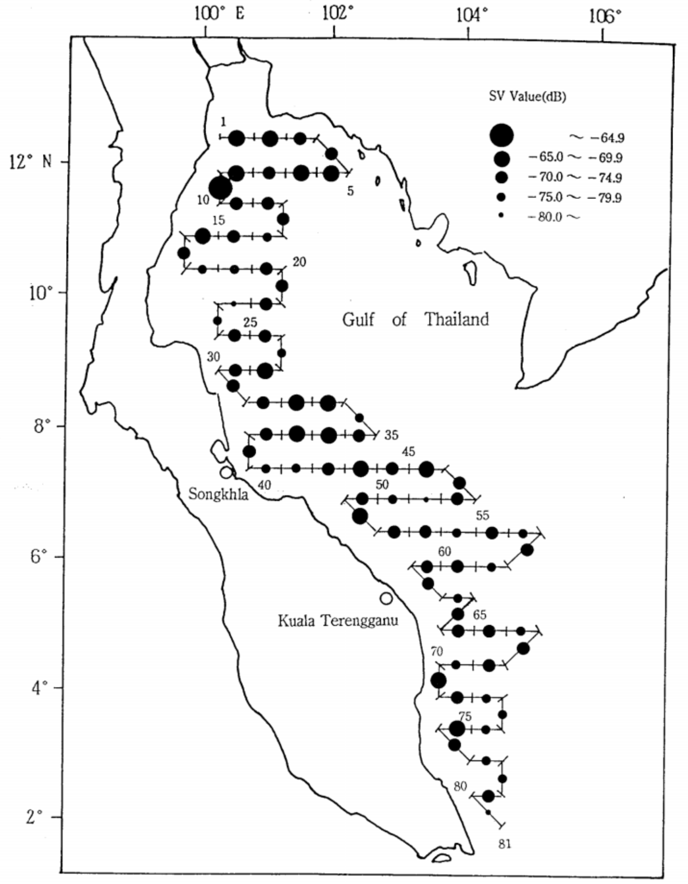


Fig. 2. SV values distribution for pelagic fish along transects in the Gulf of Thailand and off the east coast of Peninsular Malaysia in September 1995 during the pre-Northeast monsoon season. Number indicates the oceanographic survey station.

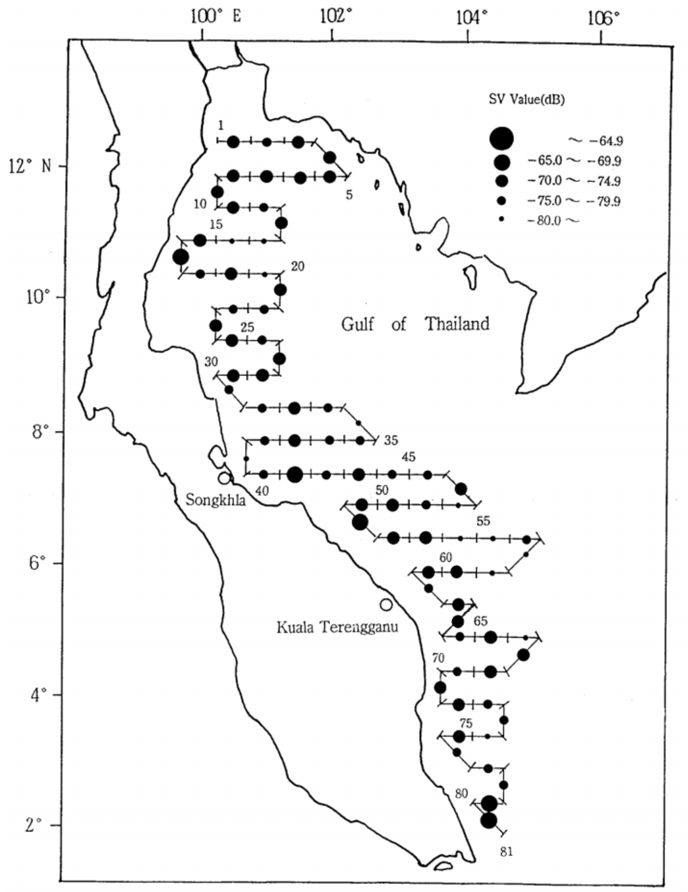


Fig. 3. SV values distribution for pelagic fish along transects in the Gulf of Thailand and off the east coast of Peninsular Malaysia in April/ May 1996 during the post-Northeast monsoon season. Number indicates the oceanographic survey station.

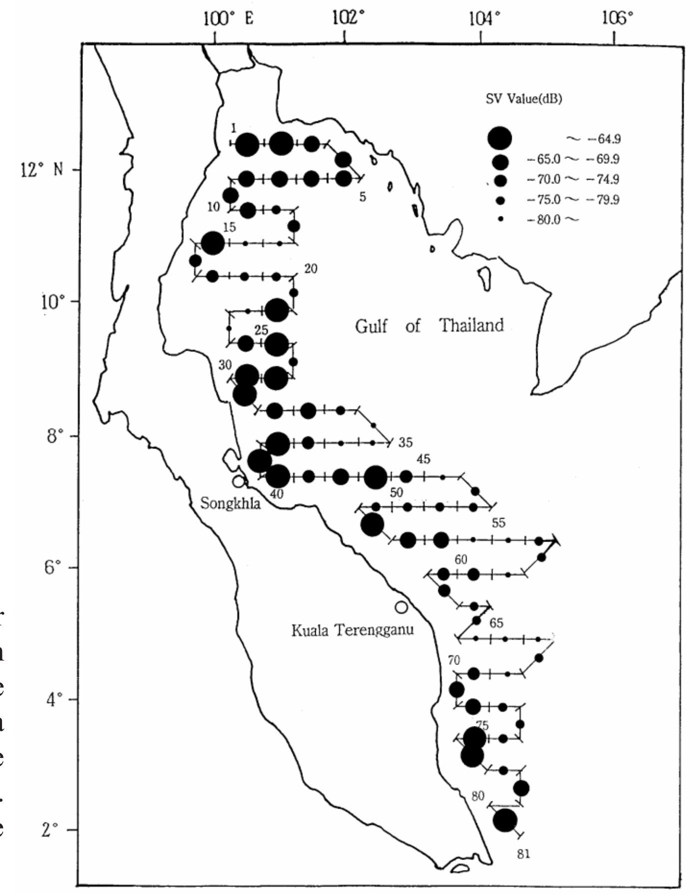


Fig. 4. SV values distribution for demersal fish along transects in the Gulf of Thailand and off the east coast of Peninsular Malaysia in September 1995 during the pre-Northeast monsoon season. Number indicates the oceanographic survey station.

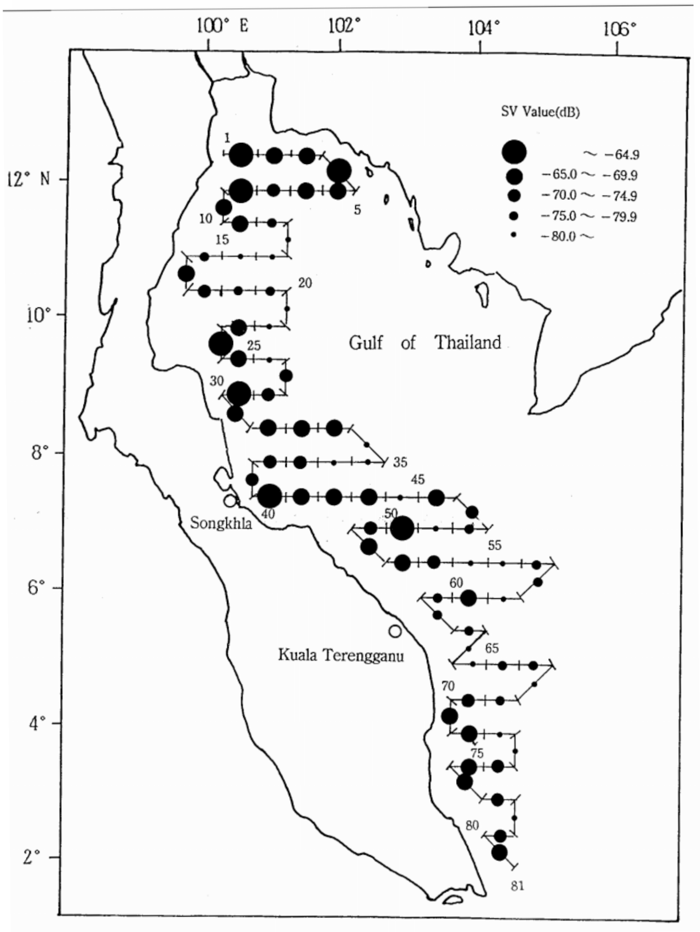


Fig. 5. SV values distribution for demersal fish along transects in the Gulf of Thailand and off the east coast of Peninsular Malaysia in April/May 1996 during the post-Northeast monsoon season. Number indicates the oceanographic survey station.

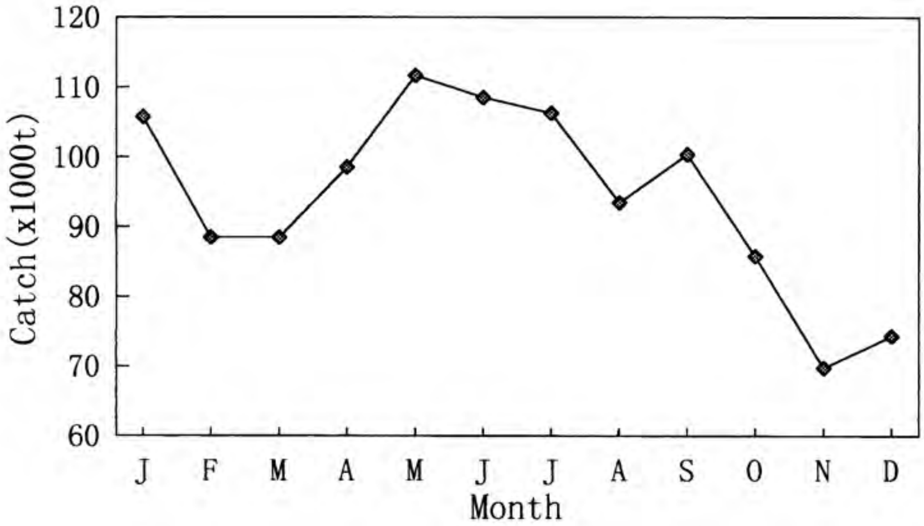


Fig. 6. Monthly fish catch in the Gulf of Thailand within Thai EEZ by selected fishing gear in 1992.

