REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

Proceedings of the First ASEAMS Symposium on Southeast Asian Marine Science and Environmental Protection

UNEP Regional Seas Reports and Studies No. 116

Prepared in co-operation with

ASEAMS Association of Southeast Asian Marine Scientists

UNEP 1990

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PREFACE

The United Nations Conference on the Human Environment (Stockholm, 5-16 June 1972) adopted the Action Plan for the Human Environment, including the General Principles for Assessment and Control of Marine Pollution. In the light of the results of the Stockholm Conference, the United Nations General Assembly decided to establish the United Nations Environment Programme (UNEP) to "serve as a focal point for environmental action and co-ordination within the United Nations system" [General Assembly resolution (XXVII) of 15 December 1972]. The organizations of the United Nations system were invited "to adopt the measures that may be required to undertake concerted and co-ordinated programmes with regard to international environmental problems", and the "intergovernmental and non-governmental organizations that have an interest in the field of the environment" were also invited "to lend their full support and collaboration to the United Nations with a view to achieving the largest possible degree of co-operation and co-ordination". Subsequently, the Governing Council of UNEP chose "Oceans" as one of the priority areas in which it would focus efforts to fulfil its catalytic and co-ordinating role.

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes ten regions 1/ and has about 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental problems and addresses them through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned.

The development of the East Asian Seas action plan was initiated by the decision of the fifth session of the Governing Council of UNEP [UNEP/GC/106, annex I, Decision 88(v), section D] in 1977, at the request of the Governments of the East Asian Seas Region.

The action plan for the East Asian Seas region was adopted by the representatives of Indonesia, Malaysia, Philippines, Singapore and Thailand, at the Intergovernmental Meeting on the Protection and Development of the Marine Environment and Coastal Areas of the East Asian Region (Manila, 27-29 April 1981). The "development and protection of the marine environment and the coastal areas for the promotion of the health and well-being of present and future generations" was adopted as the principal objective of the action plan.

Within the Action Plan, the Governments have approved a number of projects and assigned priority to some of them. UNEP has provided technical backstopping and support for the implementation of these projects, in co-operation with a number of national institutions and specialized agencies. In this context, the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of UNEP closely co-operated with the Association of Southeast Asian Marine Scientists (ASEAMS) in planning and convening the first Scientific Symposium of the Association with the title "Southeast Asian Marine Science and Environmental Protection" (Quezon City, The Philippines, 7 February 1989).

1/ Mediterranean Region, Kuwait Action Plan Region, West and Central African Region, Wider Caribbean Region, East Asian Seas Region, South-East Pacific Region, South Pacific Region, Red Sea and Gulf of Aden Region, Eastern African Region and South Asian Seas Region.

The Symposium brought together a number of marine scientists and other professionals from Southeast Asia, and provided an excellent opportunity for the exchange of information and experience between experts working in fields related to marine science and protection of the marine environment.

The present report is a compilation of sixteen (16) scientific papers that were presented at the Symposium, and were made available to ASEAMS and UNEP for publication.

EDITOR'S PREFACE

The Association of Southeast Asian Marine Scientists (ASEAMS) was formally established on 6 February 1989 at the first General Assembly of its founding members who numbered about one-hundred and twenty (120). On the following day, the first scientific symposium of the Association was held with the title "SOUTHEAST ASIAN MARINE SCIENCE AND ENVIRONMENTAL PROTECTION." It was held in conjunction with the Third Meeting of Experts on the East Asian Seas Action Plan. All the above activities were sponsored by the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP) within the framework of its Regional Seas Programme. They were held in Quezon City, the Philippines, with organizational support provided by the Marine Science Institute of the University of the Philippines.

The formation of ASEAMS may be said to have been catalyzed by the very vigorous efforts of UNEP in the East Asian Seas region for the protection and conservation of its marine and coastal environment. Because of a shared political, social and cultural heritage, and the use of a common resource (the regional seas), marine scientists and other professionals from Southeast Asia acknowledged the need for a more unified and concerted effort to achieve common goals. The framework for interaction was already established by UNEP's East Asian Seas Action Plan which was implemented since 1981 under the authority of the Governments of the region, represented by the Co-ordinating Body on the Seas of East Asia (COBSEA). Specifically, concrete recommendations for the formation of an Association of marine scientists and other professionals from Southeast Asia were made at the UNEP-sponsored First Meeting of Experts on the East Asian Seas Action Plan held in Bangkok, Thailand, 8-12 December 1986.

Many of the scientific papers presented at the first ASEAMS symposium embody results of studies carried out under the various projects comprising the East Asian Seas Action Plan. Others draw on related activities in the region which have been funded from sources other than UNEP. Altogether, they present a picture of the marine environmental concerns facing Southeast Asia at present. They also provide an introduction to the types of research and other activities being undertaken in the effort to understand and then, hopefully, solve such problems.

The present volume is a compilation of sixteen (16) scientific papers that were presented at the Symposium. Abstracts of two papers which were presented but were not submitted for publication are also included. They represent the fields of meteorology, physical oceanography, pollution, coastal ecosystem research, management, and legislation.

For the preparation of the Proceedings, the substantial support of Mr. Edgardo D. Gomez, ASEAMS Chairman, and Ms. Evangeline F.B. Miclat is gratefully acknowledged. The following Research Assistants of the Marine Science Institute, University of the Philippines also rendered invaluable service: Ms. Marivic Pajaro, Ms. Hildie Maria Nacorda and Mr. Augustus Rex Montebon.

HELEN T. YAP
Editor

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PRECIPITATION AND PRESSURE DISTRIBUTION OVER THE SOUTH CHINA SEA AND ADJACENT AREAS

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ABSTRACT

Rainfall estimates over the South China Sea region are obtained using the Tucker's method which makes use of the element ww of the weather group contained in the ship surface observations. The rainfall and pressure data in the region are then subjected to harmonic analysis to obtain the annual and semi-annual vectors.

The results show that the estimated oceanic rainfall is generally lower than that measured from nearby land stations except where the land stations are sheltered from the northeast monsoon winds. Southeast and East Asia generally experience maximum pressure during the winter months. Large amplitudes of annual cycles of pressure are to be found over eastern China and small amplitudes in the equatorial region. There is no oceanic type of annual pressure variation over the Southeast and East Asian regions. More rainfall is experienced over the central and northern South China Sea during the summer and autumn months. High pressure over eastern China in winter is associated with more rainfall over the southern half of the South China Sea during the same period.

1. INTRODUCTION

This paper involves the study of two meteorological elements, precipitation and pressure. Each element will be discussed accordingly.

1.1 Precipitation

Studies on precipitation over the oceans have generated great interest because of the effect the precipitation-evaporation relationship has on the salinity of the oceans, the release of latent heat into the atmosphere which in turn provides the driving force in atmospheric circulation and convection, the seasonal march of the monsoonal rainfall, and the movements of the tropical storms.

Measurement of precipitation by convectional rain gauges on board ships has been conducted before and the World Meteorological Organization (WMO) Report No. 1 (Olbruck, undated) has noted four major sources of errors. These are the disturbing effects of the ship itself on the airflow, the air turbulence created by the gauges, the motion of the gauges due to the ship's acceleration, and the effect of sea spray and drippings from the ship's structures. Methods have been suggested to minimize these errors and they include the modification of the shapes and sizes of the rain gauges to reduce the effects of wind flow, and the strategic installation of the rain gauges to avoid sea spray and drippings. An experiment conducted by the Automated Shipboard Aerological Program (ASAP) in 1983/84 showed that the amount of rainfall collected by the rain gauges was strongly dependent on the positions of the rain gauges on the upper deck of the ship and also on the relative wind speed and direction.

Direct measurement of rainfall over the ocean is difficult due to various obvious reasons. Estimation of precipitation over the oceans has been attempted using different methods. Extrapolation seawards of rainfall amount derived from coastal and island stations has been done but this method did not take into consideration oceanic observations although a reduction factor was applied (Korzum 1974, Baumgartner and Reichel 1975). These methods were, however, found to be unsatisfactory.

Precipitation over the oceans has now been estimated using satellite technology. In one of the techniques, the visual satellite cloud picture brightness was extracted and correlated with the rainfall measured from the coral islands in the ocean (Kilonsky and Ramage 1976). Another rainfall estimation technique was the Bristol method (Barrett 1971) which evaluates a cloud index from the satellite-image cloud field to homogenize rainfall mapping for a period of time and for a large region. Infra-red cloud pictures have also been used to evaluate precipitation. Yet another method involves using the selective response of the satellite microwave radiometer to water in the atmosphere to estimate rainfall (Rao and Theon 1977). This method has shown great potential for worldwide estimates of precipitation over the oceans.

Estimation of precipitation could also be done by using the present weather group codes ww of ships' weather reports. This method was developed by Tucker (1961) who used measured rainfall data from British meteorological stations and correlated them with the present weather group reported in the synoptic weather observations from these stations. A number was then assigned to each present weather group which corresponded to the precipitation amount that would occur in a 3 hour period. These relationships were then applied to the ships' present weather group (Codes 50-99) to estimate the rainfall amount over the ocean areas. The method devised by Tucker underestimated rainfall amount with increasing temperature. Dorman and Bourke (1978) improved on it by using a temperature correction factor. In this study, additional computations based on the rainfall data were made for the first and second harmonics of annual precipitation cycles.

1.2 Pressure

Results of earlier works by Hann and Suring (1939) on the annual march of surface pressure show the following significant pressure characteristics:

(i) the equatorial type - the annual variations of surface pressure in the equatorial regions are very small;

(ii) the continental type - in the higher latitudes maximum pressure occurs in winter and minimum pressure occurs in summer;

(iii) the oceanic type - in the higher latitudes, maximum pressure occurs in summer and minimum pressure in late autumn; and

(iv) the arctic and subarctic type - maximum pressure is in April or May and minimum pressure in January and February with a second maximum in November.

Wahl (1942) and Hsu and Wallace (1976) have also applied harmonic analysis to the study of the annual and semi-annual cycles of surface pressure.

The aim of this study is to provide information on the annual and semi-annual cycles of surface pressure and precipitation over the Southeast and East Asian regions using vectors.

2. DATA

Ships that participated in the WMO Voluntary Observing Ships' Schemes have been routinely reporting the present weather group codes ww and pressure in their weather observations. The ww codes consist of 100 code figures (00-99) which would cover all the occurable weather phenomena. In this study only the code figures, ww 50-99, of 3 hour ship observations have been taken into consideration for computation (Tucker 1961). The code figures 20-29 were not used as they did not give any distinction between slight, moderate and heavy precipitation, and also because the amount computed which included these code figures was not significantly different from the result obtained using only the code figures 50-99 (Reed and Elliot 1977, Dorman and Bourke 1979).

Ship observations for the years 1978-1985 available on magnetic tapes at the Malaysian Meteorological Service were used for extracting the present weather groups and the pressure data.

FGGE ships' data from the Winter Monsoon Experiment (MONEX), December 1978 - February 1979, were included in the study.

Measured rainfall and pressure data from land stations in the Southeast and East Asian regions were obtained from the ASEAN Compendium of Climatic Statistics (published by the ASEAN Committee on Science), the World Survey of Climatology (Arakawa 1969) and the Vietnam Climatological Summary (published by the Vietnam Meteorological Bureau). The pressure data obtained from the ASEAN Compendium of Climatic Statistics are for 0000 GMT observations only.

3. METHODS

3.1 Rainfall amount

Tucker (1961) estimated rainfall amount using present weather groups of the synoptic weather reports from stations in the British Isles. In this method he associated values with light, moderate and heavy continuous rain and then, after solving appropriate equations, assigned numbers of the present weather groups from 50-99. The sum of products of the values of the present weather groups with their respective frequencies of occurrence in a specified period would provide an estimate of the rainfall amount characterizing the period.

It was suggested that at least a five-year period of observations would be needed to compute the rainfall estimate. A correction factor M/(M+E), where M is the measured rainfall and E is the difference between the estimated and measured rainfall values, had to be applied to the monthly estimated rainfall. In the temperate latitudes, Tucker's method was in general agreement with the rainfall collected from a rain gauge, but in the tropics, three times as much rain was measured as was estimated (Reed and Elliot 1977). Kilonsky and Ramage (1976) attributed the heavier rainfall in the tropics as compared to the British Isles to the organized, large-scale convective activity.

To examine the universality of Tucker's method, Dorman and Bourke (1978) used data from twenty-eight coastal stations located along the coasts of the Atlantic and Pacific Oceans from south of the equator to 75^{o}N. These authors investigated the possibility of a temperature effect and showed that there was a latitudinal bias related to local air temperature. The rainfall estimates were greatly underestimated with increasing temperature. This effect could be corrected by empirical formulae. A best-fit curve for the data in the graph of temperature against M/E was in the form M/E = a+bT+cT2 where T is the main air temperature in degrees Celsius, and a, b and c are temperature curve coefficients. This curve has a correlation-square fit of 0.83 and is for the temperature range of -10^{o} to 30^{o}C.

Dorman and Bourke (1979) estimated rainfall amount, in millimeters, for a region within a specified period with the formula:

$$R = \left(\sum_{i=1}^{N} a_i f_i\right) F(T)(b/c)$$

where a_i - frequency of occurrence of a particular ww

f_i - value of a particular ww (in mm) assigned by Tucker (1961)

T - mean air temperature

F(T) - air temperature correction function derived by Dorman and Bourke (1978)

b/c - ratio for correction of uneven distribution of observations in each region per analysis period, where b is the number of 3 hour observations possible for the period and c is the total number of observations during the period.

Rainfall estimates improve with increasing number of observations per region. Three thousand observations per region were considered to give reliable estimates and 600 were the minimum number considered for providing meaningful estimates.

Figure 1 shows the total number of ship observations per region in the Southeast Asian area from the equator to 25°N and from 95°E to 125°E. These regions were selected for reasons of marine climatological interest and were also regions with dense ship traffic. There were no research weather ship data of long duration in the region for comparison of the reliability of the computed estimates. The dimension of each region used by Dorman and Bourke (1979) to compute the rainfall estimates was $2^o \times 5^o$.

Charts showing rainfall estimates for annual and mean precipitation during the winter, spring, summer and autumn months for the marine regions were plotted. In this study, winter, spring, summer and autumn were deemed to commence from December, March, June and September, respectively.

3.2 Rainfall vectors

The mean monthly rainfall data for the marine regions derived by Tucker's method and the mean monthly rainfall for the land stations extracted from the publications mentioned in Section 2, were subjected to harmonic analysis using the method proposed by Whittaker and Robinson (1958) to yield the amplitudes and phases of the first and second harmonics of the annual precipitation cycle. Applying the format of Hsu and Wallace (1976), normalized amplitudes were obtained by dividing the computed amplitudes by the average monthly precipitation (i.e., one-twelfth of the average annual precipitation). A station whose normalized amplitudes is greater than one and where the peak vectors of the annual and semi-annual cycles tend to be parallel to each other has a pronounced dry season.

Normalized rainfall vectors were drawn with the midpoints as the centres of the respective marine regions/land stations. These vectors displayed the amplitudes and phases of the precipitation for each cycle. For example, a vector pointing to the south indicated a maximum rainfall with the annual phase of 0^o on 1 January. The vector rotated clockwise approximately 1^o per calendar day and on 1 April pointed westward with a 90^o phase angle. The annual rainfall cycle is illustrated as vectors with arrows and the semi-annual cycle is illustrated as vectors without arrow heads.

3.3 Pressure vectors

The harmonic analysis applied to the pressure data is essentially similar to that used for rainfall data except that the derived amplitudes of the pressure cycles are not normalized. Only stations which are less than 500 m above mean sea level are included in the study. Data from stations with high elevations are treated with caution or discarded. Annual and semi-annual cycles of surface pressure whose magnitudes are less than 0.5 mb and 0.1 mb, respectively, are denoted by open circles.

4. RESULTS

The mean annual rainfall distribution over the South China Sea region is shown in Figure 2. It is noted that maximum rainfall occurs in the Straits of Malacca (marine region (henceforth known as M) 1) and off the northwest coast of Borneo, Sabah (M 8). Minimum rainfall takes place in the region southeast of Hainandao (M 15), east of Johore, Malaysia (M 2) and in the Sulu Sea (M 9). The region of low rainfall estimates extends from southeast of Hainandao, southwestwards to the coasts of Indochina, and then stretches further southwestwards to the areas east of Johore. A comparison of the measured rainfall observed from coastal land stations, whose elevations are equal to or less than 30 meters, with the estimated rainfall computed for the nearby oceanic regions is shown in Table 1. The estimated oceanic rainfall is generally lower than the nearby measured rainfall from the coastal land stations. This difference may be 30% to

50% lower in the coastal waters whose nearby land mass is in the direct path of the northeast monsoon, e.g., east coast of Peninsular Malaysia. Elsewhere the difference may be in the region of 2% to 30% lower. The estimated rainfall may be higher than in the nearby land stations when the stations are sheltered from the direct impact of the northeast monsoon winds, e.g., the Straits of Malacca.

Table 1. Comparisons between annual rainfall measured from coastal and island stations and that estimated from nearby oceanic regions.

Station	Latitude	Longitude	Elevation	Annual Rainfall (mm)	
			(m)	Measured	Estimated
Taitung, Taiwan	22° 45'N	121° 10'E	-	1841	1760
Hong Kong	22° 18'N	114° 10'E	30	2223	1787
Aparri, Philippines	18° 22'N	121° 38'E	2	2288	1574
Yulin, China	18° 14'N	109° 32'E	2.1	1330	1298
Chon Buri, Thailand	13° 22'N	100° 59'E	3	1319	1716
Ho Chi Minh City Vietnam	10° 57'N	106° 46'E	8.8	2020	1660
Iloilo, Philippines	10° 42'N	122° 34'E	1	2177	1675
Puerto Princesa, Philippines	9° 45'N	118° 44'E	14	1728	1975
Phuket, Thailand	8° 6'N	98° 18'E	5	2467	1681
Kota Bharu, Malaysia	6° 10'N	102° 17'E	4.6	2706	1647
Jolo, Philippines	6° 3'N	121° 3'E	11	2094	1437
Sigli, Indonesia	5° 23'N	95° 57'E	1	1600	1681
Labuan, Malaysia	5° 18'N	115° 15'E	29.3	3424	2159
Kuantan, Malaysia	3° 47'N	103° 13'E	15.3	2923	1403
Malacca, Malaysia	2° 16'N	102° 15'E	8.5	2101	2230
Kuching, Malaysia	1° 29'N	110° 20'E	21.7	4107	2004
Kwandang, Indonesia	0° 51'N	122° 54'E	9	2725	1645

Figures 3 to 6 show the seasonal rainfall distributions for the South China Sea. In winter months (Fig. 3) more rainfall occurs over the southern half of the South China Sea. This rainfall configuration agrees fairly well with the satellite-estimated tropical Far East precipitation distribution for January 1967 obtained by Barrett (1971), although the rainfall amounts may differ. In spring (Fig.4) the whole of the South China Sea receives rainfall which is less than 100 mm per month. Figure 5 shows the summer monthly rainfall distribution where more rain occurs over the Philippines and the rainfall gradient decreases southwestwards and southwards. The satellite estimated precipitation map by Barrett (1971) of the tropical Far East for July 1966 shows a fairly similar rainfall pattern. In autumn (Fig. 6) more rainfall occurs in the central South China Sea and the Straits of Malacca as compared to the east of Johore and the Sulu Sea.

Figure 7 shows the annual cycle of precipitation for the Southeast Asian region. The vectors agree well with the oceanic vectors derived by Dorman and Bourke (1979) and with those computed by Hsu and Wallace (1976). It may be deduced from the chart that southern mainland China and the western region of Taiwan experience maximum rainfall in June and that the month for occurrence of a rainfall maximum generally progresses in chronological order as the latitude decreases towards the equator. In the northeastern region of Peninsular Malaysia, the maximum rainfall occurs in early November and the maximum rainfall pattern then advances along the east coast to reach Singapore in early December and the southern region of Sarawak in late December. On Borneo Island, the maximum rainfall occurs on the west coast of Sabah in August. The maximum rainfall pattern then moves southwestwards to reach the northern region of Sarawak in October, and proceeds towards west Borneo in late December. On the west coast of Peninsular Malaysia the maximum rainfall pattern is not as systematic as that on the east coast.

Figure 8 shows the semi-annual cycle of precipitation. The semi-annual vectors are generally smaller than the annual vectors. When the semi-annual vector is larger than the annual vector, it indicates the presence of two distinct wet seasons at the station (e.g., the Celebes Sea).

Figure 9 shows the long term mean annual surface pressure over the Southeast and East Asian regions. It is observed that eastern China has a large mean annual pressure and that the value of the mean pressure decreases latitudinally towards the equator. The pressure gradient in the equator region is generally very weak.

The amplitudes and phases of the annual cycle of surface pressure are shown in Figure 10. It may be deduced that almost all of the regions in Southeast and East Asia generally experience maximum pressure during the winter months. Large amplitudes of annual cycles of pressure are to be found over eastern China and small amplitudes are located in the equatorial regions which agree with the findings of Hann and Suring (1939). No oceanic type of annual pressure variation is observed in the regions. Figure 11 shows the semi-annual cycle of surface pressure. Pronounced semiannual oscillations are located to the north of 20^{o}N and occur near the time of the equinoxes.

5. CONCLUSION

From the above discussion it can be noted that less rain occurs along the path of the northeast monsoon over the South China Sea than over the coast of Sabah. The central and northern South China Sea experience more rainfall in the summer and autumn months. This may be due to the occurrence of tropical storms and typhoons during that period. A large value for mean annual surface pressure is found on the eastern maritime sea board of China north of 20^{o}N. The equatorial regions experience low mean surface pressure. Large surface pressure over China and a high amount of rainfall over the southern half of the South China Sea occur in winter. It is difficult to correlate the occurrence of surface pressure and rainfall in the equatorial regions.

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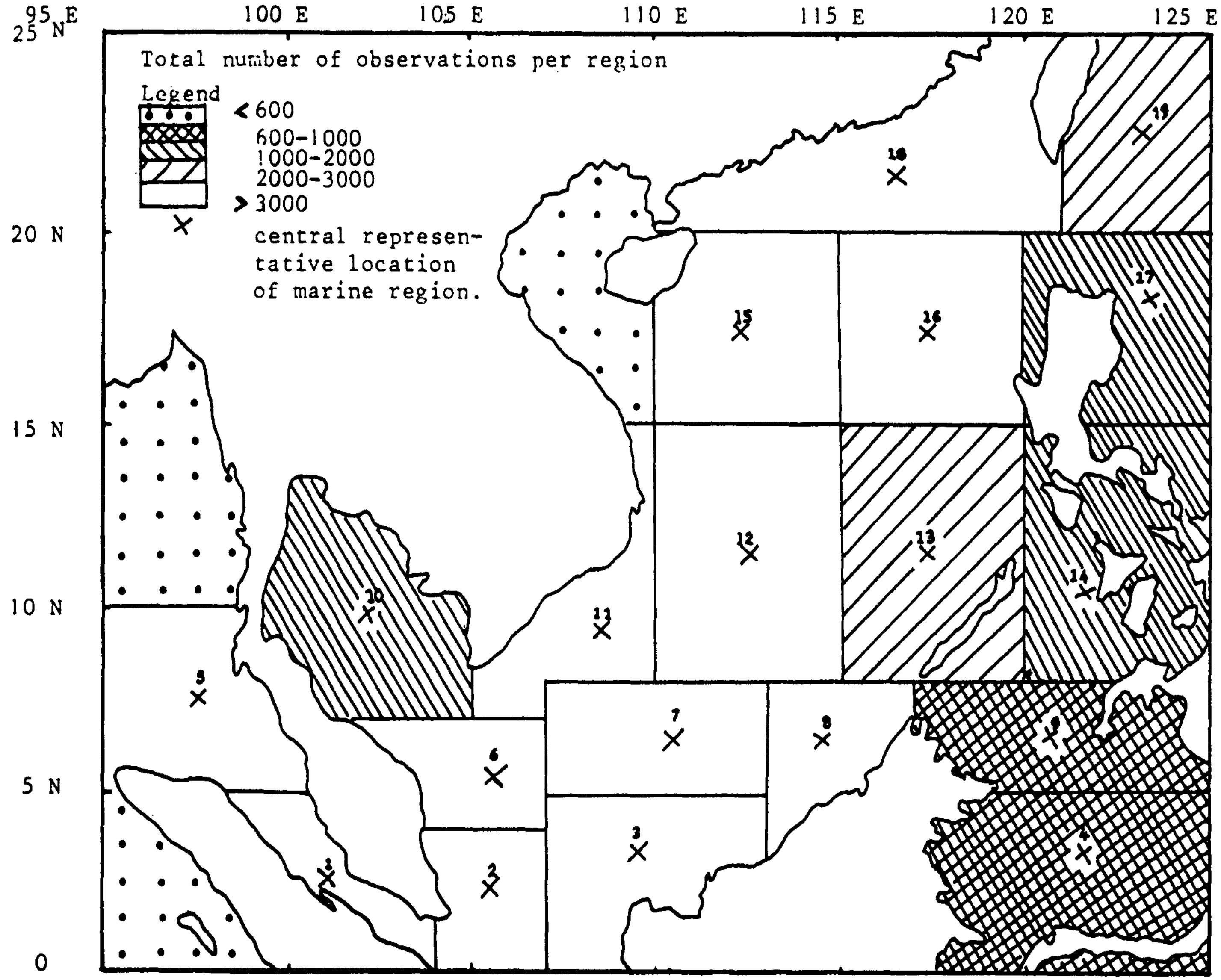

Fig. 1. Total number of ship observations per marine region for the period 1978 - 1985.

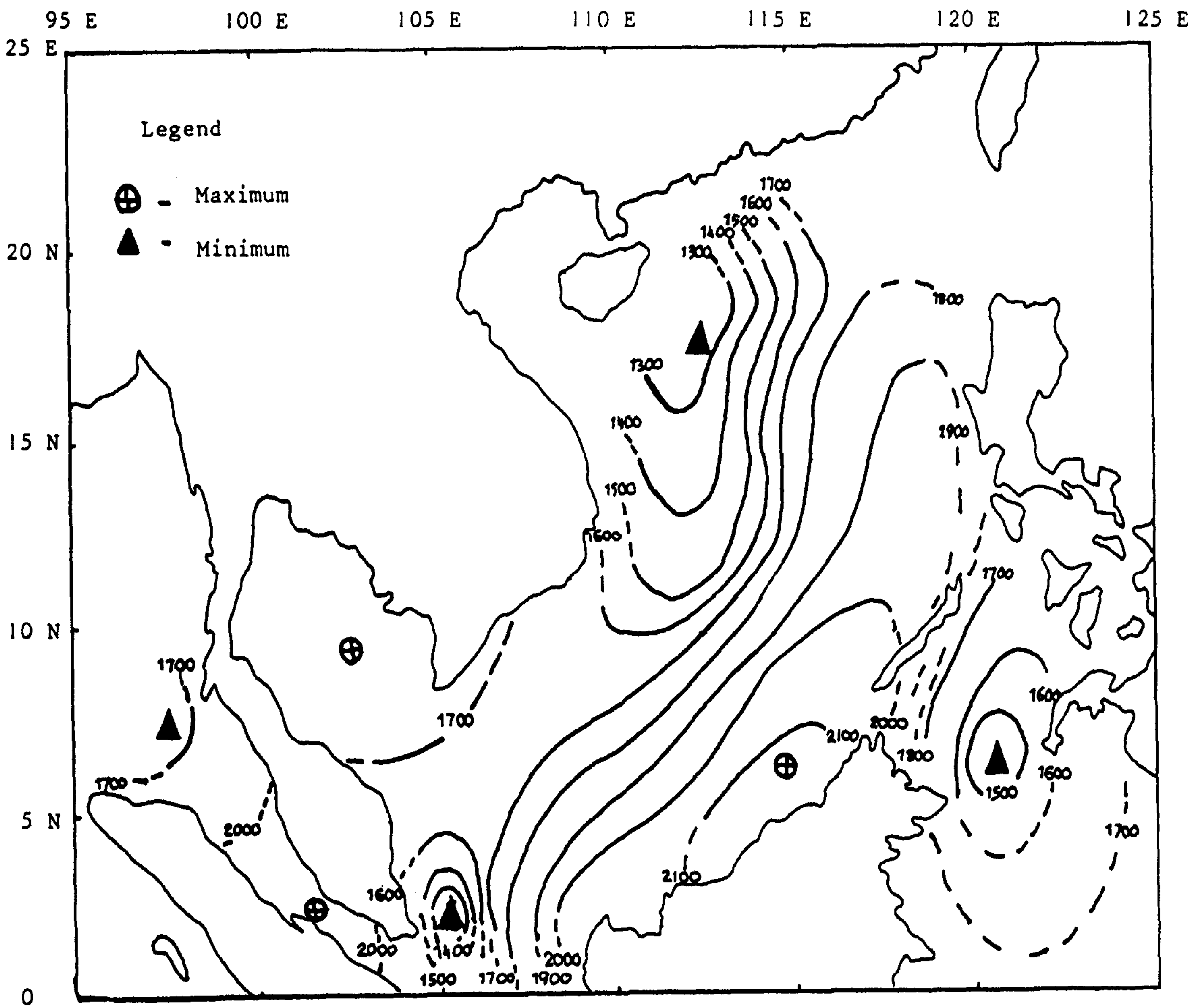

Fig. 2. Mean annual rainfall (mm) over the South China Sea region.

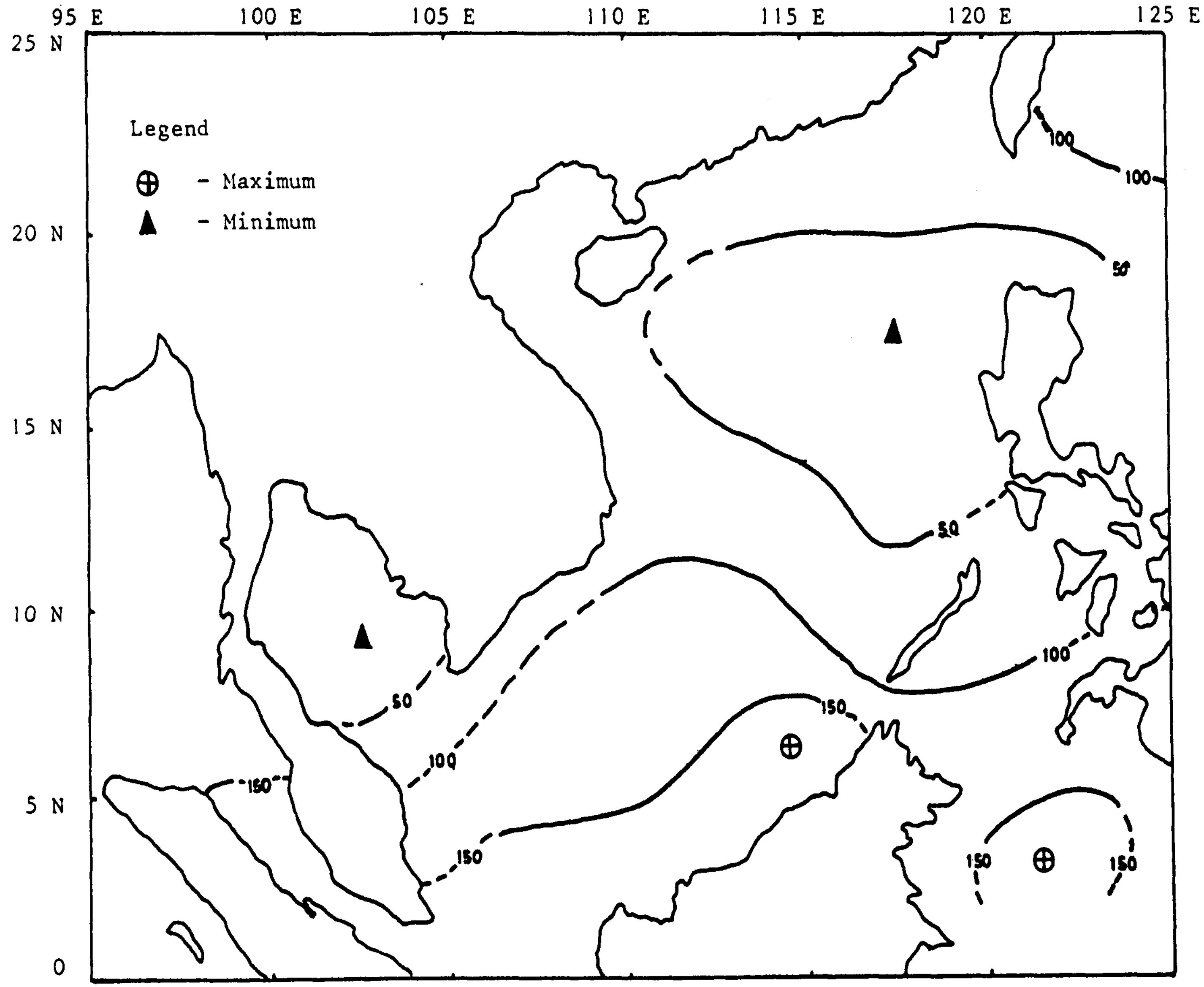

Fig. 3. Mean winter rainfall (mm) in the South China Sea.

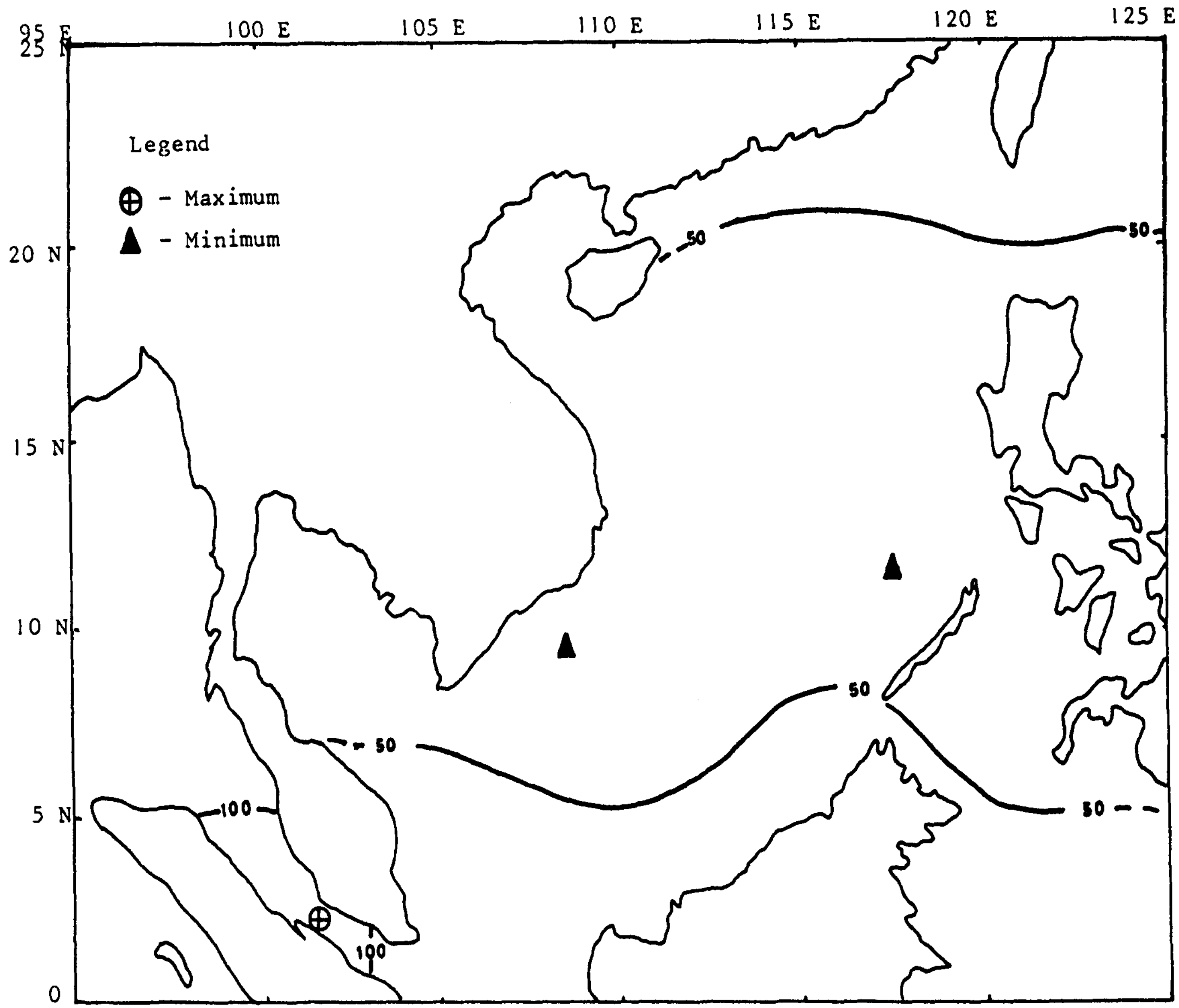

Fig. 4. Mean spring monthly rainfall (mm) in the South China Sea.