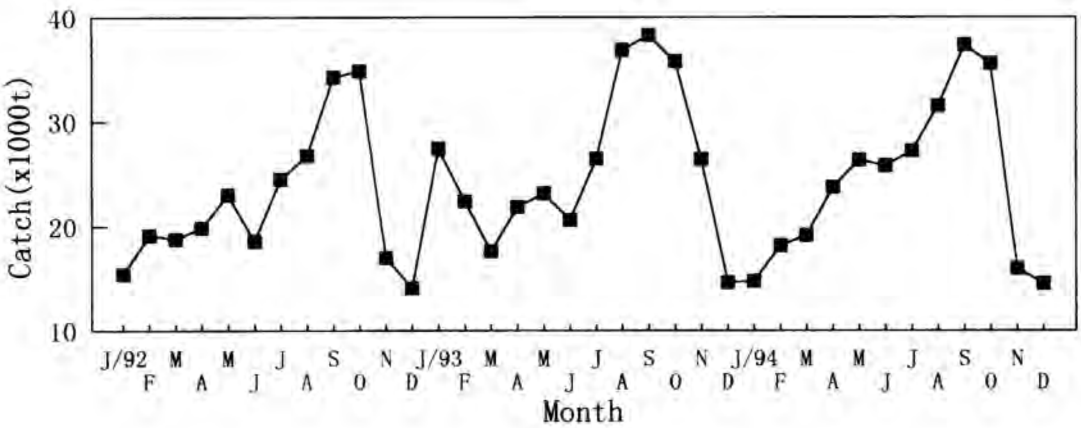


Fig. 7. Monthly fish catch off the east coast of Peninsular Malaysia within Malaysian EEZ by selected fishing gear during 1992 and 1994.

Aglen A., L. L. Foyn, O.R. Godo, S. Myklevoll, and O.J. Ostvedt. 1981. Survey of the marine fish resources of Peninsular Malaysia, July-July 1980. Institute of Marine Research, Bergen, 69p.

Anon. 1987. Deep Sea Fisheries Resource Survey Within the Malaysian Exclusive Economic Zone. Vol. 2. Department of Fisheries, Ministry of Agriculture Malaysia, 101p.

Department of Fisheries Malaysia. 1993. Annual Fisheries Statistics 1992. Ministry of Agriculture, Malaysia.

Department of Fisheries Malaysia. 1994. Annual Fisheries Statistics 1993. Ministry of Agriculture, Malaysia.

Department of Fisheries Malaysia. 1995. Annual Fisheries Statistics 1994. Ministry of Agriculture, Malaysia.

Department of Fisheries Thailand. 1995. The Marine Fisheries Statistics 1992 based on the sample survey. Ministry of Agriculture and Cooperative, Thailand.

Furusawa, M. 1990. Study on Echo Sounder for Estimating Fisheries Resources. Bull. National Res. Institute of Fish. Engineering, 11, 173-249.

Johnnesson, K. A. and R.B. Mitson. 1983. Fisheries acoustic; a practical manual for aquatic biomass estimation. FAO. Tech. Rep., 240, 249p.

Kimoto, K. and I. Johari. 1996. The stock status and management scheme of Kerisi (*Nemipterus peronii*) on the east coast of Peninsular Malaysia. SEAFDEC MFRDMD Res. 1, 24p.

Mansor, M. I. and S. Abdullah. 1995. Growth and mortality of Indian mackerel (*Rastrelliger kanagurta*) and slender scad(*Decapterus russelli*) off the East Coast of Peninsular. Sci. Mar., 59:533-54.

Pititgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. ICES J. mar Sci.,50, 285-298.

Biomass Estimation by Hydro-acoustic Methods in the Gulf of Thailand and Peninsular Malaysia.

Yuttana Theparoonrat
Suvimon Seakow
Siriporn Seurungreong

Training Department, Southeast Asian Fisheries Development Center, Thailand

ABSTRACT

The abundance of fisheries resources and their structure in the Gulf of Thailand and East coast of Peninsular Malaysia were investigated during the SEAFDEC Collaborative Research Survey. Hydro-acoustic surveying using a scientific echo sounder model FQ-70 was conducted to estimate the fish abundance and biomass. Two survey cruises were carried out by M.V.SEAFDEC during the pre and post-northeast monsoon seasons. The scientific echo-sounder was equipped with an echo-integrator and two quasi-ideal beam transducers with operating frequencies of 50 and 200 kHz. The volume back scattering strength (SV) of the fish schools were collected from the layer of water at a depth from 10 m to the bottom along the track of survey cruise. The estimated biomass measured by high frequency shows clearly that a high concentration is observed at the upper and middle part of the Gulf of Thailand and the boarder area between Thailand and Malaysia waters during the pre-northeast monsoon season. Whereas, high biomass concentration shows only in the middle part of the Gulf of Thailand during the post-northeast monsoon season.

Key words: Biomass estimation, Acoustic survey, Gulf of Thailand

Introduction

At present, quantitative acoustic methods are known to represent a powerful tool for fisheries management. Fisheries biologists are interested in the numbers of fish per unit volume or per unit area because it forms the basis of their analysies of population, and the catch or catch per unit of effort of a fishing vessel (Cushing, 1973). Acoustic surveys of fish are mostly based on the assumption that total echo intensity from a fish school is equal to the arithmetic sum of echo contributions from individual fish. In order to convert data collected in acoustic surveys into population estimations, it is essential to have as precise an estimates as possibles of a fish target strength (Johnnesson and Mitson, 1983). Due to the external and internal geometry of a fish, its target strength can vary widely with its size, the insonifying frequency and the insonified aspect. Hence, empirical approximations to the target strength of an individual fish are required as a function of size, frequency and aspect. These approximations may then be applied to fish school models in order to predict school volume back scattering strength (Love, 1977).

Marine fisheries resources migrate according to the change of season and their maturity state. The abundance estimation of such migratory species are needed to design the survey which covers all that particular area. The Gulf of Thailand and east coast of Peninsular Malaysia are adjacent waters with fish migrating along and across the exclusive economic zone between the two countries.

The first estimation of the abundance of the small pelagic resources by acoustic survey in the Gulf of Thailand was carried out from June to October 1979 by research vessel "Fishery Research No. 2" of the Department of Fisheries of Thailand (DOF Thailand, 1979). The objective of the survey was to make a quick quantitative assessment of fishery resources, especially pelagic fish in the Gulf of Thailand. The survey results showed that the dominant small pelagic species found during survey were *Sardinella* spp*., Rastrelliger* spp*., Caranx* spp., and *Decapterus* spp. The highest fish density were found in shallow waters at the upper gulf and middle part of the Gulf of Thailand.

Southeast Asian Fisheries Development Center (SEAFDEC) was proposed to conduct the Collaborative Research Survey on the marine fisheries resources and the environmental factors in the South China Sea off SEAFDEC member country's waters. Two survey cruises were performed by M.V.SEAFDEC during the pre-northeast monsoon season from 4 September to 4 October 1995 and the post-northeast monsoon season from 23 April to 23 May 1996. The objective of the survey being to estimate the abundance of fisheries resources and their structures in the Gulf of Thailand and East Coast of Peninsular Malaysia, and to study the variation of abundance during the pre-northeast monsoon and post-northeast monsoon season.

Materials and Methods

The survey area was divided into 81 oceanographic survey stations (Fig 1). The stations were located 30 nautical miles apart. The hydro-acoustic survey using a scientific echo-sounder, model FQ-70, was carried out parallel to the cruise track of 30 nautical miles. The scientific echo-sounder was equipped with dual frequencies by using two quasi-ideal beam transducers with frequencies of 50 kHz and 200 kHz. This acoustic survey system was equipped with an echo integrator, calibration system and data recorder. The system was designed so that a vast amount of data could be stored onto floppy disk memory and processed by a data analyzer.

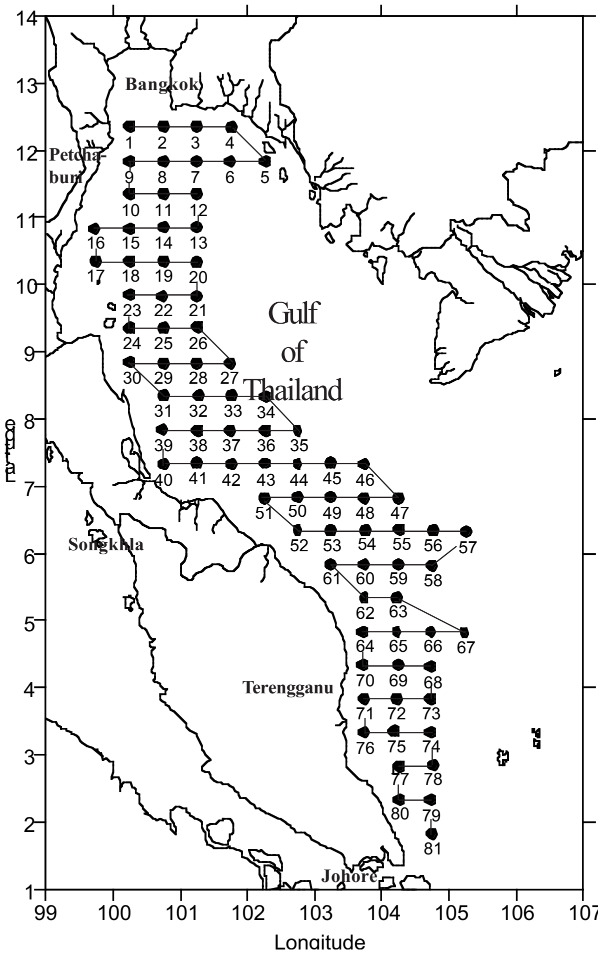


Fig. 1. Area and stations of collaborative research survey in the Gulf of Thailand and East Coast of Peninsular Malaysia.

The data of the hydro-acoustic survey during the cruises of M.V. SEAFDEC No. 26-8/1995 and No. 34-4/1996 recorded from the scientific echo sounder were analyzed by the author-edited computer programs. The raw data from Furuno FQ-70 software in the form of K3 ASCII code are used for the calculations. The volume back scattering strength (SV) of low frequency (50 kHz) and high frequency (200 kHz) were calculated from data recorded from the surface to the bottom layer.

Calibration of FQ-70 Scientific Echo Sounder

The calibration of FQ-70, conducted one day before the survey cruise was performed on 4 September 1995 and 23 April 1996 at Ko phai in the Gulf of Thailand. M.V.SEAFDEC was anchored in a water depth of 35 metres in a calm sea and weak current of 0.2 knots. The calibration was performed using a standard hydrophone model TW-9103-S attached 1 metre under the transducer sound beam axis. Both low (50 kHz) and high frequency (200 kHz) transducers were calibrated. The calibration items are shown as the followings:

- Transmitting Power
- Main Attenuation and Gain
- Transmitting Sensitivity of the Transducer
- Receiving Sensitivity of theTransducer.

The calibration result from both survey cruises showed a similar performance. The calibration on the first survey cruise are shown in table I to IV of Appendix.

Hydro-acoustic Data Collection

The hydro-acoustic data of fish schools in the area of the Gulf of Thailand and East Coast of Peninsular Malaysia are recorded using a scientific echo sounder (FQ-70) which is installed on board M.V.SEAFDEC. The total distance of the survey was 2495 nautical miles with a parallel track of 30 nautical miles. The data of mean volume back scattering were recorded by low (50 kHz) and high (200 kHz) frequency with the transmission rate of 160 ping/min. The ship cruising speed was 10 knots. During the survey cruise, the raw data of reflected echo signal from fish schools was also recorded on to VHS Video tape for data bank reservation. The processed echo information from the echo integrator with a distance interval of 0.1 nautical mile were calculated by echo integrator and data analyzer. The integration of volume back scattering strength (SV) of fish schools were calculated from the water depth layer of 10 m to 80 m with an interval of 10 m for each integration layer. Two bottom integration layers were calculated at 1 m to 5 m and 5 m to 10 m above the sea bottom. The integration of SV and density of fish were recorded on floppy disk as well as printed out on a printer and also plotted on the echogram. The recorded data on floppy disk was used for re-calculation for biomass estimation of fisheries resources and their distribution in the survey area. The parameter setting for echo integrator unit are shown below:

The Parameter Setting for the Echo Integrator Unit

Range

1. REC RANGE		0 - 80 m
2. LAYER	1	10 - 80 m
	2	10 - 20 m
	3	20 - 30 m
	4	30 - 40 m
	5	40 - 50 m
	6	50 - 60 m
	7	60 - 70 m
	8	70 - 80 m
	9	B10 - B5 m

10 B5 - B1 m

SONAR PARAMETER

1. Calculation	SV-H	SV-L
2. SL	219.5	215.3
3. ME	-194.9	-185.8
4. Absorption	92.7	9.9
5. 10 Log ψ	-16.1	-14.5
6. AMP Gain	50.1	49.0
7. Pulse Length	1.2	1.2
8. Sound Velocity		1500

SYSTEM PARAMETER

1. Threshold	-76.0		-76.0
2. Interval			0.1
3. VDC Range	-80	–	-30
4. Record Mode			DUAL
5. Position			SATNAV + DR
6. Speed			SATNAV + DR (Log)
7. Date, Time			MANUAL
8. Draft			4.5
9. Bottom	10.0	-25.0	0.5
10. Print Out			ENABLE

TRANSDUCER

CAL. K.P.	2
MODE	NORM
Tx. OUT	HIGH - D
	LOW - D

Calculation of Volume Back Scattering Strength (SV)

The volume back scattering strength (SV) of a fish school is obtained from the following equation;

$$SV = 20 \log V_{sv} - (SL + ME) + 20 \log r + (2\alpha r/1000) - 10 \log (c\tau/2) - 10 \log\psi$$

where SV : Volume Back scattering Strength, (dB)
V_{sv} : Voltage output (Vrms)
SL : Source Level, (dB)
ME : Receiving Sensitivity, (dB)
r : Range of target (m)
α : Absorption Coefficient (dB)
c : Underwater Sound speed (m/sec)
τ : Pulse duration (ms)
ψ : Equivalent beam width

The scientific echo sounder FQ-70 automatically calculated the mean volume back scattering strength (Sv_{avg}) in a particular layer width and log interval of the ship cruising. The calculation can be performed with pre-setting parameters by the following equation;

$$SV_{avg} = (S_{\Delta r}\, S_l\, sv_i)/\Delta r\ l$$

where Δr : Layer width
l : Log interval

During the survey cruise of M.V.SEAFDEC, the layer width and log interval were set at 10 m for the pelagic layer and 0.1 nautical mile, respectively. The fish density can be calculated as the following formula;

$$N = 10^{(SV-BSV)/10}$$

where N : Density of fish in the integrated layer (n/m^3)
BSV : Back scattering strength of a single fish per unit volume (=TS)

Averaging the Vertical SV Values

The average of SV of each transmission along the vertical layer of the log interval can be calculated using the following equation:

$$SV_{avg} = 10 \log \left(\frac{\Sigma(L_i \, 10^{(SVi/10)})}{\Sigma L_i} \right)$$

where SV_{avg} : SV value after averaging
SV_i : SV value of layer i
L_i : width of layer i

The calculation of SV was performed by averaging the SV from the 2nd layer which started at 10 m depth down to the bottom layer. The layer at which the sea bottom appeared was excluded from the calculation and substituted by SV values from the two layers of layer 9 and 10.

Averaging the SV Value in Sections of the Distance Run

The average of SV value in section of the distance run can be calculated using the following equation:

$$SV_{avg} = 10 \log \left(\frac{\Sigma \, 10^{(svi/10)}}{K} \right)$$

where SV_{avg} : SV value after averaging
SV_i : SV value of the layer Vi
K : Number of integrals per section of distance run

The integrated average SV from the FQ-70 were manually checked and the high SV value caused by the interference from the ship electronic equipment was eliminated.

Biomass estimation

Biomass is defined as the density of fish (Tones per square nautical mile) in the area surveyed, derived from the integrated echoes. The biomass estimation can be performed by using Algebraic Method (Johannesson and Mitson,1983). The basic principle is schematically illustrated in Fig. 2. Each sample observation (ai) is assigned to a corresponding rectangular area, here called "Elementary Statistical Sampling Rectangle" (ESSR). For a parallel survey grid with equidistant inter-transect spacing (Dt) (30 nautical mile) all ESSR's will have equal area sizes given by

$$ESSR = Dt \times (ESDU) \ \ mile^2$$

where ESDU is the selected "Elementary Sampling Distance Unit". When the inter-transect spacing equals one ESDU, it follows that the ESSR becomes a square of size $(ESDU)^2$. The abundance of biomass in each ESSR is obtained by multiplying the population density (N) in the ESSR to the mean weight of a single fish. The total biomass in the survey area is estimated from the biomass in each ESSR area.

The estimation of biomass was calculated by using the Algebraic Method estimating the mean SV of each Elementary Statistical Sampling Interval (ESSR) which covers area of 30x30 nautical miles. The population density (fish/m^2) was calculated by using the parameter of mean SV in each ESSR and fish target strength (TS). The average TS of fish was calculated by the equation (Miyanohana et al, 1987; Furusawa, 1990) as follows;

$$\textbf{TS} = \textbf{20 log l - 66} \quad \text{(dB)}$$

where l is fish length in cm.

Since, the maximum cath of pelagic species in the Gulf of Thailand is contributed by sardine with an annual catch ranging between 113,860 tons to 142,634 tons from 1991 to 1994 (SEAFDEC 1993, 1994, 1995, 1997), thus sardine was selected as the representative species for determining the TS of single fish for biomass estimation. The target strength (TS) of sardine (*Sadinella gibbosa*) with the first capture body length of 10 cm and weight of 10 gm (Somjaiwong, 1991) gives -46.0 dB which is used for the calculation. The abundance of biomass in each ESSR is obtained by multiplying the population density in the ESSR to the mean weight of sardine.

Result and Discussion

The hydro-acoustic survey for biomass estimation in the Gulf of Thailand and Peninsular Malaysia were carried out during pre-northeast monsoon and post-northeast monsoon season. The data recorded from the scientific echo sounder FQ-70 were analyzed by the author-edited computer programs. The volume back scattering strength (SV) of high frequency (200 kHz) and low frequency (50 kHz) were calculated from the surface layer at 10 m down to the bottom layer. The total running survey distance was 2489 nautical miles with a minimum water depth of 12 metres, where-as , the maximum depth is 80 metres, and the average depth is 53.2 metres. Fig.3 shows the echogram of a

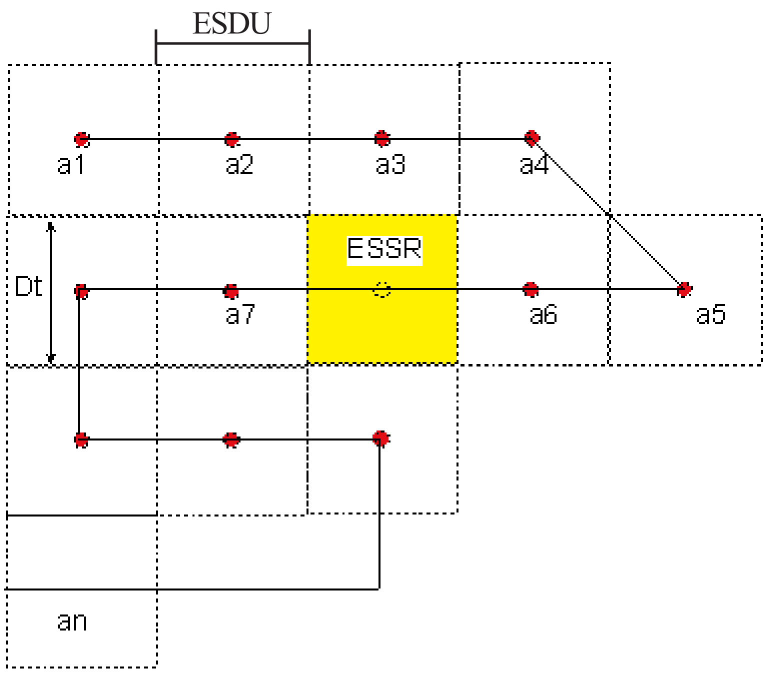


Fig. 2. Elementary statistical sampling interval (ESSR) along the cruise track when the inter-transect (Dt) equals one elementary sampling distance unit (ESDU). Tatal biomass estimation is the summation of all the abundance of the ESSR area.

fish school and plankton layer presented on the monitor of the display unit with upper screen and lower screen representing 50 kHz. and 200 kHz., respectively. The pelagic and demersal fish schools presented with the plankton layer are shown in Fig. 3 a) and b), respectively. The vertical migration of plankton layer from surface down to the bottom are shown in Fig. 3 c) to f). Fig.4 shows the echogram of pelagic and demersal fish schools detected by 200 kHz. and 50 kHz. The echogram also shows the vertical distribution curve (VDC) with the scale ranging from -80 dB to -30 dB. The VDC detected by 50 kHz. shows a high reverberation level from the surface to the bottom. Where-as VDC detected at 200 kHz. showing reduced values. The samples of average volume back scattering strength (SV) and density of fish (N) in each depth layer with integration for each 0.1 nautical mile of 200 kHz. and 50 kHz. are presented in Table 1.

The results of the pre-northeast monsoon survey showed that the average volume back scattering strength (SV) from station 1 to 33 (off shore Petchaburi to Songkhla Province, Thailand) were -61.2 dB for high frequency and -54.4 dB for low frequency. The average SV from station 34 to 66 (off shore Songkhla to Terengganu) were -62.9 dB for high frequency and -56.6 dB for low frequency. The average SV from station 67 to 80 (off shore Terengganu to Jahor) for high and low frequency were -66.4 and -57.3 dB, respectively (Fig.5). The SV difference between low and high frequency fluctuated from 0 to 30 dB. Thus showed that the low operating frequency (50 kHz) can detect plankton layers (Deep Scattering Layer) better than high frequency (200 kHz). The SV level showed high values in the area of the inner Gulf of Thailand, but decreasing southward to Peninsular Malaysia.