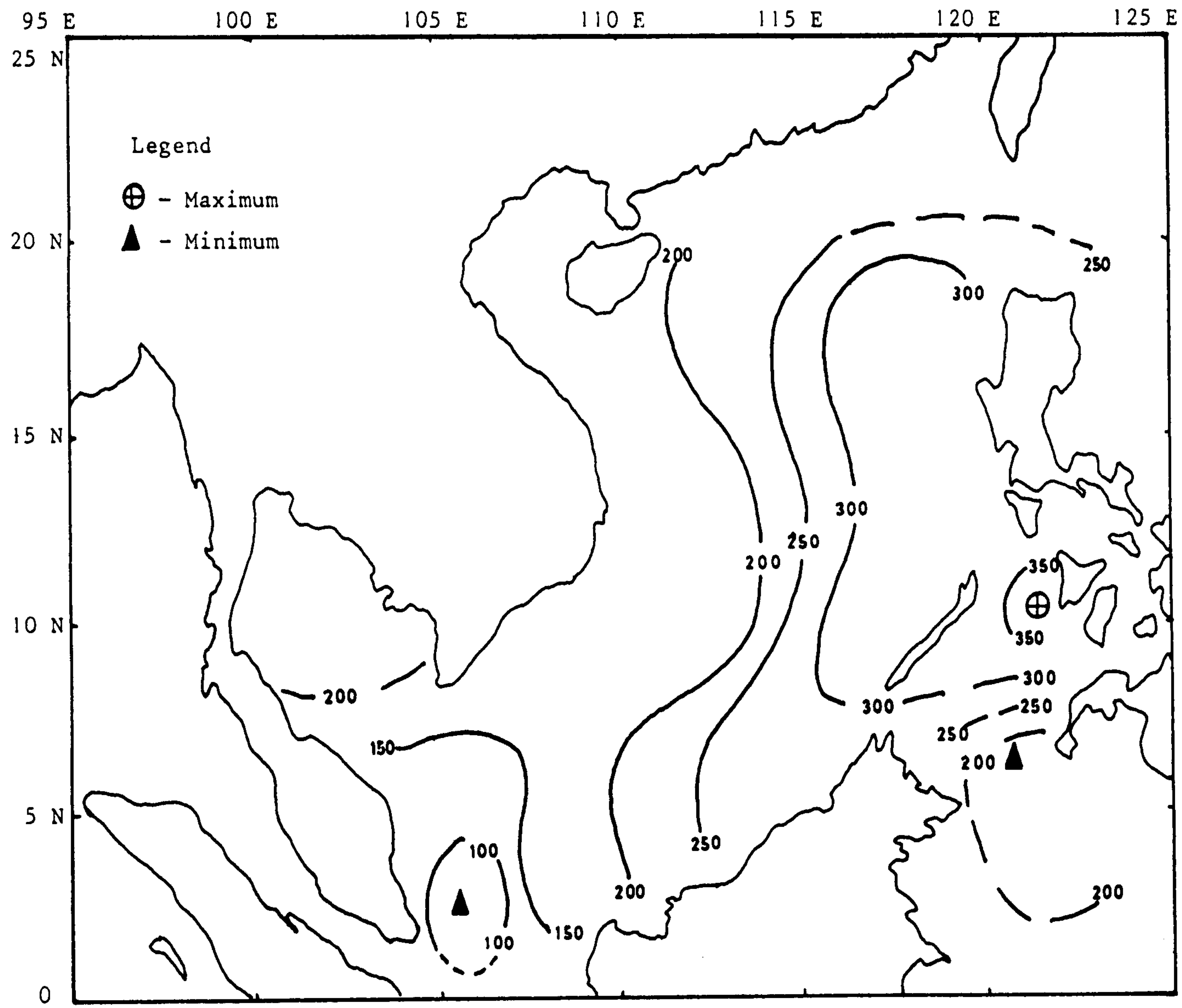

Fig. 5. Mean summer monthly rainfall (mm) in the South China Sea.

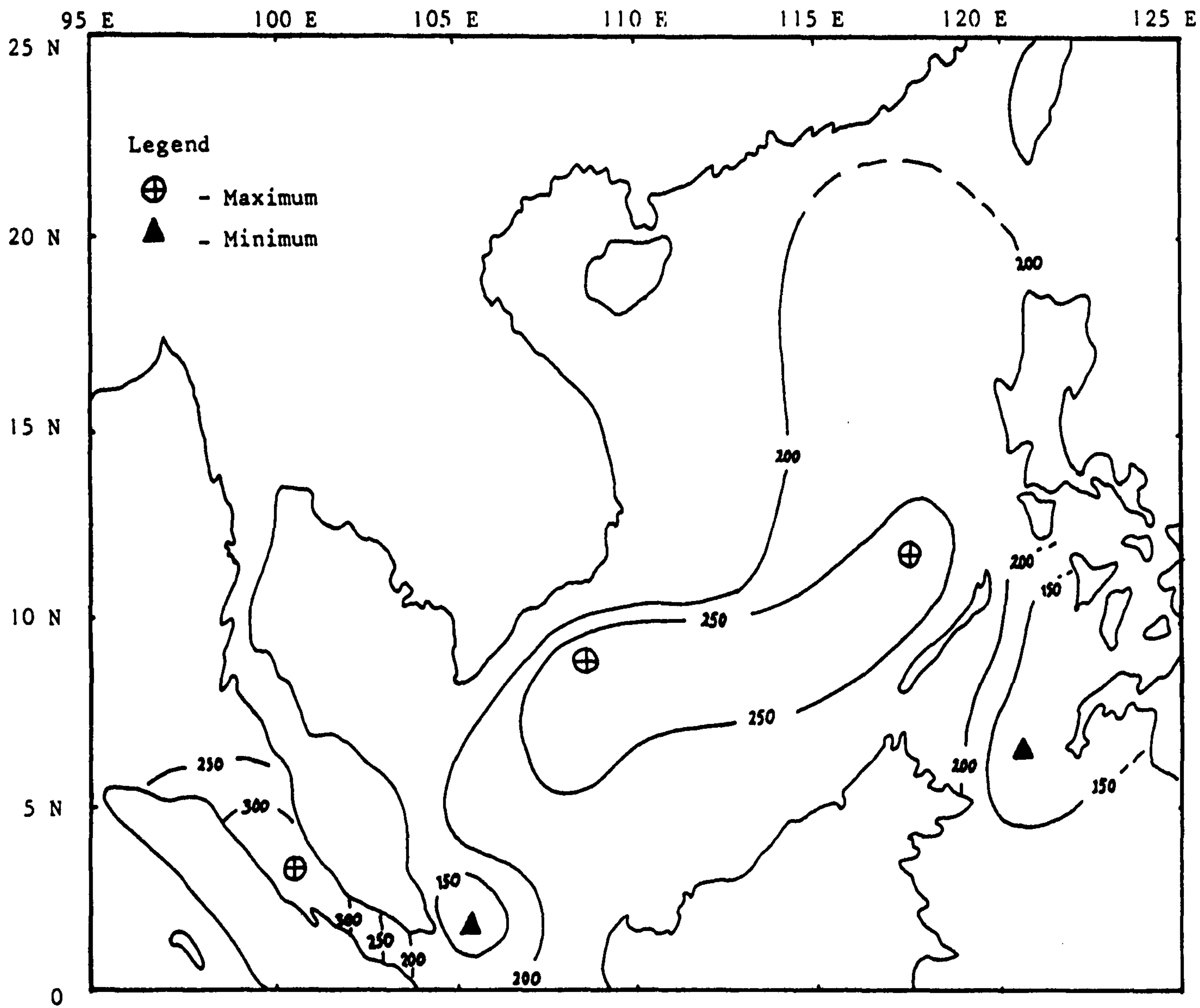

Fig. 6. Mean autumn monthly rainfall (mm) in the South China Sea.

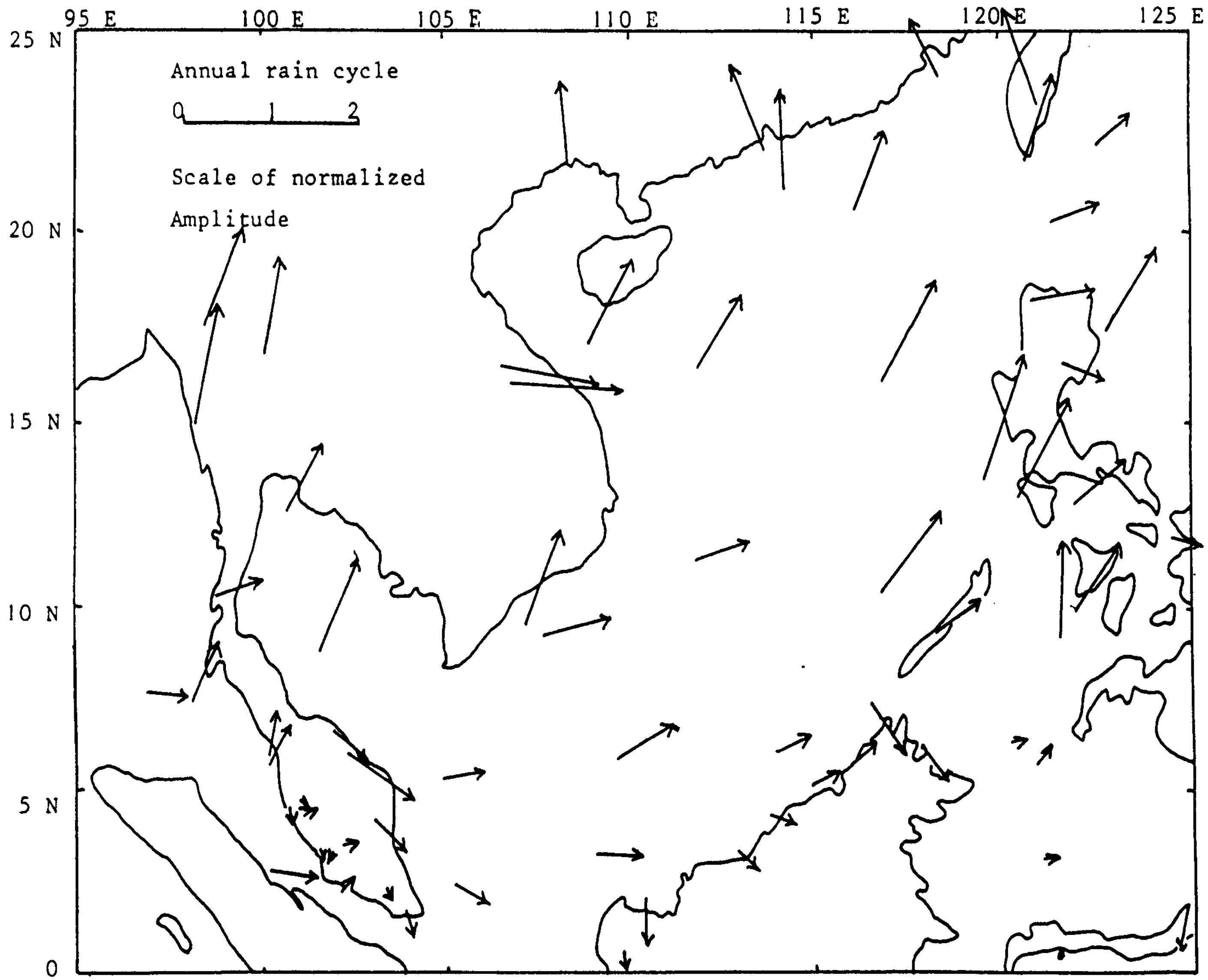

Fig. 7. Normalized amplitudes and phases of the mean annual rainfall cycle over the South China Sea region.

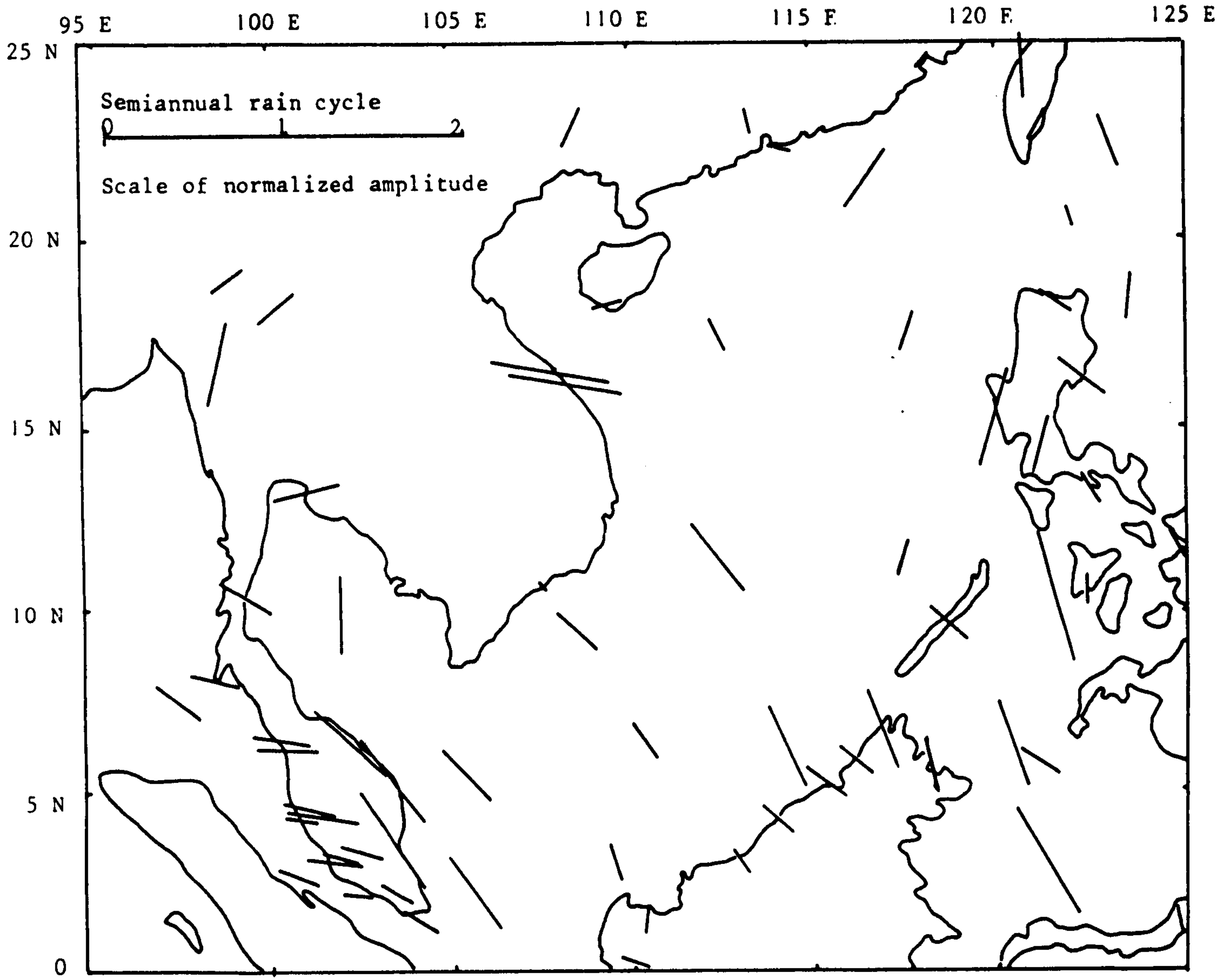

Fig. 8. Normalized amplitudes and phases of the mean semi-annual rainfall cycle over the South China Sea region.

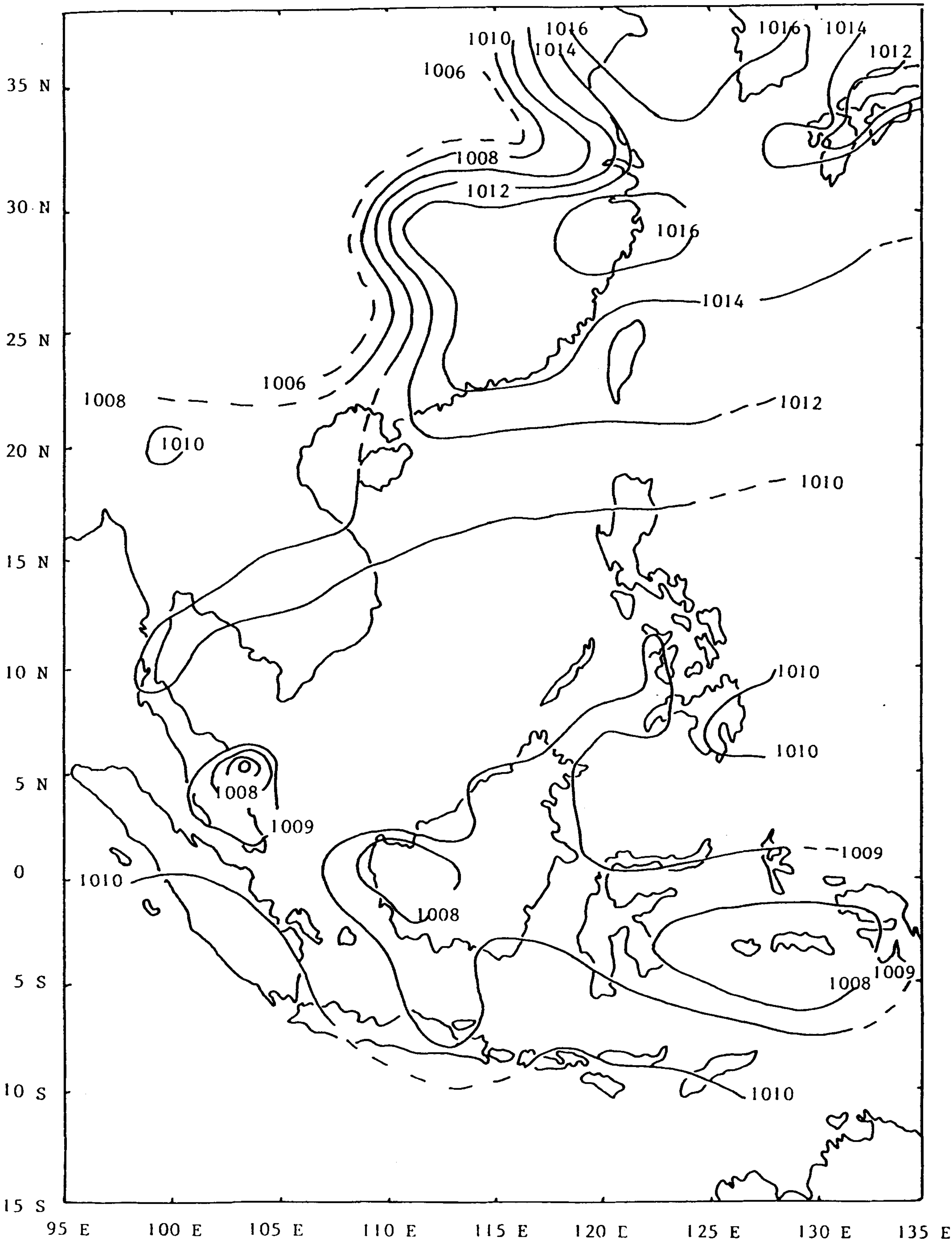

Fig. 9. Long term mean annual surface pressure (ME) over the Southeast and East Asian regions.

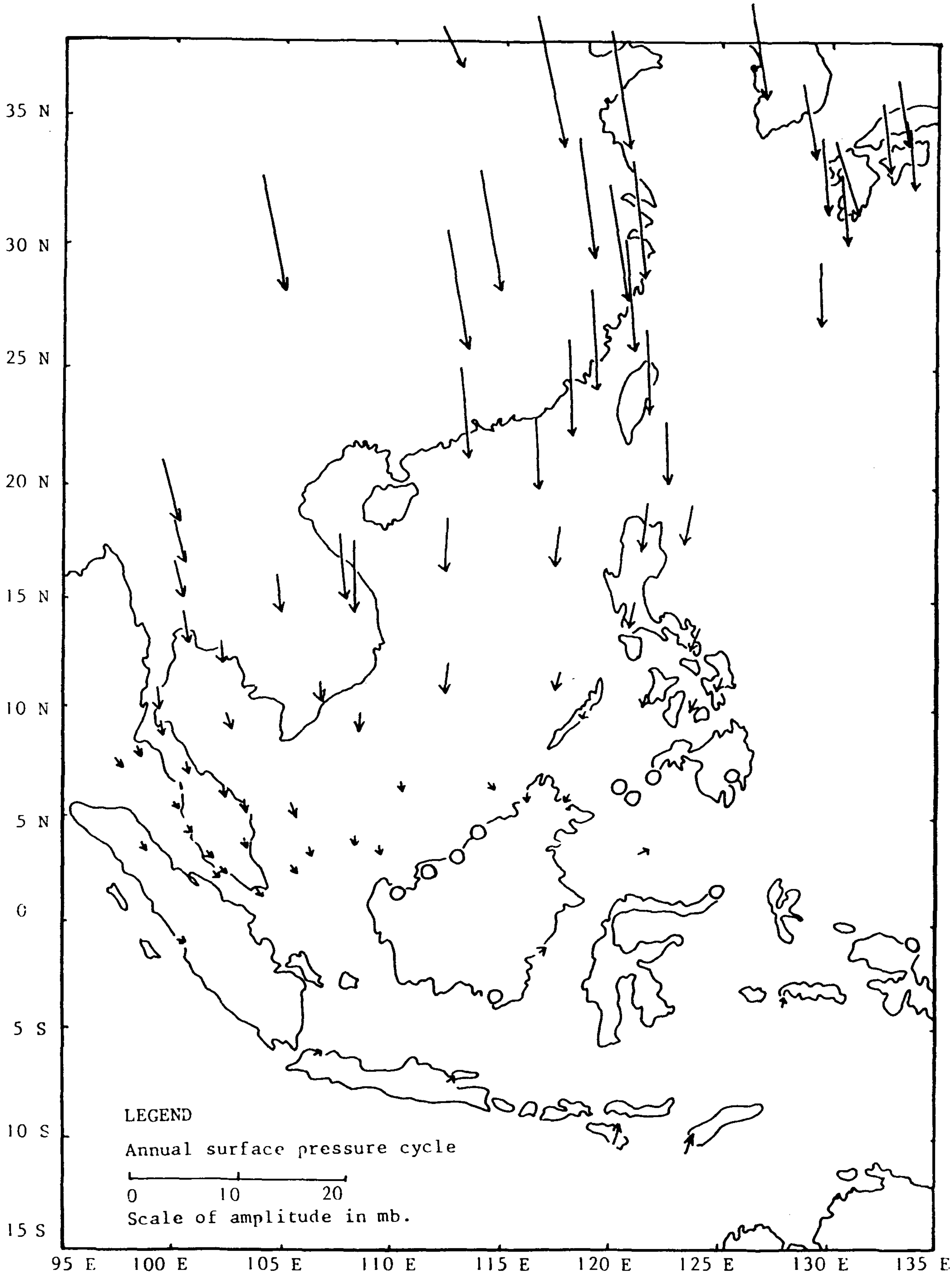

Fig. 10. Amplitudes and phases of the annual cycle in surface pressure over the Southeast and East Asian regions.

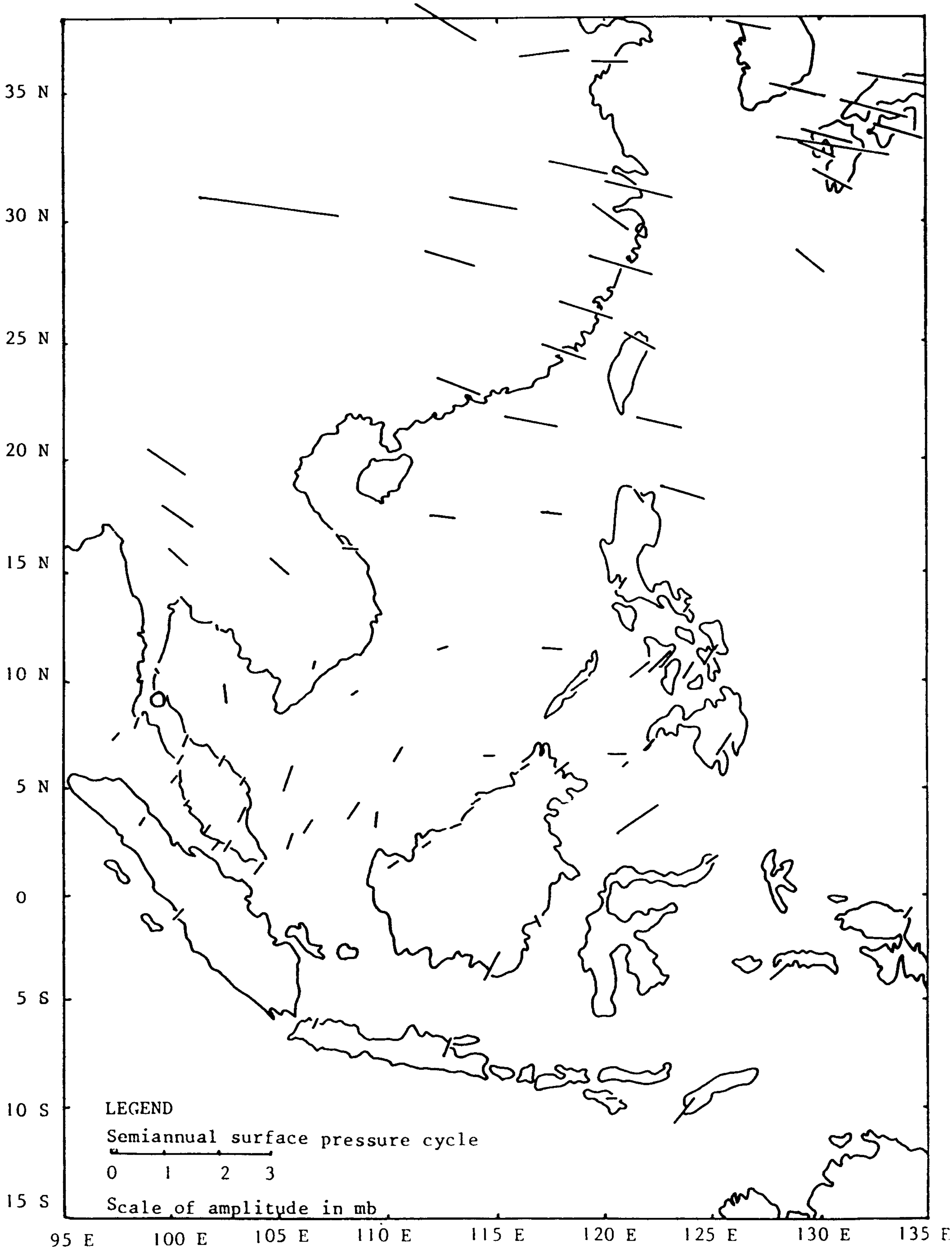

Fig. 11. Amplitudes and phases of the semi-annual cycle in surface pressure over the Southeast and East Asian regions.

THE CAUSES OF CIRCULATION IN THE GULF OF THAILAND

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ABSTRACT

The monthly surface current vectors in the Gulf of Thailand were averaged per one degree square from Geoelectrokinetograph (GEK) and ship's drift data. The pattern and strength of these currents were related to the monsoon wind field, river discharge and some physical and chemical sea water properties such as salinity, temperature, density, dissolved oxygen and nutrient variations. In the open sea, the effect of the monsoon wind is significant. In channels with constrictions of the land and bottom boundaries, the pressure gradient force of thermohaline circulation and tidal effects are prominent. An example is the Malacca Strait where surface current flows out to the Andaman Sea all year round, even when the monsoon wind changes direction seasonally. In the Upper Gulf of Thailand, the combined effect of river discharge with wind drift and tidal currents on some occasions causes mesoscale eddies of different sizes as seen from satellite imageries. The strength of the surface current is generally greater during the northeast monsoon season than in the southwest monsoon season and the pattern changes direction according to the monsoon winds. Tropical cyclones also have some effects on surface circulation. The knowledge of circulation and air-sea interaction processes is important in studying pollutant transport in the sea.

1. INTRODUCTION

The surface circulation in the Gulf of Thailand and the South China Sea as derived from historical GEK (Geoelectrokinetograph) and ship's drift data was analyzed by Siripong (1984) for 4 seasons. In this paper, the author analyzes the same kind of data but focuses on monthly variation instead of on 3-month averages. The area covers latitude 0^{o} to 15^{o}N and longitude 99^{o}E to 123^{o}E.

The purposes of this study are:

(a) to know the pattern and magnitude of monthly surface circulation in the Gulf of Thailand;
(b) to investigate the causes of surface circulation in the Gulf of Thailand.

The benefits of this study are in being able to infer fish migrations and the surface transport of pollutants such as oil, suspended sediment or any floating materials in the sea. The results may also be an input or a kind of verification for any model on surface transportation of floating pollutants in the sea.

2. TOPOGRAPHY OF THE GULF OF THAILAND

The Gulf of Thailand extends northwestward from the southern part of the South China Sea. Its mouth is defined as a line between the southwestern tip of the Mekong Delta and a small island off the coast of the Thai-Malay Peninsula near latitude 6^{o}N. It is a shallow and semi-enclosed bay on the Sunda Shelf and covers an area of approximately 350,000 km^2. The mouth is about 320 km wide at the surface, but below 50 m, there is only a 50 km wide channel connecting with the inner deep basin of the South China Sea. The sill depth is 67 m, located roughly midway between Cape Camau in Vietnam and Kota Bharu in Malaysia (Fig. 1). This channel cuts between a 30-m ridge on the north extending southwest from Cape Camau and a 50 m ridge extending northeast from Kota Bharu (6.3^{o}N, 132.2^{o}E).

The Gulf is relatively shallow with a mean depth of about 45 m. The eastern side is generally shallower and flatter than the rocky steep slopes of the western coast. There are many narrow beaches along the coasts except on Chanthaburi and Trad which are covered by extensive mangrove forests. The bottom topography of the Gulf shows shallow contours along the coast and gradually increases in depth towards the deepest basin in the middle of the Gulf. There are numerous ridges with a wide flat top which are about 5 m in height and from 50 to more than 4,000 m in length in the central part of the Gulf. The distance between neighbouring ridges ranges from 500 to 2,000 m. The rising angle of the slope of the ridges averages 10^{o}.

The Gulf is divided into two parts: the upper or inner, and the lower or outer parts. The upper part starts from latitude $12^{o}30'N$ to the Chao Phraya River mouth. It is relatively shallower than the lower part with an average depth of 15 m, an area of 100 x 100 km^2, and a volume of water of about 131 km^3. From the shallow northern coast, the bottom slopes gradually downward to a depth of 25 m at the mouth between Sattahip and Hua Hin.

The lower part extends to the line which passes Cape Camau and the Kota Bharu River mouth. The average depth is about 45 m. The continental shelf seaward of the Gulf and off the Vietnamese coast exhibits an irregular increase in depth to the shelf break at about 130 m.

Numerous rivers discharge fresh water and sediment into the Gulf of Thailand. Among them, the Chao Phraya River has the biggest volume transport next to the Mekong River. The average runoff per year ($x10^3$ m^3) of the Chao Phraya River is 13.22 while that of the Mekong is 326. It is estimated that considerable amounts of nutrients are also discharged from these rivers and promote primary productivity in the Gulf.

3. MONTHLY SURFACE CIRCULATION IN THE GULF OF THAILAND

Using historical GEK and ship's drift data from the Japan Oceanographic Data Center, the monthly mean surface current vectors were plotted by computer (Figs. 2a-n). The patterns of surface circulation are influenced by those of the monsoon, that is, they change direction and magnitude according to the NE (from December to February) and SW (from May to September) wind direction. During the two transitional periods (March to April and October to November), the current is variable and weak. The NE monsoon wind is usually stronger than the SW monsoon wind, which is reflected in the magnitude of the current. The average of all vectors in each month is shown in Figure 2a.

In the open sea, the influence of the monsoon wind is clearly evident. However, in the Gulf of Thailand which is a semi-enclosed sea of shallow depth experiencing combined riverine and tidal effects, the currents seem to fluctuate and form a number of gyres of various sizes. This characteristic is also seen from satellite imageries and is depicted in Figures 3-4.

In restricted channels such as the Malacca Strait and the Makassar Strait, the surface currents flow from the South China Sea to the Andaman Sea and from the Sulawesi or Celebes Sea to the Java Sea all year round. So, in these enclosed seas, the influence of wind on the surface current is less dominant than the topographic and density effects. In the Karimata and Gasper Straits, the surface water flows from the South China Sea to the Java Sea from October to April, and reverses direction from May to September. Generally, the flows along the western side are stronger than along the eastern side.

The central vector diagram averaged per month for the whole study area is illustrated in Figure 3a. It can be seen that at latitude $11^{o}N$ and longitude $101^{o}E$, the surface currents flow:

- N in January,
- E in March, June and July,
- SE in February, April, September and October,

- S in August, and
- SW in November, May and December.

The magnitude of the surface flow is strongest in September and second maxima occur in January. From Figure 3b, the annual progressive vector diagram in the same area in the lower part of the Gulf of Thailand, the vector is seen to circulate in a clockwise fashion or an anticyclonic gyre, mostly out of the Gulf.

Figure 4a is the central vector diagram of monthly surface currents at latitude 8°N and longitude 105°E, which is approximately located at the sill or the entrance to the Gulf of Thailand. The surface currents flow:

- N in May (into the Gulf),
- NE in April and June (out of the Gulf),
- E in July to October (out of the Gulf), and
- W in January to March and November to December (into the Gulf).

The magnitude of the current is maximum in September with a secondary peak in February. The patterns of currents are in the E-W component rather than in the N-S component. Figure 4b shows the annual progressive vectors in the same area which seem to divide into 3 eddies, 2 clockwise and 1 anticlockwise.

The stability of the currents in the NE (December) and SW (July) season is shown in Figures 5a and b, respectively. The currents show many eddies with cyclonic (counterclockwise) gyres, encompassing low pressure areas, as well as anticyclonic (clockwise) gyres, encompassing high pressure areas, all with different magnitudes.

4. CONCLUSION

In the open sea, the effect of the prevailing wind such as the monsoon wind is the dominant influence. The direct and approximate method using GEK and ship's drift data seems to be good for studying the direction and magnitude of the surface advective transport of pollutants. However, near the coast and in restricted channels, we have to consider other effects such as the topography of the sea bottom and coastline, river discharge, tidal currents, as well as wind-driven and density currents which can have some influence on pollutant transport. GEK and ship's drift data or indirect methods such as Ekman transport or geostrophic approximation (which can be applied in the deep sea only) are not appropriate for studying pollutant transport due to currents (advective flux). In the coastal area, where many land-based pollutants are discharged into the sea, well-planned direct current measurements are needed to monitor pollutant transport. These kinds of data are still lacking in the East Asian Seas region.

REFERENCE

Siripong, A. 1984. Surface circulation in the Gulf of Thailand and China Sea in 4 seasons from direct measurements. Paper presented at the National Seminar on Water Quality and Marine Resources in Thai Waters, National Research Council, Bangsaen, Thailand, 26-28 March 1984, 10 pp.

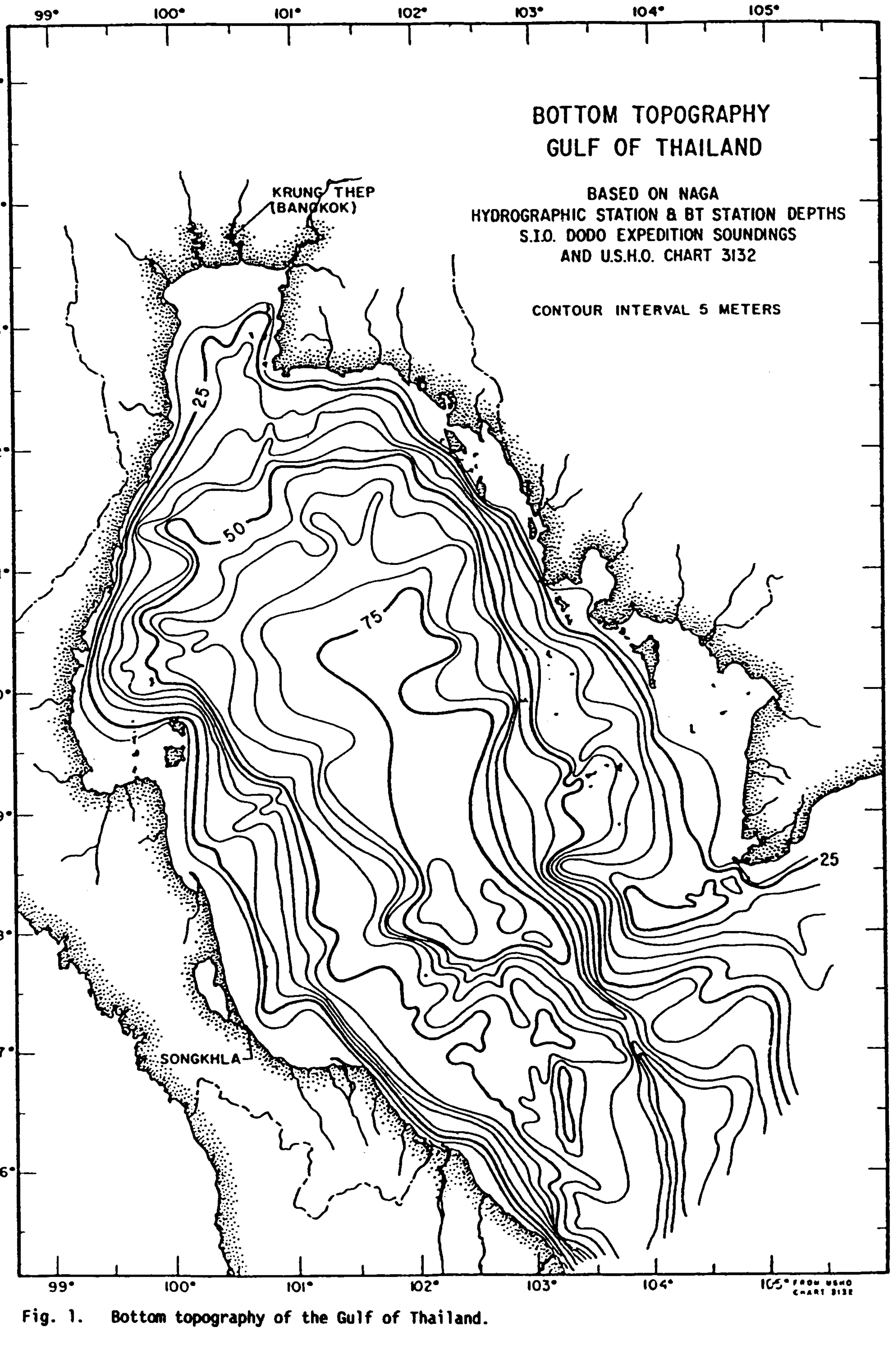

Fig. 1. Bottom topography of the Gulf of Thailand.

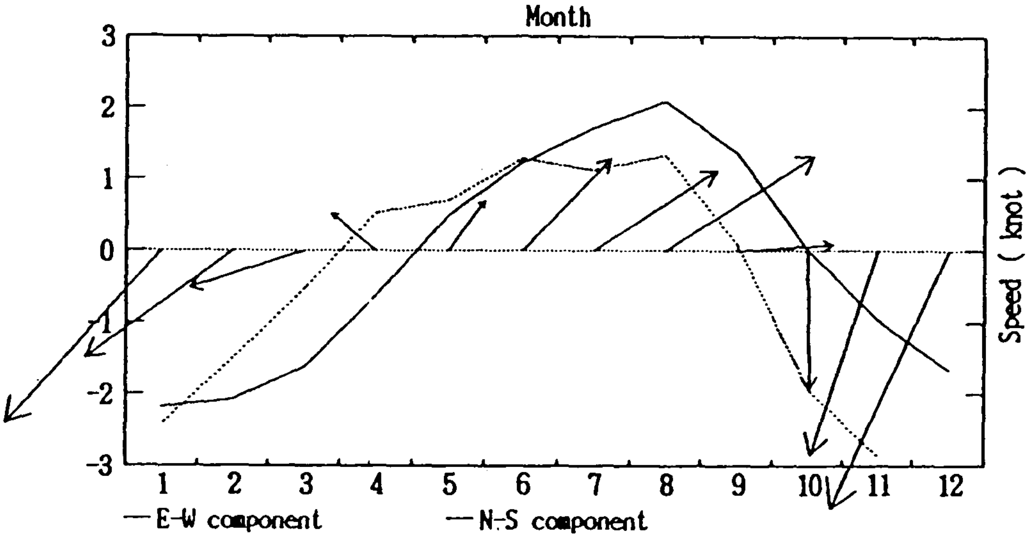

Fig. 2a. The average current vector per month (1-12) for the whole study area in E-W and N-S components.

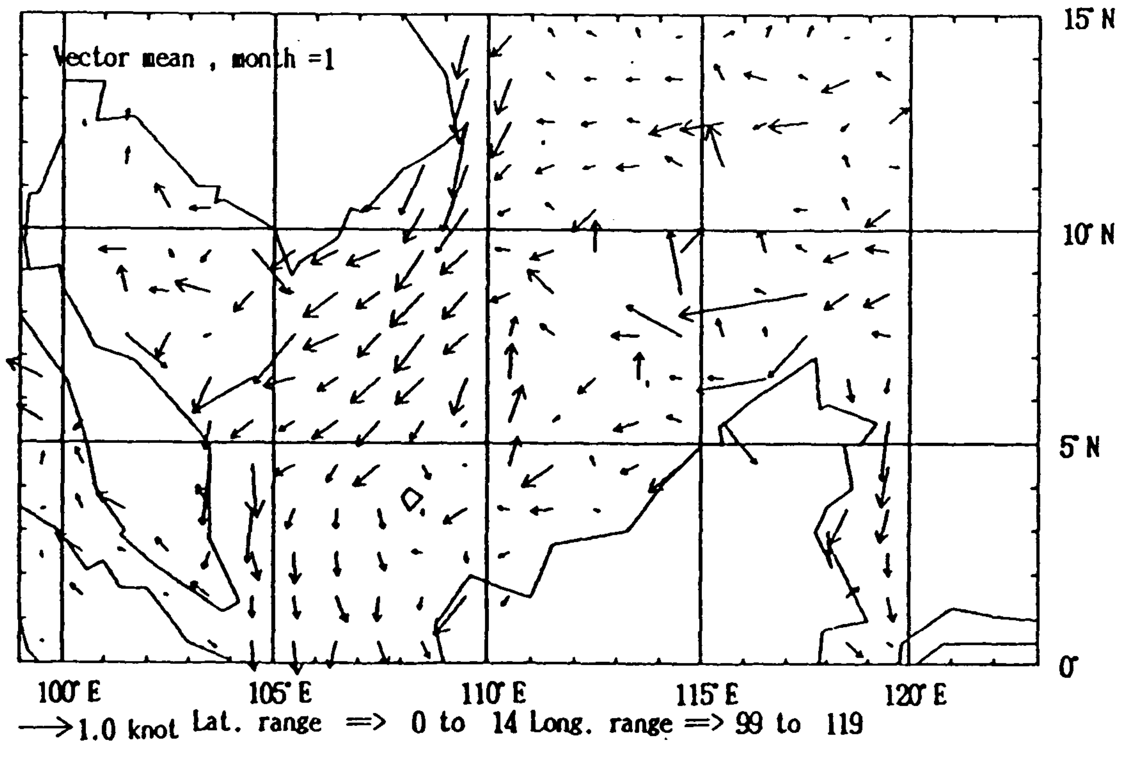

Fig. 2b. The monthly mean current vectors in January.

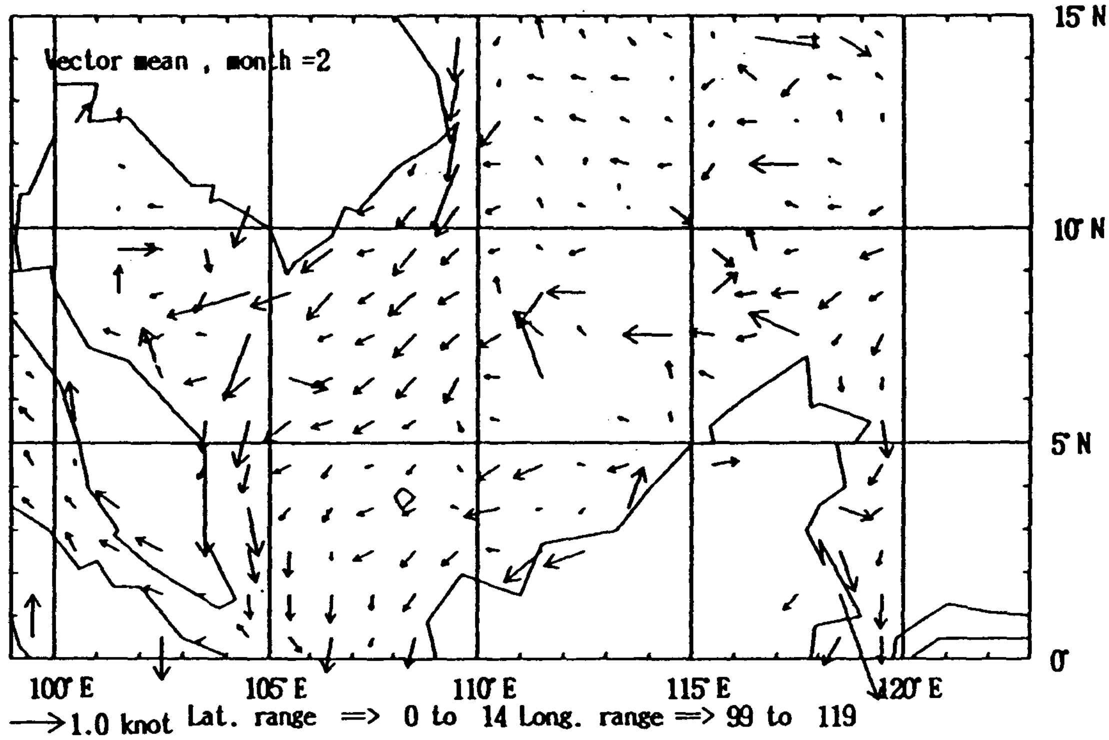

Fig. 2c. The monthly mean current vectors in February.

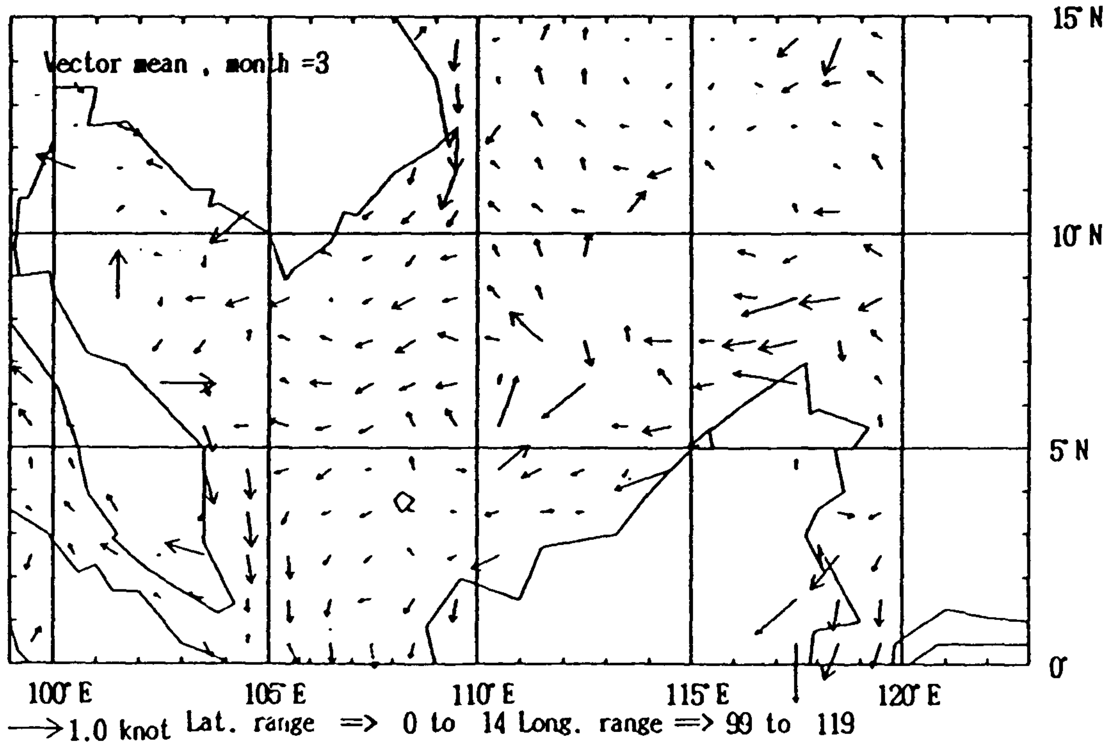

Fig. 2d. The monthly mean current vectors in March.

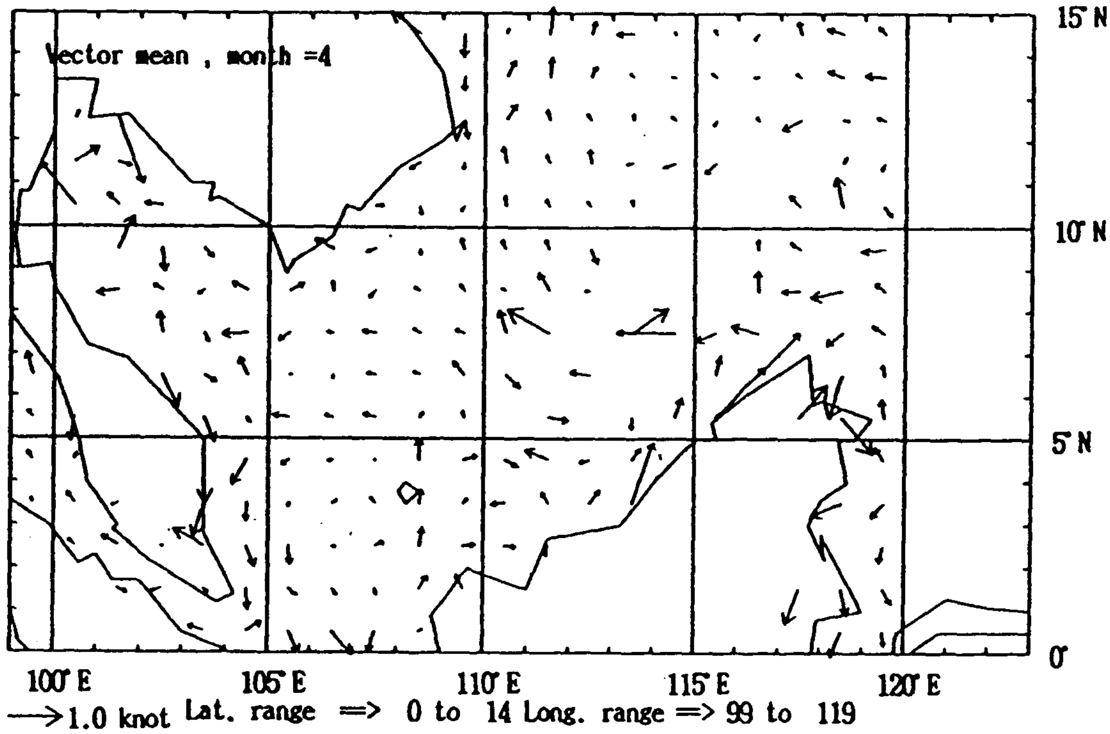

Fig. 2e. The monthly mean current vectors in April

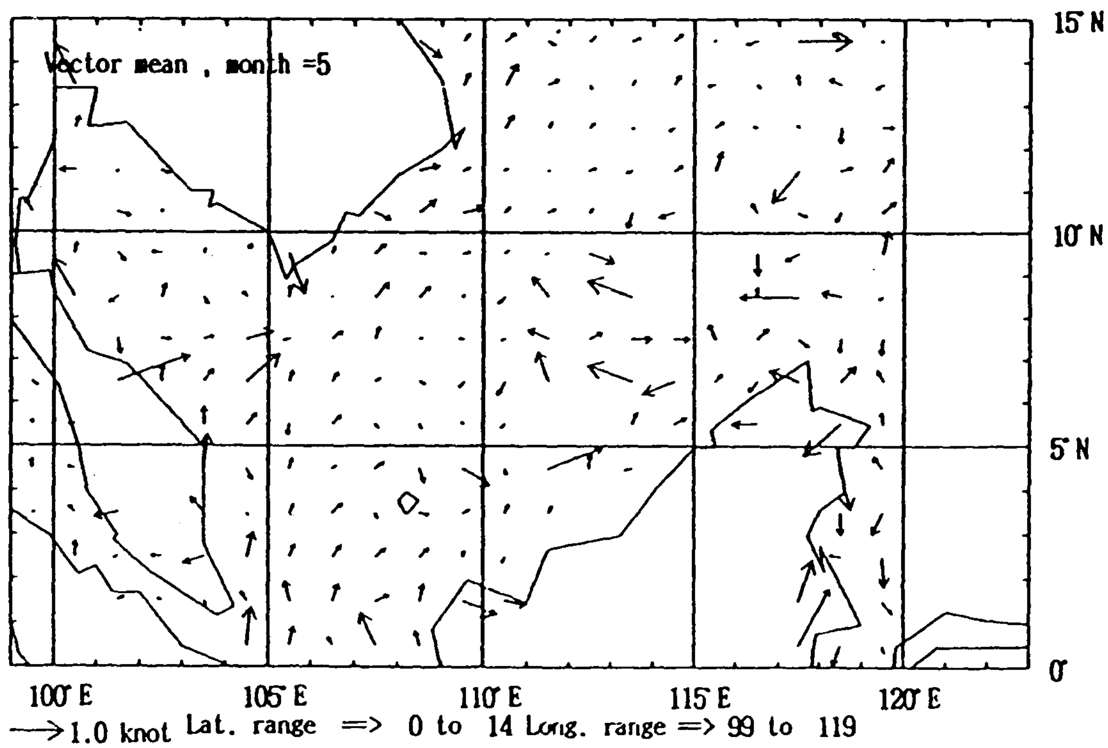

Fig. 2f. The monthly mean current vectors in May.

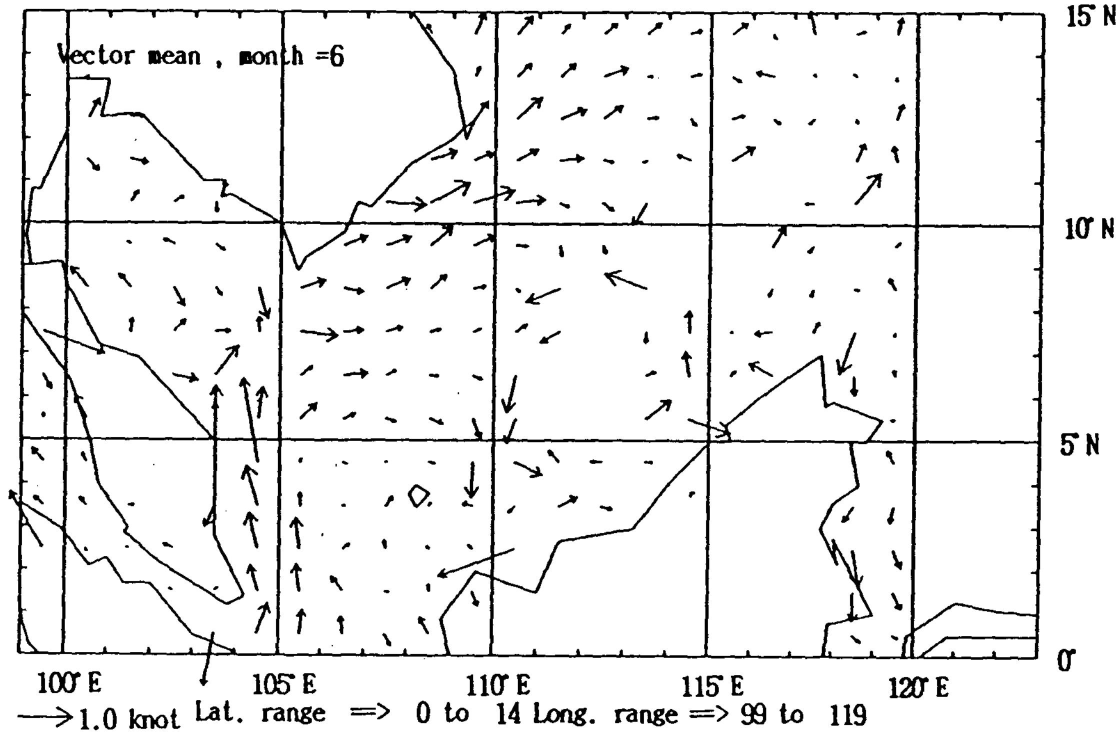

Fig. 2g. The monthly mean current vectors in June.

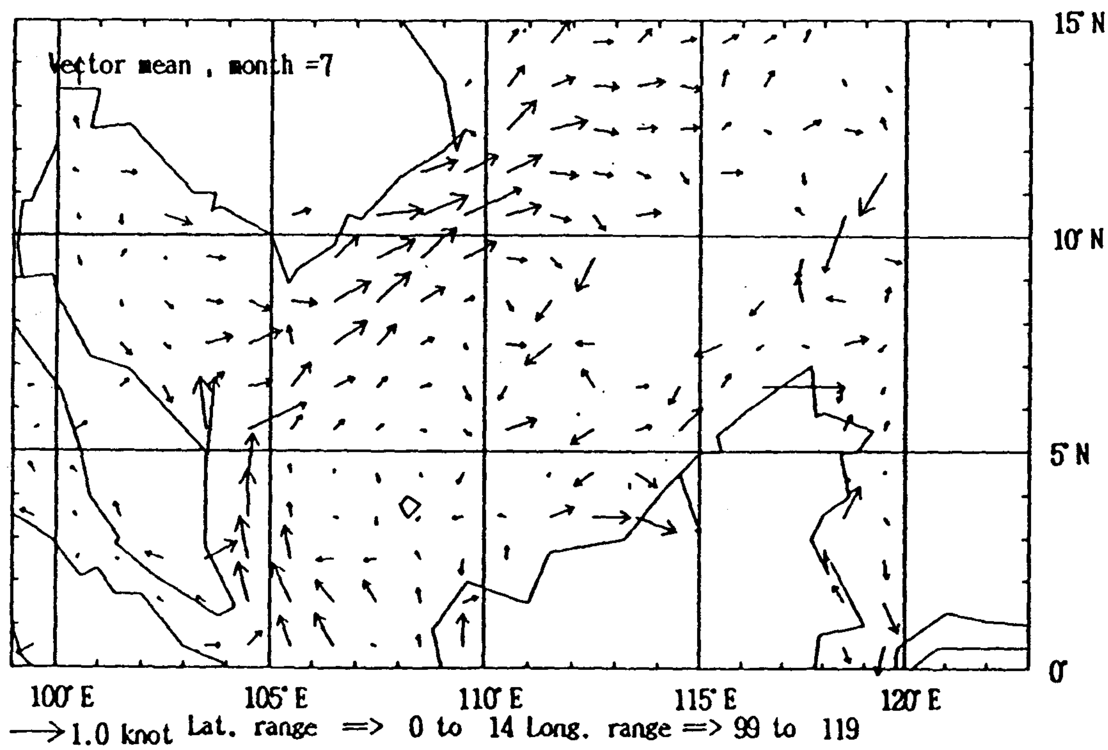

Fig. 2h. The monthly mean current vectors in July.

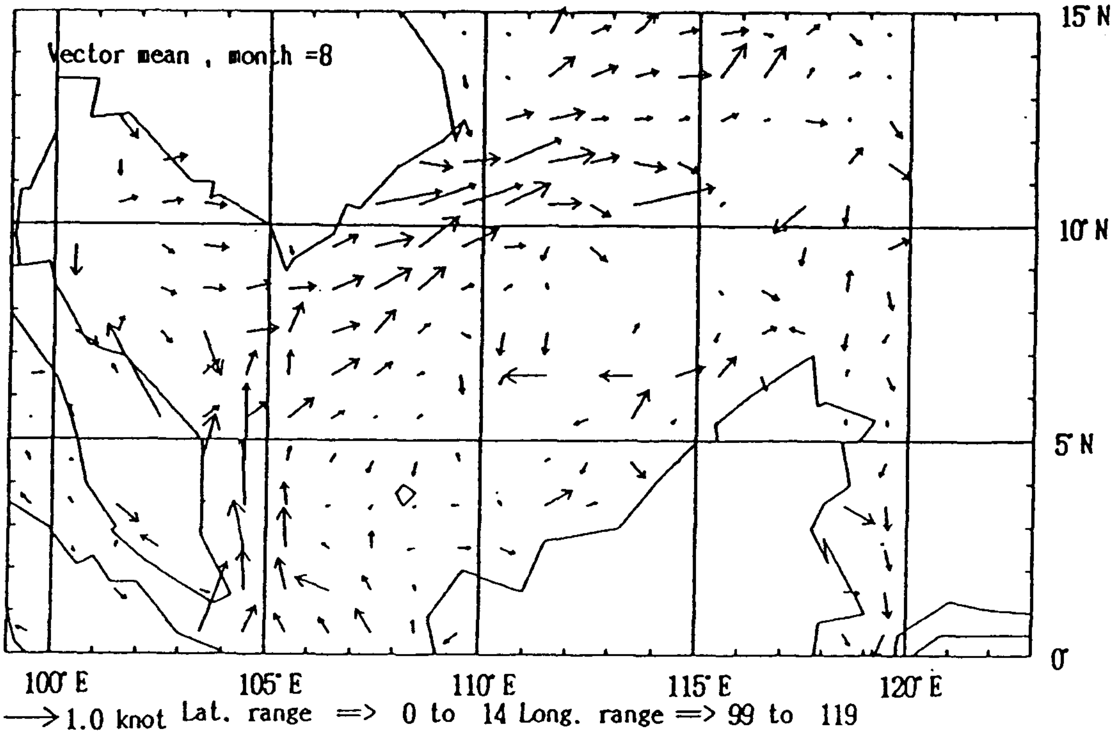

Fig. 2i. The monthly mean current vectors in August.

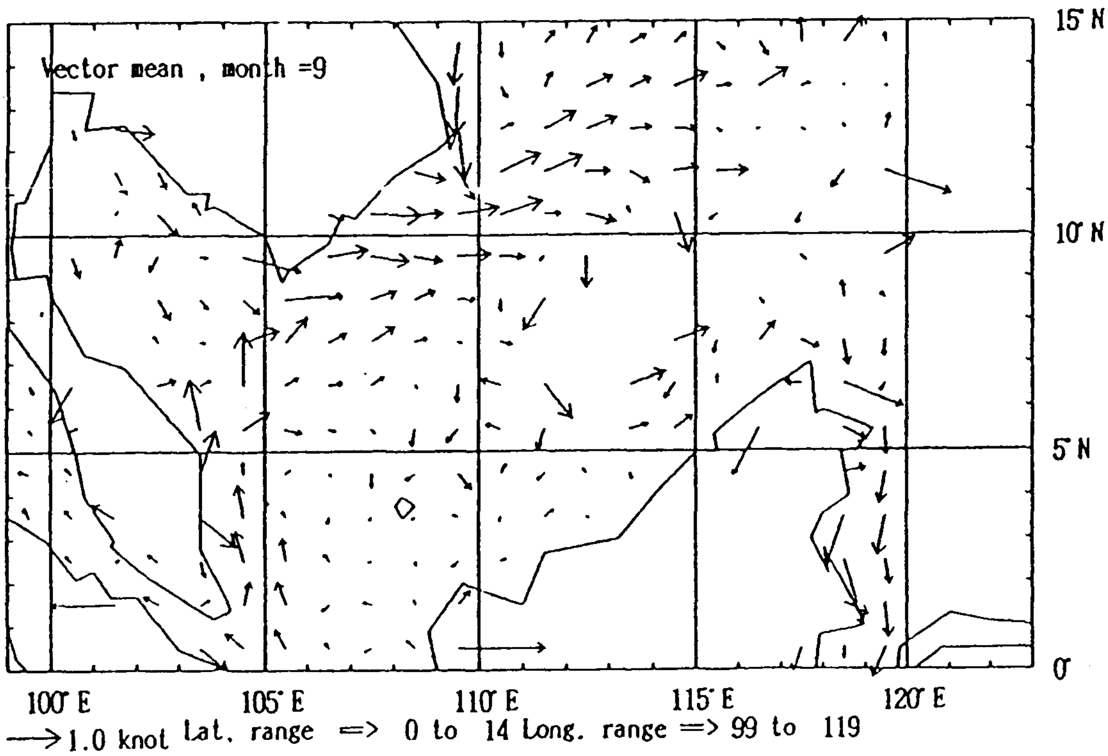

Fig. 2j. The monthly mean current vectors in September.

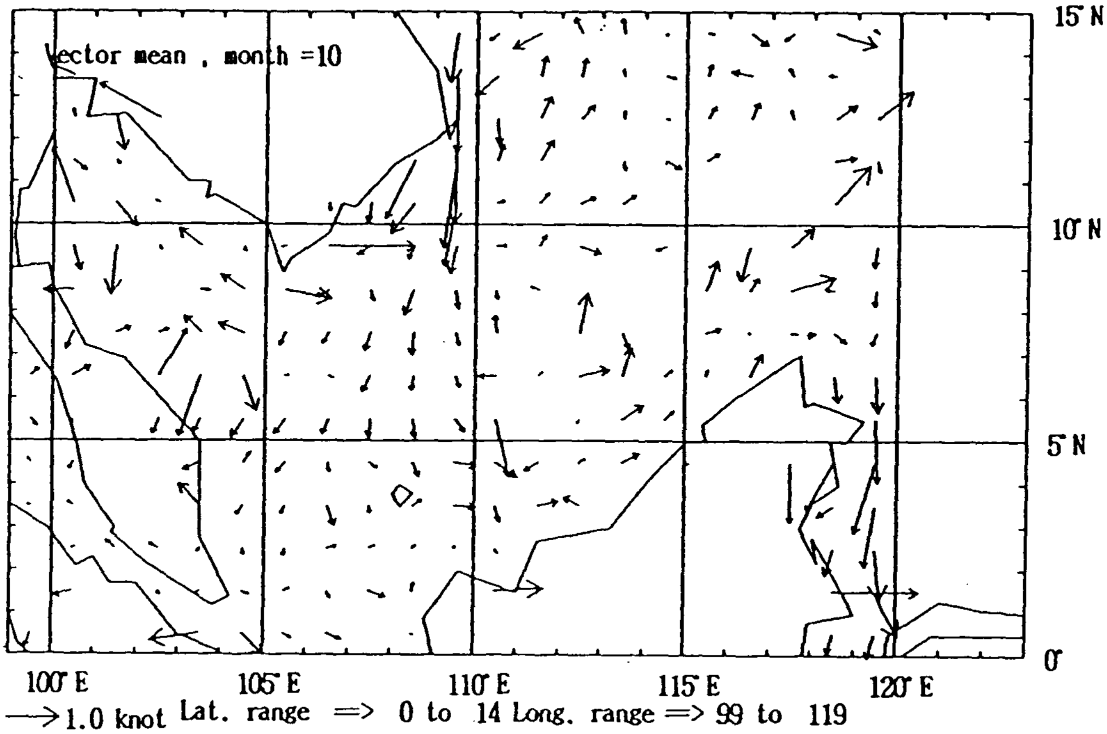

Fig. 2k. The monthly mean current vectors in October.

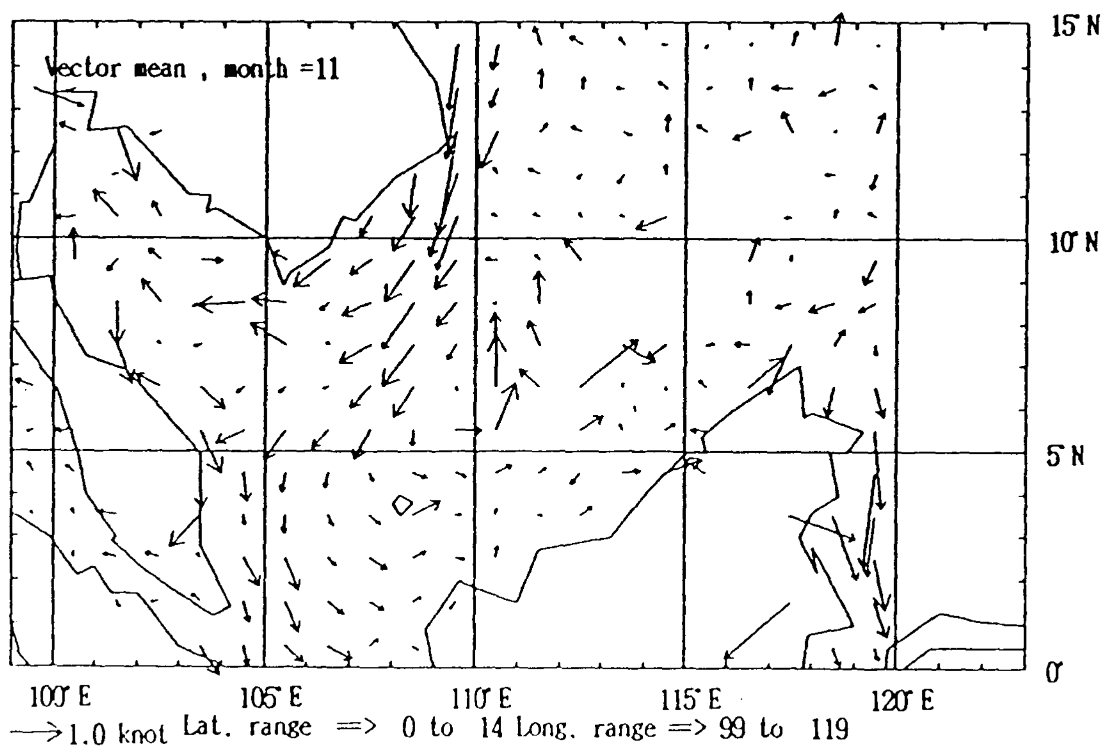

Fig. 2l. The monthly mean current vectors in November.

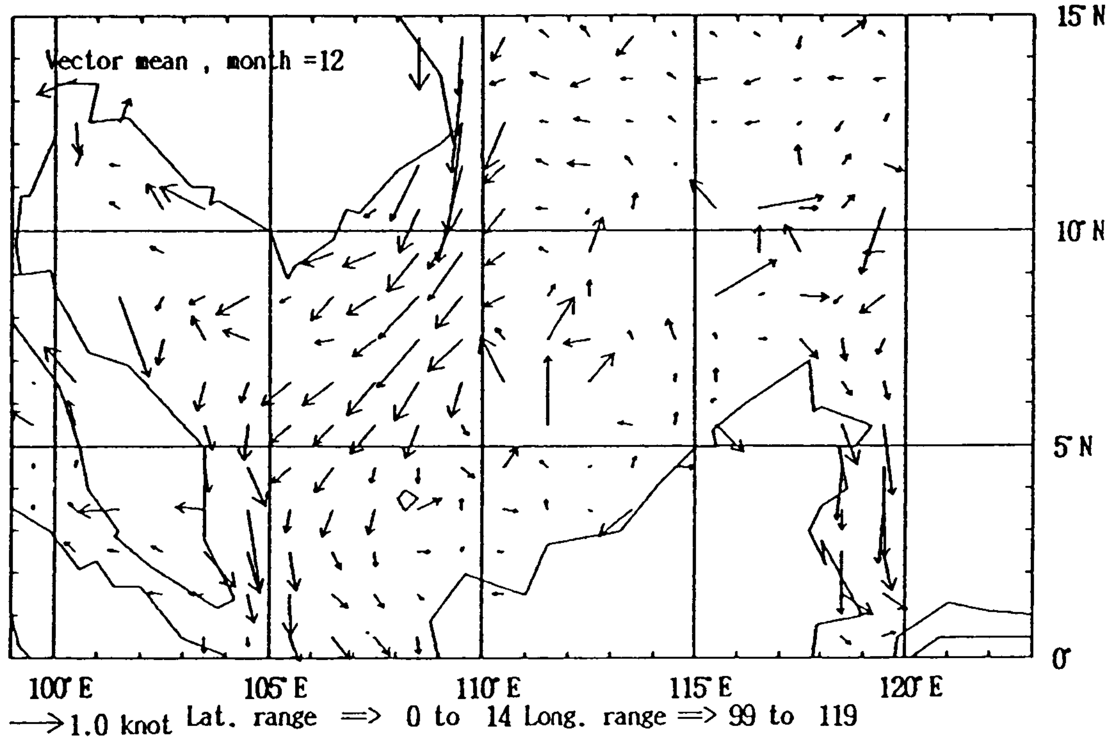

Fig. 2m. The monthly mean current vectors in December.

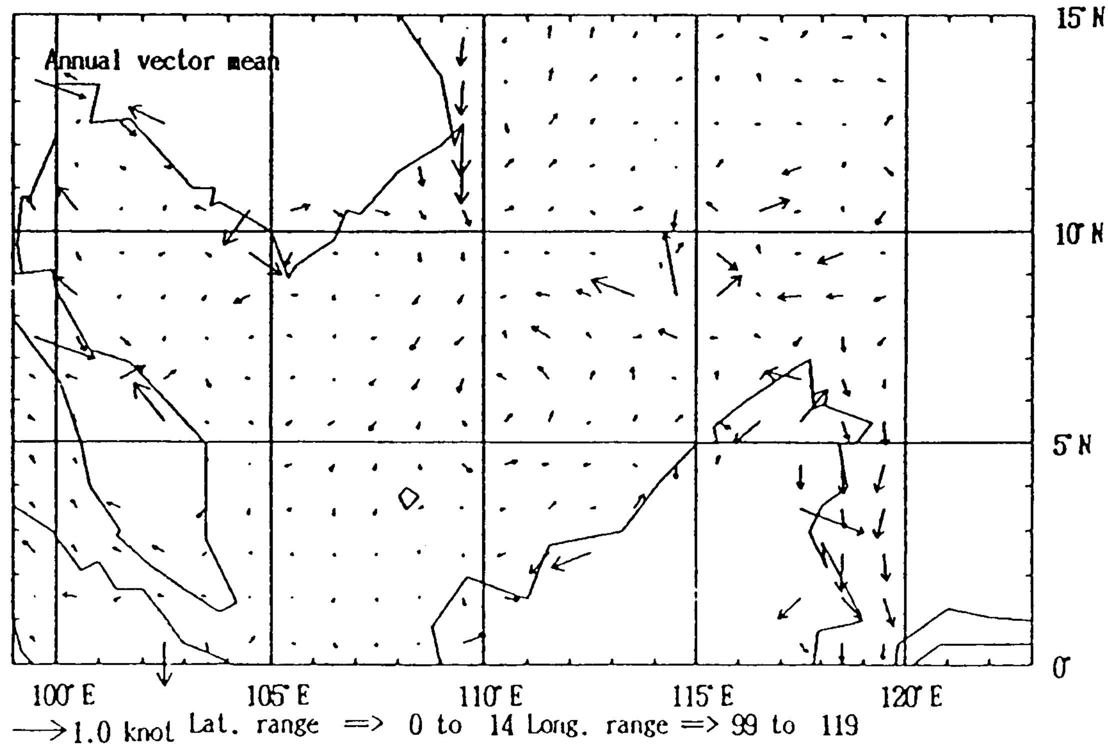

Fig. 2n. The annual mean current vectors.