The observed SV level during the post-northeast monsoon season from station 1 to 33 were -63.1 dB for high frequency and -51.3 dB for low frequency. The average SV from station 34 to 66 were -69.0 dB for high frequency and -56.0 dB for low frequency. The average SV from station 67 to 79 for high and low frequency were -68.0 and -54.4 dB, respectively (Fig.6). The SV difference between low and high frequency fluctuated from 0 to 35 dB. The SV level shows the highest value in the upper Gulf of Thailand and the area between Terengganu to Jahor of Malaysia.

Fig.7 and Fig.8 showed the biomass distribution presented by means of the SV at each 0.1 nautical mile measured using 200 kHz during the pre-northeast monsoon and post-northeast monsoon seasons, respectively. The SV showed highest value for both seasons in the shallow water especially the upper Gulf of Thailand down to the coastal of the Southern part of Thailand with a water depth of not more than 40 m. Also, high SV values were observed in the coast area at the border between Thailand and Malaysia (Station 52,53,60 and 61) and also off the coast of Jahor in both seasons. The high SV present in the middle of the Gulf of Thailand during the pre-northeast monsoon season, showed a low level during post-northeast monsoon season.

Fig.9 and Fig.10 also show the biomass distribution presented by mean SV measured using 50 kHz during the pre- and post-northeast monsoon seasons, respectively. The SV measured using 50 kHz showed was higher levels than the SV measured by 200 kHz in both seasons. The highest concentration of SV was present in the upper Gulf of Thailand and along the coastal area of Peninsular Malaysia. The distribution of biomass (SV) measured using 50 kHz seemed not to be different between pre and post-northeast monsoon seasons.

The summary of biomass estimation by high and low frequency during the pre-northeast monsoon and post-northeast monsoon seasons are shown in Table 2 and 3, respectively. The total estimated biomass during the pre-northeast monsoon season measured by high and low frequencies were 2,754,773 tons and 13,136,860 tons, respectively. The maximum and minimum biomass measured by high frequency (200 kHz) were 390,906.80 tons at station No.47 and 1,688.03 tons at station No.34, respectively. The maximum and minimum biomass measured by low frequency (50 kHz) were 530,809.60 tons at station No.36 and 30,091.80 tons at station No.73.

The total estimated biomass during the post-northeast monsoon season measured by high and low frequencies were 1,323,154 tons and 20,942,590 tons, respectively. The maximum and minimum biomass measured by high frequency (200 kHz) were 170,998.50 tons at station No.18 and 416.30 tons at station No.34. The maximum and minimum biomass measured by low frequency (50 kHz)

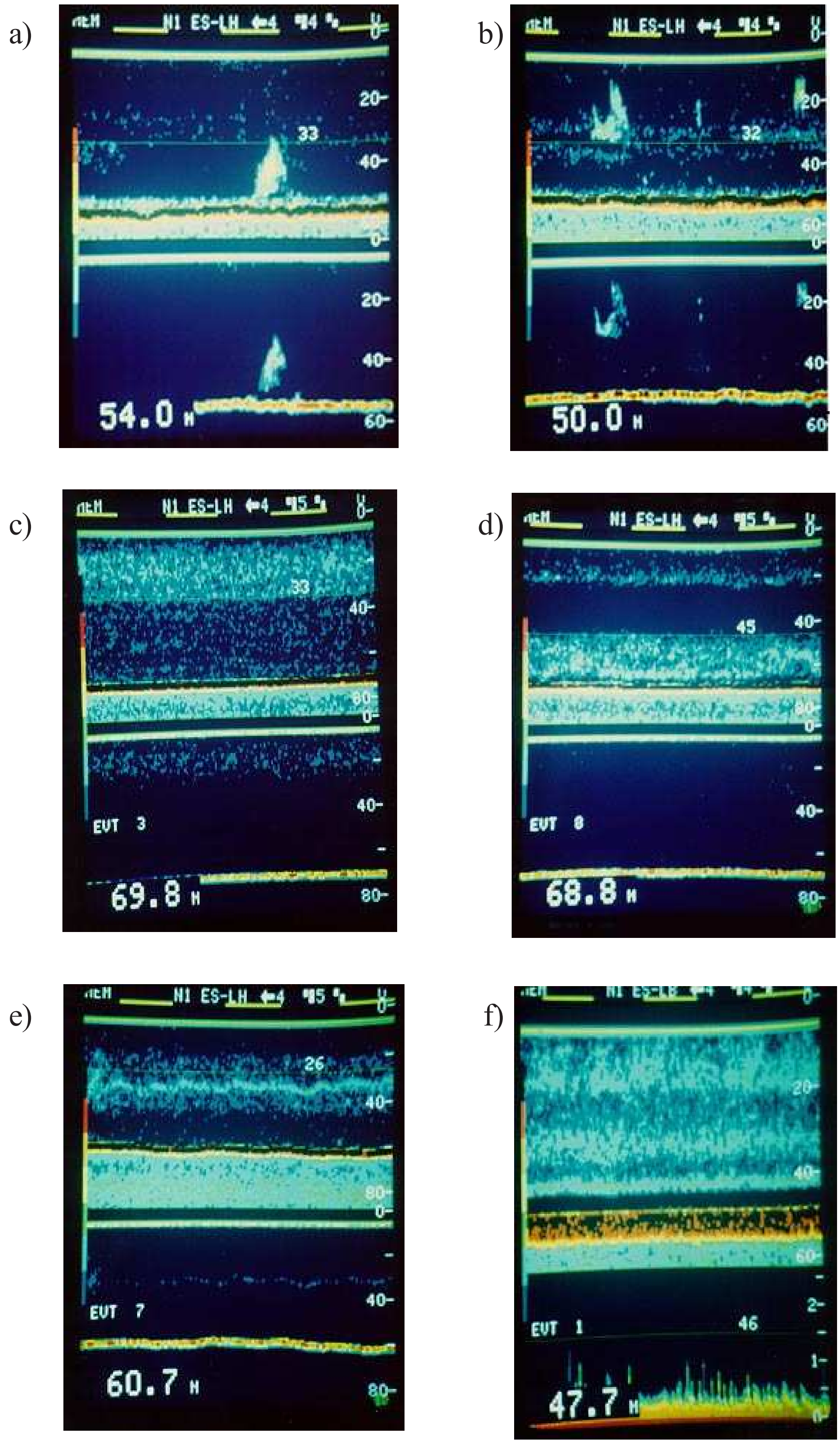


Fig. 3. The echogram of fish schools and plankton layers presented on the monitor of display unit with the upper screen and the lower screen present for 50 kHz. and 200 kHz., respectively. a) pelagic fish schools superimposed with plankton layers, b) demersal fish schools, c) plankton layers presented at the upper water layer in night time, d) plankton separated in to three layers, e) plankton layer concentrated on the mid water, and f) plankton layer present at bottom in the day time.

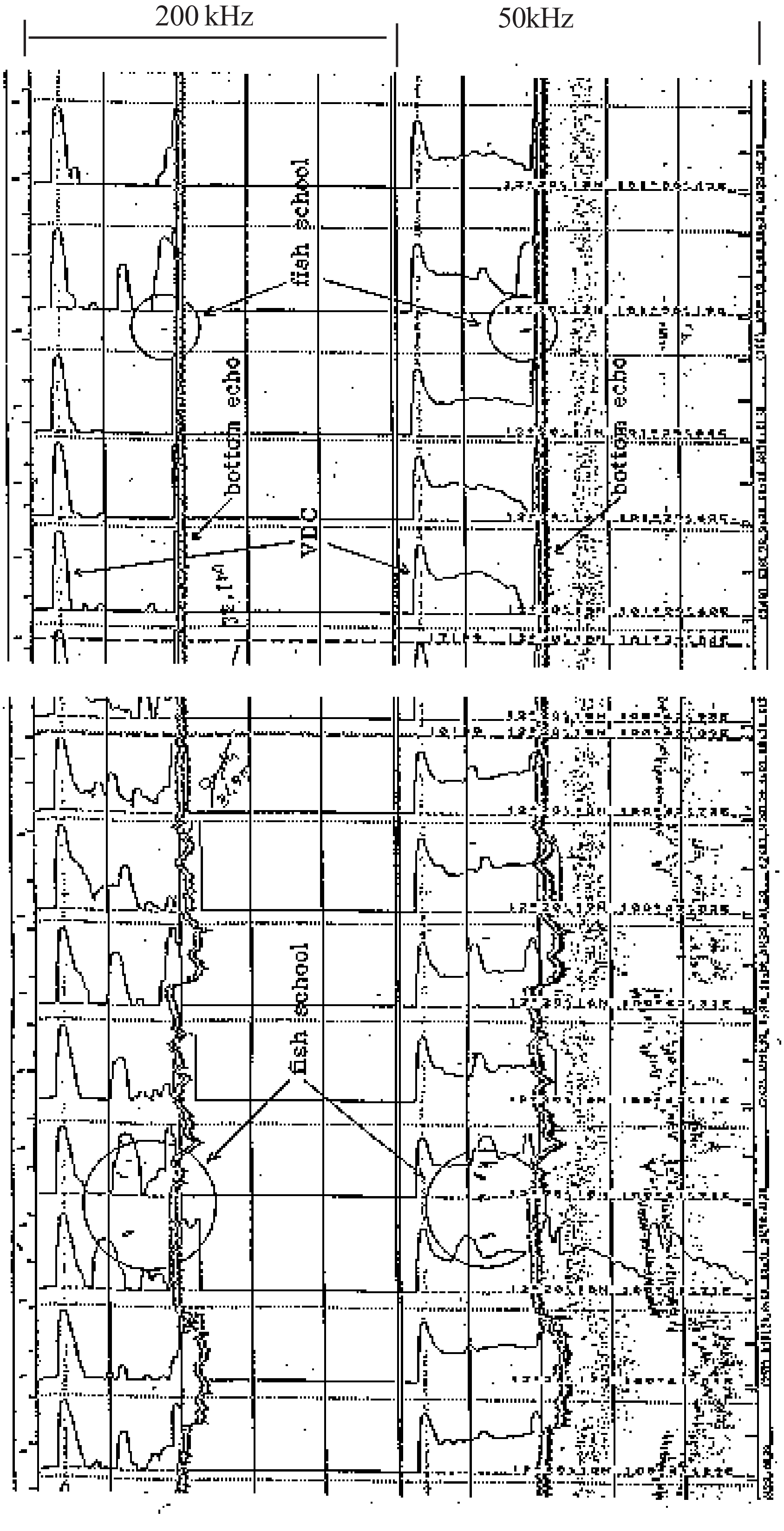


Fig. 4. The echogram of pelagic and demersal fish schools superimposed with Vertical Distribution Curve (VDC) detected by 50 kHz. and 200 kHz.