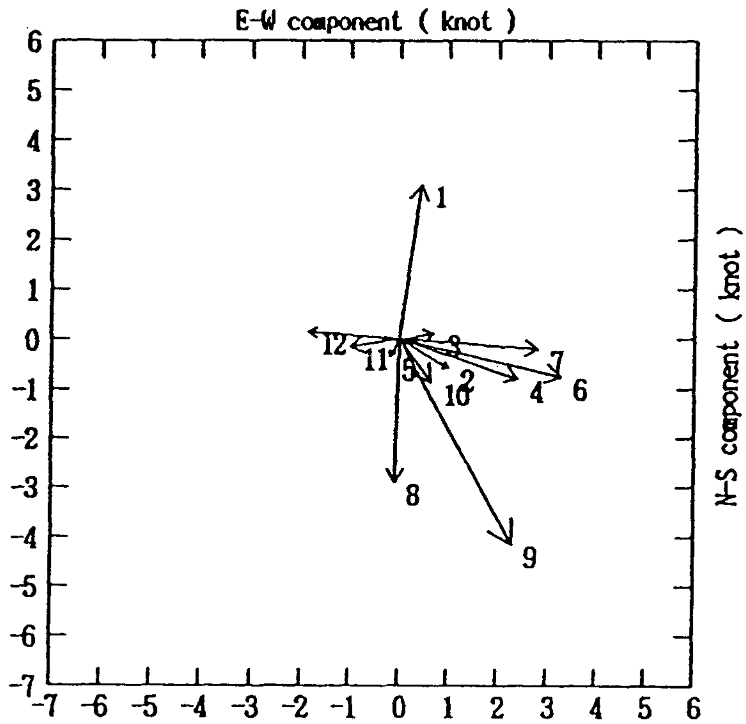

Fig. 3a. Monthly (1-12) variation of vectors at latitude 11°N, longitude 101°E.

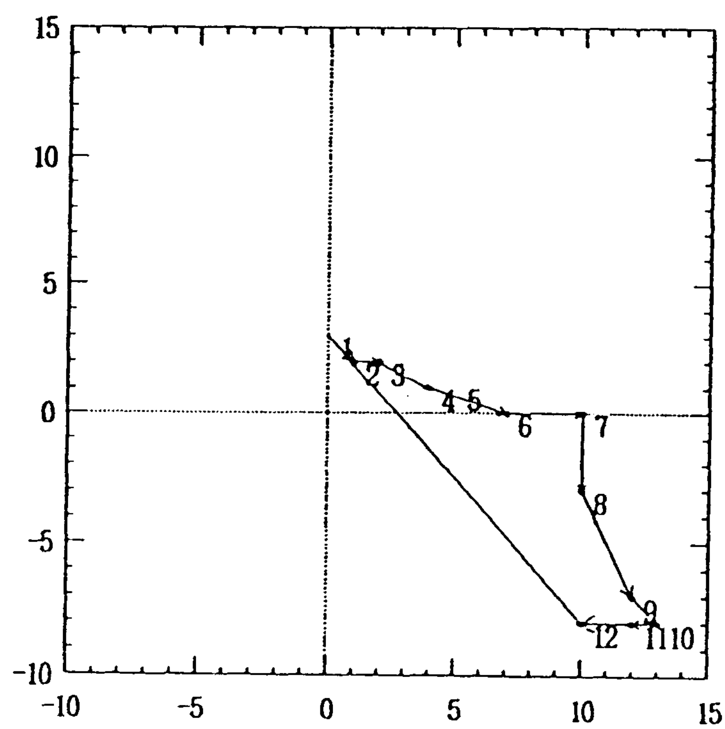

Fig. 3b. Annual progressive vectors at latitude 11°N and longitude 101°E.

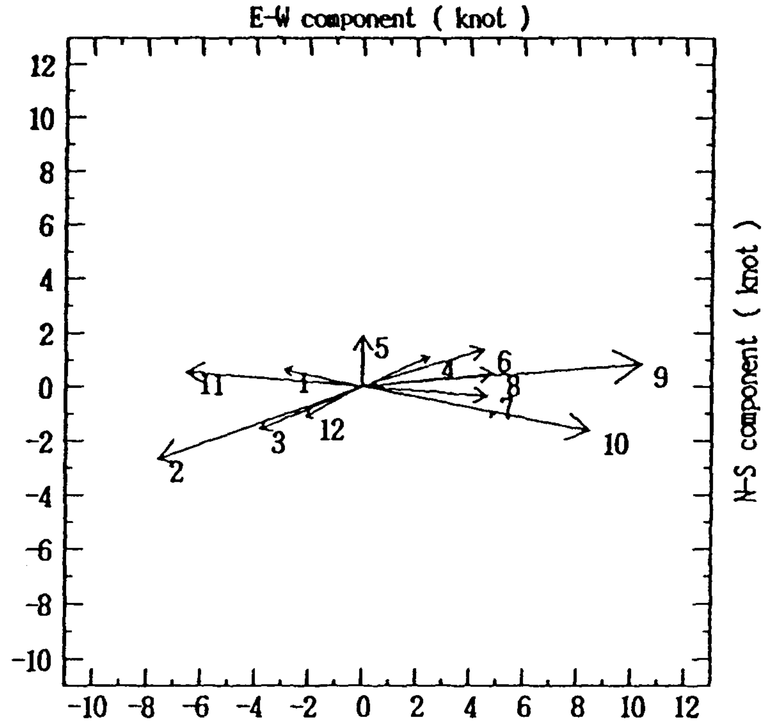

Fig. 4a. Monthly variation of vectors at latitude 8°N, longitude 105°E.

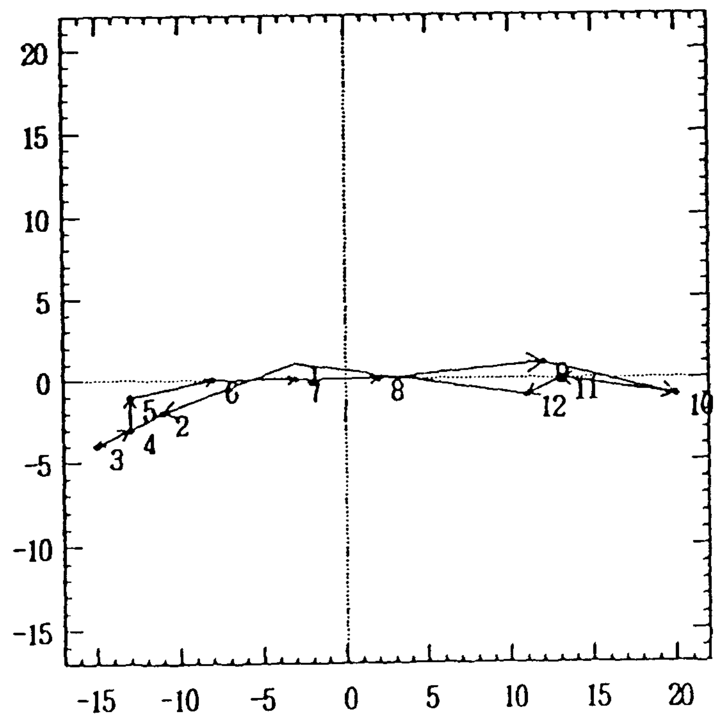

Fig. 4b. Annual progressive vectors at latitude 8°N and longitude 105°E.

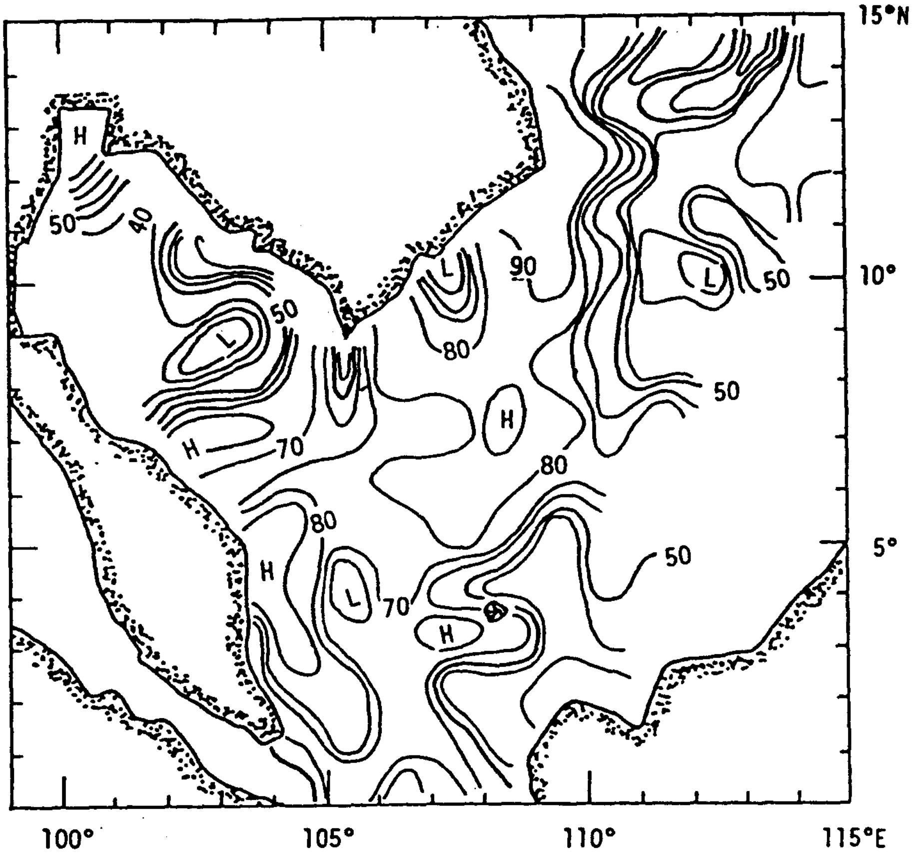

Fig. 5a. Stability of currents, December.

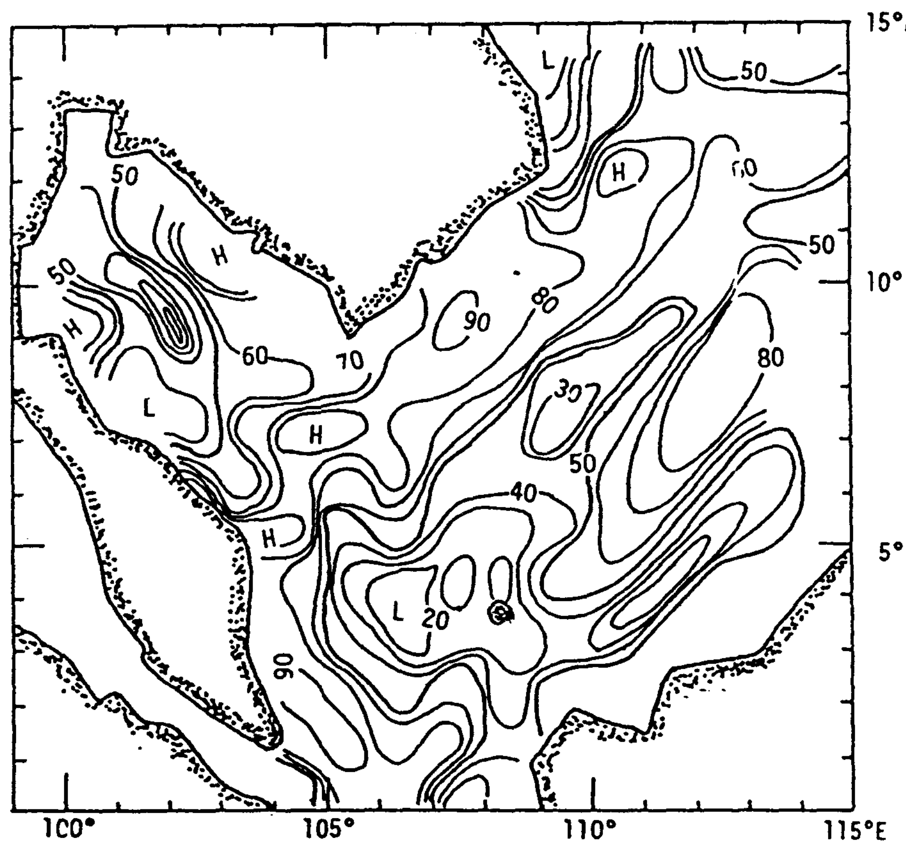

Fig. 5b. Stability of currents, July.

MUSSEL-WATCH TYPE PROGRAMME IN THAILAND (1980-1987)

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ABSTRACT

Since 1980, concern for marine food quality with respect to heavy metal, chlorinated hydrocarbon and bacterial contamination has intensified in Thailand. Several groups of scientists have periodically monitored these parameters in the coastal aquaculture areas. The Department of Marine Science concentrated on trace metals, the Department of Medical Science worked on chlorinated hydrocarbons and the Department of Microbiology focused on the microbiological aspects of the water and bivalves.

The bivalves studied for heavy metals were the following: cockles, Anadara granosa, short-necked clams, Paphia undulata, oysters, Crassostrea commercialis and C. lugubris, green mussels, Perna viridis, and moon scallops, Amusium pleuronectes. The metal levels of these bivalves for the Upper Gulf of Thailand and the Ban Don Bay in southern Thailand were within the safety limit for human consumption all through the year. From undetectable to very low levels of chlorinated hydrocarbons were found in bivalves and selected economically important fishes.

Concerning the microbiological quality of marine food, it was found that, during the low flow season, all bivalves passed the U.S. microbiological standard. On the other hand, up to 40% of oysters collected during the high flow season fell below the standards. There is as yet no microbiological standard for seafood in Thailand.

1. INTRODUCTION

Seafood is very popular in Thailand. Most people obtain their protein from marine fishes which are available widely and at low cost compared to other sources of protein. The Gulf of Thailand used to be abundant with fishes but recently, due largely to overexploitation and destructive methods of fishing, and partly to deteriorating coastal marine water quality, the production has decreased. However, increasing effort is being expended on upgrading mariculture methods. Seafood analysis shows that the quality with respect to pollutants like heavy metals and organochlorines poses no problem as the contents are still low, but precaution should be taken in eating raw seafoods as they are sometimes (during the high fresh water runoff season) contaminated with coliform bacteria and Vibrio parahaemolyticus (Saitanu et al. 1987).

2. HEAVY METALS

The first report on the accumulation of certain heavy metals in fish and shellfish from Thai coastal and inland waters was made by Huschenbeth and Harms in 1975. For the marine areas, they took samples from the Upper Gulf, Rayong Bay on the East Coast, and Phuket and Songkhla in southern Thailand. Their findings did not at all show any metal contamination of marine organisms.

Later on, beginning in 1981-1982 as a part of Thailand's participation in the global "Mussel Watch" programme, an investigation of selected metals in commercially popular bivalves was made. The organisms studied were the green mussel, Perna viridis, oysters, Crassostrea commercialis and C. lugubris, cockle, Anadara granosa, short-necked clam, Paphia undulata and moon scallop, Amusium pleuronectes. The results are shown in Table 1, and further work done in the South of Thailand (Hungspreugs et al. 1987) is presented in Table 2.

The area where most of these samples were taken was the Upper Gulf of Thailand where the coastline is fairly populated. However, on comparing the metal levels found with those from other areas of the world, they seemed comparable to the unpolluted localities. No evidence of metal pollution was suggested.

On comparing the concentrations of metals in green mussels (Hungspreugs and Yuangthong 1983) during different months of the year and applying statistical analysis to individual samples, it appeared that the difference between July and November for both Cr and Cu was real, i.e., the concentrations of both metals increased as salinity of the water decreased. This is in agreement with Huggett et al. (1975) who explained the increase as due to less competition by trace metals for absorption sites on the organisms when the concentrations of major divalent cations (mainly Mg and Ca) go down with decreasing salinity. Siriruttanachai (1980) found similar trends when he analyzed the metal contents of oysters in an oyster farm every month for a whole year. He found significant increases for all 5 metals - Cd, Cu, Pb, Zn and Mn - during the period September to November (rainy months).

Rojanapantip et al. (1987) reported on the 14-year work (1973-1986) done at the Department of Medical Science, Bangkok, on mercury levels in marine animals. A total of 1680 samples from 37 surveys of the Gulf of Thailand and the Andaman Sea were analyzed using the Flameless Atomic Absorption Spectrophotometer. An average level of 0.024 mg/kg (fresh weight) was found with only 4% of the samples containing mercury higher than 0.1 mg/kg.

Boonyashotmongkol et al. (1987) made intensive studies from 1982 to 1986 on the green mussel, Perna viridis, oyster, Crassostrea commercialis and cockles, Anadara granosa from the East and West Coast of the Upper Gulf of Thailand. Among the 272 samples from 54 monthly surveys, the average content of mercury was 0.017 mg/kg with the highest value of 0.193 mg/kg found in one lot of cockles at Ang Sila.

3. CHLORINATED HYDROCARBONS

Thoophom et al. (1987) also from the Department of Medical Science, monitored the pesticides and PCB's in bivalves (277 samples) and sea water (195 samples) from the same area for the same period (see above), and found residues of DDT, Dieldrin, BHC, Endrin and Lindane in some bivalve samples, all at less than 0.01 mg/kg. In the water samples, DDT residue was detected in 7% of those collected from the East Coast and Lindane found in 3% of the West Coast samples. No PCB was found in either bivalves or water.

In the South of Thailand (Lower Gulf of Thailand), Vongbuddhapitak and Atisook (1988) did not find any organochlorine or organophosphate residues in all 59 water samples from Ban Don Bay in March and August 1987 except for 2 coastal stations in August when Endrin was detected at 0.19 and 0.02 ug/l, respectively. For marine organisms, which included Crassostrea lugubris, Anadara granosa, Paphia undulata, several species of fish, Penaeus merguiensis and Loligo sp., DDT and dieldrin were found in some samples at below the 0.01 mg/kg level (Table 3).

Table 1 Levels of trace metals Cd, Cr, Cu, Pb and Zn in bivalves from the Gulf of Thailand

Species	Cd	Cr	Cu	Pb	Zn	Sources
Anadara granosa 1/	1.88-2.77	0.14	1.36-2.21	1.64-2.16	79.15-92.30	Hungspreugs and Yuangthong (1983)
A. granosa 1/	1.33-6.47	0.18-0.41	4.89-8.75	0.37-1.41	65.0-125.0	Phillips and Muttarasin (1985)
A. granosa 2/	0.28		5.6	0.18	16.2	Huschenbeth and Harms (1975)
A. granosa *1/	0.58±0.39	-	1.29±0.25	-	13.84±4	Nuchpramool et al. (1986)
A. granosa 1/	0.54-1.66	0.49-2.12	5.89-6.91	0.25-1.05	85.6-109.4	Hungspreugs et al. (1987)
Perna viridis 1/	0.09-2.51	0.07-1.60	0.66-17.92	0.19-3.80	58.27-285.7	Hungspreugs and Yuangthong (1983)
P. viridis 1/	0.41±0.25		8.50±2.4	0.73±0.51		Hungspreugs et al. (1984)
P. viridis 1/	0.88-6.84	0.28-1.12	9.38-15.63	0.31-1.53	61.11-76.47	Phillips and Muttarasin (1985)
P. viridis 1/	0.38		7.3	0.11	14.2	Huschenbeth and Harms (1975)
P. viridis *1/	1.34±1.22	-	1.80±0.35	-	14.59±2	Nuchpramool et al. (1986)
Crassostrea commercialis 1/	0.33-4.58	0.15-0.24	4.89-24.50	0.54-9.21	83.07-67.08	Hungspreugs and Yuangthong (1983)
C. commercialis 1/	2.05-3.82	0.27-0.59	100-180.9	0.20-0.53	571.4-1047.6	Phillips and Muttarasin (1985)
C. lugubris 1/	1.88-2.60	0.55-2.00	22.79-51.21	0.14-0.76	348.6-699.4	Hungspreugs et al. (1987)
Ostrea pliculata 1/	1.6±0.6		114±50	0.24±0.18		Hungspreugs et al. (1984)
Paphia undulata 1/	0.42		0.26			Hungspreugs and Yuangthong (1983)
P. undulata 1/	0.25-0.80	0.32-1.50	4.55-7.37	0.55-1.39	42.0-57.9	Phillips and Muttarasin (1985)
P. undulata *1/	0.23±0.14	-	1.59±0.30	-	9.78+4	Nuchpramool et al. (1986)
Amusium pleuronectes 1/	0.36-0.70 (white meat)		0.21-0.79			Hungspreugs and Yuangthong (1983)
A. pleuronectes 1/	0.58+0.38 (white meat)		3.0±1.8	0.01±0.01		Hungspreugs et al. (1984)

1/ ug g^{-1} dry weight
2/ ug g^{-1} wet weight
* The meat of these bivalves was washed in distilled water before the neutron activation analysis. The other workers used the samples as hucked out from shells.

Table 2. Levels of trace metals Cd, Cr, Cu, Pb and Zn in cockles, *Anadara granosa*, and oysters, *Crassostrea lugubris*, from the Lower Gulf of Thailand (ug/g).

	MARCH 1987		AUGUST 1987	
Metal	*Anadara granosa*	*Crassostrea lugubris*	*A. granosa*	*C. lugubris*
Cd	1.71 - 3.67	3.73 - 4.58	1.82 - 4.15	1.08 - 5.61
Cr	0.11 - 1.80	0.44 - 1.10	0.22 - 1.02	0.55 - 2.00
Cu	4.24 - 6.10	52.6 - 102.5	1.11 - 4.38	54.0 - 103.5
Pb	0.13 - 0.74	0.35 - 0.61	0.25 - 1.05	0.15 - 0.87
Zn	121.0 - 158.5	484 - 730	82.4 - 110.9	374 - 1059

Table 3. Chlorinated hydrocarbons in economically important marine organisms from the Lower Gulf of Thailand, in mg/kg fresh weight

	MARCH 1987		AUGUST 1987	
Species	DDT	Dieldrin	DDT	Dieldrin
Plotosus canius	<0.01-0.02	0.01		
Rastrelliger neglectus	<0.01	<0.01	n.d.	
Mugil spp.	n.d.	<0.01	0.01	<0.01
Loligo sp.	n.d.			
Sepioteuthis sp.	-	-	n.d.	<0.01
Penaeus merguiensis			<0.01	<0.01
Sciaena spp.	-	-	n.d.	n.d.
Auxis thazard	-	-	n.d.	n.d.
Nemipterus sp.			<0.01	0.01
Caranx sp.			n.d.	n.d.
Paphia undulata	n.d.			
Crassostrea lugubris	<0.01-0.01	0.01	<0.01	
Anadara granosa	n.d.-0.01	n.d.	n.d.	n.d.

4. PETROLEUM HYDROCARBONS

Thailand has taken part in the IGOSS Marine Pollution Monitoring (Petroleum) Programme (MAPMOPP) since 1976. Beach tar was monitored along the beaches in the Gulf of Thailand and the Andaman Sea coast during the period 1976-1980. Dissolved petroleum hydrocarbons were also investigated in relation to the dry and the wet seasons. In addition, a baseline study of petroleum-derived n-paraffins in sea water and sediments of the Upper Gulf and the Lower Gulf was made in 1977 (Hungspreugs and Switachart 1980) for both seasons.

No difference was found in the level of such parameters in water for the two periods studied. During May-June the range of C10 to C30 n-paraffins was 20.5-329 ug/l (mean value 110.9) while that of September to November was 23.4-428 ug/l (mean value 151.4). But near the Oil Refinery in Cholburi Province the mean value was 233.1 ug/l. For the sediments, the Upper Gulf area had a higher mean value of 3.7 ug/g during the dry season as compared to 2.9 ug/g for the wet season (on a wet weight basis). The mean value for the Lower Gulf was 1.2 ug/g. The Cholburi area showed a mean of 7.9 ug/g for both seasons.

In 1983, the dissolved petroleum hydrocarbons in sea water, sediments, and some fish and bivalves were measured using the spectrofluorimetric method with chrysene as a standard. The results are shown in Table 4 (Sompongchaiyakul et al. 1986).

Table 4. Petroleum hydrocarbons in the Gulf of Thailand, 1983.

In sea water (Upper Gulf)			
	April-May	0.380 - 5.646 ug/l	
	Mean	1.305 ± 1.724 ug/l	
	September-November	0.059 - 6.095 ug/l	
	Mean	0.782 ± 1.148 ug/l	
In the sediments			
	April-May	0.064 - 2.164 ug/g	(wet sediment extraction)
		0.047 - 1.820 ug/g	(dry sediment extraction)
	September-November	0.059 - 6.095 ug/g	(wet sediment extraction)
	Mean	0.096 ± 0.055 ug/g	
In tissues of marine organisms (analysis made on freeze-dried tissue)			
Fish	*Polynemus* sp.	0.117 ug/g (dry weight)	
	Cynoglossus sp.	0.598 ug/g	
	Parastramateus niger	0.415 ug/g	
Bivalves	*Paphia undulata*	0.462 ug/g	
	Perna viridis	0.059 ug/g	
	Anadara granosa	2.376 ug/g	

5. POLYCYCLIC AROMATIC HYDROCARBONS

Concentrations of polycyclic aromatic hydrocarbons (PAH's) were first measured in bivalves collected in the Upper Gulf of Thailand in 1982 (Hungspreugs et al. 1984). PAH's detected included acenaphthene, acenaphthylene, benzo[a]pyrene, fluoranthene, methylphenanthrene, phenanthrene and triphenylene. Benzo[a]pyrene was detected in all species at concentrations varying from 1.0 to 8.2 ng/g. High rates of degradation were observed when radio-labelled chlorobenzene, phenanthrene and chrysene were added to water and sediment of the Chao Phraya River. Rates were lower in the waters and sediment of the Gulf of Thailand. The calculated half-lives of chlorobenzene in the Gulf and the Chao Phraya River were about 130 and 68 days, respectively.

PAH's were detected in Ostrea plicatula, Perna viridis and Amusium pleuronectes. These filter-feeding bivalves are useful indicators of PAH levels in coastal waters. High PAH concentrations occur in bivalves from oil-polluted harbours (Lee et al. 1981). The PAH's present in bivalves indicate the presence of low levels of these compounds in water of the Upper Gulf of Thailand.

6. MICROBIOLOGICAL QUALITY OF SEAFOOD

Due to comparatively high loads of organic waste released to the coastal water of the Upper Gulf of Thailand, bacterial growth is favoured. Although some papers reported high coliform numbers in oysters during the high flow season (low salinity coastal water), these levels decreased as salinity increased.

Coliform bacteria were widespread on both sides of the Upper Gulf with the highest density near the mouth of the Chao Phraya (Saitanu et al. 1987). In the sea water of the East Coast, minimum MPN in water was 2 and the maximum was 1,600 per 100 ml. A minimum of 4 and a maximum of 90 MPN/g were noted in the sediment. In the farming area near Bang Pakong River mouth, cockles, Anadara granosa, were more contaminated (flood season: 697 MPN/100 ml) than the oysters, Crassostrea commercialis (7 MPN/100 ml in the dry season and 176 MPN/100 ml for the flood season) or green mussels, Perna viridis (20 MPN/100 ml for the flood season) (Saitanu et al. 1987). The East Coast was more polluted than the West Coast.

7. CONCLUSION

From this review it can be seen that the quality of marine food from the Gulf of Thailand is, in general, acceptable. However, care should be taken when eating raw oysters during the low salinity season due to bacterial contamination. The situation is improving fast as by now most oyster farmers are increasingly applying the depuration process to their live oysters before marketing them.

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RED TIDES AND OTHER FISH KILLS IN PHILIPPINE WATERS

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1. INTRODUCTION

The Philippine Archipelago includes bodies of water such as coves and semi-enclosed bays which serve as "cul de sacs" where the movement of coastal water is much reduced. This condition prevents water exchange (flushing) and therefore enhances the enrichment of such waters, conducive to the growth of certain dinoflagellates if and when environmental factors are favourable. Maqueda Bay, Samar Sea, Mati Bay, Villareal Bay, Carigara Bay, Lagonoy Gulf, Manila Bay, San Miguel Bay, Sorsogon Bay, Ragay Gulf, some coastal areas of the Zambales coast with small coves, Tinagong Dagat, Sapian Bay, Sogod Bay and Panguil Bay (Fig. 1) are examples of such areas especially if they are shallow and are continually polluted by domestic, industrial, agricultural and maricultural waste.

The commonly occurring "fish kills" in marine coastal waters are usually caused by such dinoflagellate populations which produce a phenomenon known as "red tide".

2. RED TIDE OCCURRENCES IN THE PHILIPPINES

The red tide which occurred in the summers of 1983, 1987 and 1988 in the Samar Sea and from December 1988 to January 1989 in Carigara Bay, Leyte were related to the above mentioned conditions. In June 1983, some 23 people died there and elsewhere (e.g., Pampanga, Sorsogon, Masbate and Manila), due allegedly to ingestion of infested shellfish, mostly mussels (Perna viridis), harvested from Maqueda Bay and Villareal Bay. The 1983, 1987 and 1988 occurrences of red tide in the country were brought about by a dinoflagellate (Pyrodinium bahamense var. compressa) (Fig. 2) which produces a lethal neurotoxin responsible for paralytic shellfish poisoning (PSP). This species is behind fish kills in other parts of the world such as Papua New Guinea, Palau, Sabah, and Brunei Darussalam, especially in semi-enclosed bays. It is carried by the global water currents and may have been brought to our shores from Palau and/or Papua New Guinea.

Mati Bay, Davao Oriental was infected in the early 1980s. Lately, in 1988, the infestation was reported in Manila Bay, Zambales and elsewhere. Our studies in Maqueda Bay are related below.

In 1973, the Research Division of the Bureau of Fisheries and Aquatic Resources (BFAR) established a special project on mussel culture in Jiabong, Western Samar in Maqueda Bay. This development programme was undertaken with the Department of Agriculture (Special Funds) under the author's supervision. Of the several areas selected, the Jiabong Farm was the most successful for such culture.

+Deceased.

In about six years, the project was accepted by the people and it became an industry worth 100 million pesos by the end of 1970. However, we noted that mussel farmers were setting the bamboo poles (for the animals to attach and grow) very close to each other (32 cm) instead of the recommended one metre distance. This gave greater quantities of mussel harvest but led to rapid sedimentation and eutrophication of the area.

The growth of the red tide alga is enhanced by the addition of nutrients. When the "El Niño" phenomenon occurred as in 1983 and again in 1987 with extended summer months, late rains at the onset of the rainy season (June) brought a lot of runoff carrying nutrients from land. Such fertilization served as a trigger mechanism and the red tide organisms multiplied profusely.

Mollusc and fish poisoning may constitute an increasing problem in the future as has happened in 1988 in Manila Bay. In view of the toxin's potency it is best to prevent the ingestion of mussels and oysters during infestation. An individual may be attacked and killed within one half hour after ingestion of the infected mussels.

Cases of mollusc and fish poisoning deserve more attention from ecologists and biochemists. Governments should provide for research along this line so that scientists may ultimately be able to predict and perhaps control the occurrence of red tides.

3. OTHER CAUSES OF FISH KILLS

There are other incidents of fish kills by non-toxic dinoflagellates. For example, in July 1987, after a long summer and very strong rains for a few days, the water in Cañacao Bay near Bacoor Bay in Cavite City became red. Fish and invertebrates surfaced for lack of oxygen and all aquatic life died. These included groupers being grown in cages, as well as shrimps, crabs and mussels.

Investigations demonstrated the absence of oxygen in the water column, and showed that the bloom of another dinoflagellate, Noctiluca, caused the fish kill. This bioluminescent organism is well known in Manila Bay. However, the fish kills usually occur when extra nutrients from land are carried to the coastal waters after the start of the rainy season.

Such fish kills in Manila Bay (the Cavite side) are well known phenomena in the locality which may occur from June to September yearly, and are known as luno and tingkayad in the local dialect. Fish and shrimps are observed to die because of the absence of dissolved oxygen in the sea water. They can be seen gasping for air at the water surface.

4. CAUSES OF POLLUTION

A possible cause of pollution of the Parañaque-Cavite coastal area is the clockwise movement of heavily polluted water from Pasig River which flows southward while the strong southwest monsoon winds blow continuously towards the bay. During the summer months, there is a continuous incoming water current through the mouth of Manila Bay. This prevents the accumulation of polluted water in the Parañaque area because of the flushing effect, as the water moves counter-clockwise towards the Bulacan area. This is minimized by the southwest monsoon winds which start in May and last until October, when some heavily polluted water may move clockwise and affect Bacoor Bay.

The red tide which occurred last June 1988 in Bacoor Bay was a massive one and lasted for a few days. People stopped eating fish, crabs, mussels and oysters as these animals were also affected and killed by asphyxiation due to lack of oxygen in the water.

Fish kills may also be caused by the heavily polluted waters in shallower areas of Manila Bay, where the Pampanga River, Meycauayan River and Pasig River empty. The heavily polluted water (with a high B.O.D.) flows to the coastal areas especially after the summer months, following the heavy downpours of the rainy season.

These fish kills are sporadic cases which are brought about simply by the absence of dissolved oxygen due to the polluted condition of the water. In addition, sustenance fishermen living along the banks of Bigaa and Bulacan Rivers experience fish kills where large electro-chemical corporations have been discharging toxic chemical effluents. Many similar industrial plants exist in different parts of the country.

In the Philippines, 15 active mining firms generate more than 200,000 tons of mine tailings daily and some discharge this load into different rivers and creeks. The main pollutants are silt, and traces of chemicals and minerals such as cyanide, lead, cadmium, mercury, acids, alkalis, and salts which are used in the extraction of the precious ores. More studies on heavy metals in water discharged from these plants are needed before it is too late.

A most important problem that is associated with the effects of pollutants on aquatic life in estuarine areas is the impairment of the reproductive capacity of many freshwater and marine fish species due to accumulation of insecticides and heavy metals in their bodies. If and when this happens, then, there is the danger of cessation of the spawning activities of mullet, milkfish, and other estuarine fishes which certainly would affect the fisheries of the country.

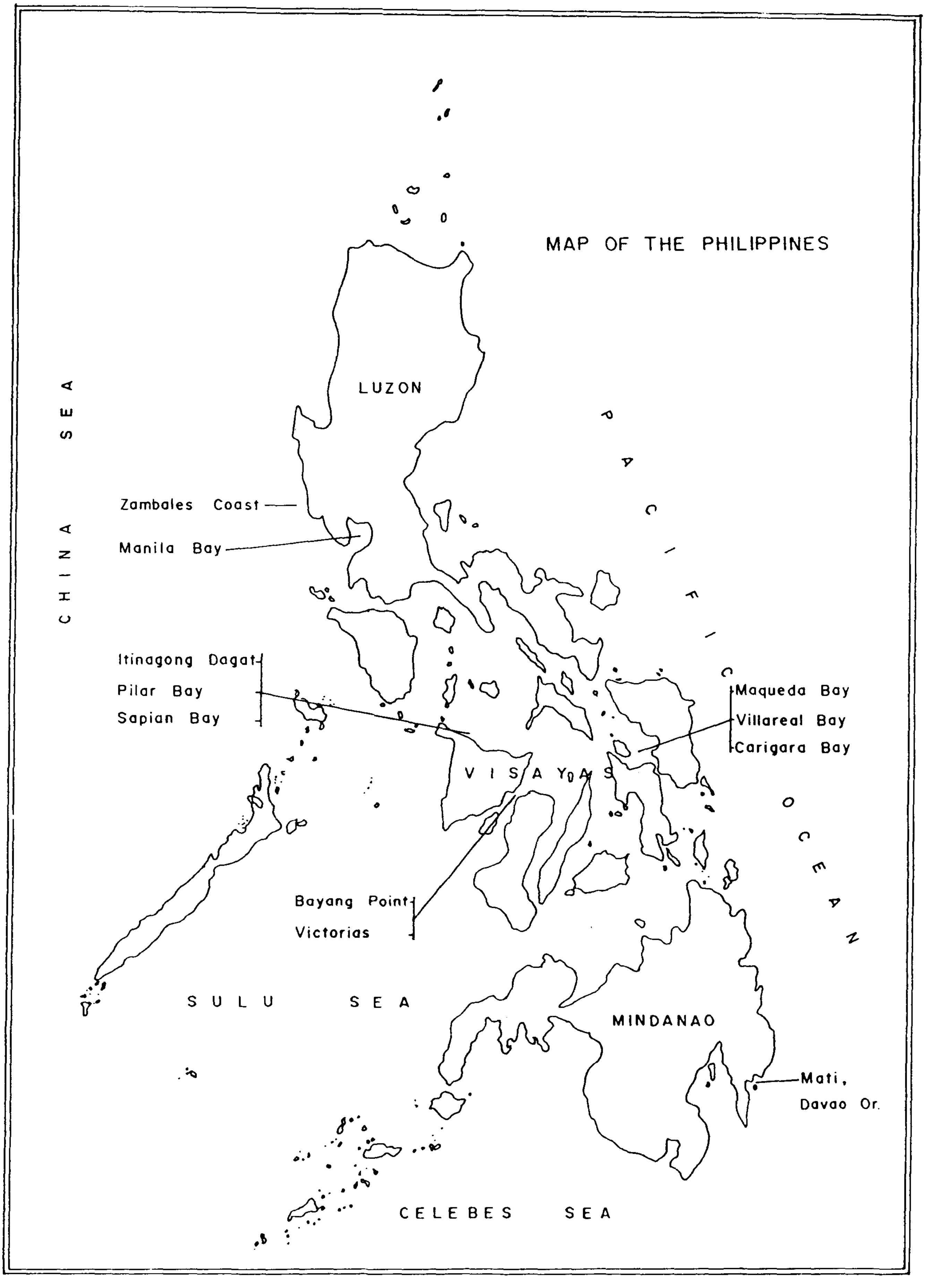

Fig. 1. Some areas of the Philippines where red tides have been reported from 1963 to 1989.