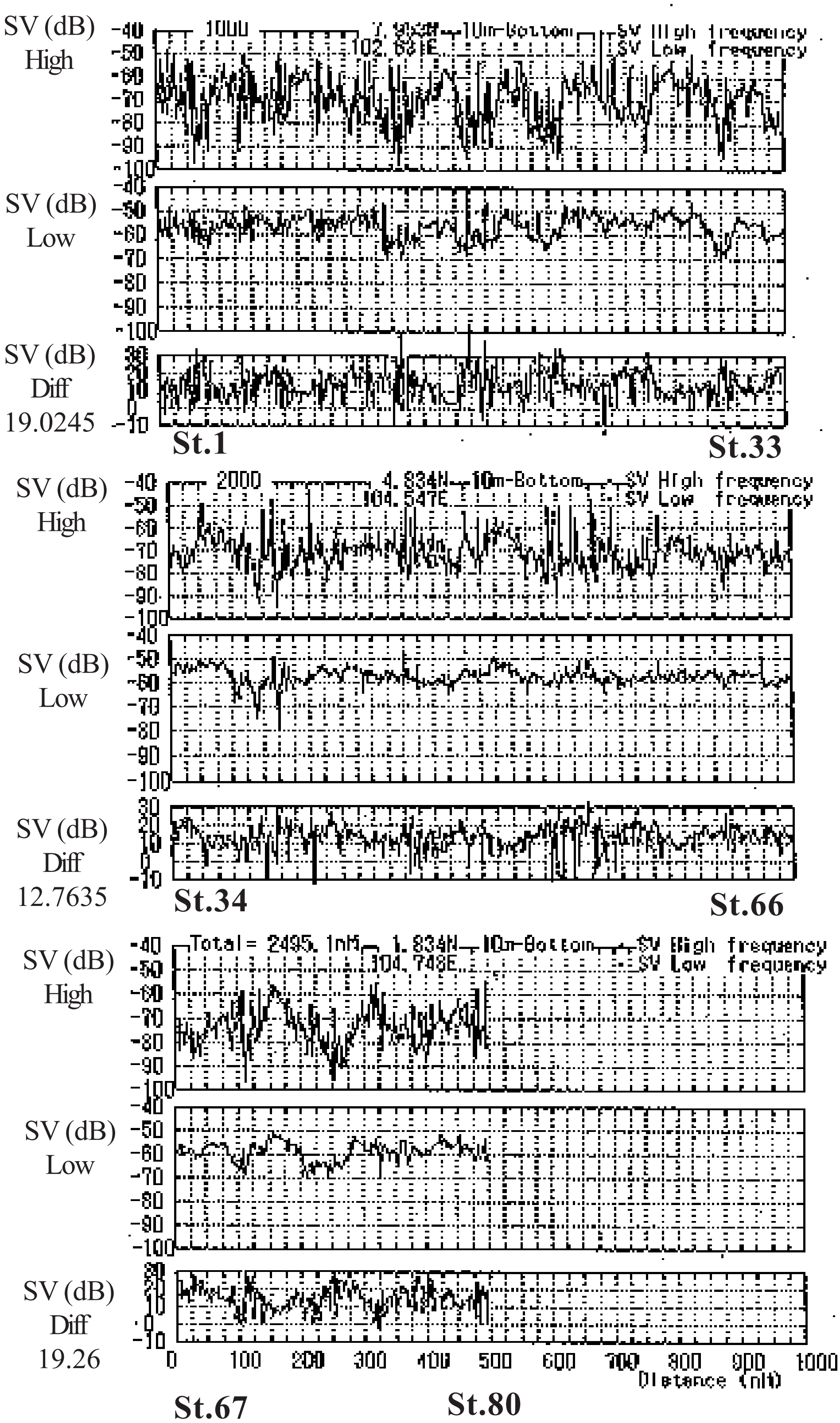


Fig. 5. The average volume back scattering strength (SV) measured by high (200 kHz.) and low (50kHz.) frequency during the pre-northeast monsoon season.

Table 1. The average volume back scattering strength (SV) and density of fish (N) in each layer with integrated for each 0.1 nautical mile for 200 kHz. and 50 kHz.

Layer		1	2	3	4	5	6	7	8	9	10
Upper		5	10	20	30	40	50	60	70	B10.0	B5.0
Lower		80	20	30	40	50	60	70	80	B 5.0	B1.0
Log (nm)	Time	Latitude		Longitude		Ship -spee	Current		Water Ten	Depth	B. LVL
0	11:37	1:50:07N		101:44.64E		9.5 268.	**.*	***.*	28.9	52	-19.9
(001) 0.1	11:38	1:50.07N		101:44.54E		9.5 273.(	**.*	***.*	28.9	52	-14.8
ATT = 30dB	SV	-50.5	-68.7	-67.7	-72.2	-70.9	-46.3	-99.9	-99.9	-70.5	-74.6
TH = 76dB	N	0.351	0.005	0.007	0.002	0.003	0.919	0	0	0.003	0.001
ATT = 30dB	SV	-51.3	-54	-54	-51.9	-49.9	-46.9	-99.9	-99.9	-49.3	-52.2
TH = 76dB	N	0.293	0.157	0.157	0.255	0.4	0.414	0	0	0.461	0.237
(002) 0.2	11:38	1:50.08N		101:44.44E		9.8 274.(	**.*	***.*	28.9	52	-7.2
ATT = 30dB	SV	-50.6	-69.2	-70.7	-74.2	-73.8	-46.4	-99.9	-99.9	-71.9	-77.7
TH = 76dB	N	0.341	0.005	0.003	0.001	0.002	0.912	0	0	0.002	0.001
ATT = 30dB	SV	-51.8	-54.7	-52.9	-51.81	-51.3	-47.7	-99.9	-99.9	-50.9	-52.5
TH = 76dB	N	0.263	0.135	0.201	0.258	0.293	0.671	0	0	0.32	0.223
(003) 0.3	11:39	1:50.09N		101:44.33E		9.9 275.(	**.*	***.*	28.9	52	-1.1
ATT = 30dB	SV	-50.2	-66.6	-70.5	-72.8	-72	-45.9	-99.9	-99.9	-72	-76.7
TH = 76dB	N	0.377	0.009	0.004	0.002	0.002	1.016	0	0	0.002	0.001
ATT = 30dB	SV	-51.9	-53.3	-51.7	51.5	-51.8	-49.3	-99.9	-99.9	-51.5	-53.2
TH = 76dB	N	0.252	0.184	0.264	0.279	0.26	0.467	0	0	0.281	0.188
(004) 0.4	11.39	1:50.10N		101:44.23E		9.8 275.(	**.*	***.*	28.9	52	-9.3
ATT = 30dB	SV	-50.2	-66.6	-71.2	-72.3	-66.9	-46.2	-99.9	-99.9	-68.5	-65.2
TH = 76dB	N	0.375	0.009	0.003	0.002	0.008	0.945	0	0	0.006	0.012
ATT = 30dB	SV	-50.2	-53	-52.8	-52.1	-49.9	-47.1	-99.9	-99.9	-50	-50.5
TH = 76dB	N	0.297	0.198	0.208	0.243	0.399	0.762	0	0	0.389	0.351
(005) 0.5	11:40	1:50.10N		101:44.14E		9.4 270.(	**.*	***.*	28.9	53	-14.6
ATT = 30dB	SV	-51.2	-66.2	-72	-72.9	-66.3	-46.5	-99.9	-99.9	-65.6	-66.1
TH = 76dB	N	0.301	0.009	0.002	0.002	0.009	0.871	0	0	0.011	0.01
ATT = 30dB	SV	-51.3	-53	-52.1	51.6	-49.7	-47.6	-99.9	-99.9	-49.7	-49.7
TH = 76dB	N	0.294	0.197	0.243	0.27	0.422	0.688	0	0	0.423	0.42
(006) 0.6	11:41	1:50.10N		101:44.04E		9.3 267.(	**.*	***.*	28.9	53	0.7
ATT = 30dB	SV	-51.1	-69.7	-73.2	-77.2	-73.7	-46.5	-99.9	-99.9	-71	-80.4
TH = 76dB	N	0.305	0.004	0.002	0.001	0.002	0.875	0	0	0.003	0
ATT = 30dB	SV	-52.7	-55.4	-53.7	-52.6	-53.6	-48.9	-99.9	-99.9	-53.7	-54.7
TH = 76dB	N	0.21	0.114	0.169	0.216	0.172	0.512	0	0	0.17	0.133

were 1,203,375.00 tons at station No.24 and 36,963.81 tons at station No.54.

The average weight of fish (biomass) measured by high and low frequency during the pre- and post-northeast monsoon season are presented in Fig. 11 and 12. The estimated biomass measured by high frequency show clearly that the high concentration of biomass was observed at the upper Gulf of Thailand and the boarder area between Thailand and Malaysia during the pre-and post-northeast monsoon seasons. However, the observation of biomass by low frequency did not show significant differences over the whole survey area during the pre- and post-northeast monsoon seasons.

The layers of plankton (Deep Scattering Layer) were observed over the survey area. Most of the plankton found during the survey were classified as Copepod and Tunicate. The echo sounder operating at 50 kHz seemed to be more effective at detecting the plankton layers than at 200 kHz. The