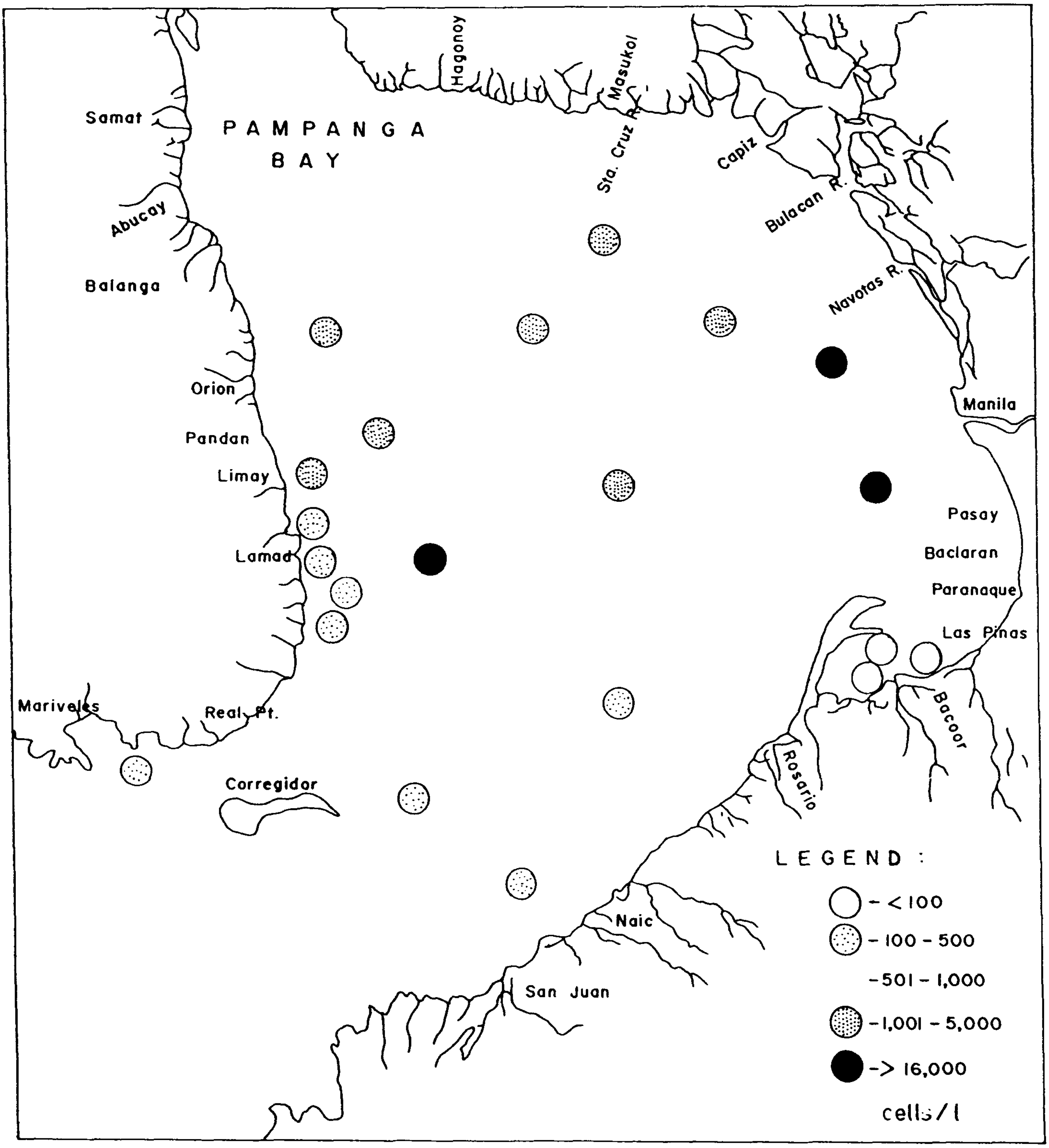

Fig. 2. Density of Pyrodinium bahamense var compressa in Manila Bay on September 1-7, 1988.

STUDIES ON POPULATION DYNAMICS OF PHYTOPLANKTON AND ZOOPLANKTON IN CONNECTION WITH THE EASTERN SEABOARD DEVELOPMENT PROJECT

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ABSTRACT

The Eastern Seaboard Development Project is one of the main development projects of the Fifth Five-Year National Economic and Social Development Plan of the Government of Thailand (1982-1986). In connection with this ESD Programme, research projects on environmental problems including coastal water quality, water pollution, sewage effluents, coastal ecosystems and population dynamics of fauna and flora are being undertaken.

Population dynamics studies on phytoplankton and zooplankton in the Laem Chabang and Map Ta Phut coastal areas during the period 1986-87 revealed the existence of at least fifty-four genera of phytoplankton. Those mostly found in abundance were Chaetoceros, Bacteriastrum, Rhizosolenia, Nitzschia and Thalassiothrix. Maximum and minimum densities of phytoplankton were noted in September and March, respectively.

A study on zooplankton revealed that there were five dominant groups of zooplankton: protozoans, copepods, gastropods, nauplii and cladocerans. Maximum and minimum densities of zooplankton were observed in May and November, respectively.

1. INTRODUCTION

The development of the Eastern Seaboard (ESB) is a major element of the Fifth Five-Year National Economic and Social Development Plan (1982-1986). Government policy recognizes the importance of the Eastern Seaboard and has established three major national objectives to which the development of the subregion should contribute (Hofer 1984). They are:

1. Changing Thailand's industrial structure by introducing heavy industries based on gas and minerals and encouraging manufacture for export at port sites;
2. Decentralizing growth away from the capital; and
3. Improving markets for products of rural regions, particularly in the northeast, by providing alternative routes for exports and encouraging agro-industries.

Thailand will probably face various environmental problems in the ESB area within the next decade. These will include coastal pollution, detrimental effects on fisheries, coral communities, mangrove forests and beaches, tourism and oil spills. The ESB development activities are concerned directly with industrial plants, oil refineries and oil transportation. Therefore, an adequate plan is needed for environmental protection and prevention of oil spills.

This research work focuses on the population dynamics of phytoplankton and zooplankton along the eastern coast, especially at the Laem Chabang and Map Ta Phut areas which are the sites of deep-sea ports and industrial plants. It is expected that, from the results of this study, useful environmental indicators may be identified.

2. MATERIALS AND METHODS

Laem Chabang is a small town located on the eastern coast of the Gulf of Thailand, approximately 140 km from Bangkok. It is an appropriate setting for a deep-sea port. Along with the latter, there will be many activities including various kinds of industries: electrical/electronic products, mechanical equipment, agricultural products and equipment, rubber and para-wood products, medical and scientific equipment and products, etc.

Collection was done along two transects: one was 1,500 m away from the shoreline, while the other was 3,000 m distant. There were a total of 8 collecting stations, 4 on each transect. The distance from station to station was 2,000 m (Fig. 1). Sampling was carried out once a month, starting in February 1986 and ending in January 1987.

The method of collection used is as described in the Unesco report (1974). At each station a plankton net (mesh size 70-90 um) was used to pull up samples vertically from the bottom of the sea to the surface. Both phytoplankton and zooplankton were preserved in bottles containing 4% formalin. Counting and identification of plankton also followed the method recommended by Unesco (1968).

3. RESULTS

The survey yielded 8 orders, 24 families, and 56 genera of phytoplankton, and a number of 18 groups of zooplankton in 8 phyla (Tables 1 and 2). The quality of water where the samples were collected was also tested once a month. The results are shown in Table 3.

Table 1. Phytoplankton found at Laem Chabang, Chon Buri Province during the period February 1986 - January 1987.

Phylum	Class	Order	Family	Genus
Chrysophyta	Bacillariophyceae	Centrales	Coscinodiscaceae	6
			Leptocylindraceae	2
			Skeletonemaceae	2
			Thalassiosiraceae	4
			Corethronaceae	1
			Rhizosoleniaceae	1
			Bacteriastraceae	1
			Chaetoceraceae	1
			Biddulphiaceae	5
			Eucampiaceae	2
		Pennales	Fragilariaceae	3
			Tabellariaceae	1
			Naviculaceae	6
			Nitzschiaceae	1
			Surirellaceae	2
Cyanophyta	Cyanophyceae	Oscillatoriales	Oscillatoriaceae	2
		Chroococcales	Chroococcaceae	1
Protozoa	Mastigophora	Chrysomanadina	Dictyochaceae	1
		Dinoflagellata	Prorocentridae	1
			Peridiniidae	7
	Ciliata	Peritricha	Vorticellidae	1
		Holotricha	Codonellidae	1
			Ptychocylidae	1
			Tintinnidae	1
Total				54

Table 2. Zooplankton found at Laem Chabang, Chon Buri Province during the period February 1986 - January 1987.

Phylum	Groups
Protozoa	Foraminifera
	Tintinnida
Coelenterata	Actinula larvae
	Obelia sp.
	Arachnactis larvae
	Scyphomedusae
Annelida	Annelid larvae
	Polynoidae
	Nereis larvae
	Polynoid larvae
Chaetognatha	Chaetognaths
Mollusca	Gastropoda
	Bivalves
Arthropoda	Cladocera
	Ostracods
	Copepods
	Cirriped larvae
	Stomatopod larvae
	Mysidacea
	Euphausiacea
	Decapod larvae
	Nauplii
	Lucifer sp.
Echinodermata	Bipinnaria larvae
	Auricularia larvae
	Ophiopluteus larvae
	Echinopluteus larvae
Chordata	Appendicularians
	Amphioxus
	Fish larvae

Table 3. Sea-water parameters measured at Laem Chabang, Chon Buri Province during the period February 1986 - January 1987.

Month	Year	Temperature (^oC)	pH	Salinity ($x10^3$)	Dissolved Oxygen (mg/l)	Nitrate (ug-at l^{-1})	Phosphate (ug-at l^{-1})
February	1986	28.8	9.34	33.8	5.26	0.02	0.21
March	1986	28.7	8.53	33.2	6.58	0.01	0.26
April	1986	30.7	8.66	34.2	5.03	0.27	0.33
May	1986	30.5	8.57	32.6	5.55	0.16	0.64
June	1986	31.1	9.20	32.2	6.67	0.19	0.20
July	1986	29.8	8.38	30.2	4.86	0.21	0.39
August	1986	29.5	8.26	28.6	7.12	0.05	0.23
September	1986	30.0	8.51	32.2	6.94	0.02	0.08
October	1986	29.7	8.35	33.1	6.21	0.10	0.13
November	1986	29.0	8.51	31.9	6.37	0.02	0.41
December	1986	26.5	8.79	35.8	6.62	0.03	0.32
January	1987	25.5	8.94	35.9	6.49	0.16	0.15

The dominant genera of phytoplankton which were found all year round were Chaetoceros, Rhizosolenia, Trichodesmium, Nitzschia, Thalassiothrix and Bacteriastrum. The numbers of cells per litre were 39645.76, 2437.78, 556.43, 1382.86, 2644.21 and 9029.46, respectively (Table 4).

Table 4. Average annual, maximum and minimum densities (cells/l) of phytoplankton (February 1986 - January 1987).

	$\bar{X}$	Max	Min
Chaetoceros	39,645.76	140,630.00	0.00
Rhizosolenia	2,437.78	12,600.00	0.76
Trichodesmium	556.43	2,779.92	8.13
Nitzschia	1,382.86	9,430.00	1.36
Bacteriastrum	9,020.46	12,325.00	0.00
Ceratium	81.54	196.70	1.80
Noctiluca	17.25	112.28	0.00
Navicula	29.52	75.60	0.47
Coscinodiscus	258.58	2,097.80	2.37
Richelia	308.53	904.40	0.00
Thalassiothrix	2,644.21	17,630.00	2.46
Thalassionema	699.96	5,664.40	0.00
Pleurosigma	80.07	290.20	0.00
Guinardia	53.57	272.50	0.00
Climacodium	39.21	142.10	0.00
Skeletonema	180.17	2,095.10	0.00
Biddulphia	69.20	369.00	0.00
Lauderia	125.66	1,063.95	0.00
Thalassiosira	33.23	272.00	0.00
Dinophysis	8.82	41.00	0.00
Pyrophacus	0.87	5.60	0.00
Peridinium	10.18	57.40	0.00
Zoothanium	0.74	6.40	0.00

The highest density of phytoplankton occurred in the month of September (Fig.2). The average was 242,740 cells/l. The lowest density of phytoplankton was in March, with a mean of 187 cells/l. The genera which were found most abundant in September and March were Chaetoceros and Trichodesmium, the proportions of which were as high as 58.13% and 85.38%, respectively (Table 5).

The most dominant group of zooplankton which were found all year round were the copepods, with an average density of 57,522.46 m^{-3} (Table 6). The highest densities occurred in the months of March and September, with values of 82,028.91 and 78,137.20 m^{-3}, respectively. The month with the lowest number of copepods was November with an average of 73,600.07 m^{-3}.

The annual average density of gastropods was 5,576.78 m^{-3}, with the highest and lowest peaks at 30,688.70 and 865.46 m^{-3}, respectively.

Nauplii, mostly copepod nauplii, had an annual average density of 9,602.40 m^{-3} and tended to increase in September. The month when the fewest nauplii were found was April, with an average of 1,524.81 m^{-3}.

Another group of zooplankton found in abundance were the cladocerans. The annual average density was 5,128.92 m^{-3}. The highest numbers were found in April and May, with mean values of 11,640.18 and 12,081.39 m^{-3}, respectively.

Table 5. Densities and percentages of dominant phytoplankton genera found during the period February 1986 - January 1987 at Laem Chabang, Chon Buri.

Month	Year	Density (cell/l)	Dominant genera	Percent
September	1986	242,740	Chaetoceros	58.13
August	1986	134,220	Chaetoceros	94.75
October	1986	127,200	Chaetoceros	81.42
December	1986	56,290	Chaetoceros	52.25
June	1986	41,110	Chaetoceros	79.40
January	1987	38,040	Chaetoceros	45.62
May	1986	23,240	Chaetoceros	81.48
November	1986	22,370	Rhizosolenia	55.97
April	1986	4,350	Chaetoceros	40.80
July	1986	3,500	Trichodesmium	82.44
February	1986	2,480	Rhizosolenia	65.20
March	1986	187	Trichodesmium	85.38

Table 6. The highest, lowest and annual average densities of zooplankton (organisms m^{-3}) during the period 1986 - 1987.

Zooplankton	Density (cells m^{-3}) Highest	Lowest	Annual Average
Protozoans	18,398.15	349.02	2,745.30
Coelenterates	308.44	29.47	131.11
Annelids	5,211.30	1,139.43	2,654.01
Gastropods	30,688.70	865.46	5,576.78
Bivalves	10,736.72	768.17	3,738.56
Cladocerans	12,081.39	544.41	5,128.92
Ostracods	1,003.99	63.65	248.13
Copepods	82,028.91	37,600.07	57,522.46
Cirripedia	3,405.18	196.60	876.10
Nauplii	30,043.73	1,542.81	9,602.40
Euphausiaceans	589.35	44.20	245.79
<u>Lucifer</u> sp.	1,619.21	65.24	360.77
Decapods	757.31	0.0	125.86
Chaetognaths	5,846.31	542.61	1,698.74
Echinoderms	3,516.68	39.29	884.86
Appendicularians	8,118.54	1,407.59	3,851.78
Amphioxus	485.41	0.0	92.03
Fish larvae	508.95	35.36	188.72

Chaetognaths were densest in September (mean of 5,846.31 m^{-3}) and decreased gradually to their lowest numbers in March with an average of 627.21 m^{-3}.

Amphioxus larvae were found only during the period of February to May, and the greatest abundance was in April and May with mean values of 433.27 and 485.41 m^{-3}, respectively. The lowest levels were in March with an average of 23.57 m^{-3}.

The annual average density of fish larvae was 188.72 m^{-3}. These were found in abundance during the months of August to January. The peaks occurred in the months of August and December, with averages of 508.95 and 421.38 m^{-3}, respectively.

The zooplankton covered in this study fell under 8 broad groups. These were the annelids, molluscs, copepods, other crustaceans, echinoderms, other zooplankton, lesser deuterostomes and fish larvae (as well as, to a lesser extent, appendicularians, amphioxus and chaetognaths) (Fig. 3).

As mentioned above, copepods were the most dominant, comprising approximately 41.88-79.98% of the total. Although echinoderms were found all year round, they were small in number (0.06-2.06%) when compared with other groups (Fig. 4).

The zooplankton could be divided into 3 groups: natural food, economically important species, and environmental indicators (Fig. 5).

4. DISCUSSION

The data presented here are the preliminary results of a long term and continuous study. The latter may be extended through the Sixth and/or Seventh Five-Year National Economic and Social Development Plan (1987-1991, 1991-1996). The results so far show that the dominant species found in the study are almost the same species as reported by Bhovichitra and Manowejbhan (1984), except for only one, Coscinodiscus sp., which was not found in this survey. However, the annual fluctuations were different.

The study in 1982 showed that the average highest and lowest densities of phytoplankton occurred in the months of October and July while in this study they took place in the months of September and March, respectively. This might be due to the fact that seasonal changes from year to year are different. Boonyapiwat (1984) found 58 genera and 166 species of phytoplankton in the Chao Phraya River Estuary. The greatest phytoplankton density occurred in December at the mouth of the river with the highest cell count of 38 x 10^6 cells/l dominated by Chaetoceros sp.

Two groups of zooplankton, copepods and chaetognaths, were found in abundance during summer (March-May) and the rainy season (June-October). The results mentioned above are similar to those from the previous work of Sudara and Udomkij (1984).

All groups of animals were found all year round. This would be an indication that the physical and chemical components of sea water were not critically changed. The results presented here are similar to those reported by Kowsivikul (1982).

The phytoplankton peaked in the period of July to November while the zooplankton maximum occurred during the interval February to June. Tamiyavanich (1984) reported a significant correlation between zooplankton and phytoplankton abundance.

Taylor and Stephens (1980) indicated significant correlations between variability of the plankton and fisheries of the North Sea, as well as sea-surface temperature and salinity. Robinson and Hunt (1986) stated that it was useful to separate the correlations between the entities in the matrix into different categories. In the plankton there were positive correlations at the 10% level or greater between the zooplankton and both phytoplankton pigments and total copepods.

The year-to-year fluctuation in abundance was observed from 1958 to 1983 and involved 16 species of phytoplankton and 20 species of zooplankton which are usually numerous at some period of the year (Robinson and Hunt 1986). Boalch and Harbour (1981) stated that the mean number of species did not vary greatly in either group between about September and April, but in summer the number of diatom species was lower whereas the number of dinoflagellates was higher.

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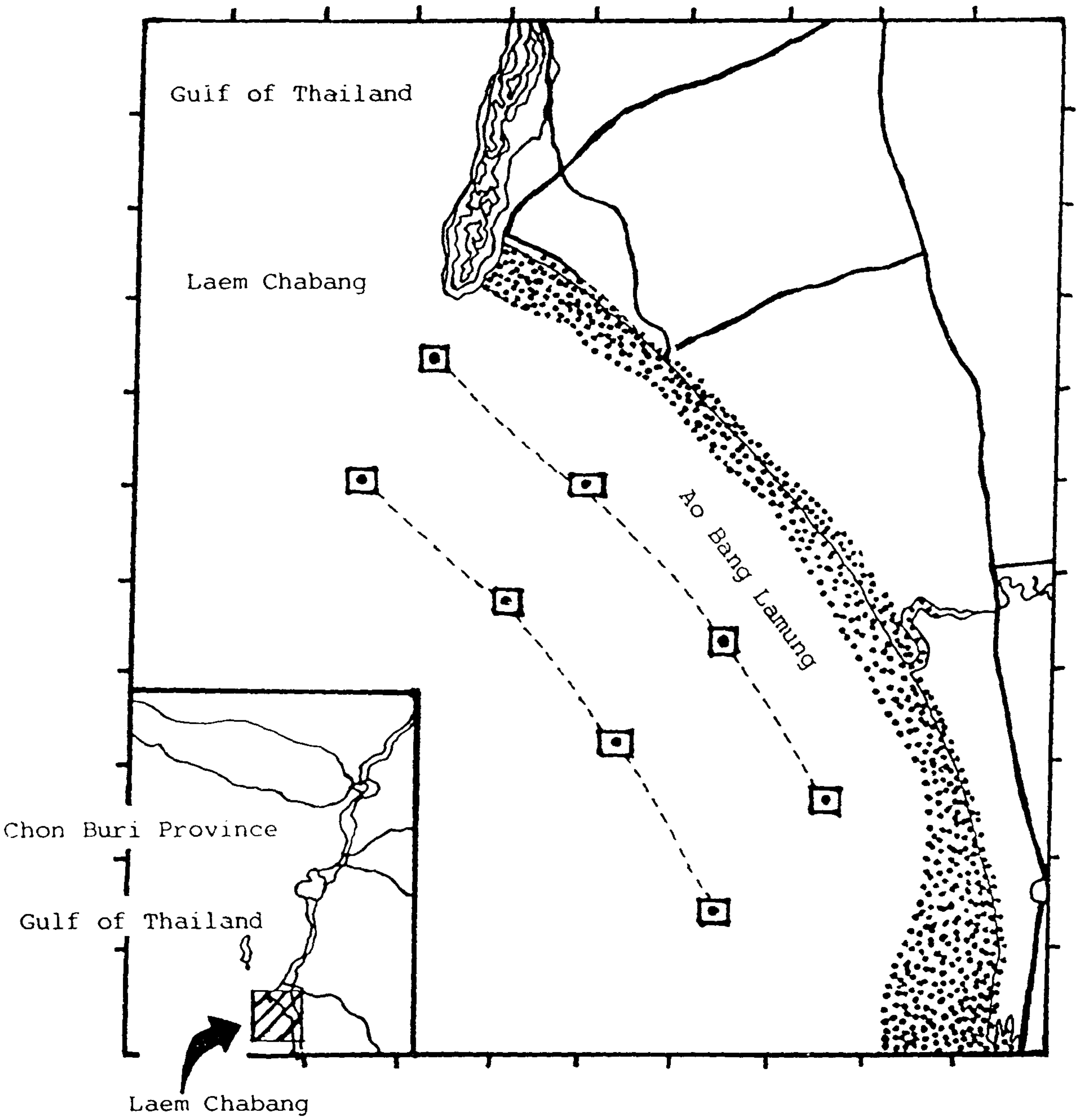

Fig. 1. Collecting stations [•] of phytoplankton and zooplankton at the Laem Chabang area.

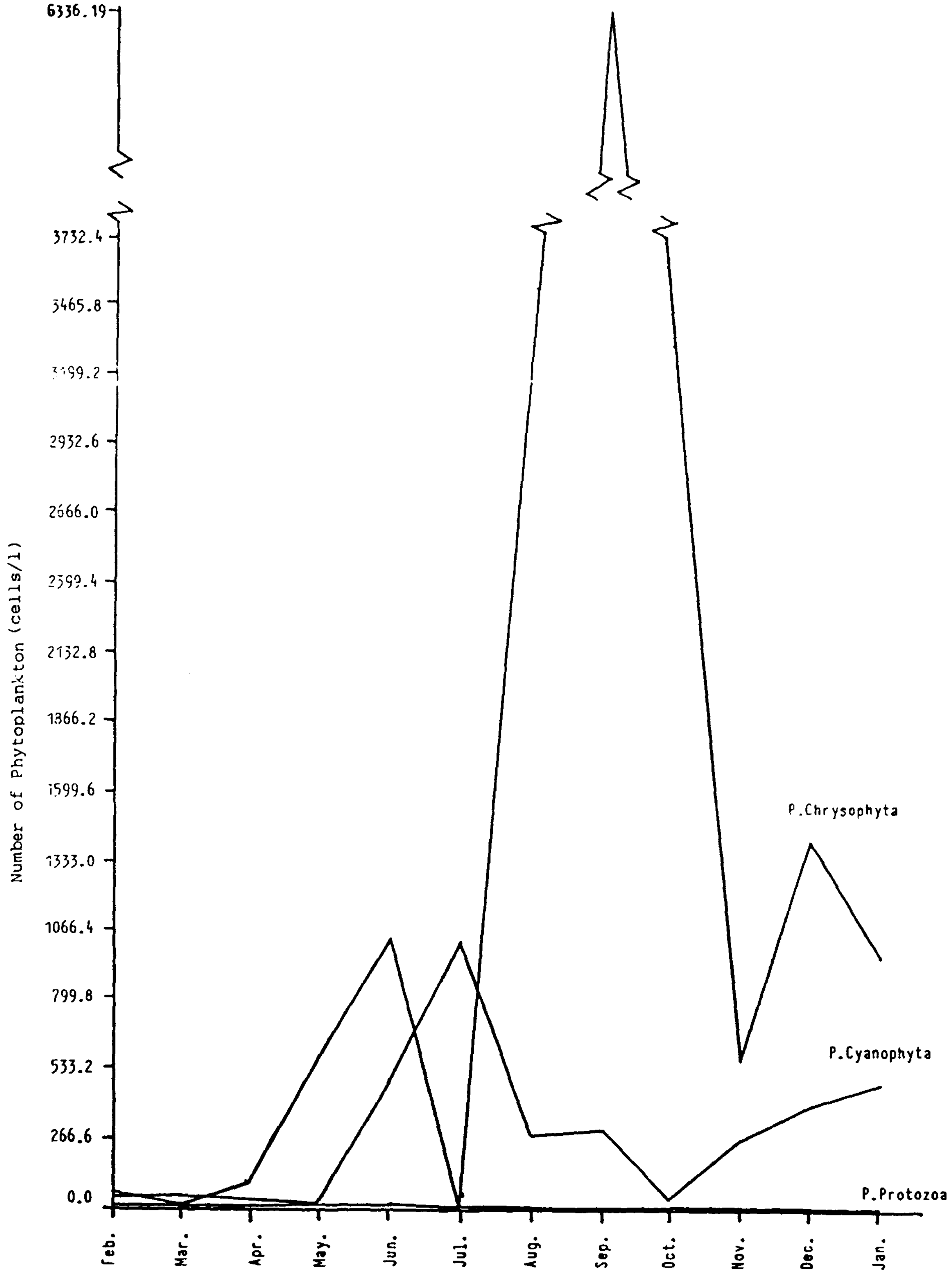

Fig. 2. Monthly fluctuations in abundance of the phytoplankton in the Laem Chabang coastal area during the period February 1986 - January 1987.

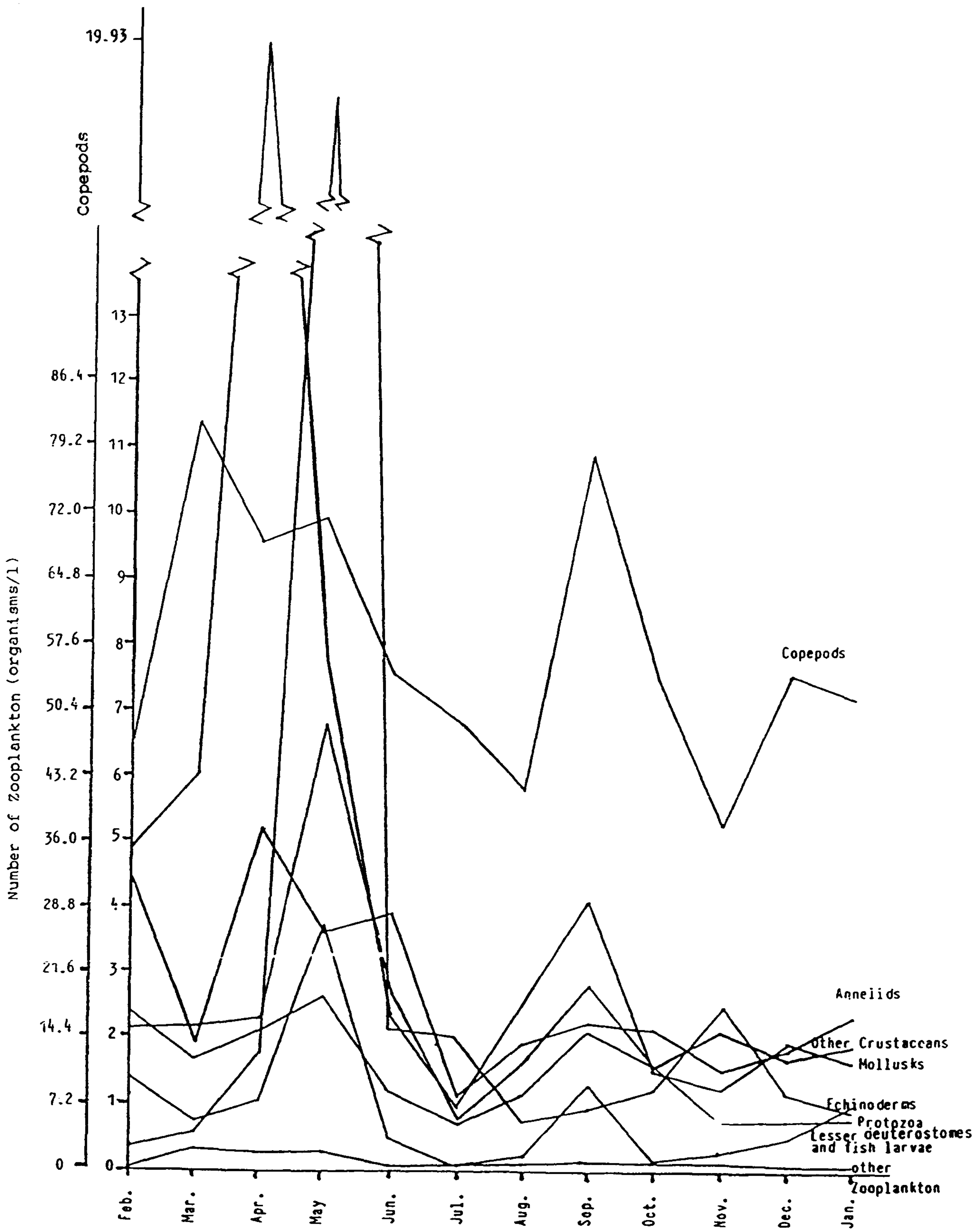

Fig. 3. Monthly fluctuations in abundance of the zooplankton in the Laem Chabang coastal area during the period February 1986 - January 1987.

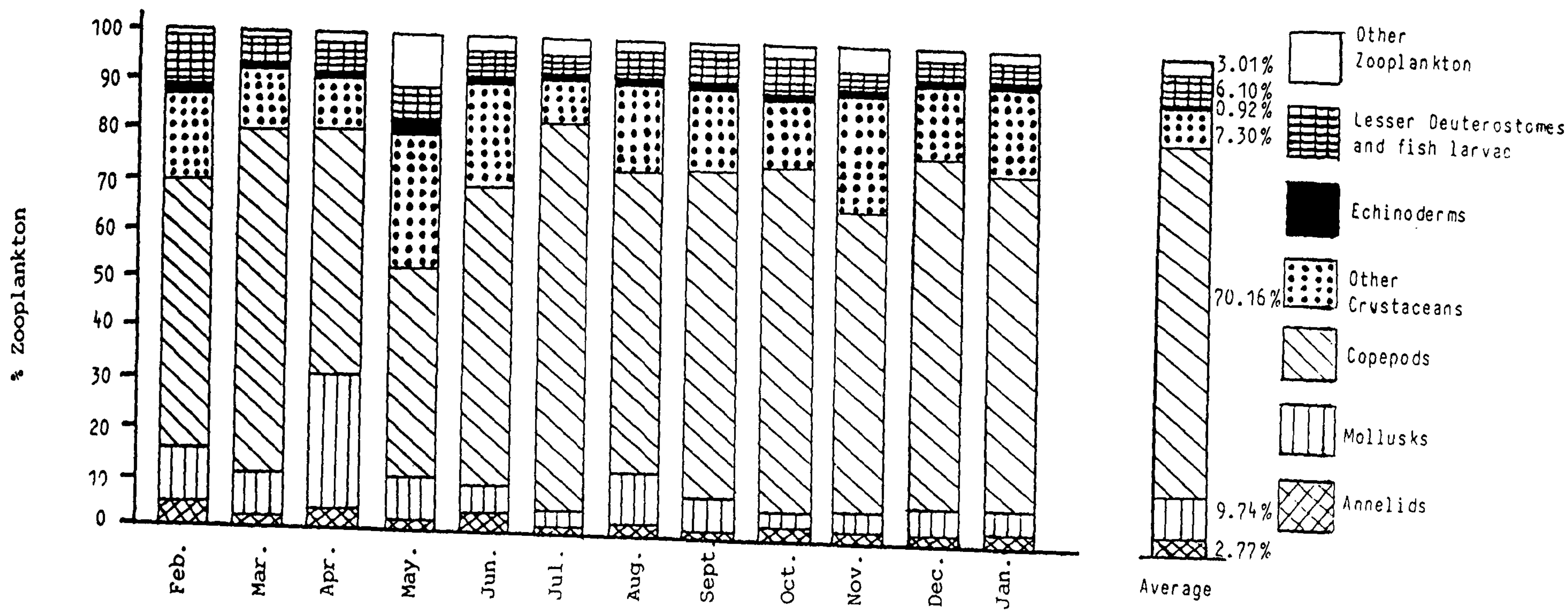

Fig. 4. Percentage composition of zooplankton (broken down into groups) found each month from February 1986 to January 1987.

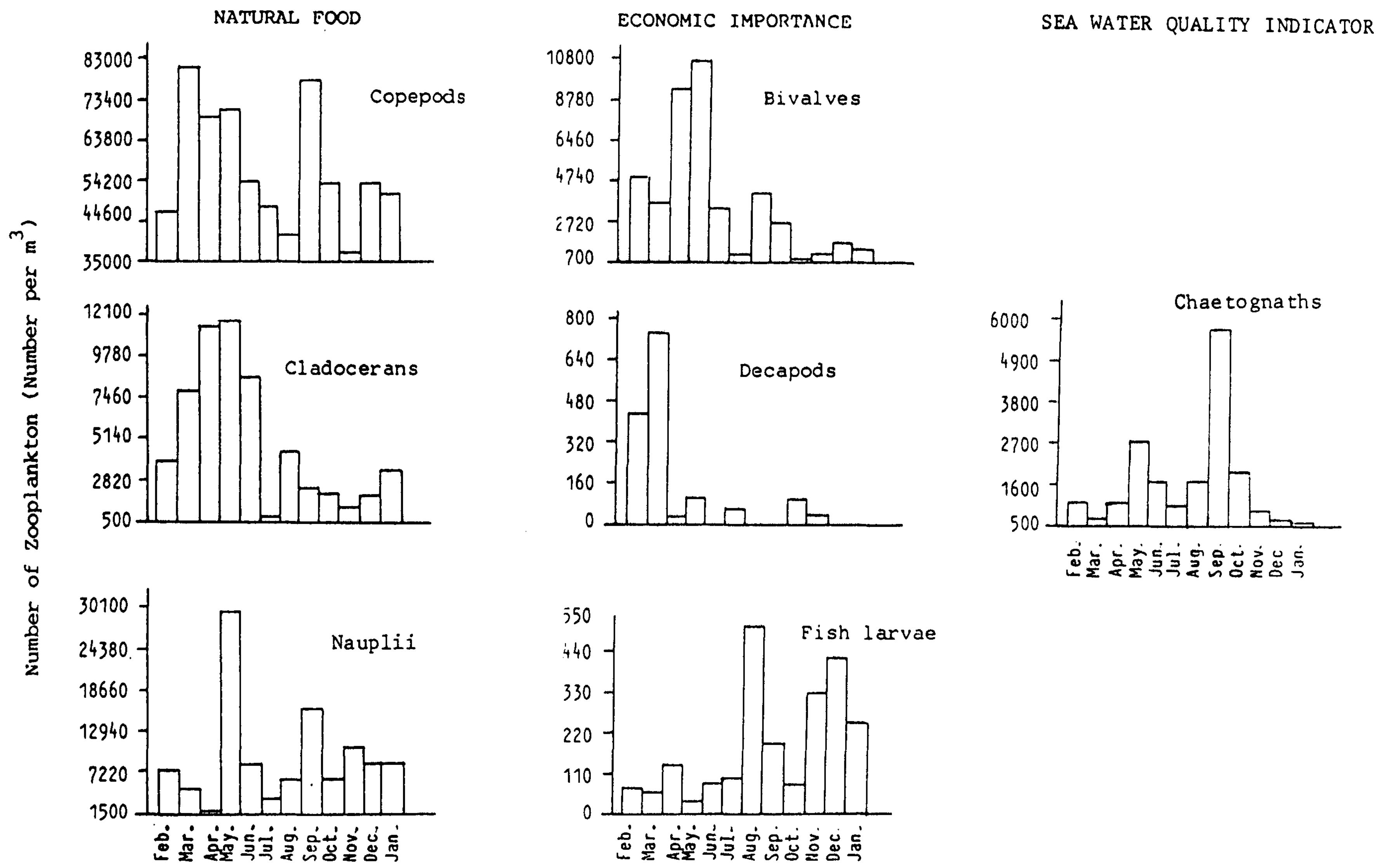

Fig. 5. Frequency histograms of zooplankton divided into three groups: natural food, economically important species, and sea-water quality indicators.

STOCK ASSESSMENT OF THE BOLINAO REEF FLAT FISHERY: I. FISHING PATTERNS AND SPECIES COMPOSITION*

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ABSTRACT

The catch rates and species composition resulting from various fishing methods for a small-scale, reef flat fishery in Bolinao, Philippines were monitored for 12 months from May 1987. The mean catch rates for the various fishing methods were 1.43 kg/mhr for spearfishing, 0.14 kg/trap for traps, 3.53 kg/corral for fish corrals, 0.20 kg/hr for bottom-set gill nets and 0.36 kg/person for drive-in gill nets. In terms of total annual catch, spearfishing comprised 39%, traps 32.1%, fish corrals 16.9% and gill nets (two types) 12.0%. Comparisons of relative seasonality and/or abundance of catch and effort by gear are made. Of the gear types, catches from fish corrals represent minimum selection bias and may be used to make observations regarding the natural processes that govern the population dynamics of the most common species.

Two hundred eighty species of fishes belonging to fifty-three families were recorded from the catches. The rabbitfish, Siganus canaliculatus, dominated catches from spearfishing, fish corrals and gill nets. It comprised about 40% of the total catch from all gear types monitored. Length-weight relationships and length frequency distributions by gear are presented for the most common species caught. Estimates of annual yield and comparisons with similar systems will be presented in a subsequent paper.

* This paper was also presented at the ASEAMS symposium. However, a full manuscript was not submitted for publication. Ed.