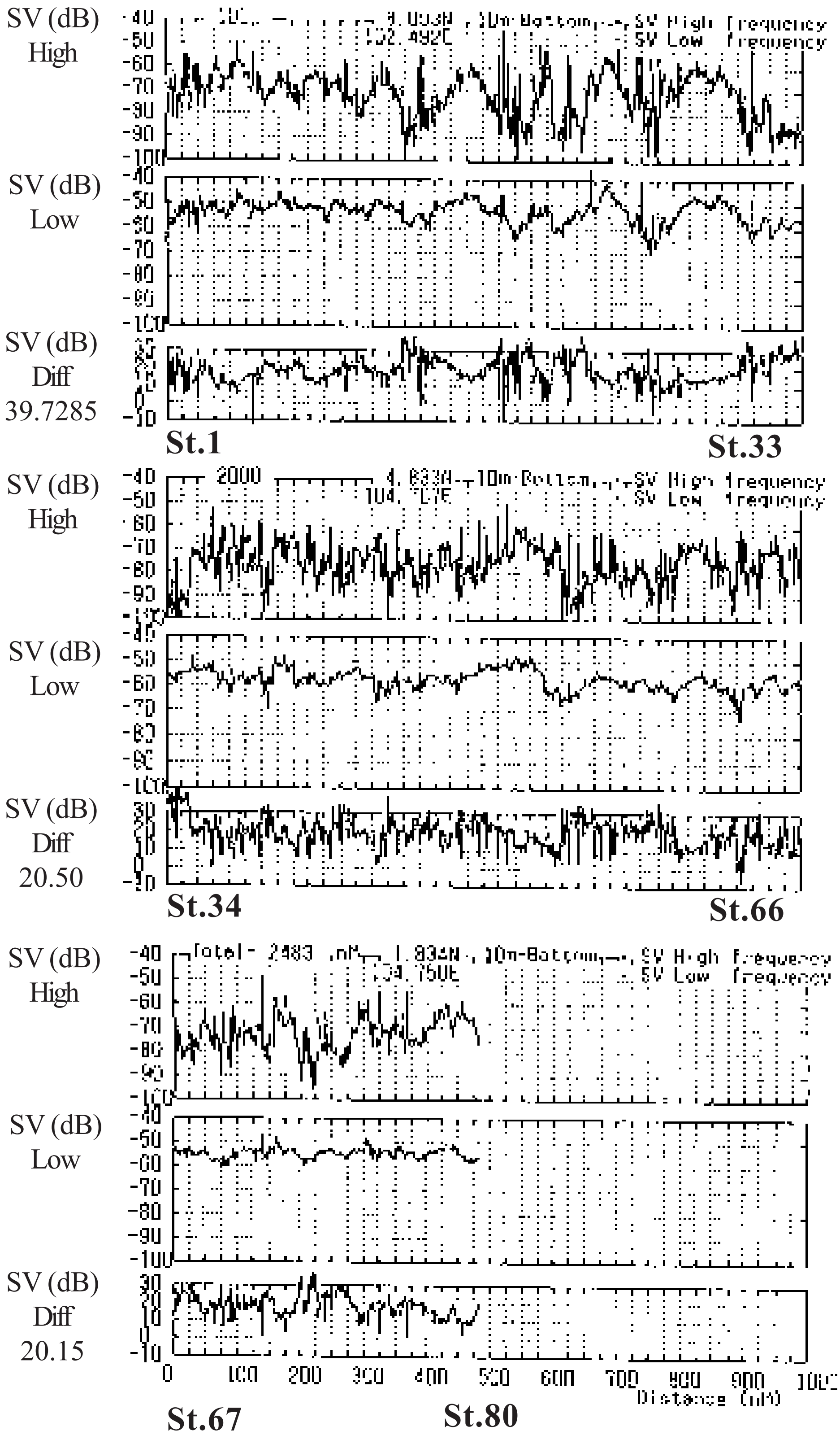


Fig. 6. The average volume back scattering strength (SV) measured by high (200 kHz.) and low (50 kHz.) frequency during the post-northeast season.

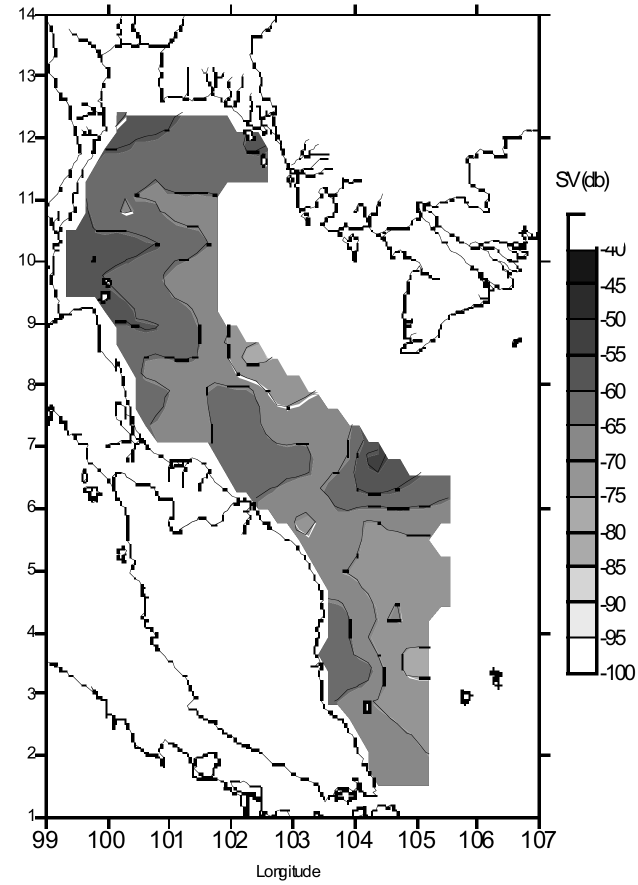


Fig.7. Distribution of volume back scattering strength (SV) of fish biomass measured using 200 kHz. during the pre-northeast monsoon season in the Gulf of Thailand and East Coast of Peninsular Malaysia.

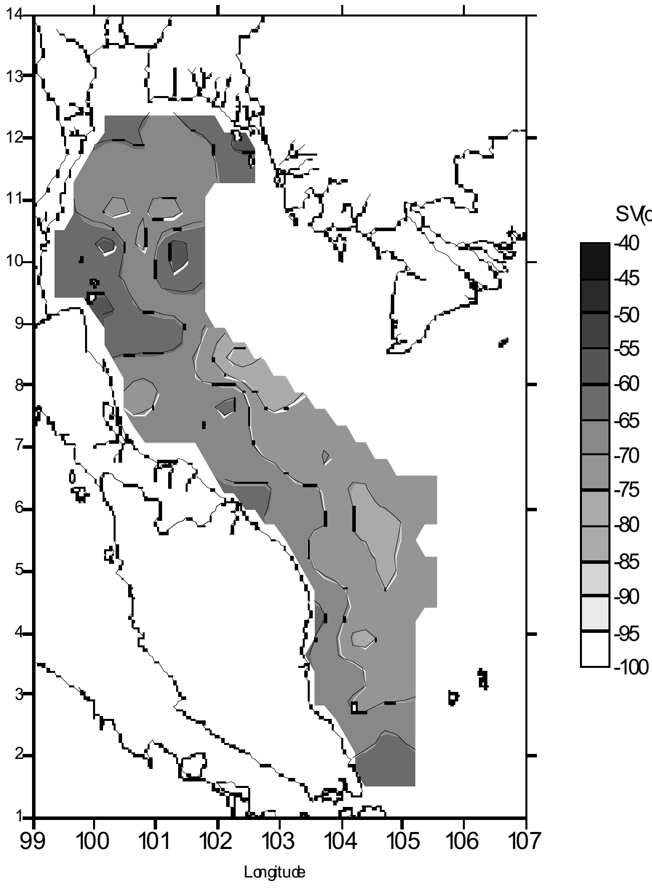


Fig.8. Distribution of volume back scattering strength (SV) of fish biomass measured using 200 kHz. during the post-northeast monsoon season in the Gulf of Thailand and East Coast of Peninsular Malaysia.

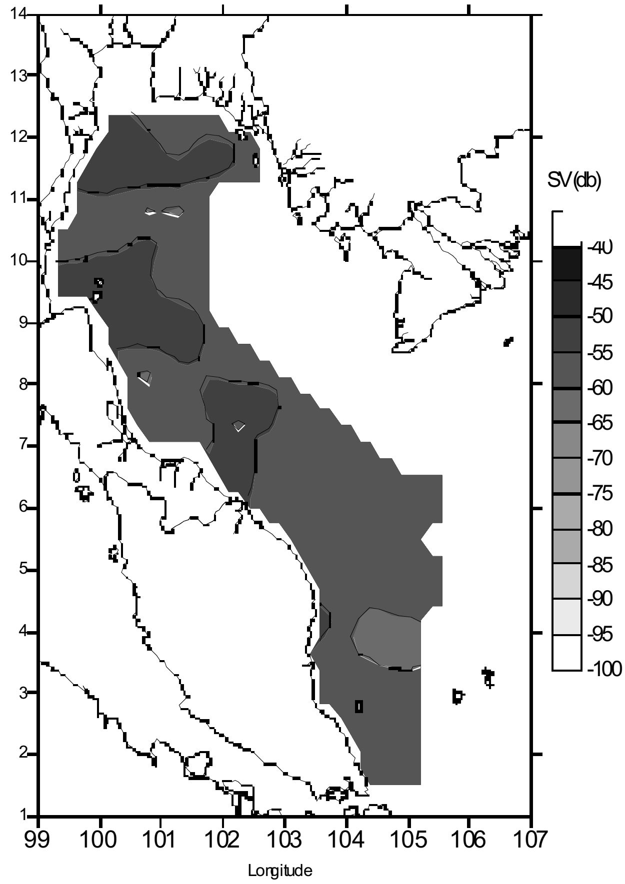


Fig.9. Distribution of volume back scattering strength (SV) of fish biomass measured using 50 kHz. during the pre-northeast monsoon season in the Gulf of Thailand and East Coast of Peninsular Malaysia.

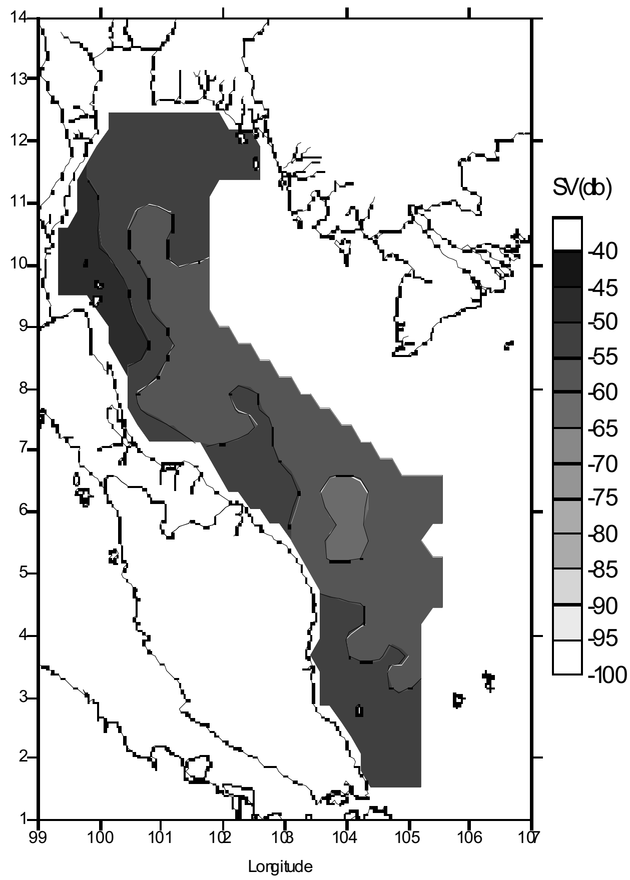


Fig.10. Distribution of volume back scattering strength (SV) of fish biomass measured using 50 kHz. during the post-northeast monsoon season in the Gulf of Thailand and East Coast of Peninsular Malaysia.

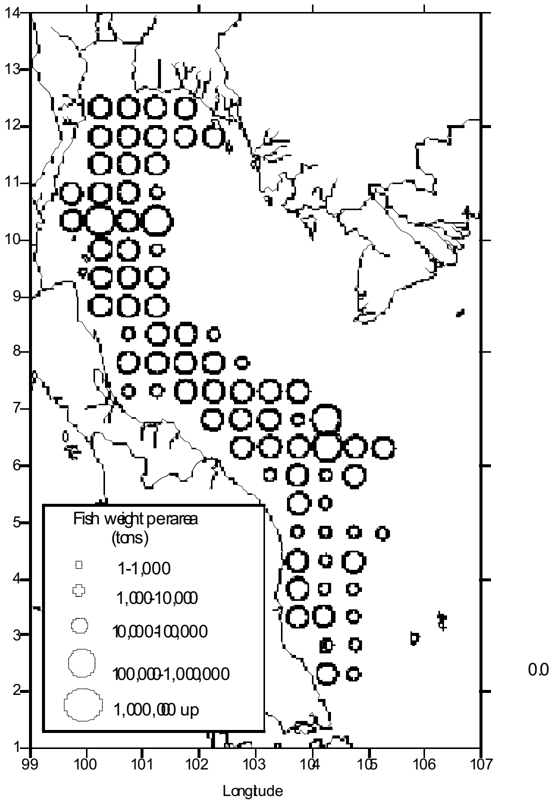
Table 2. Summary of biomass estimation by high frequency (200 kHz) and low frequency (50 kHz) during the pre-northeast monsoon season survey in the Gulf of Thailand and Peninsular Malaysia. The table shows the estimation for each station (ESSR) which covers an area of 30x30 nautical miles.

Station No.	Means SV High Freq.(dB)	Means SV Low Freq.(dB)	Depth (m)	Weight (High Freq. (tons)	Weight (Low Freq.) (tons)
1	-60.46	-54.36	27.6	15,236.63	62,066.29
2	-58.22	-55.54	29.6	54,722.12	101331.10
3	-60.32	-56.91	34.8	39,673.79	87,073.88
4	-61.61	-56.84	28.9	24,522.06	73,594.64
5	-59.24	-55.12	37.9	55,532.68	143436.20
6	-65.29	-53.45	52.8	19,197.32	293533.60
7	-62.31	-56.31	51.2	36,914.91	147219.50
8	-61.06	-53.40	45.2	43,583.01	254227.80
9	-59.63	-52.80	39.8	53263.00	257218.90
10	-62.74	-54.17	48.8	31,911.16	229387.60
11	-65.41	-52.89	54.7	19,347.94	345182.10
12	-60.21	-53.00	61.6	72,224.68	379760.80
13	-70.53	-61.25	63.0	6,853.92	58,079.12
14	-64.29	-60.88	57.9	26,510.85	58,096.43
15	-66.24	-55.59	50.1	14,652.28	170040.80
16	-59.70	-55.95	52.7	69,472.39	164522.30
17	-60.03	-56.75	53.4	65,186.63	138819.80
18	-56.46	-57.67	65.3	181368.40	137379.40
19	-59.27	-53.27	66.0	96,067.34	382230.40
20	-59.07	-55.54	69.2	105424.40	237375.30
21	-69.78	-60.13	61.9	7,998.53	73,823.52
22	-63.75	-54.07	48.6	25,185.12	234000.40
23	-61.70	-50.75	27.7	22,989.67	286114.20
24	-59.15	-52.31	40.1	59,920.43	289320.30
25	-62.36	-53.95	60.0	42,859.53	297073.00
26	-64.70	-54.13	59.3	24,709.64	281800.10
28	-62.17	-52.08	42.8	31,902.44	325698.60
29	-58.85	-51.49	28.9	46,343.92	252307.20
30	-60.82	-52.49	27.0	27,503.92	187039.50
31	-67.80	-61.06	42.1	8,585.28	40,529.33
32	-65.52	-55.05	64.4	22193.30	247176.30
33	-65.44	-55.54	75.5	26,496.29	258935.30
34	-77.45	-58.82	76.4	1,688.03	123240.80
35	-72.45	-54.23	74.3	5,197.14	344797.30
36	-59.49	-52.00	68.5	94,697.55	530809.60
37	-64.41	-53.68	50.6	22,493.49	265992.10
38	-65.78	-60.22	37.6	12,196.87	43893.70
39	-62.51	-59.39	25.2	17,409.31	35,687.95
40	-65.31	-58.01	27.0	9,755.48	52395.00
41	-69.61	-59.02	47.7	6419.40	73,455.61
42	-64.22	-55.30	49.3	22,939.33	178688.00
43	-63.35	-55.70	53.9	30,675.25	178505.10
44	-67.63	-54.73	55.4	11,756.64	229264.30
45	-65.50	-57.22	59.7	20,685.47	139285.50
46	-67.41	-57.46	53.8	12,017.42	118625.20
47	-52.88	-56.45	61.8	390906.80	171990.30
48	-70.12	-59.59	56.2	6,716.32	75,990.46
49	-63.91	-58.15	52.8	26,378.23	99,379.02
50	-63.47	-56.62	49.1	27167.90	131430.50
51	-61.10	-52.82	47.5	45,326.94	305186.20
52	-65.22	-55.85	49.2	18,151.65	156938.90
53	-65.95	-58.27	59.5	18,554.53	108784.20
54	-61.46	-59.14	67.4	59,120.89	100980.20
55	-57.00	-56.28	60.8	149182.50	176301.90
56	-60.12	-57.61	59.9	71,568.59	127590.50
57	-62.77	-58.23	60.5	39,301.99	111688.00
58	-67.66	-58.58	62.6	13,172.56	106763.10
59	-70.77	-57.71	63.6	6,554.84	132405.40
60	-65.83	-56.85	53.7	17,225.68	136363.60
61	-71.84	-57.44	54.8	4,408.46	121410.70
62	-67.09	-57.29	60.3	14,484.46	138232.20
63	-71.18	-56.70	63.1	5917.20	165846.00
64	-70.72	-58.26	64.1	6,678.94	117535.10
65	-70.75	-59.17	66.2	6,849.81	98,606.53
66	-75.71	-58.48	72.4	2,388.88	126162.40
67	-74.39	-57.24	75.5	3,374.92	175318.00
68	-67.81	-59.01	71.4	14,513.35	110269.20
69	-69.81	-59.78	60.4	7,759.72	78,080.86
70	-61.94	-54.13	39.2	30,854.85	186284.10
71	-62.44	-55.33	42.4	29,650.41	152684.90
72	-70.35	-62.76	62.7	7112.90	40,850.89
73	-75.13	-64.59	70.4	2,656.97	30091.80
74	-75.20	-59.20	64.9	2,407.31	95,985.61
75	-61.80	-55.49	42.7	34676.80	148244.70
76	-64.28	-57.49	32.0	14,642.07	69,995.52
77	-70.44	-58.00	52.7	5,853.05	102716.00
78	-72.10	-57.54	64.9	4,919.29	140561.90
79	-69.02	-55.10	50.0	7,703.25	189940.40
80	-66.07	-57.09	40.5	12,306.16	97,212.39
			Total =	2754773.00	13136860.00

Table 3. Summary of biomass estimation by high frequency (200 kHz) and low frequency (50 kHz) during the post-northeast monsoon season survey in the Gulf of Thailand and Peninsular Malaysia The table shows the estimation for each station (ESSR) which covers an area of 30x30 nautical miles.

Station No.	Means SV High Freq.(dB)	Means SV Low Freq.(dB)	Depth (m)	Weight (High Freq.) (tons)	Weight (Low Freq.) (tons)
1	-62.18	-55.04	27.9	10,372.43	53,750.02
2	-64.99	-52.96	29.0	11301.60	180290.10
3	-65.96	-52.27	30.3	9429.00	220841.80
4	-61.27	-52.11	32.0	29,371.95	242177.90
5	-59.36	-50.04	37.8	53,879.44	460022.60
6	-68.67	-51.22	52.3	8,735.19	484613.30
7	-67.12	-49.93	50.6	12,051.58	631487.90
8	-64.75	-51.65	41.9	17,227.55	352213.70
9	-66.24	-51.97	39.2	11,437.34	305529.70
10	-66.76	-50.87	48.3	12517.00	485338.00
11	-68.63	-52.83	52.7	8,886.23	337965.50
12	-65.11	-50.03	60.1	22,745.33	733071.10
13	-73.99	-54.85	64.3	3,155.24	258745.20
14	-69.24	-52.10	59.5	8,709.68	179429.80
15	-72.51	-51.47	54.0	3,723.48	473511.80
16	-64.82	-48.36	50.2	20,343.99	901040.10
17	-63.28	-48.58	49.5	28,567.79	843304.90
18	-56.43	-52.10	61.1	170998.50	462840.80
19	-72.80	-59.38	62.9	4059.20	89,113.78
20	-57.83	-53.05	71.1	143897.50	433242.90
21	-58.72	-55.20	67.3	111144.00	249723.90
22	-69.95	-54.74	58.3	7,247.77	240435.50
23	-63.52	-48.54	35.1	19,185.65	604238.80
24	-58.49	-45.23	32.7	56,769.93	1203375.00
25	-66.52	-54.67	49.0	13,413.05	205520.50
26	-68.17	-61.41	61.0	11,426.26	54,231.18
28	-60.19	-55.36	53.1	62,440.61	189887.80
29	-62.31	-48.73	32.5	23,487.23	535287.40
30	-62.59	-48.18	26.0	17,569.38	484492.30
31	-66.74	-50.43	33.8	8,795.62	376399.00
32	-69.29	-58.01	54.8	7,921.09	106331.90
33	-71.68	-57.05	71.6	5,982.68	173656.70
34	-83.53	-56.90	76.3	416.30	191674.20
35	-78.51	-55.52	74.4	1,288.47	256657.20
36	-61.56	-53.52	71.5	61,364.93	390406.50
37	-67.83	-56.78	54.8	11,106.37	141190.70
38	-67.87	-57.53	44.3	8,889.92	96,010.47
39	-73.27	-57.34	25.7	1,485.27	58,306.16
40	-67.98	-52.36	22.7	4,451.81	162326.90
41	-66.48	-54.95	41.5	11,485.83	163123.60
42	-64.82	-57.09	48.6	19,674.83	116689.30
43	-67.75	-56.64	51.2	10,572.92	136483.60
44	-72.53	-54.37	54.1	3,720.13	243323.50
45	-71.24	-58.57	56.9	5,253.67	97171.30
46	-70.88	-58.90	56.6	5,682.91	89,502.18
47	-71.68	-58.33	58.4	4,867.88	105297.30
48	-69.55	-56.66	58.1	7,925.98	153978.60
49	-73.6	-57.55	54.1	2,899.22	117009.70
50	-70.01	-54.19	51.2	6273.10	239406.60
51	-67.18	-51.70	48.6	11,455.98	403855.30
52	-63.43	-50.25	44.5	24,845.85	516491.10
53	-69.23	-54.95	52.8	7,748.62	207446.90
54	-70.20	-63.16	62.3	7,303.96	36,963.81
55	-76.75	-60.72	66.0	1,713.68	68,767.15
56	-71.01	-56.18	60.2	5,859.37	178237.20
57	-71.89	-57.99	58.9	4,684.93	114950.30
58	-76.45	-58.45	61.3	1704.70	107653.30
59	-75.77	-60.01	66.0	2,149.41	80,958.34
60	-69.26	-59.37	58.5	8,532.68	83,205.41
61	-68.91	-56.39	51.8	8171.80	146012.20
62	-73.29	-61.29	57.7	3,324.69	52784.70
63	-73.84	-60.58	62.7	3,183.19	67,516.83
64	-69.74	-56.51	62.0	8,085.02	170404.30
65	-71.05	-57.35	67.6	6,518.27	152811.80
66	-76.55	-54.95	73.0	1,985.25	287117.60
67	-70.44	-56.03	74.2	8,244.57	227517.00
68	-72.33	-57.48	68.4	4,909.69	150048.30
69	-71.50	-54.07	51.3	4,463.47	246813.40
70	-63.63	-53.06	36.7	19,566.68	223103.60
71	-66.59	-53.62	48.6	13,102.01	259779.30
72	-77.95	-57.17	68.1	1,342.68	160504.30
73	-74.24	-54.39	68.5	3173.90	306568.00
74	-74.76	-55.28	58.8	2,416.83	214199.40
75	-65.63	-52.92	32.6	10,977.21	204480.40
76	-65.98	-54.65	37.5	11,652.78	158066.00
77	-71.87	-54.43	58.6	4,683.73	259660.10
78	-69.63	-54.86	62.7	8,385.77	252029.40
79	-64.12	-52.18	39.5	18,814.61	293975.50
			Total =	1323154.00	20942590.00

a)



b)