ESTIMATE OF POTENTIAL YIELD FROM AN ARTIFICIAL REEF OFF DUMAGUETE CITY, PHILIPPINES

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ABSTRACT

This study aims to determine the potential yield and the catch per man-hour from an experimental artificial reef built by the Silliman Marine Laboratory, Dumaguete City. A visual survey was used to determine the virgin biomass of the stock of Pterocaesio pisang in the artificial reef. Unbaited bamboo traps were used to harvest the fish. Mortality (Z) was estimated from length-frequency data using the Beverton and Holt Z-equation and the potential yield was estimated using the formula Py = 0.2 Z Bv. The estimate of mortality Z was 2.59. The potential yield was 223 kg. The total catch from the stock of P. pisang was 73.3 kg, representing 33% of the potential yield. This suggests that the population in the artificial reef is still underexploited. The catch rate is 1.4 kg/man-hour. This rate increases to 1.8 kg if the weight of other prime caught fishes is included.

1. INTRODUCTION

Recently a substantial number of artificial reefs (ARs) have been deployed in the central Philippines. Some of these reefs are either underexploited or overexploited, partly due to the lack of knowledge on artificial reef fishery. The present situation calls for studies on how to exploit the aggregating fish stock in ARs.

In the Philippines, previous studies of ARs dealt with their feasibility and productivity (Murdy 1979), and growth rates of associated fish and corals (Alcala et al. 1981, Gomez et al. 1982). The aim of this study was to estimate the potential yield and the catch rate per man-hour of one such structure situated off Dumaguete City.

2. MATERIALS AND METHODS

The site is an 85 m^2 experimental reef made of 189 old rubber tyres deployed in a sandy bottom at depths of 20-23 m off Dumaguete airport. It is approximately 150 m away from a coral reef and 100 m away from a seagrass meadow. The species Pterocaesio pisang (family Caesionidae) is the predominant reef fish. Apparently it is recruited from the plankton and subsequently breeds and spawns in the AR. This particular stock appears to be strongly attached to its artificial habitat (Fig. 1). There is preliminary evidence indicating the limited movement of P. pisang from the AR (Luchavez, in prep.). Movements of reef fishes are seldom extensive (see Sale 1982).

Fishing in the AR is strictly for research only. The P. pisang stock was lightly fished by the author in 1987. It probably was prey to such animals as eels, barracudas, groupers, snappers, lizardfishes, emperor breams, jacks, triggerfishes and other predatory groups. However, the stock is assumed to be relatively unexploited.

A visual survey was used to determine the original biomass of the stock of P. pisang. To collect length-frequency data, 3 units of unbaited traps of equal volume (1 cubic m) and mesh size (1 mm) were placed in the AR. The traps were hauled 17 times in between the middle of April 1988 to early December 1988. An average of three hours was spent in setting and hauling the traps every 4-5 days.

Marketable fishes among the catches were sorted out from unmarketable ones. The marketable fishes (fusiliers, sweetlips, goatfishes, snappers and emperor breams) were measured (TL cm) and weighed (g). Only P. pisang was analyzed for potential yield. Catch data of other fishes (Fig. 2) were comparatively too few to be analyzed.

Mortality (Z) was estimated from length composition data using the Beverton and Holt Z-equation:

$$Z = K \frac{Loo - L}{L - Lc} \quad \text{(see Munro 1983, Sparre 1985)}$$

where L is the length of fish of length Lc and longer and Lc is some length for which all fish of that length and longer are under full exploitation. The asymptotic length Loo was estimated using the formula:

$$Lmax/0.95 = L(oo) \qquad \text{(Pauly 1984)}$$

The Lmax was obtained from the average length of the oldest P. pisang among the catch.

As mentioned previously, this stock was lightly fished by the author in 1987. In such a case, Gulland (1982) and Pauly (1984) proposed the use of the modified equation Py=0.2 ZBv (where Bv is the virgin biomass of the stock) rather than Py=0.5 MBv in computing for the potential yield.

3. RESULTS

The size composition of samples of P. pisang is shown in Figure 3. The mean length is 13.02 cm + 0.09. Table 1 presents the relative rate of decline in abundance of successive length groups of P. pisang at full recruitment. The first estimate of asymptotic length is 17.98 cm. Cabanban (1984) reported the K value of P. pisang at 1.054. With these values of L(oo) = 17.98 and K = 1.054, the mortality (Z) can be calculated as follows:

$$Z = 1.054 \frac{17.98 - 14.44}{14.44 - 13.0} \qquad \text{(see Table 1)}$$

$$Z = 2.59$$

Gulland (1982) suggested that the estimate of total stock abundance from surveys, combined with the estimate of M (here Z substitutes for M; see Gulland 1982, Pauly 1984), can provide a first approximation of the potential yield of the stock. The visual survey done by the author gave a rough average estimate of 10,241 individuals in the stock (Table 2). The virgin biomass was obtained by multiplying the estimated average number (10,241) of the stock with the average weight (42 g) per individual based on the total number of fish caught. Thus, the estimated potential yield is

$$Py = 0.2 \; Z \; Bv$$

$$= 0.2 \times 2.59 \times 10241 \times 42 \text{ g}$$

$$= 227684 \text{ g}$$

$$= 223.0 \text{ kg}$$

Table 3 shows the total weight (g) of each species caught in 76 trapping days with an actual working time of 52 hours. These totalled about 95 kg. Using a non-motorized canoe, the catch per fisherman per hour was 1.8 kg.

Table 1. Derivation of mortality rate of <u>Pterocaesio</u> <u>pisang</u> from the relative abundance of successive length-groups at full recruitment (13.0 - 13.9 cm) from the artificial reef. L(oo) = 17.98 cm and K = 1.054.

Length-Group TL (cm)	Frequency	Relative Abundance
13.0 - 13.9	256	1.00
14.0 - 14.9	241	.94
15.0 - 15.9	128	.50
16.0 - 16.9	38	.15
17.0 - 17.9	4	.02

$Lc = 13.0$ cm

Mean $TL = 14.44$

$$Z = K \frac{L_{oo} - \bar{L}}{\bar{L} - L_c}$$

$$= 1.054 \frac{17.98 - 14.44}{14.44 - 13.0}$$

$$= 2.59$$

Table 2. Summary of catch and effort for <u>P</u>. <u>pisang</u> at the artificial reef.

Estimated stock abundance from visual survey	No. of traps	No. of fish caught in 17 haulings	Total wt (g)	Total work hours in 17 trap settings and haulings	Total no. of soaking days
4,097 - 16,384 midpoint = 10,241	3	1,709	73,349	52	76

Table 3. Species list of trap catches exclusive of unmarketable fishes.

Species	Weight (g)
1. Pterocaesio pisang	73,349
2. Plectorhynchus pictus	5,146
3. Acanthurus bleekeri	3,190
4. Parupeneus pleurospilos	2,796
5. Parupeneus barberinus	1,815
6. Gymnothorax spp.	1,780
7. Lutjanus monostigma	1,500
8. Caranx spp.	1,200
9. Lutjanus lineolatus	800
10. Scolopsis personatus	800
11. Sepia spp.	600
12. Aethaloperca rogaa	486
13. Plotosus lineatus	450
14. Lethrinus miniatus	450
15. Caesio caerulaureus	131
16. Gerres spp.	105
17. Lutjanus fulvus	93
18. Lutjanus spilurus	62
	94,753

4. DISCUSSION

There seems to be evidence to show that bigger P. pisang are fast decreasing in number (Fig. 3). Theoretically, the decrease in population size can be attributed to a combination of factors, some of these being fishing mortality, natural mortality, and migration. But P. pisang, being a reef fish, may not be considered a migratory animal. Fishing mortality in this study is a minor factor since the stock is relatively unexploited. At present it can only be speculated that natural mortality has decreased the numbers of longer sized P. pisang.

Whatever the cause, the fact remains that the longer sized fish are fast decreasing and as such it would be advisable to increase fishing effort when the length of this fish exceeds the full recruitment size (about 14 cm). However, increasing the fishing effort will have to take into consideration the fact that P. pisang reaches sexual maturity at 13.0 cm (Cabanban 1984).

The potential yield is 223.0 kg. This figure is only a "first estimate"; an approximation of a precise value pending the development of a sophisticated method. The 223.0 kg potential yield results from using a very conservative formula, Py = 0.2 Z Bv (Gulland 1982, Pauly 1984). The equation is "not supposed to give a precise estimate of potential yield. However, if nothing is known in advance, such as estimate of the order of magnitude, the potential yield may be very valuable" (Sparre 1985).

The fish yield per man-hour is 1.8 kg when the weight of all prime fishes is considered. The yield for P. pisang alone is 1.4 kg per fisherman per hour. The total yield (73.3 kg) of P. pisang is only 33% of the potential yield (223 kg) of the stock. The stock is therefore underexploited.

Some studies conducted in coral reefs have identified topographic complexity as an indicator of fish assemblages (see discussion in Sale and Douglas 1984). A correlation between reef size and fish abundance has been demonstrated by Sale and Douglas (1984). Relationships between fish community parameters and the biological diversity of the substrate were found to be negative (see Bell and Galzin 1985). These sources of information provide an important clue for the management of ARs. These suggest that the potential yield or the number of fish in an AR can be increased through the construction of a complex and extensive substrate.

ACKNOWLEDGEMENTS

I am grateful to the Evangelical Church (EZE) of West Germany which funded the Silliman University Marine Laboratory (SUML) AR Project and to the donors of rubber tyres for the AR construction. Deserving special mention are Mr. Roberto J. Raymundo and Dr. Nicanor Rosario who, in behalf of the Rotary Club of Dumaguete North, took much of their time to acquire used tyres, Mr. Veronico Duran and son Tata who helped in the fishing, Dr. Angel C. Alcala, SUML director, for his support, Ms. Annadel Cabanban of Silliman University who reviewed this paper, Ms. Marti Dy-Liacco for editing the manuscript and Mr. Roy Olsen de Leon and Mr. Roberto Raymundo for their help in data analysis.

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ERRATUM
The photographs in Figures 1 and 2 should be reversed.

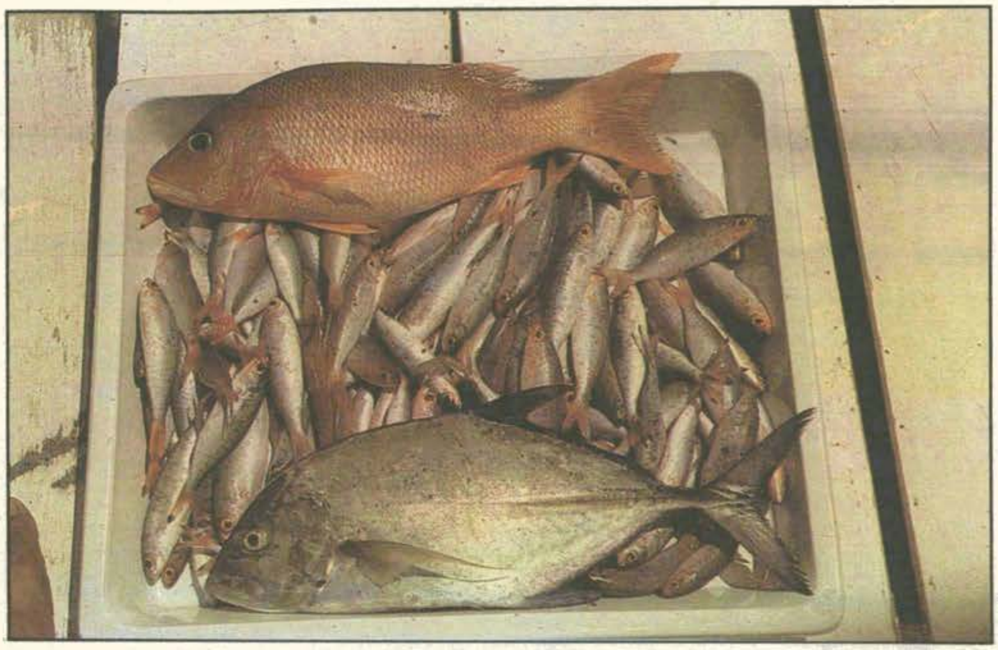

Fig. 1 Partial view of the school of P. pisang swimming around the rubber tyre reef.

Fig. 2. Pterocaesio pisang and other prime yield from the artificial reef.

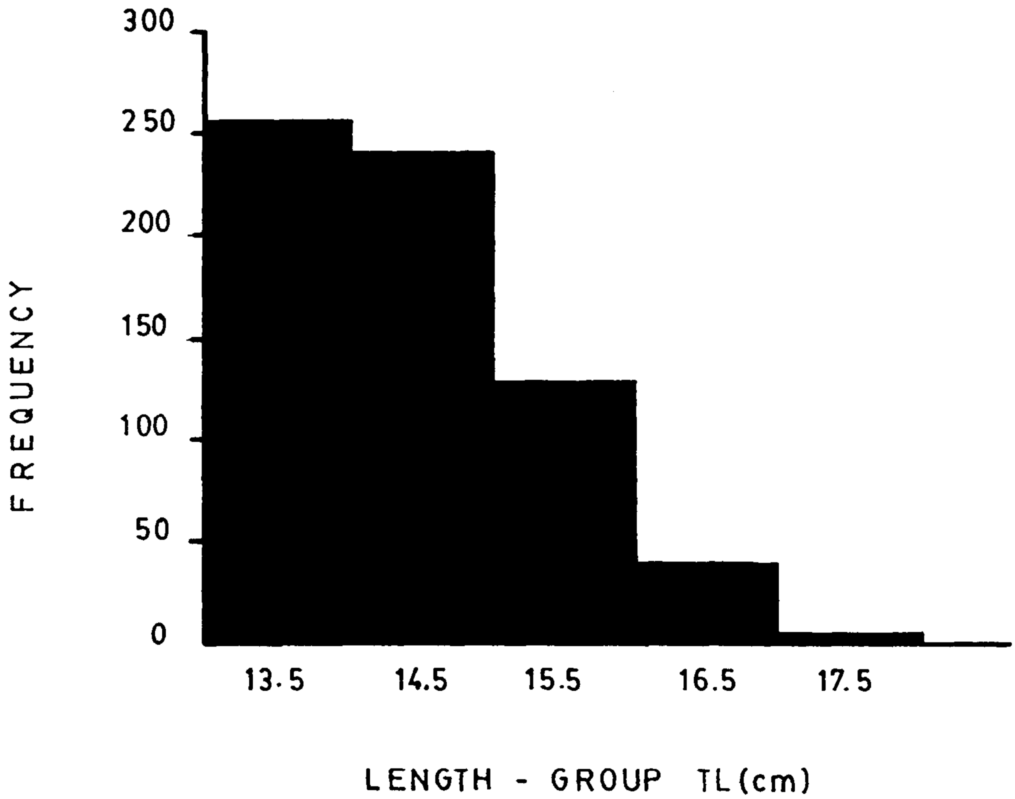

Fig. 3. Length-frequency distribution of trap catches of P. pisang from the artificial reef.

COMPARATIVE GROWTH OF HARD CORALS ON NATURAL AND ARTIFICIAL SUBSTRATA IN THE CENTRAL PHILIPPINES

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ABSTRACT

The growth of certain hard corals on a 4.6-6.0 m deep fringing reef at Basdiot, Moalboal, Western Cebu, Philippines was determined by actual measurements four years after a typhoon code-named "Nitang" destroyed the reef. The mean annual increase was 3.57 cm (short diameter) and 6.60 cm (long diameter) for Acropora; 2.68 cm and 3.39 cm, respectively, for Pocillopora; 1.85 cm and 2.68 cm, respectively, for Galaxea; and 1.05 cm and 1.76 cm, respectively, for Pavona. The growth rates of Acropora and Seriatopora on the natural substratum were greater than those on the artificial surface (rubber tyres), but the growth rates of Pocillopora on both substrate types were about the same. The growth of Acropora may have been influenced by substratum type and water depth.

1. INTRODUCTION

Typhoon Nitang destroyed several reefs in the Western Cebu area on September 2, 1984. The recovery of one of these reefs, Pescador Island reef, has been reported on in an earlier paper (Alcala et al. 1986) and in another one in the present symposium (Alcala and Gomez, this volume). The present paper describes the extent of recovery of another reef, at Basdiot, located on the Cebu mainland facing Pescador Island, and compares the growth rates of the hard coral genera Acropora, Seriatopora, and Pocillopora on the natural substratum (coralline rock) at Basdiot with those on the artificial reefs (made of tyres) off Dumaguete and Sibulan, Negros Oriental.

2. MATERIALS AND METHODS

Two of the three reef sites (Basdiot and Sibulan) lie along Tañon Strait between Negros and Cebu Islands. The third site, Dumaguete, lies in the Bohol Strait, which is continuous with the southern end of Tañon Strait. Sibulan is about 10 km north of Dumaguete, and Basdiot is about 100 km away. All three sites have excellent water circulation patterns and are exposed to one, but not both, of the two monsoons.

The short and long diameters of the corals were measured with a caliper by a scuba diver who recorded the measurements on a slate board. The number of samples for each genus are given in Tables 1 and 2. Identifications were made only to the generic level in order to avoid species misidentification.

3. RESULTS AND DISCUSSION

The data on growth of five genera of hard corals that colonized Basdiot reef within four years after its destruction by Typhoon Nitang are presented in Table 1. The tabular and branching forms of Acropora grew at an average of 5-6 cm in diameter per year, but the bottle brush forms had a lower annual growth rate of 3-4 cm. Pocillopora and Seriatopora grew at a slower rate of about 3 cm per year. The annual growth rate of 5-6 cm in Acropora is smaller than the 5-10 cm growth rate for branching species as reported by Endean (1976). All colonies measured at Basdiot must have settled on the reef as larvae, as there was no evidence of surviving colonies in the samples measured. However, the role of live fragments that might have been introduced into the reef is unknown.

Table 1. Growth of hard corals on Basdiot reef, Moalboal, Western Cebu, Philippines after destruction of the reef by Typhoon Nitang on September 2, 1984. Annual growth rate in parenthesis.

Coral Genus	Number of Samples	Mean Growth (cm ± S.D.) in Four Years Short Diameter	 Long Diameter
Acropora (branching)	18	21.05 ± 3.86 (5.26)	23.71 ± 4.81 (5.93)
Acropora (tabular)	11	21.06 ± 6.81 (5.27)	26.38 ± 10.11 (6.60)
Acropora (bottle brush)	4	14.28 ± 3.79 (3.57)	16.05 ± 3.57 (4.01)
Galaxea	3	7.40 ± 4.95 (1.85)	10.73 ± 6.36 (2.68)
Pavona	3	4.20 ± 1.35 (1.05)	7.03 ± 1.80 (1.76)
Pocillopora	12	11.08 ± 2.87 (2.77)	13.20 ± 3.53 (3.30)
Seriatopora	3	10.73 ± 6.20 (2.68)	13.57 ± 6.28 (3.39)

The growth of branching coral colonies at Basdiot (Table 1) was compared with that at the artificial reefs (Table 2). Figure 1 shows the comparative growth rates of the three genera Acropora, Pocillopora, and Seriatopora on natural and artificial substrata. Acropora and Seriatopora appeared to grow faster on the rocky coralline substratum at Basdiot reef than on the tyres, but Pocillopora grew at about equal rates on the two substratum types. However, Acropora had a more variable growth rate than the other two genera, as indicated by a wide range of the coefficients of variation (Fig. 1).

The slower growth of Acropora on the tyre reefs is probably due to depth and nature of the substratum. These structures were set at depths of 18-27 m, whereas Basdiot reef is only 4.6-6.0 m deep. In addition, evidence exists which indicates that the tyre material itself may have initially slowed down coral growth: the annual growth rate of Acropora at the Dumaguete tyre reef two years after its deployment was about 3 cm (Alcala et al. 1981) compared to the growth rate given in Figure 1, which is 4-5 cm. In contrast, the growth rate of Pocillopora appeared not to be affected by depth nor substrate.

Table 2. Growth of certain species of hard corals on an artificial reef made of tyres off Dumaguete City and Sibulan, Negros Oriental, Philippines. Annual growth rate in parenthesis.

	Dumaguete			Sibulan		
Coral Genus	No. of Samples	Mean growth (cm ± S.D) in 11.42 Yr Short Diameter	Long Diameter	No. of Samples	Mean growth (cm ± S.D) in 8.83 Yr Short Diameter	Long Diameter
Acropora	8	49.70 ± 26.44 (4.35)	70.39 ± 27.23 (6.16)	9	28.45 ± 22.70 (3.22)	44.0 ± 45.42
Cyphastrea	-	-	-	3	13.83 ± 5.20 (1.57)	28.80 ± 17.69 (3.20)
Favia	5	16.86 ± 3.62 (1.40)	18.78 ± 3.39 (1.64)	-	-	-
Favites	3	22.30 ± 5.29 (1.95)	29.73 ± 8.64 (2.60)	-	-	-
Hydnophora	3	34.17 ± 16.43 (2.99)	44.67 ± 24.13 (3.91)	-	-	-
Leptoria	4	16.83 ± 1.77 (1.47)	22.33 ± 2.79 (1.96)	-	-	-
Montipora	3	40.97 ± 10.27 (3.59)	51.47 ± 9.11 (4.51)	7	8.47 ± 4.86 (0.96)	10.81 ± 5.20 (1.20)
Pachyseris	-	-	-	4	9.55 ± 2.47 (1.08)	17.80 ± 6.31 (1.98)
Pocillopora	7	32.69 ± 4.30 (2.86)	39.76 ± 6.31 (3.48)	6	25.80 ± 6.01 (2.92)	30.27 ± 9.11 (3.36)
Porites		19.21 ± 4.01 (1.68)	28.09 ± 6.51 (2.46)	15	13.16 ± 6.91 (1.49)	21.98 ± 13.04 (2.44)
Seriatopora	-	-	-	4	12.62 ± 7.06 (1.43)	20.0 ± 10.04 (2.22)
Stylophora	5	31.10 ± 4.30 (2.72)	38.68 ± 3.41 (3.39)	11	11.28 ± 7.06 (1.28)	14.30 ± 8.70 (1.59)
Tubastrea	-	-	-	4	7.95 ± 4.42 (0.90)	10.90 ± 6.81 (1.21)

4. CONCLUSION

The growth of certain branching hard corals following damage of a reef by a typhoon can be fairly rapid under favourable conditions, as shown in the case of Basdiot reef. In this example, the favourable conditions are lack of human disturbance (the reef was converted into a marine reserve two years ago); presence of a firm rocky substratum free of competing benthic organisms; and good water circulation. However, more observations are needed to confirm this tentative conclusion.

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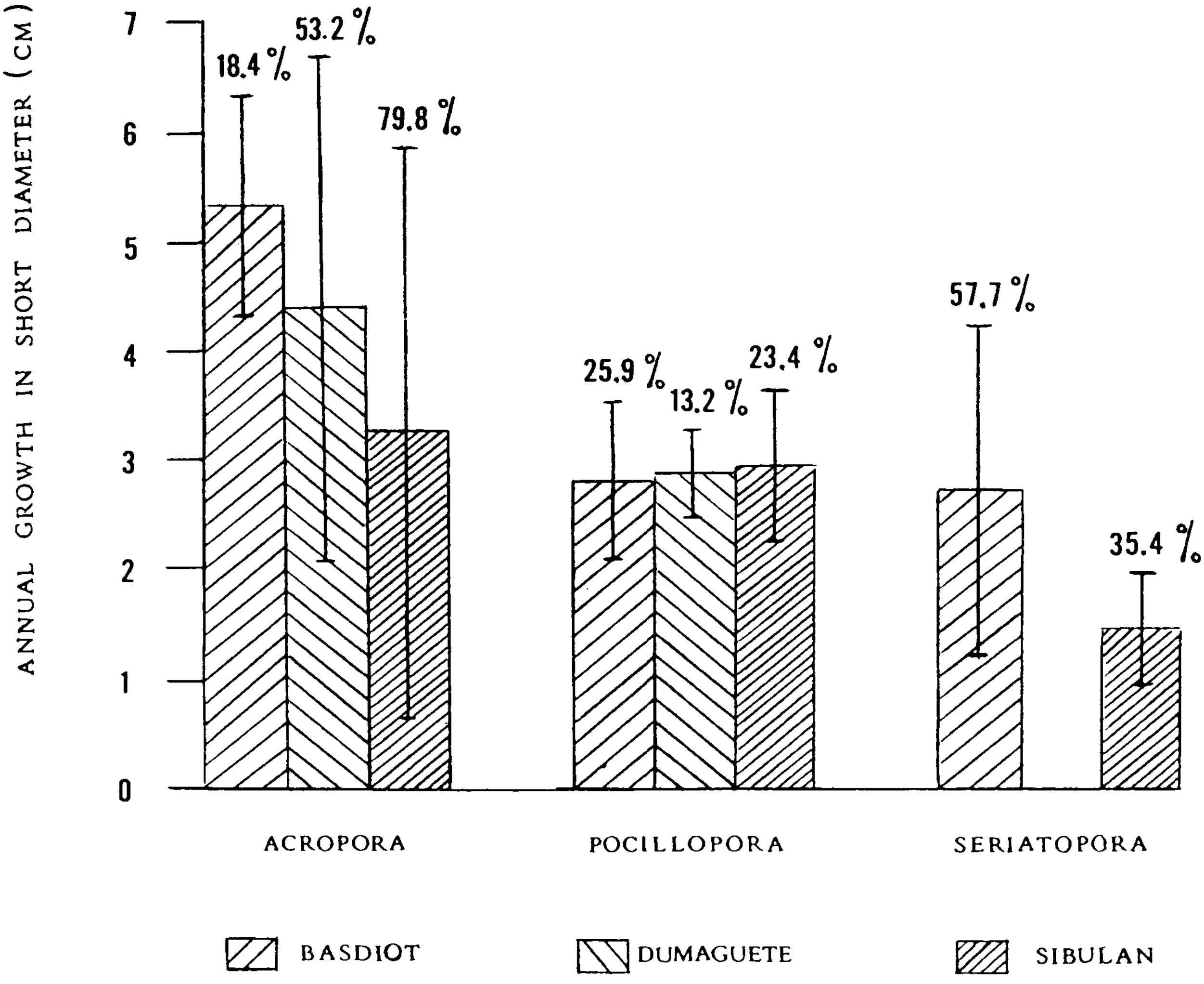

Fig. 1. Comparative annual growth rates of Acropora, Pocillopora and Seriatopora on natural substrata in Basdiot and on tyre surfaces in Dumaguete and Sibulan. Figures above bar graphs are coefficients of variation. Error bars are standard deviations.

COASTAL HABITAT OF TANJUNG JATI, JEPARA WITH EMPHASIS ON THE EFFECT OF SEDIMENTATION ON THE CORAL REEF COMMUNITY

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ABSTRACT

The present study was performed in connection with the construction of a steam power plant at Tanjung Jati, Jepara. The field observations were done twice, i.e., in May and August 1988. Quadrat transects perpendicular to shore and line transects parallel to shore were established to observe reef benthos and coral condition. The reef flat is densely inhabited by Sargassum molleri and scarcely inhabited by other benthic organisms including stony corals. The maximum depth of coral growth is very shallow, i.e., ± 6 m. The community of stony corals is dominated by resistant groups belonging to the genera Porites and Goniopora. This condition may be caused by highly turbid water resulting from sedimentation coming from the north side which is indicated by the extensive mud zone found in the northeast station (CT3). It is concluded that the condition of the study area can be classified as Kuehlmann's stage 3 of coral degradation.

1. INTRODUCTION

Coral reefs and associated environments are of great economic importance for Indonesia. They constitute a permanent resource of food for the local populations, providing not only fish but several other edible organisms as well. They are an important source of building and other materials. They can be quite attractive to tourists and often serve to protect coastlines, harbours and anchorages. Meanwhile, the increasing human activities both on land and along the coast lead to higher rates of ecosystem degradation. The most widespread cause of reef damage appears to be siltation, followed by blast fishing, other destructive fishing methods such as "muro ami", coral mining, and pollution.

Studies on the condition of coral reefs in Indonesian waters are still very limited. They concentrate mainly on the habitats in relatively clear waters such as around the Seribu Islands and Ambon, and very little information on coral condition in turbid water exists. The aim of the present study is to provide data on the condition of the reef benthos in turbid water due to sedimentation in Tanjung Jati, Jepara. The investigation is also a part of a marine environment and entrainment study in connection with the establishment of an electric steam power plant.

2. MATERIALS AND METHODS

The field observations were done twice, i.e., in May and August 1988. The benthic reef community was studied using the transect method based on changes in depth and distance offshore as well as major zonation features. The study site is located at Tanjung Jati in Bondo Village of Jepara District about 90 km from Semarang (Fig. 1A). The transect stations were situated at the proposed discharge site (CT1), intake site (CT3) and midway between them (CT2) (Fig. 1B).

All transects were made perpendicular to the shore starting from the high water line to the reef slope at more or less 10 m depth. Plotting was done every 5 m on the reef flat and every 10 m on the reef slope along the transect line using a 1 m^2 metal frame divided into 16 squares, each measuring 25 cm x 25 cm. For algae, corals, sponges and hydroids, percentage cover was visually estimated (Loya 1978). The other organisms such as molluscs, crustaceans and echinoderms were quantified by number of individuals. Three replicates of the quadrat transect were made on the reef flat and none on the reef slope.

To assess the coral condition quantitatively, the modified line transect method of Loya (1978) was applied. A 50 m line transect ran parallel to the zone of coral growth on the reef slope at a depth of 3 m at the same sites (CT1, CT2, and CT3). All benthic forms underlying the transect line were recorded and their length intersected by the line measured to the nearest centimetre. The percentage cover of living corals was calculated by adding up all of their intersected lengths, and then dividing by the total length payed out. Two diversity indices, the Shannon species diversity index and the Pielou equitability index, were calculated (Odum 1971).

Coral reefs were photographed using a NIKONOS IV camera with a light. Most of the photographs were taken from a distance of 0.8 m–1.5 m which was constrained by the very turbid water.

3. RESULTS

3.1 Reef flat

Detailed results of the reef benthos quadrat transects on the reef flat at CT1, CT2 and CT3 are presented in Figures 2, 3 and 4. In general, three zones could be distinguished. The first is a sand-rubble zone that begins from the shoreline and extends 20–25 m offshore. It is poorly inhabited by reef benthos except at CT1 where 9 species of molluscs were recorded (Table 1). The dominant species were Clypeomorus brevis, Lunella cinereus and Morula marginata.

The second zone can be designated a Sargassum zone which is characterized by a bottom of dead coral mixed with gravel and which is densely overgrown by that alga. Other dominant seaweeds are Padina javanica and Ulva reticulata (Table 1). A significant dense growth of Ulva was found at CT2. The zone begins at about 20–25 m from the shoreline and stretches until 50–60 m offshore.

The third zone forms the beginning of the reef slope and can be called the algae-coral zone. It extends to about 100 m offshore with water depth ranges between 1.5 and 2 m. Beyond this zone, the algal growth sharply decreases and is replaced by stony corals. The most flourishing coral growth is at 3 m depth.

Table 1 shows the distribution of reef benthos recorded from the transects at the three stations. A total of 21 species of reef benthos were recorded, consisting of 10 species of algae, 10 species of molluscs and 1 species of echinoderm. Descriptions of the sites are as follows:

CT1. This station has about 60 m length of reef flat and based on its bottom type (Fig. 2), the flat can be divided into three zones. The first zone (zone A) is as described above. The second zone (zone B) has coarse sand and dead coral densely overgrown by algae dominated by Sargassum molleri and Padina javanica. The third zone (zone C) is located close to the reef slope, and is characterized by the presence of living coral mainly of the family Faviidae.

CT2. The reef flat length of this station is about 60–70 m. Three zones as described in general above could also be distinguished (Fig. 3).

CT3. Has about 65–70 m length of reef flat. As with the other two stations, three zones could be discerned based on the bottom types (Fig. 4). The first zone (zone A) has a black sand bottom mixed with coral rubble and no living benthos. The second zone (zone B) has a substrate of gravel and dead corals overgrown by algae dominated by Sargassum molleri, Ulva reticulata and Gracilaria lichenoides. The third zone (zone C) is similar to that of the other stations.

Table 1. Distribution of benthic organisms recorded at the transect sites at Tanjung Jati reef flat, Jepara. CT1, CT2 and CT3 are stations; R1, R2 and R3 are replicates.

	Species	CT1			CT2			CT3		
		R1	R2	R3	R1	R2	R3	R1	R2	R3
A.	**ALGAE**									
	CHLOROPHYTA									
	Ulva reticulata	+	+	-	+	+	+	++	++	+
	PHAEOPHYTA									
	Hydroclathrus clathratus	-	-	+	-	-	-	-	-	+
	Lobophora sp.	-	-	-	-	-	-	-	-	+
	Padina javanica	+	+	+	+	+	+	-	+	+
	Sargassum molleri	++	++	++	++	++	+	++	++	++
	Turbinaria ornata	-	-	-	-	+	-	-	-	-
	RHODOPHYTA									
	Acanthophora spicifera	-	-	-	-	+	+	-	+	+
	Amphiroa fragilissima	-	-	+	-	+	-	-	+	+
	Gracilaria lichenoides	-	+	+	+	+	+	+	-	+
	Hypnea musciformis	-	+	+	-	+	-	-	-	+
B.	**MOLLUSCS**									
	GASTROPODA									
	Clypeomorus brevis	++	++	++	-	-	-	-	+	-
	Engina zonalis	-	+	-	-	-	-	-	-	-
	Euchelus atratus	+	-	-	-	-	-	-	-	-
	Lunella cinereus	+	+	+	-	-	-	-	-	-
	Morula marginata	+	+	+	-	-	-	-	-	-
	Nerita albicilla	-	+	-	-	-	-	-	-	-
	Nerita undata	+	+	-	-	-	-	-	-	-
	Trochus pyramis	+	-	-	-	-	-	-	-	-
	PELECYPODA									
	Anadara inflata	-	-	-	-	-	-	-	+	-
	Gafrarium disfar	+	+	+	-	-	-	-	-	-
C.	**ECHINODERMS**									
	HOLOTHUROIDEA									
	Holothuria edulis	-	-	-	-	-	-	-	-	+

3.2 Reef slope

Results of coral line transects at 3 m depth are summarized in Tables 2, 3 and 4. Values of percent cover and number of species of stony corals, and diversity and evenness indices of all biotic components are shown in Figure 5.

A total of about 17 species (excluding the sponges which were not identified) of sessile benthic organisms consisting of 12 species of stony corals, 2 species of soft corals and at least 3 species of algae were recorded from the transect line at CT1. Stony corals comprised 38.8% by cover, and were dominated by Porites lutea (Table 2).

Table 2. Results of coral transect at 3 m depth in CT1.

Species	Intercept (cm)	Percent Cover (%)	Total Percent Cover (%)
STONY CORALS			
Family Acroporidae			
Acropora listeri	140	2.8	
Montipora tuberculosa	290	5.8	
Montipora Verrucosa	40	0.8	
Montipora sp.	40	0.8	
Family Faviidae			
Favia matthaii	140	2.8	
Favia rotumana	100	2	
Favites abdita	70	1.4	
Favites halicora	10	0.2	
Platygyra daedalea	10	0.2	
Family Mussidae			
Lobophyllia hemprichii	50	1	
Family Poritidae			
Porites lobata	10	0.2	
Porites lutea	1040	20.8	38.8
SOFT CORALS			
Lobophytum crassum	170	3.4	
Sarcophyton tracheliopharum	90	1.8	5.2
SPONGES	170	3.4	3.4
ALGAE			
Padina javanica	30	0.6	
Sargassum molleri	80	1.6	
Turf algae	200	4.0	6.2
ABIOTIC COMPONENTS			
Dead coral	1490	29.8	
Gravel	300	6.0	
Sand	530	10.6	46.4
	5000	100	100

A total of about 21 species (excluding the sponges which were not identified) of sessile benthic organisms consisting of 15 species of stony corals, 2 species of soft corals and at least 4 species of algae were recorded from the transect line at CT2. The percentage cover of stony corals was 28.8%. Dominant species were the Faviidae, Platygyra lamellina and Favites bennettae (Table 3).

Table 3. Results of coral transect at 3 m depth in CT2.

Species	Intercept (cm)	Percent Cover (%)	Total Percent Cover (%)
STONY CORALS			
Family Acroporidae			
Montipora tuberculosa	120	2.4	
Montipora undata	110	2.2	
Family Faviidae			
Favia favus	40	0.8	
Favia matthaii	30	0.6	
Favia sp.	20	0.4	
Favites abdita	50	1	
Favites bennettae	270	5.4	
Platygyra daedalea	10	0.2	
Platygyra lamellina	320	6.4	
Family Merulinidae			
Merulina ampliata	20	0.4	
Family Oculinidae			
Galaxea fascicularis	140	2.8	
Family Pectiniidae			
Pectinia lactuca	60	1.2	
Family Poritidae			
Goniopora tenuidens	40	0.8	
Porites lobata	60	1.2	
Porites lutea	150	3.0	28.8
SOFT CORALS			
Sarcophyton trachеliopharum	40	0.8	
Sinularia polydactyla	140	2.8	3.6
SPONGES	80	1.6	1.6
ALGAE			
Caulerpa racemosa	40	0.8	
Padina javanica	250	5	
Sargassum molleri	230	4.6	
Turf algae	270	5.4	15.8
ABIOTIC COMPONENTS			
Dead coral	1630	32.6	
Sand	380	7.6	
Mud	500	10.0	50.2
	5000	100	100

A total of 11 species of sessile benthic organisms, consisting of 7 species of stony corals, 1 species of soft coral and 3 species of algae were found at CT3 (Table 4). The percent coverage of stony corals was 50.2%, dominated by *Porites lutea* and *Porites lobata*.

Table 4. Results of coral transect at 3 m depth in CT3.