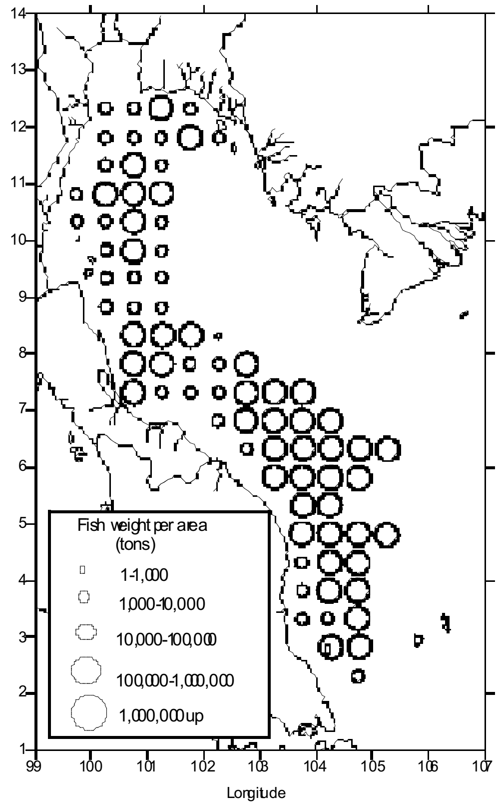
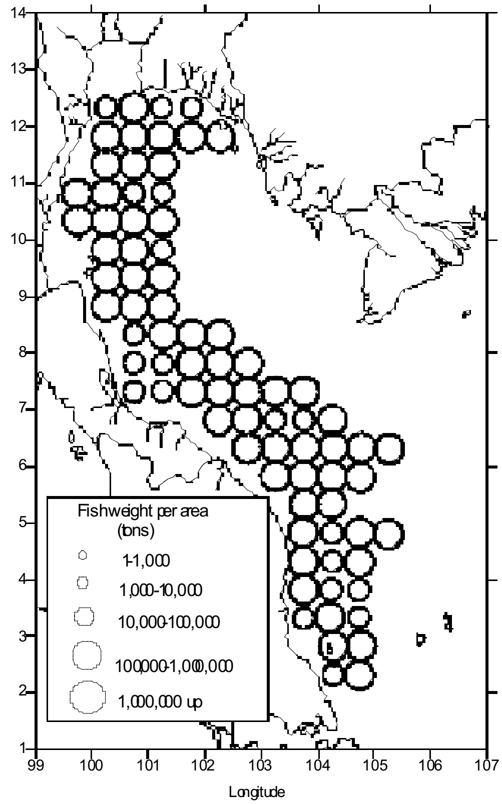


Fig.11. An average weight of fish (tons/900nm^2) in the Gulf of Thailand and East Coast of Peninsular Malaysia observed by 200 kHz. during a) pre-northeast and b) post-northeast monsoon season.

a)



b)

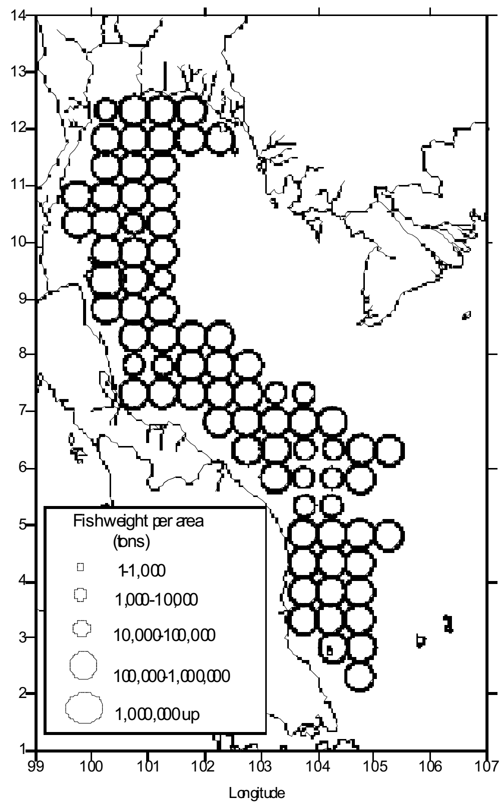


Fig.12. An average weight of fish (tons/900nm^2) in the Gulf of Thailand and East Coast of Peninsular Malaysia observed by 50 kHz. during a) pre-northeast and b) post-northeast monsoon season.

biomass estimation of fish schools using a frequency of 50 kHz seem to suffer more interference from the echo signal from the plankton layers. The biomass estimation results by low frequency showed the same amount during both seasons may be caused by the plankton layers present all year round.

The estimation by using a frequency of which 200 kHz seemed to be more effective at detecting the fish schools and less sensitive to plankton layers. The biomass estimation by high frequency can represent a better result than low frequency for this area. However, this estimation of fish biomass is the combination of the biomass of fish schools themselve as well as the biomass of high density plankton layers. The elimination of echo signal, from plankton layers can be achieved by increasing the threshold level, but it could also eliminate the echos from fish schools at the same time. Then, to eliminate the interference of plankton layers from the estimation, special equipment and techniques are required to separate the echo signal of fish schools from the plankton layers. The pure echo signal from fish schools will result in a better solution for fish school biomass estimation.

Acknowledgements

The author would like to extend the thank to Secretary General of SEAFDEC, Dr. Maitree Duangsawasdi, for his kind advice and subport for this survey. Thank are also due to Captain of M.V.SEAFDEC and his crews for their kind co-operation during the collaborative survey.

References

Cushing, D.H. 1973 .The detection of fish, Pergamon press, New York.,:200 p.

Department of Fisheries 1979. Report of Acoustic survey in the Gulf of Thailand; June - October 1997. Exploratory Fishing Division, Thailand.

Furusawa, M. 1990. Study on echo sounding for estimating fisheries resources. Bull. National Research Institute of Fisheries Engineering; 11,173-249.

Johnnesson, K.A. and Mitson, R.B. 1983. Fisheries acoustic: A practical manual for aquatic biomass estimation. FAO Fish. Tech. Rep., (240):249 p.

Love, R.H. 1977. Target strength of and individual fish at any aspect. J. Acoust. Soc. Am., 62(6) 1397-1403.

Miyanohana, Y. K. Ishii, and M. Furusawa, 1987. Measurements and analyses on dorsal-aspect target strength of six species of fish at four frequencies. Int. Symp. Fish. Acoust. Seattle, paper No. 93.

Operator’s manual; Scientific Sounder model FQ-70. Furuno Electric Co.Ltd., Japan

SEAFDEC. 1993, Fishery Statistical Bulletin for the South China Sea Area 1991. SEAFDEC, Thailand. 163 p.

SEAFDEC. 1994, Fishery Statistical Bulletin for the South China Sea Area 1992. SEAFDEC, Thailand. 159 p.

SEAFDEC. 1995, Fishery Statistical Bulletin for the South China Sea Area 1993. SEAFDEC, Thailand. 159 p.

SEAFDEC. 1997, Fishery Statistical Bulletin for the South China Sea Area 1994. SEAFDEC, Thailand. 159 p.

Somjaiwong, Damri. 1991, Population dynamics of Sardine Sardinella gibbosa (Bleeker, 1849) in the Gulf of Thailand. Marine Fisheries Division, Department of Fisheries, Thailand.

Appendix

Table I Source level (SL) for low frequency (50 kHz).

Power Selection	SL	Vtx	Vmic	MES	SE
A (100 dB)	100.0 dB				
B (190-210 dB)	196.3 dB	180 Vpp	0.40 Vpp	-126.5 dB	161.6 dB
C (200-220 dB)	205.8 dB	540 Vpp	1.04 Vpp	-216.5 dB	160.4 dB
D (210-230 dB)	215.3 dB	1600 Vpp	2.50 Vpp	-216.5 dB	158.6 dB

Average SE (160 to 180 dB) = 160.2 dB

Table II Receiving sensitivity (ME) for low frequency (50 kHz.).

Vmic	ATT	Vpre	Gain	SES	ME
1 Vpp	0 dB	0.22 Vpp	49.6 dB	121.3 dB	-185.9 dB
1 Vpp	10 dB	0.07 Vpp	39.6 dB	121.3 dB	-185.8 dB
3 Vpp	0 dB	0.66 Vpp	49.6 dB	121.3 dB	-185.7 dB
3 Vpp	10 dB	0.21 Vpp	39.6 dB	121.3 dB	-185.8 dB
10 Vpp	10 dB	0.70 Vpp	39.6 dB	121.3 dB	-185.8 dB
10 Vpp	20 dB	0.23 Vpp	29.9 dB	121.3 dB	-185.8 dB

Average ME (-175 to -195 dB) = MEA - 185.8 dB

Table III Source level (SL) for high frequency (200 kHz).

Power Selection	SL	Vtx	Vmic	MES	SE
A (100 dB)	100.0 dB				
B (190-210 dB)	201.6 dB	170 Vpp	0.68 Vpp	-213.7 dB	165.7 dB
C (200-220 dB)	210.4 dB	470 Vpp	2.00 Vpp	-213.7 dB	166.3 dB
D (210-230 dB)	219.5 dB	1340 Vpp	5.60 Vpp	-213.7 dB	166.1 dB

Average SE (160 to 180 dB) = 166.0 dB

Table IV Receiving sensitivity (ME) for high frequency (200 kHz).

Vmic	ATT	Vpre	Gain	SES	ME
1 Vpp	0 dB	1.08 Vpp	50 dB	145.3 dB	-194.6 dB
1 Vpp	10 dB	0.34 Vpp	40 dB	145.3 dB	-194.7 dB
3 Vpp	0 dB	3.10 Vpp	50 dB	145.3 dB	-195.0 dB
3 Vpp	10 dB	0.94 Vpp	40 dB	145.3 dB	-195.4 dB
10 Vpp	10 dB	3.40 Vpp	40 dB	145.3 dB	-194.7 dB
10 Vpp	20 dB	1.02 Vpp	30 dB	145.3 dB	-195.1 dB

Average ME (-175 to -195 dB) = MEA - 194.9 dB