Species	Intercept (cm)	Percent Cover (%)	Total Percent Cover (%)
STONY CORALS			
Family Acroporidae			
Montipora tuberculosa	150	3	
Family Faviidae			
Montastrea curta	200	4	
Family Oculinidae			
Galaxea astreata	200	4	
Galaxea fascicularis	140	2.8	
Family Pectiniidae			
Pectinia lactuca	60	1.2	
Family Poritidae			
Porites lobata	500	10	
Porites lutea	1260	25.2	50.2
SOFT CORALS			
Sinularia polydactyla	250	5	5
ALGAE			
Hydrochlathrus clathratus	170	3.4	
Padina javanica	340	6.8	
Sargassum molleri	190	3.8	14
ABIOTIC COMPONENTS			
Dead coral	470	9.4	
Sand	500	10	
Mud	570	11.4	30.8
	5000	100	100

The stony corals were richest at CT2 and poorest at CT3. In general, Porites lutea formed the most dominant species except in CT2 where Platygyra lamellina and Favites bennettae dominated the community. Faviidae were most represented in terms of species at CT1 and CT2, i.e., 5 and 7 species, respectively. Conversely, only 1 species of Faviidae, Montastrea curta, was found at CT3. Considerable amounts of soft coral were also found such as Lobophytum crassum, Sarcophyton tracheliopharum and Sinularia polydactyla.

In terms of life forms, branching corals were almost absent. The coral community was dominated by massive faviids, poritids and encrusting acroporids. Submassive acroporids were rarely found.

At least 48 species of reef benthos were recorded from the perpendicular transects on the reef slope at the three stations, consisting of 36 species of stony corals, 5 species of soft corals, several species of algae and 3 groups of other fauna (Table 5). The faviids had the highest number of species, i.e., 17, of which 9 and 10 occurred at CT1 and CT2, respectively, and 6 species at CT3. Of the 36 species of stony corals, only 5 species, namely, Montipora tuberculosa, Favia maxima, Galaxea fascicularis, Porites lobata and Porites lutea were recorded at all the three stations. Of these, Goniopora fruticosa and Favia maxima had the widest vertical distribution, i.e., from 3 to 6 m depth. Goniopora fruticosa occurred from the initial transect point on the reef slope to 150 m offshore, while Favia maxima extended to 130 m offshore.

There were 5 species of soft corals recorded from the transects which belonged to the genera Lobophytum, Sinularia and Sarcophyton. The genera Sinularia and Sarcophyton mostly inhabited shallower habitats. Macroalgae were very scarce and only one species, Padina javanica, was recorded from water deeper than 3 m (at CT2). The others were turf algae which were attached mostly on dead coral. Gorgonians and sponges were found more abundantly in deeper water than were stony corals. Hydroids were also found in deeper water (greater than 5 m).

The results from the quadrat transects on the reef slope are presented in Figures 6, 7 and 8. It can be seen that, in general, there are also three zones on the reef slope namely, a coral-sand zone, dead coral zone, and mud zone, especially at CT1 (Fig. 6). However, at CT3 (the intake area) the mud zone was very extensive and only 2 zones could be distinguished, i.e., the coral-mud zone and dead coral-mud zone (Fig.8).

Table 5. Organisms recorded from the perpendicular transects on the reef slope at the three stations in Tanjung Jati, Jepara.

Species	CT1	CT2	CT3
STONY CORALS			
Family Acroporidae			
Acropora listeri	+	-	-
Montipora tuberculosa	+	+	+
Montipora undata	-	+	-
Montipora verrucosa	+	-	+
Montipora sp.	+	-	-
Family Faviidae			
Favia favus	-	+	+
Favia maxima	+	+	+
Favia maritima	-	-	+
Favia matthaii	+	+	-
Favia rotumana	+	-	-
Favia sp.	-	+	-
Favites abdita	+	+	-
Favites bennettae	-	+	-
Favites complanata	-	+	-
Favites halicora	+	-	-
Favites pentagona	-	+	+
Goniastrea australensis	+	-	-
Montastrea curta	-	-	+
Platygyra daedalea	+	+	-
Platygyra lamellina	+	+	-
Platygyra pini	+	-	-
Family Merulinidae			
Merulina ampliata	-	+	-
Hydnophora pilosa	-	-	+

Table 5. (continued)

Species	CT1	CT2	CT3
Family Mussidae			
Lobophyllia corymbosa	+	-	-
Lobophyllia hemprichii	+	-	-
Family Oculinidae			
Galaxea astreata	-	-	+
Galaxea fascicularis	+	+	+
Family Pectiniidae			
Echinophyllia echinata	+	-	-
Pectinia lactuca	-	+	+
Pectinia paeonia	-	-	-
Family Poritidae			
Goniopora fruticosa	+	+	-
Goniopora palmensis	+	-	-
Goniopora tenuidens	-	+	-
Porites lobata	+	+	+
Porites lutea	+	+	+
Porites sp.	+	-	-
SOFT CORALS			
Lobophytum batarum	+	-	-
Lobophytum crassum	+	-	-
Sarcophyton tracheliopharum	+	+	-
Sinularia gynosa	-	+	+
Sinularia polydactyla	+	+	+
GORGONIANS	+	+	+
SPONGES	+	+	+
HYDROIDS	+	-	+
ALGAE			
Caulerpa racemosa	-	+	-
Hydrochlathrus clathratus	-	-	+
Padina javanica	+	+	+
Sargassum molleri	+	+	+
Turf algae	+	+	+

At the bottom, the reef slope of CT1 is comparatively gentle (Fig. 6). The maximum depth of coral growth is 6 m. The most abundant coral growth was recorded at 4 m, occupying a relatively wide area, i.e., until 80 m offshore. Percentage cover in a one square metre frame ranged between 40%-90%. From a depth of 5 m, the percentage cover of living coral decreased drastically and was mostly dominated by gorgonians. The most dominant coral species overall were Goniopora fruticosa, Porites lobata, P. lutea and Favia abdita.

The reef slope at CT2 is relatively steeper than at CT1 (Fig. 7). The maximum coral depth is also 6 m. The most abundant coral growth was recorded at 3 to 4 m depth, occupying a relatively narrow area, i.e., until 30 m offshore. The percentage coral cover at the zone of greatest abundance ranged between 75%-90%. From a depth of 5 m, living coral coverage decreased drastically. In this station, only one species of macroalga, Padina australis, was recorded at a depth of 3 to 6 m. Sponges and gorgonians dominated the deeper habitats (7 m). A species of soft coral, Sinularia gynosa, dominated the shallower habitats, followed by the hard corals Goniopora fruticosa, Galaxea fascicularis, Favites pentagona, Favia maxima and Montipora tuberculosa.

The reef slope at CT3 is also relatively steep and similar to that at CT2 (Fig. 8). The maximum depth of coral growth is likewise about 6 m. The most flourishing coral growth was found at 3 to 4 m depth, occupying a relatively narrow area, i.e., until 40 m offshore. The percentage coral cover in this zone ranged between 30% and 75%. From a depth of 4 m, the coverage of living coral decreased sharply. The community in the deeper habitats was dominated by gorgonians. Porites lobata, Goniopora fruticosa, Hydnophora pilosa, Galaxea fascicularis and G. astreata dominated the coral community at this station.

4. DISCUSSION

According to Gomez (1988), siltation is one of the greatest contributors to coral reef stress in Southeast Asia. Soekarno et al. (1986) also noted that the most widespread cause of reef damage in Indonesia appears to be siltation generated by forest denudation and development on land. The combined activities of logging and slash and burn agriculture have now depleted at least 60% of the forests of Southeast Asia (McManus 1988).

Indonesian reefs are better developed in the eastern part of the archipelago. This condition seems to be correlated with the degree of siltation or sedimentation which is indicated by Secchi disk readings from several areas as shown in Table 6. The apparently clearer water in the eastern part of the Indonesian Archipelago should provide for better coral reef growth. The data also show that Jepara waters are the most silty.

Table 6. Secchi disk extinction at several areas in Indonesian waters.

Areas	Secchi disk extinction (in metres)
I. West	
1. Malacca Strait	5.3
2. Jakarta Bay	4.9
3. Sunda Strait	10.0
4. Jepara	0.3
5. Cilacap	1.9
6. Bali/Lombok	35.0
II. East	
1. Flores Sea	28.5
2. Irian Jaya	18.0
3. Macassar Strait and Sulawesi Sea	23.5
4. Banda Sea	16.5
5. Maluku Sea	30.5

Source: Institute of Marine Research 1979a,b, National Institute of Oceanology 1982, Sapulete 1984, 1985, Arief 1985, Hadikusumah 1986, Illahude et al. 1986.

It is well known that corals depend on the photosynthetic activity of zooxanthellae both for nutrition and calcification (Muscatine 1973, Kuehlmann 1988). It is for this reason that reduction in light due to suspended particles has deleterious effects on corals. The shallowness of the maximum depth of coral growth (<6 m) in Tanjung Jati waters, therefore, might be due to the reduction in light. However, Yamazato's (1986) study made it also clear that there were detrimental effects of turbidity per se in addition to the effects of reduced light. These may be brought about by a reduced supply of nutrients as well as an increased consumption of energy in mucus secretion and in ciliary movements which are responsible for removing settled particles.

The almost total absence of Acropora branching forms and the scarcity of Acropora submassives in the stressed area is in accordance with other findings. Kuehlmann (1988) found that corals most sensitive to environmental deterioration were the important reef framework builders of the genera Acropora and Stylophora. The laboratory experiment of Yamazato (1986) on the effects of suspended particles on reef corals made clear that Acropora hebes exhibited shorter survival times than the other species tested. In the former case, a large amount of mucus was secreted to trap the suspended particles. This may account for the shorter survival times of the species concerned, since mucus secretion consumes much energy.

Kuehlmann (1985), based on his study at Ishigaki Island, was able to distinguish four stages of coral reef deterioration. Based on the results of the present study, the coral reef condition at Tanjung Jati seems to fall under Kuehlmann's stage 3 of deterioration.

The dominance of a silty substrate at CT3 indicates that sedimentation has originated from the northeast direction. Figure 9 shows the distribution of suspended solids at the surface, middle and bottom layer of the water in the study area. The highest concentration of suspended solids in the bottom layer was found at CT3 (please refer to Figure 1 for location of stations). The greatest concentration in the middle layer was close to CT2, while that of the surface layer was far southwest of CT1. This supports our earlier conclusion that most of the sediment comes from the northeastern part of the study area. Keling River (Fig. 1A) might be a major agent transporting sediment from the uplands. However, this does not exclude the surrounding area as another source of siltation since it is open and consists mostly of rice fields.

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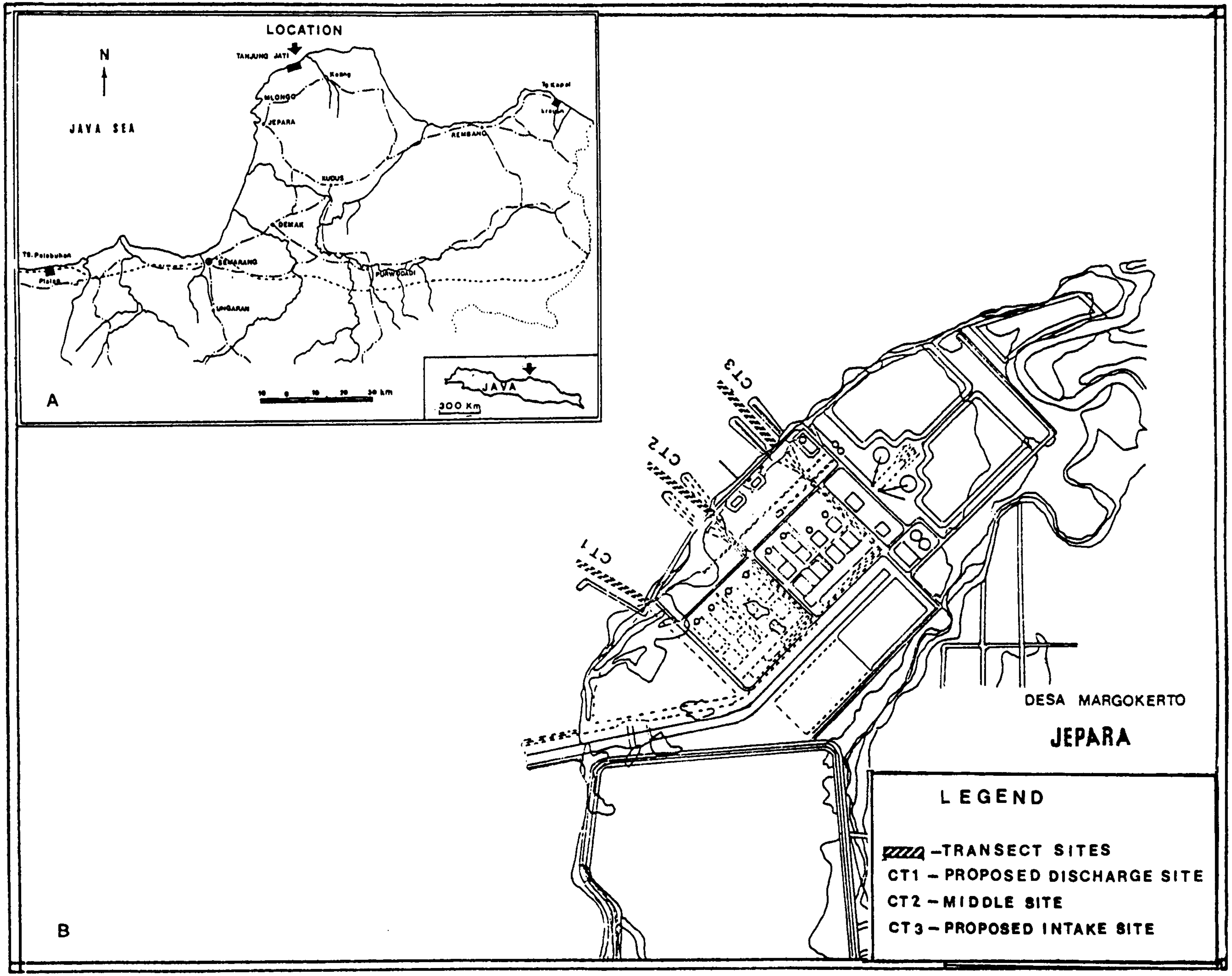

Fig. 1. Tanjung Jati study site (A) and transect sites (B).

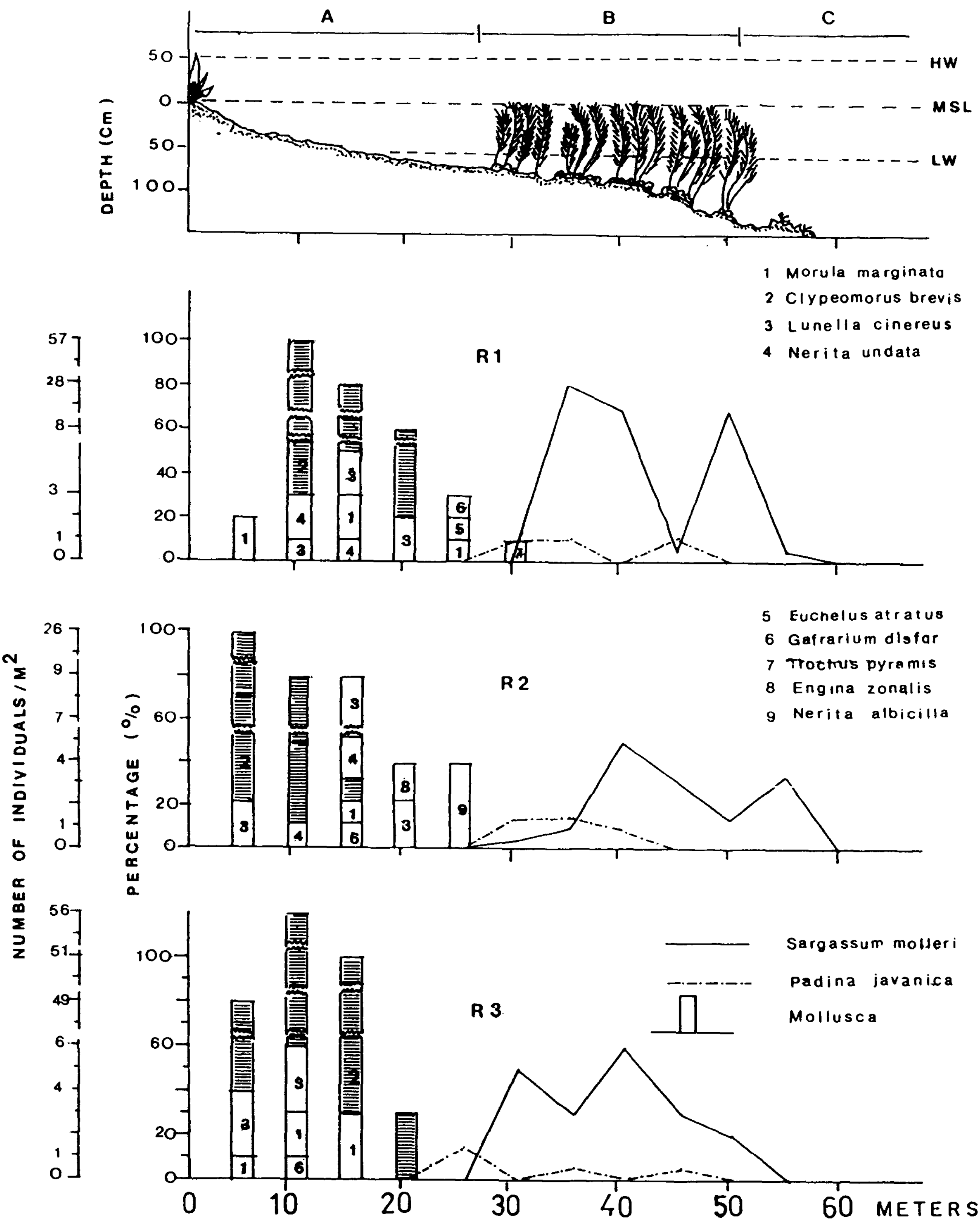

Fig. 2. Profile of CT1 reef flat showing zonation, distribution and abundance of algae (polygon) in percent cover and molluscs (histogram) in number of individuals/m^2.
A = sand-rubble zone; B = Sargassum zone; C = coral zone; HW = high water; MSL = mean sea level; LW = low water; R = replicates.

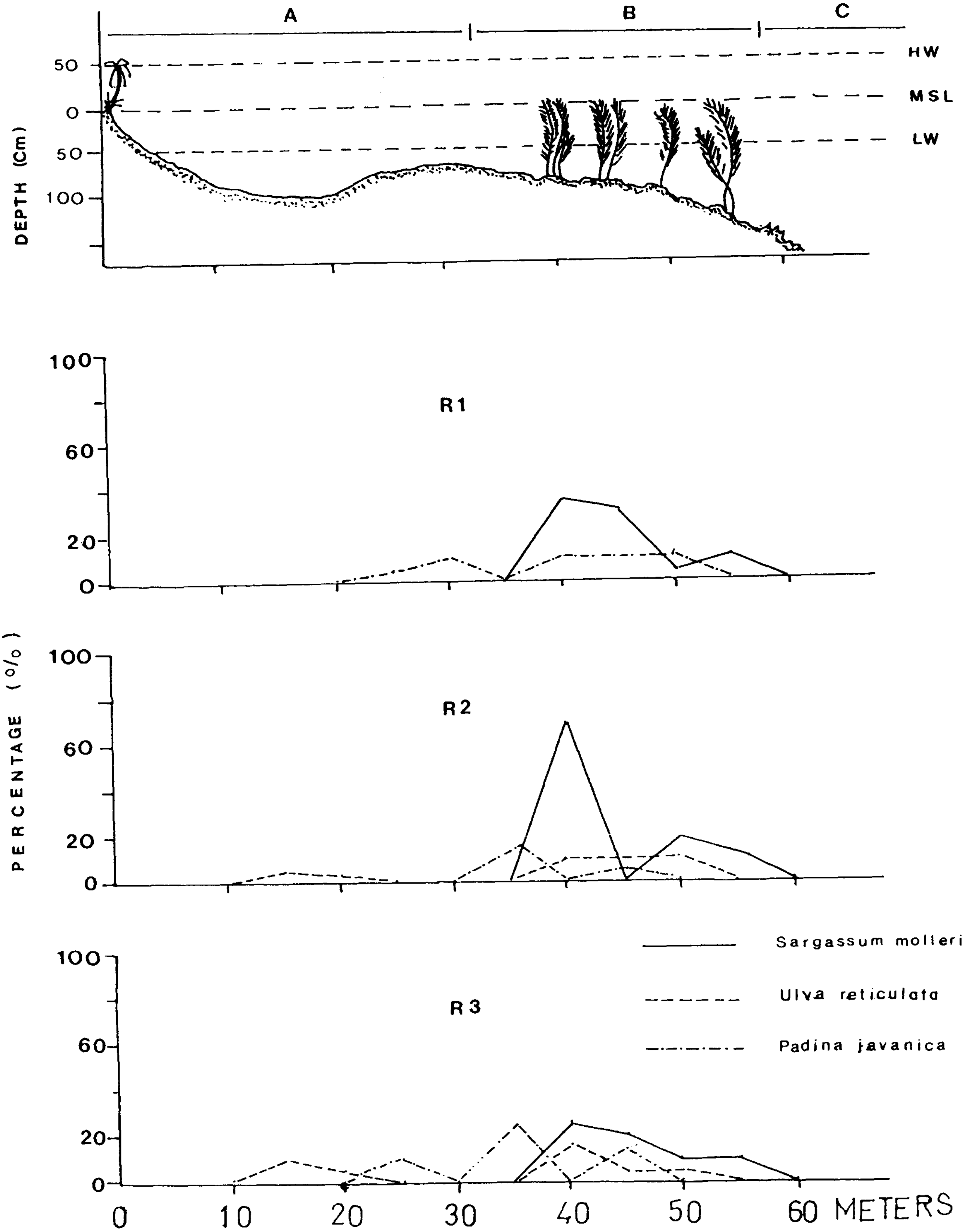

Fig. 3. Profile of CT2 reef flat showing zonation, distribution and abundance in percent cover of algae.
A = sand-rubble zone; B = Sargassum zone; C = coral zone; HW = high water; MSL = mean sea level; LW = low water; R = replicates.

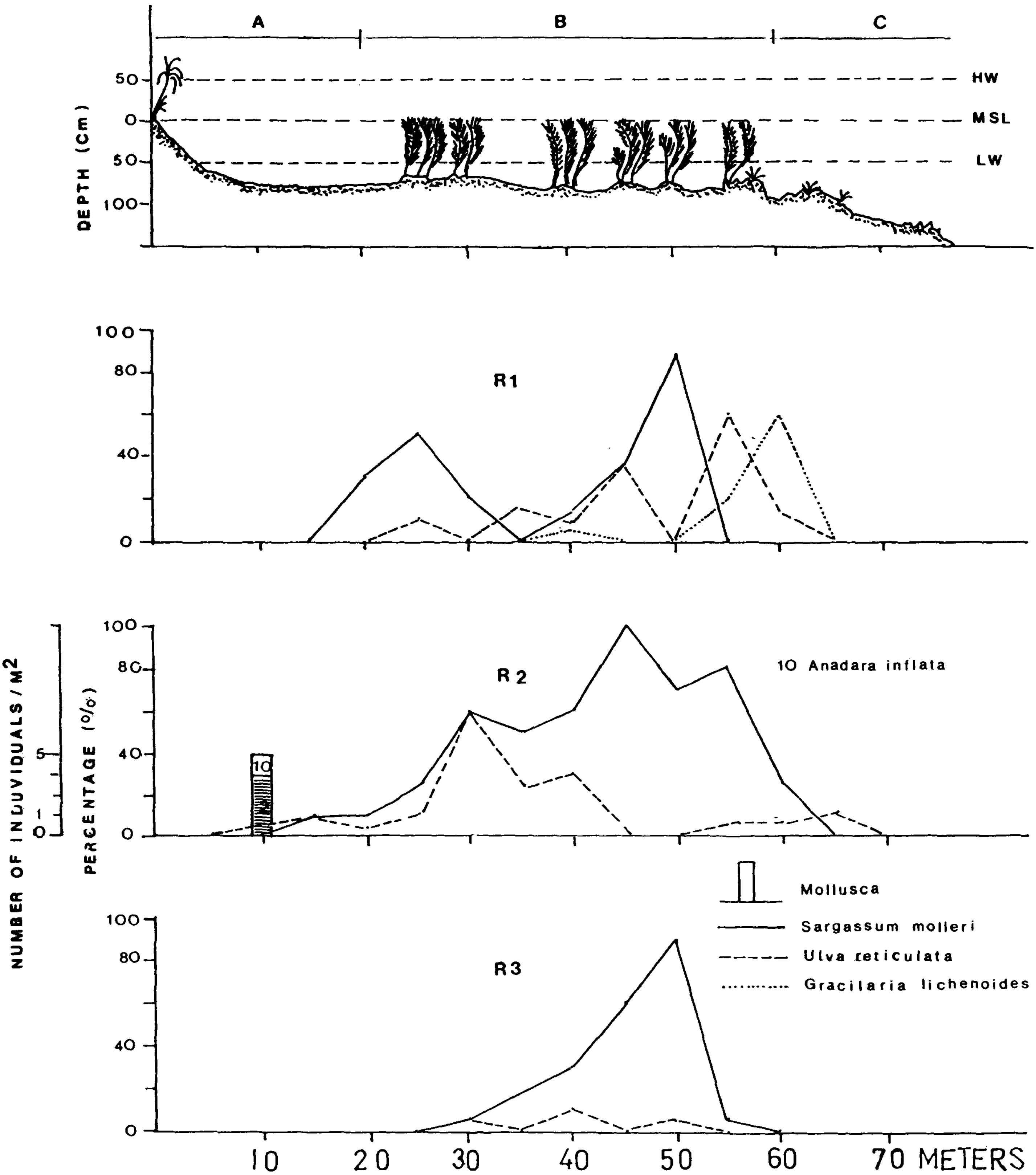

Fig. 4. Profile of CT3 reef flat showing zonation, distribution and abundance of algae (polygon) in percent cover and molluscs (histogram) in number of individuals/m^2.
A = sand-rubble zone; B = <u>Sargassum</u> zone; C = coral zone; HW = high water; MSL = mean sea level; LW = low water; R = replicates. See Figure 2 for other legends.

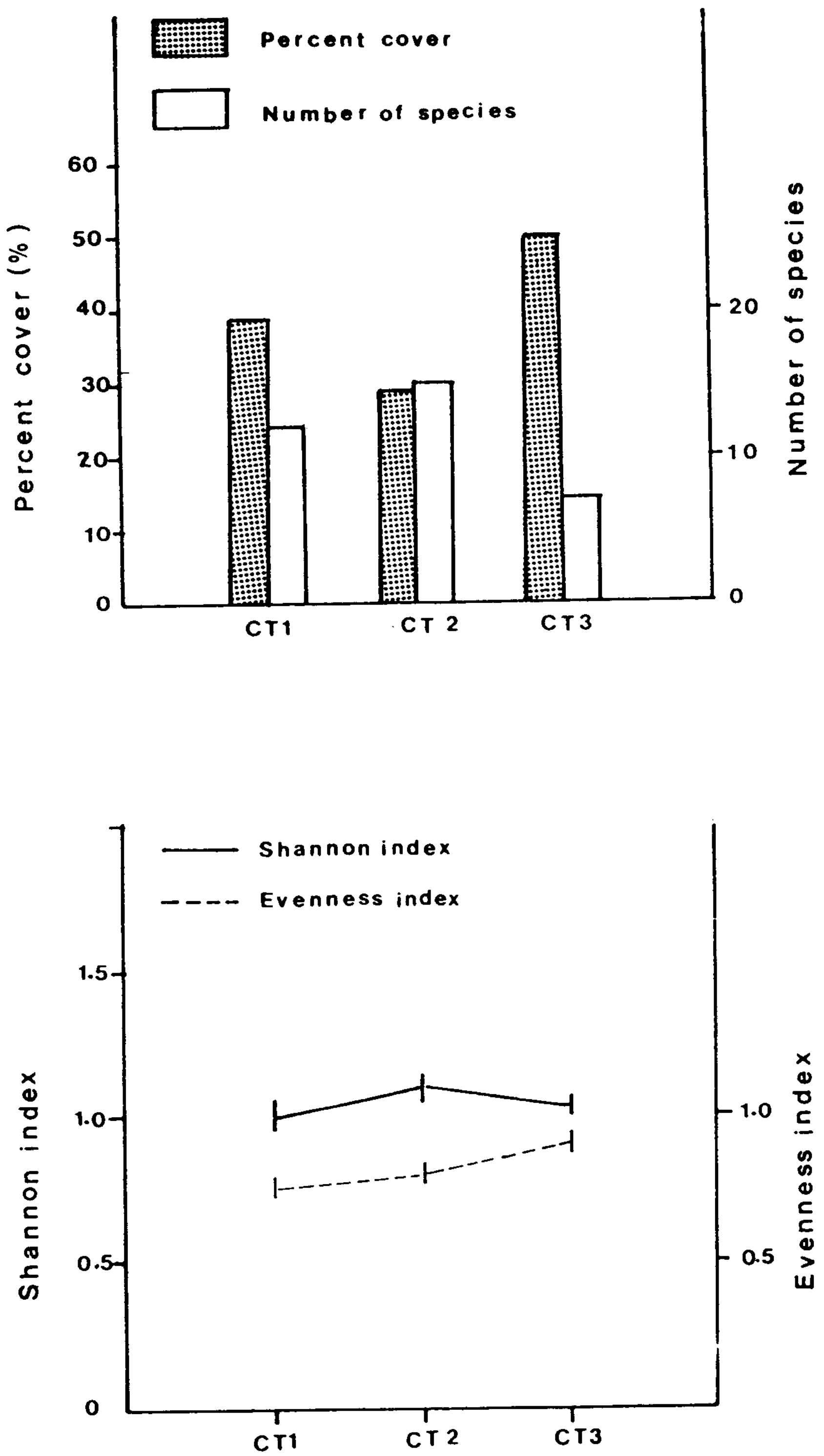

Fig. 5. Percent cover and number of species of stony corals, and diversity and evenness indices of all biotic components from transects at 3 m depth.

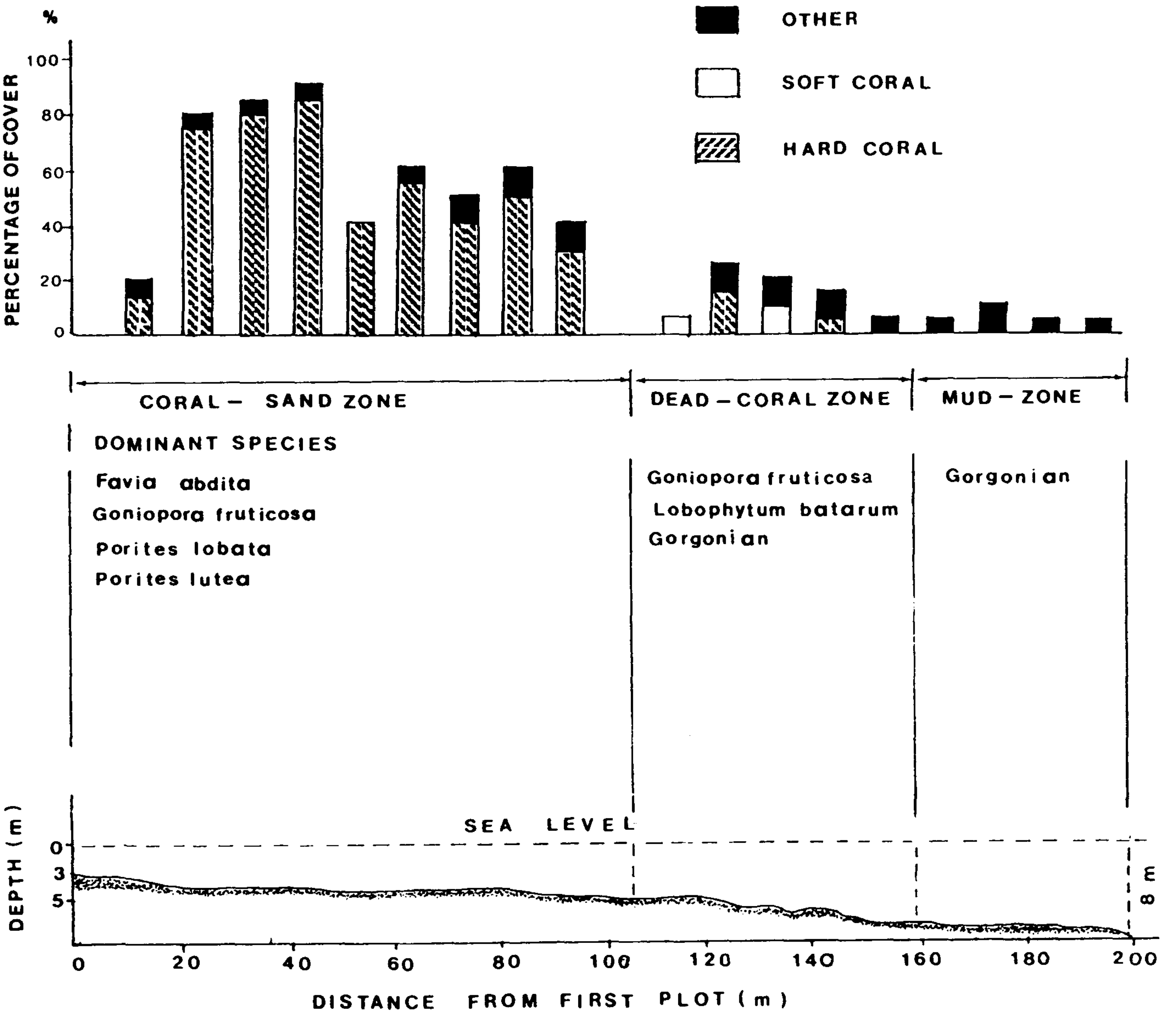

Fig. 6. Profile of CT1 reef slope showing zonation, distribution and abundance of corals and other biota and dominant species of each zone.

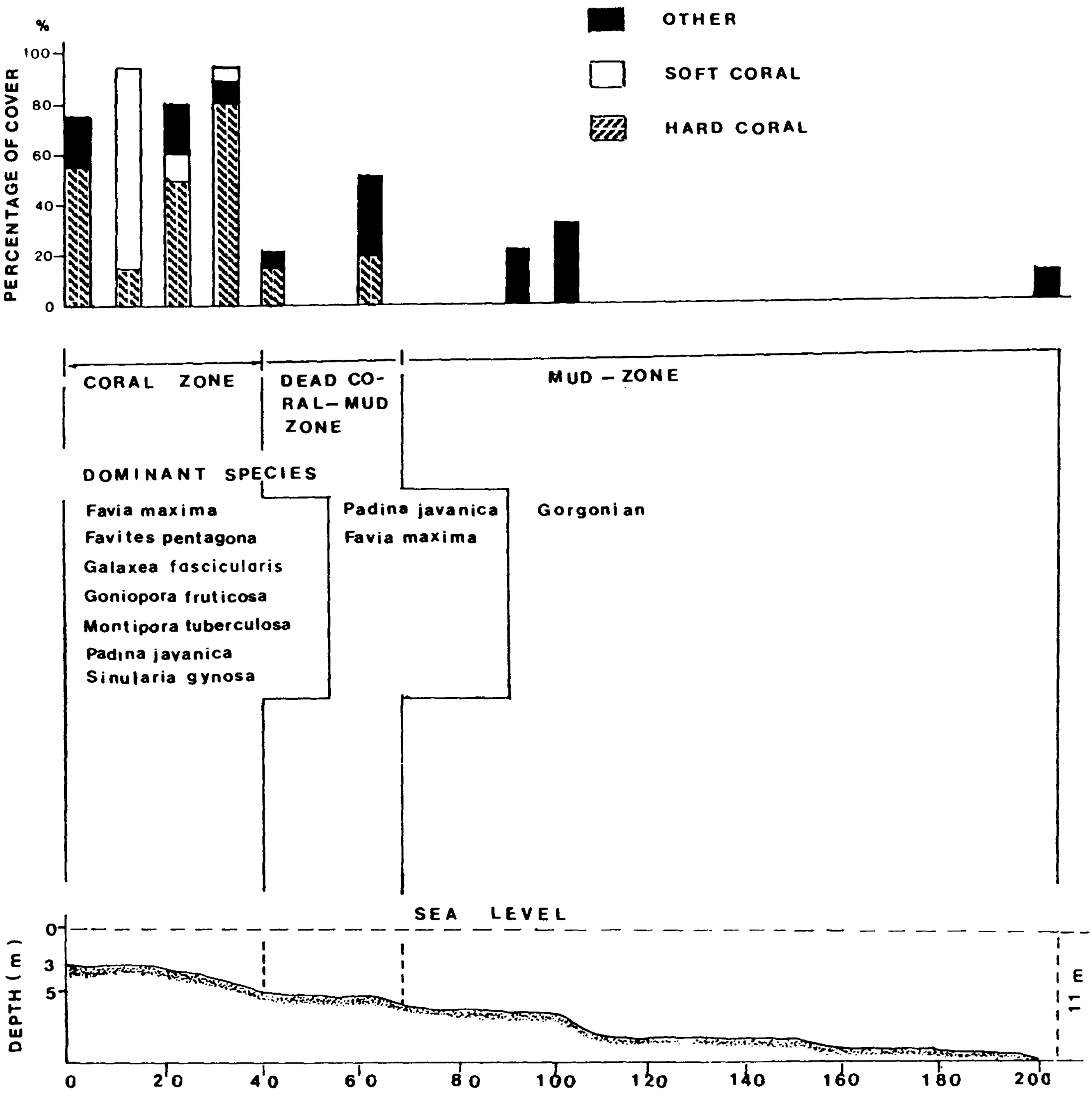

Fig. 7. Profile of CT2 reef slope showing zonation, distribution and abundance of corals and other biota and dominant species of each zone.

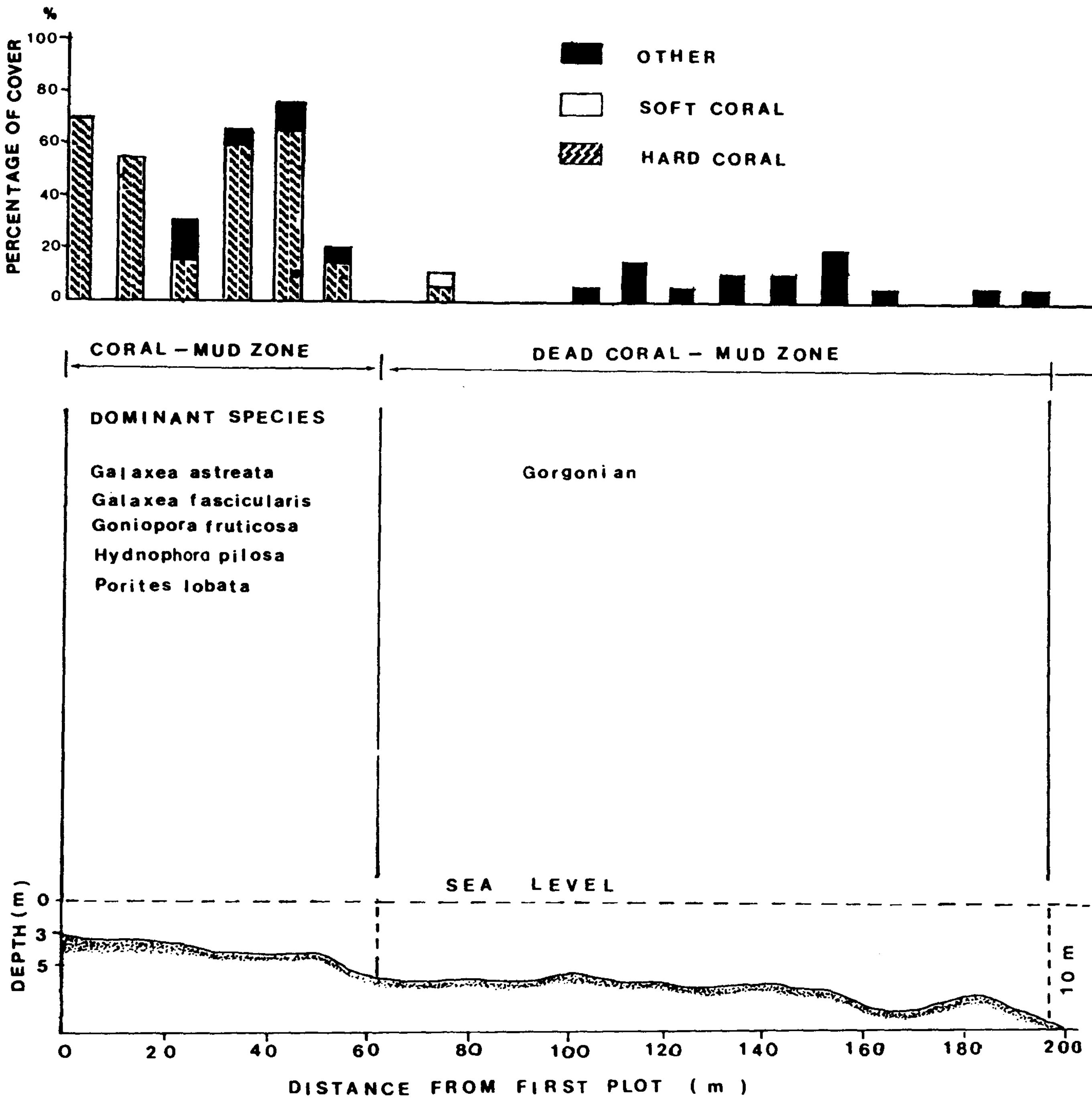

Fig. 8. Profile of CT3 reef slope showing zonation, distribution and abundance of corals and other biota and dominant species of each zone.

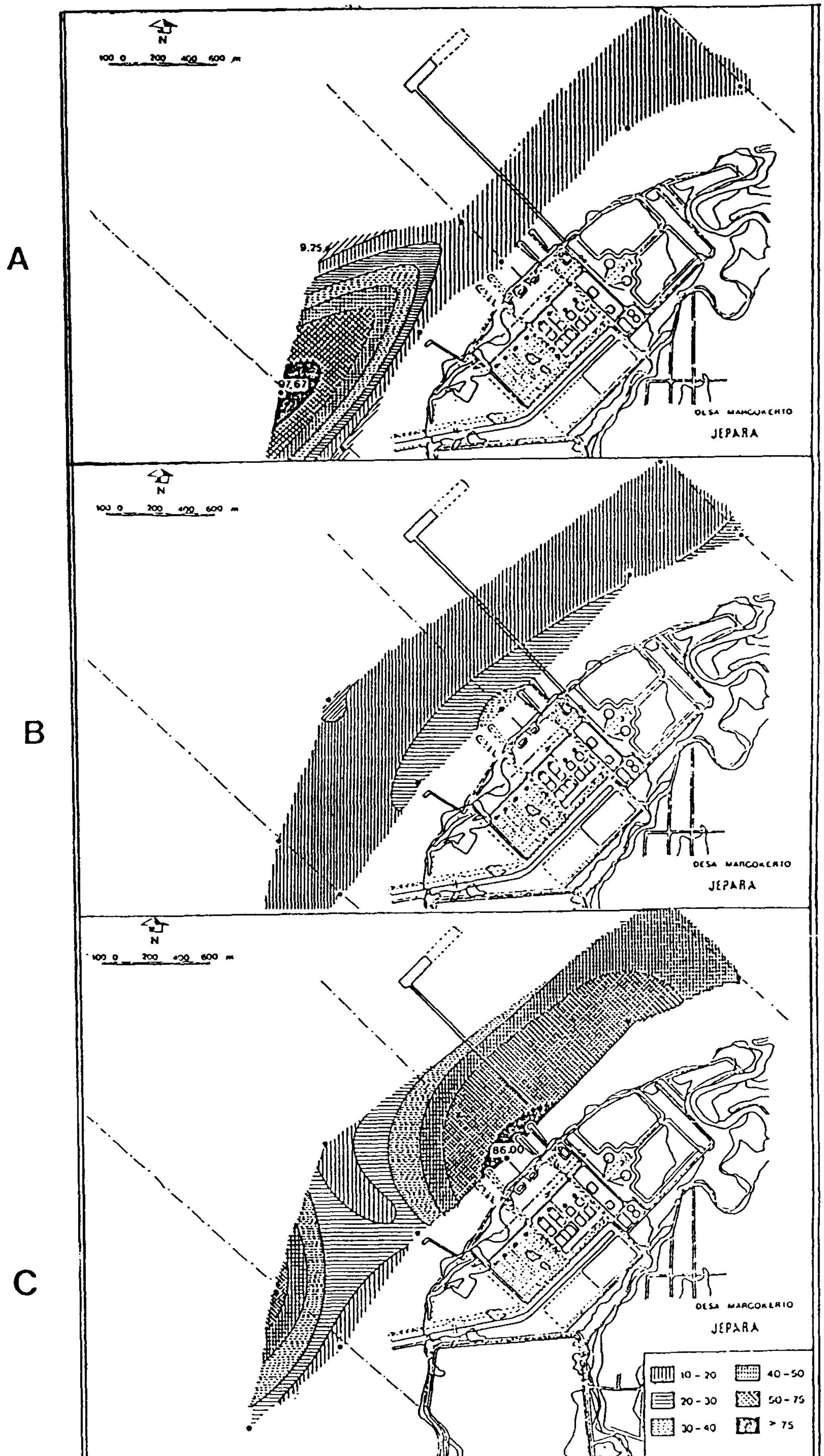

Fig. 9. Distribution of surface (A), middle (B) and bottom (C) layer suspended solids (mg/l) in Tanjung Jati waters, May 1988.

RECOVERY OF A CORAL REEF FROM TYPHOON DAMAGE AT PESCADOR ISLAND, CEBU, CENTRAL VISAYAS, PHILIPPINES

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ABSTRACT

On September 2, 1984, three weeks after typhoon "Nitang" destroyed the Pescador Island reef, sixteen 1 m x 1 m study sites were set up on its eastern side. Eighteen months later, another five 1 m x 1 m study plots were set up at the southern part. The two study areas were monitored to (a) determine recovery and survival rates of corals and (b) find out what species or genera of corals colonize reef.

Based on estimates from permanent quadrats, the percentage of live cover in the eastern part of the reef increased from 8.75% during the first year to 44.79% after four years. On the other hand, the live coral of the five study plots in the southern part of the reef was only 13.71% by actual measurement; this coral cover had an area of 6,854.87 sq.cm. The difference in recovery rates probably reflects ecological differences between the eastern and southern parts of the reef flat.

The number of colonies in the five study plots increased from 53 to 272 within two years. The survival rate of 8 hard coral genera was 54.71% after one year and 43.39% after two years.

Our data on recovery of hard corals suggest that it takes more than five years for a typhoon-damaged reef to become a "good" reef, with 50-75% live coral cover.

1. INTRODUCTION

Coral reefs have been subjected to damage not only by man-induced factors such as dynamite fishing and other destructive fishing methods, but also by catastrophic forces like hurricanes and typhoons (Shinn 1976, Alcala et al. 1986). Recovery of coral reefs destroyed by bad fishing methods and storms is very slow (Randall 1973, Grigg and Maragos 1974, Alcala and Gomez 1979, Bak and Creins 1981). On September 2, 1984, typhoon "Nitang", with maximum centre winds of 200 km/hr, swept through the Central Visayas, destroying coral reefs in its path. Pescador Island reef was one of the many reefs destroyed.

Pescador is a small coralline island about 3 km off Moalboal, western Cebu. It is located at latitude 9°55'30"N and longitude 123°20'28"E (Fig. 1). The reef flat gradually slopes down to about 30 m at the southern end but is relatively flat at the eastern and western sides at a depth of about 3 to 5 m before it drops steeply to more than 30 m. The reef is inhabited by diversified species of hard and soft corals and has a wide variety of invertebrates and coral fishes (Alcala et al. 1986). It has an area of about one hectare. The island is exposed to the two monsoons, the NE which blows from November to April and the SW which blows from June to October.

This study was carried out with the following objectives: (a) to determine the recovery and survival rates of corals, and (b) to find out what species or genera of corals colonize the reef after typhoon damage.

2. METHODS

Three weeks after typhoon "Nitang" swept through Pescador Island, sixteen (16) study sites were set up at its eastern side. These were marked by a nylon monoline for easy monitoring and were located at depths of 1-5 m in the denuded coralline reef flat. The coral cover was monitored every 4 to 6 months using a 1 m x 1 m wire grid quadrat sampler with sixteen (16) equal divisions.

Eighteen months later, five more 1 m x 1 m study plots were set up in the denuded coralline substrate, 2-3 m deep, at the southern part of Pescador reef. The long and short diameters of coral colonies, including recruits and those colonies regenerated from the remaining broken colonies inside the plots, were measured every 4 to 6 months with a Vernier caliper. The annual increment in area of corals was computed by first taking the mean of the increments in the short (W) and long (L) diameters. The area was then determined by the formula $\pi(LxW)/4$.

3. RESULTS AND DISCUSSION

Table 1 and Figure 2 present the estimated hard coral cover of the 16 1 m x 1 m study sites on the eastern side of Pescador island, ranging from 4.30% during the first year to 44.79% after 4 years. Soft corals comprised 0.42% of the total cover in 1985 and 0.45% in 1986. In 1988, no soft coral data were collected since the marker of the study site 1, the only site that had soft corals, could not be located. It should be noted that from the 6 study sites originally monitored, the number decreased progressively from 15 to 14 to 12. The reason for this was that some site markers were covered by algal growth or lost due to wave action.

Table 1. Mean estimates of live coral cover from 12-16, 1 m x 1 m quadrats made every four to six months from September 1984 to October 1988 on the denuded reef of Pescador Island (eastern side) after typhoon damage.

Condition of the reef (%)	Sampling Dates 9/24/84	8/03/85	11/18/86	12/04/87	10/10/88
Live Hard Coral (LHC)	4.30	8.79	18.79	32.81	44.79
Soft Corals (SC)	0.0	0.42	0.45	0.0	0.0
Others (dead corals, rock, coral rubble, sand turf, algae)	95.70	90.83	80.80	16.19	59.37
Remarks	Observations from 16 study sites	Observations from 15 study sites	Observations from 14 study sites	Observations from 12 study sites	Observations from 12 study sites

Eighteen months after typhoon "Nitang" damaged the reef, the percentage coral cover based on actual measurements of coral colonies from the five 1 m x 1 m study plots in the southern part (Table 2) was 3.85% (areal cover of 1,923.94 sq.cm). Two years later, the percentage coral cover went up to 13.71% of an areal cover of 6,854.87 sq.cm. (Fig. 3). The value of 13.71% coral cover after 3.5 years is very low compared to that of the 16 study sites after 4 years which was 44.79%.

Table 2. Areal increment and percentage coral cover from five 1 m x 1 m study plots, 8-15 feet deep on the denuded reef of Pescador Island (southern part) 18 months after a typhoon damaged the reef.

Dates	March 1986			March 1987			March 1988		
Plot number	Initial no. of colonies	Initial area covered (cm^2)	Percentage area covered (%)	Total no. of colonies	Total area covered (cm^2)	Percentage area covered (%)	Total no. of colonies	Total area covered (cm^2)	Percentage area covered (%)
PM - 1	13	161.09	1.61	34	514.90	5.15	70	1,726.82	17.27
PM - 2	14	140.41	1.40	38	233.07	2.33	77	751.31	7.51
PM - 3	7	127.74	1.28	24	211.51	2.12	49	711.58	7.12
PM - 4	7	1,418.53	14.19	20	1,898.21	18.98	24	2,297.53	22.98
PM - 5	12	76.17	0.76	27	380.32	3.80	52	1,367.63	13.68
TOTAL	53	1,923.94	3.85	143	3,238.01	6.48	272	6,854.87	13.71

The reason for the difference in the gain in percentage coral cover might lie in the site location of the two study areas. The 16 study sites were located on the eastern part of Pescador reef where they were exposed to moderate to strong currents and wave action resulting from the northeast and southwest monsoons. On the other hand, the five study plots located at the southern part were exposed only to the southwest monsoon during the months of June to October. During the northeast monsoon, the current was slow or absent. Massive growths of algae were present and appeared to compete with corals for substrate (see Cribb 1973). The absence or the presence of favourable currents responsible for transporting coral planulae may also have greatly affected the rate of recolonization of destroyed reefs especially if the destruction caused by catastrophic events were total or near total (see Endean 1973a).

There were 53 coral colonies measured from the five 1 m x 1 m study plots. The number rose to 143 colonies after one year and 272 after two years (Fig.4). The dominant genera of corals measured in decreasing order were Pocillopora (33 colonies), massive Porites (6 colonies), Favia (5 colonies), Platygyra (4 colonies), Tubastrea (2 colonies), Pavona (1 colony), Millepora (1 colony) and Acropora (1 colony).

Figure 5 shows the survival rates of 53 coral colonies belonging to 8 genera. The survival rate (SR) is computed by dividing the number of surviving colonies at a given time (T1) by the number of colonies at the beginning (T0) multiplied by 100. Pocillopora, with 33 colonies had a survival rate of 48.48% after one year which dropped to 33.33% after two years, while Porites had a rate of 66.67% during the first year which was maintained up to the second year. On the other hand, the survival rates of Platygyra and Favia were 100% after one year. After two years, Platygyra maintained its 100% survival rate while that of Favia dropped to 80%. Tubastrea, Pavona, Millepora and Acropora had 0% survival rates during the two years of observation.

Pescador reef belonged to the category of "good" reefs, with a 51-60% coral cover prior to typhoon "Nitang". This is based on the results from five 1 m x 1 m quadrats sampled on April 11, 1978 in which 36.3% were hard corals and 23.0% soft corals, giving a total of 59.3% coral cover (Marine Sciences Center 1979). A transect sample in 1983 by White (1984) gave an estimate of 12.5% soft corals and 39.3% hard corals, with a total of 51.8%

The rate of recolonization of destroyed reefs is dependent upon the types of substrata and causes of destruction. However, it is apparent that recovery of coral reefs depends basically on colonization of devastated areas by coral planulae and on the continued growth and reproduction of surviving coral colonies (Endean 1973a). Alcala and Gomez (1979) reported that recovery of hermatypic corals as measured by percent live coral cover is faster on hard, firm rock substrates than on unstable coral rubble. They further revealed that in dynamited reefs the percentage of live coral cover after 10 years was 39.58% on rocky substrates and 13.75% to 37.28% on coral rubble. Endean (1973b) estimated that the recovery of Acanthaster-infested reefs in the Great Barrier Reef takes between 20 to 40 years, especially when infestation is recurrent. Grigg and Maragos (1974) give 20 and 50 years as the complete recovery time in exposed and sheltered areas, respectively, for coral communities destroyed by lava in Hawaii. Shinn (1976) reported a rapid recovery within 5 years of Acropora and massive corals in a hurricane devastated area in Florida. The method of recovery was asexual regeneration of scattered broken live coral fragments.

These data from the Pescador Island reef study suggest that it probably takes more than four years for a reef destroyed or denuded by a typhoon to reach the category of a "good" reef (50-75% live coral cover), provided no disturbance occurs during the period of recovery.

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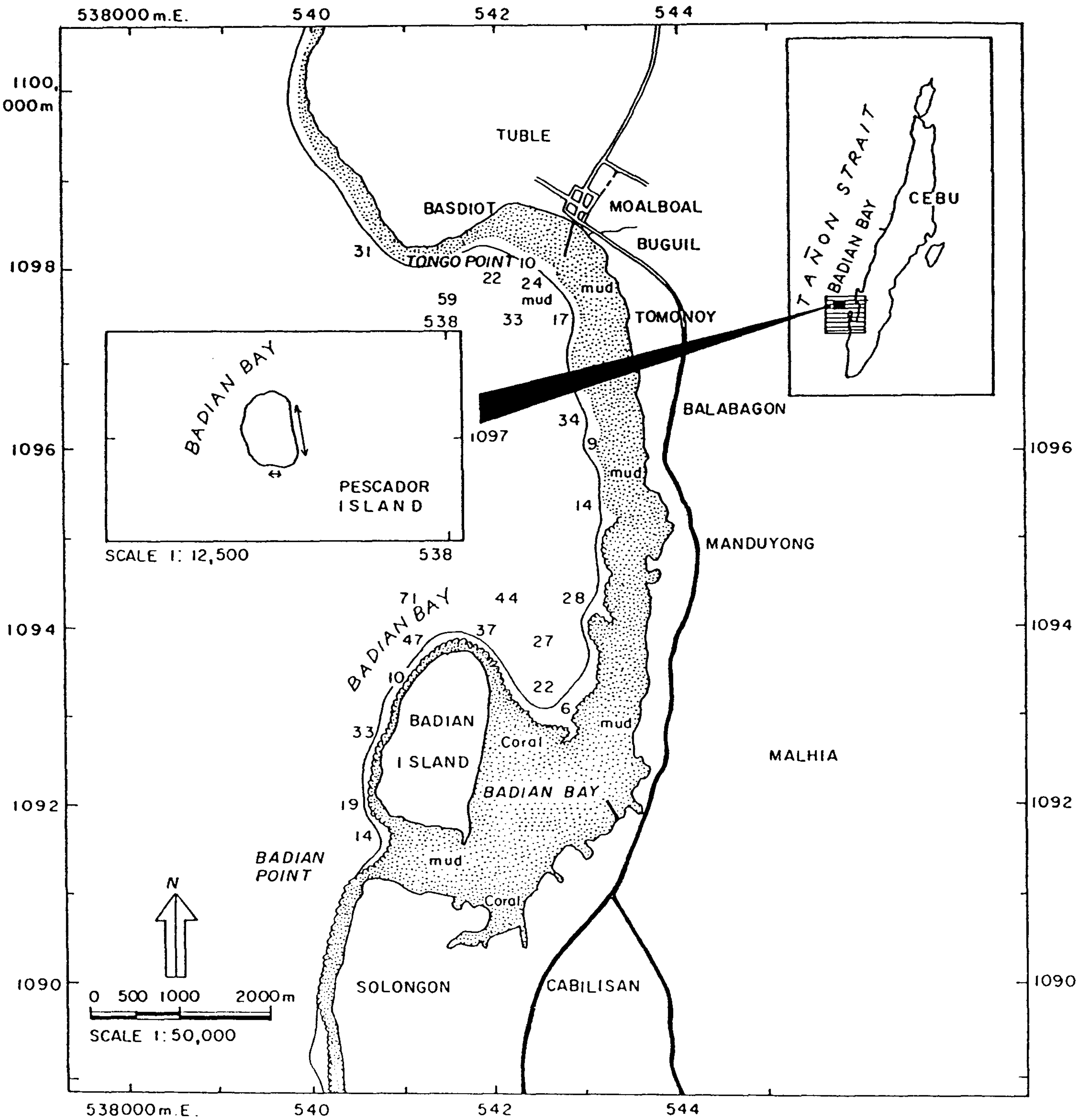

Fig. 1. Map of Pescador Island.

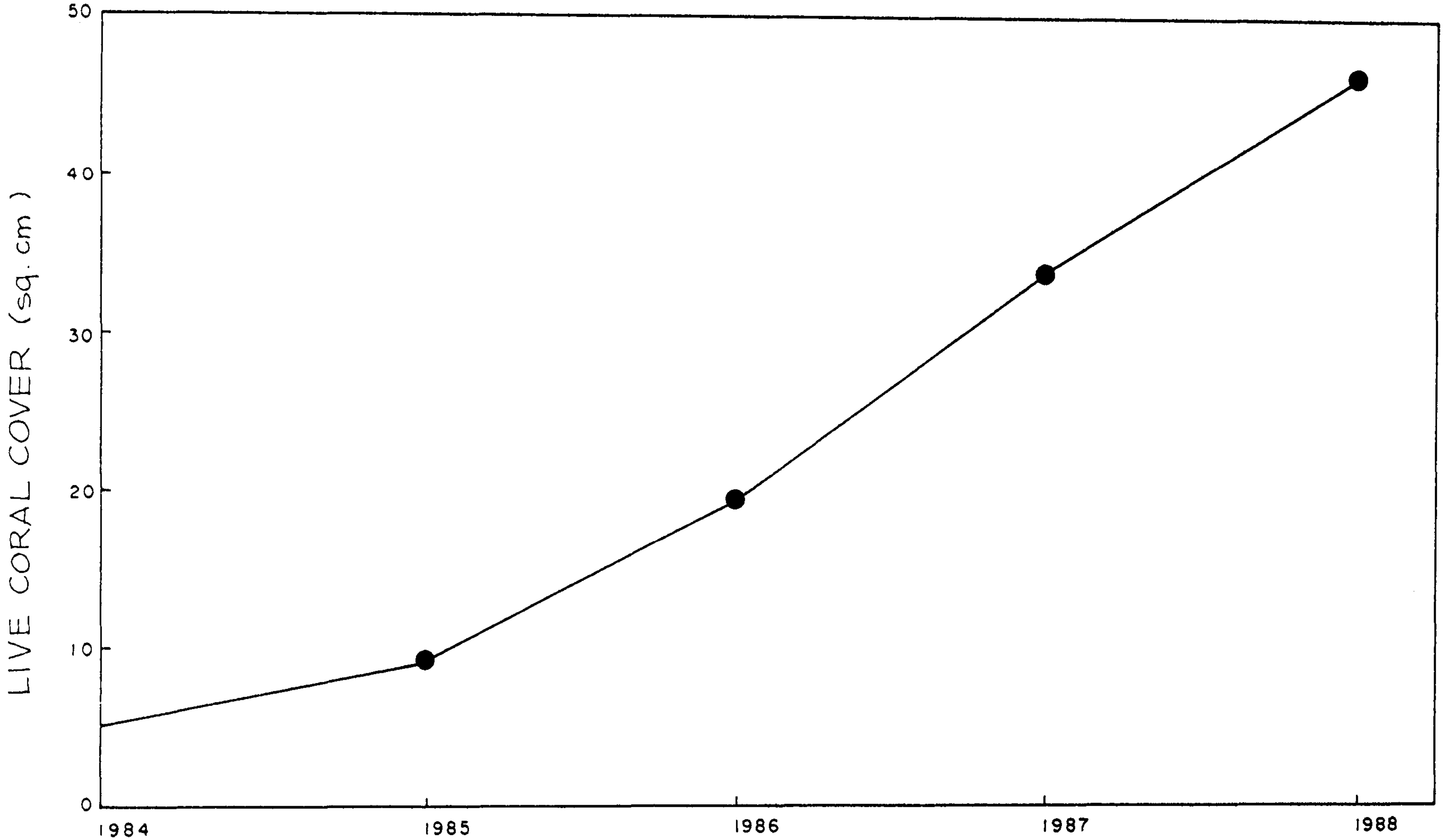

Fig. 2. Recovery of Pescador Island reef after denudation by typhoon "Nitang" on 2 September 1984. Each point represents a mean of estimates from 12 to 16 1m x 1m quadrats on the eastern side of the island made every four to six months from September 1984 to October 1988.

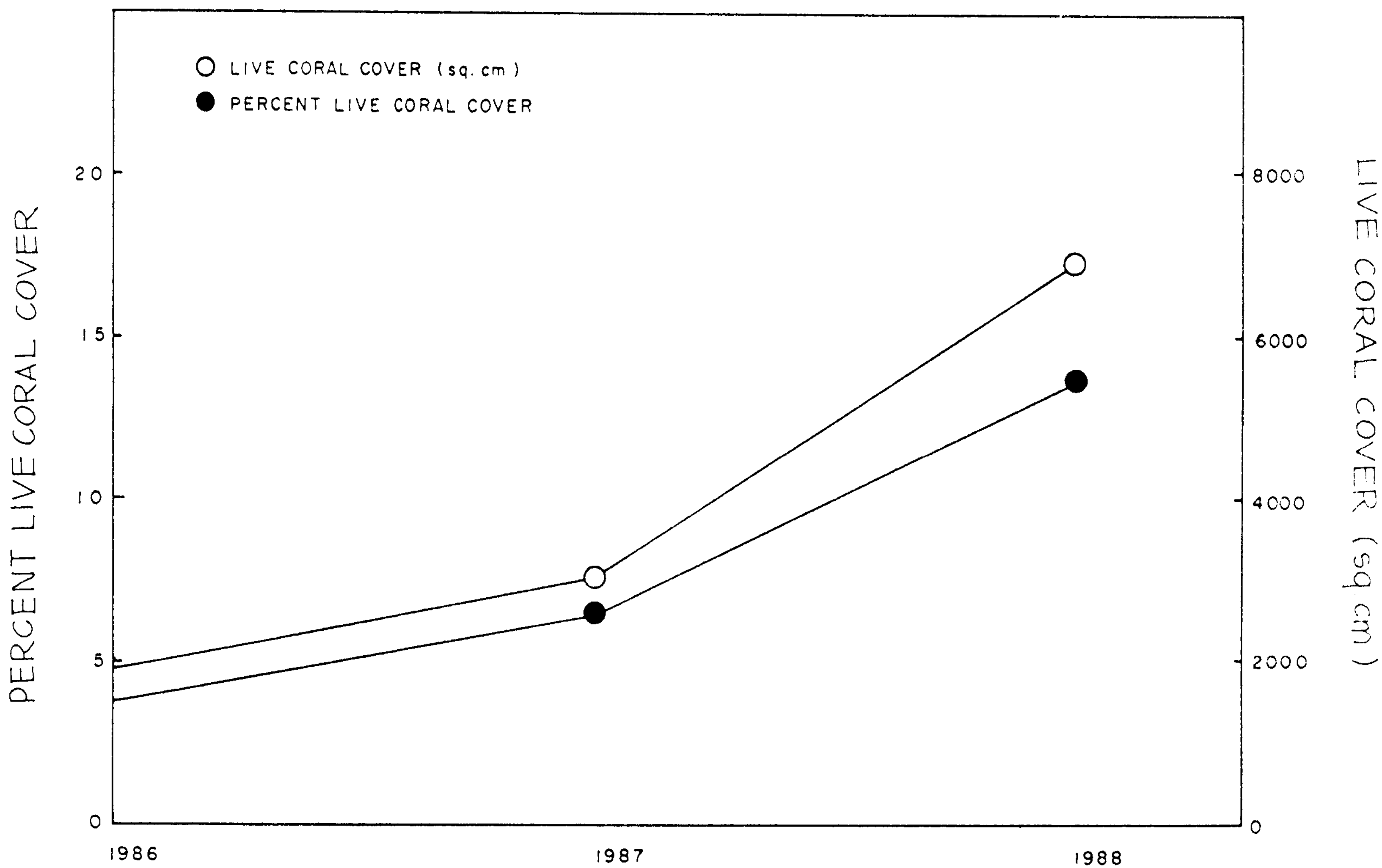

Fig. 3. Growth of hard corals on the denuded reef flat of Pescador Island (southern part) 18 months after typhoon "Nitang" destroyed the coral reef. Each point represents the mean of measurements from five 1m x 1m plots.

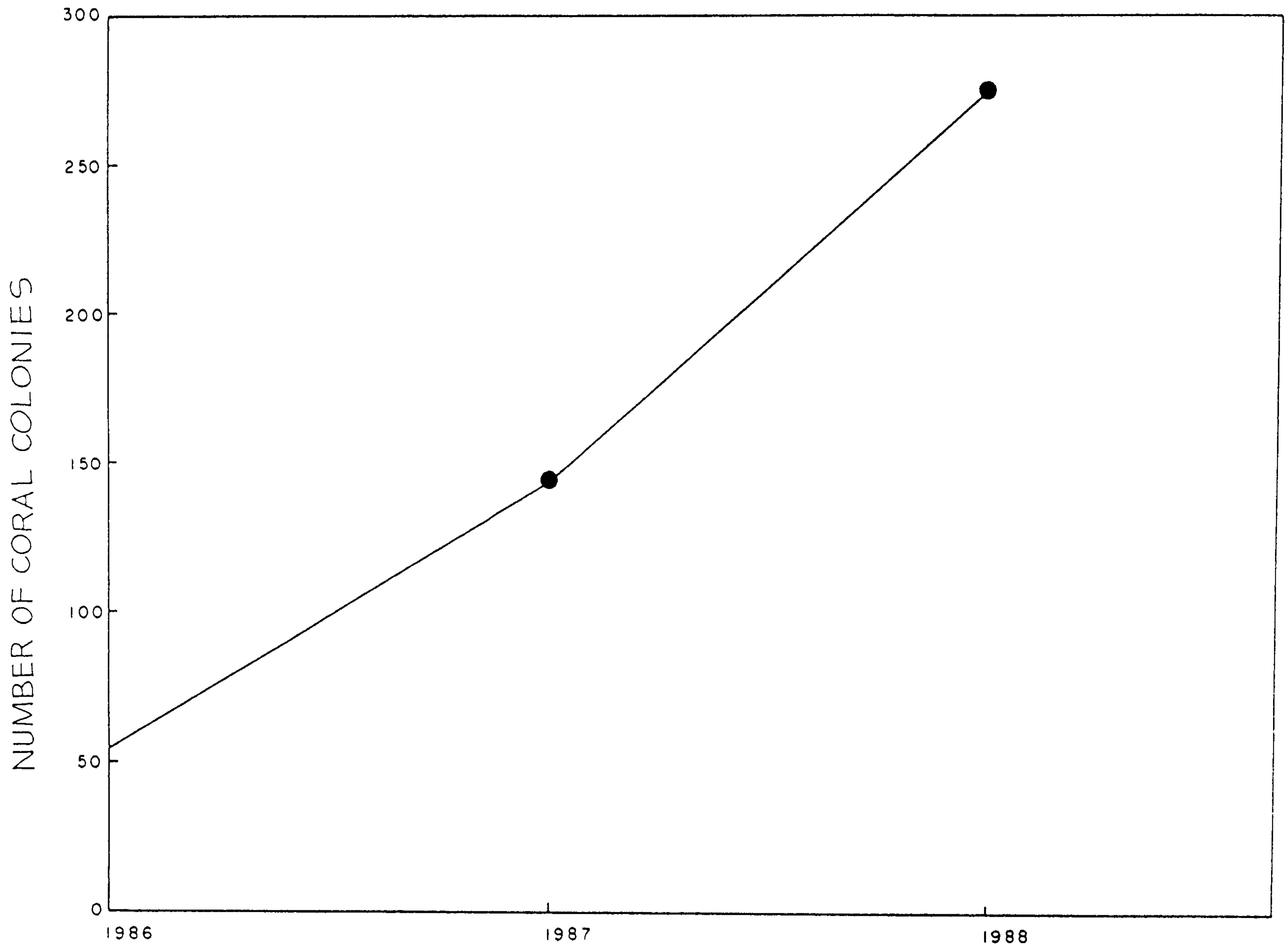

Fig. 4. Number of coral colonies measured from five 1m x 1m study plots in a denuded reef of Pescador Island (southern part) 18 months after a typhoon damaged the reef.

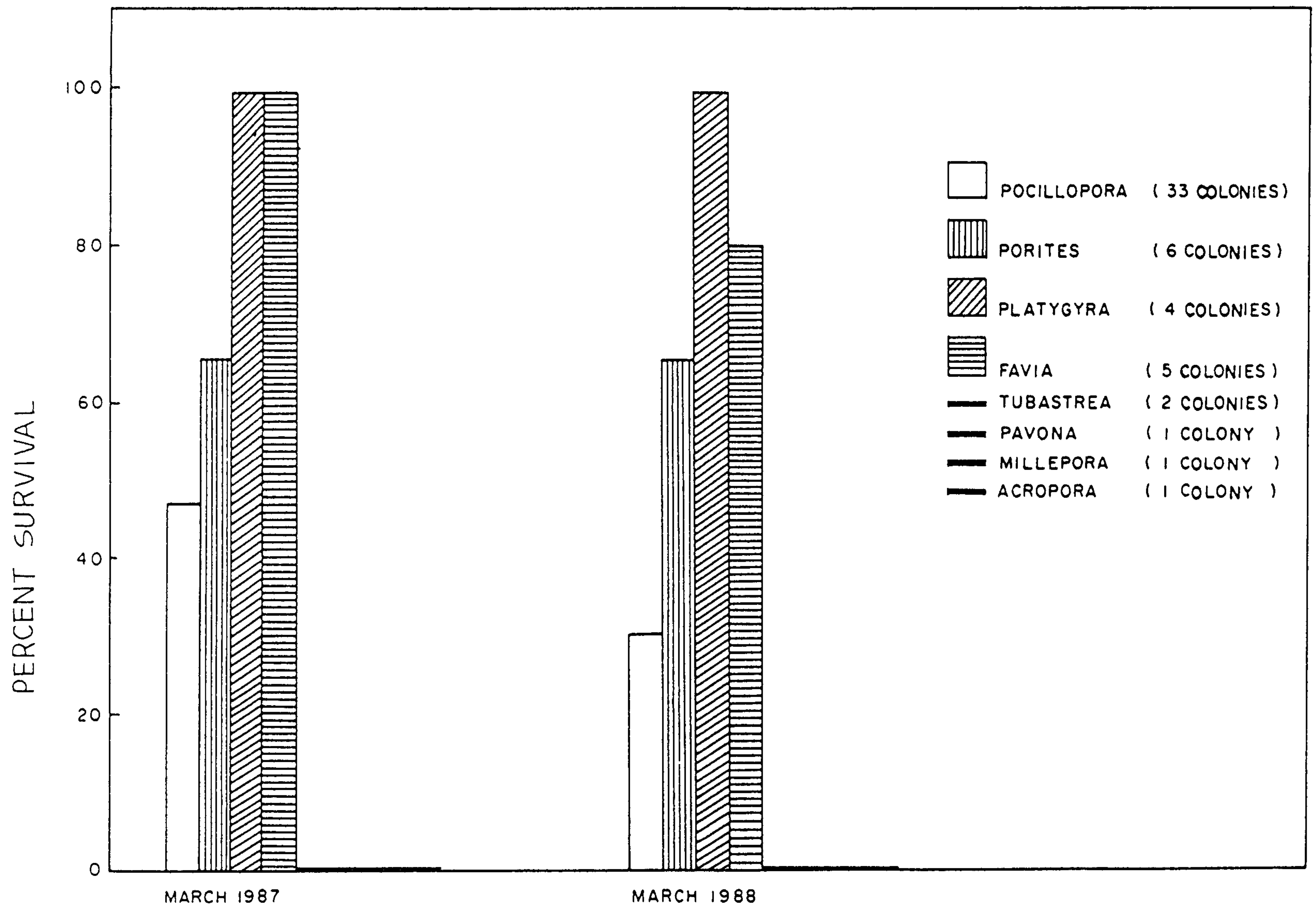

Fig. 5. Survival rates of certain hard corals colonizing Pescador Island after damage by typhoon "Nitang" on September 2, 1984.

STUDIES ON CORAL REEF RECOVERY AND CORAL TRANSPLANTATION IN THE NORTHERN PHILIPPINES: ASPECTS RELEVANT TO MANAGEMENT AND CONSERVATION

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ABSTRACT

The nature of natural recovery in a damaged section of the reef flat was investigated at Cangaluyan Island, Pangasinan in the northern Philippines. The recruitment of corals and associated organisms was monitored on two scales to take both microscopic and macroscopic processes into account. Coral reef recovery after extreme physical damage such as due to blasting was found to be relatively slow, on the order of 1-3% coral cover in a year. On the basis of results from controlled experiments, the recruitment of corals appears to be dependent on the "conditioning" of the substrate by pioneer organisms, specifically in the form of deposition of calcareous layers by coralline algae. At any rate, coral colonization appeared to be hindered by the instability of the substrate created by blasting. In view of the slowness of natural coral reef recovery, one possible way of restoring damaged areas within a relatively short period of time is to introduce adult coral colonies or healthy fragments thereof to serve as seed material for the development of new populations. Experiments have been conducted in the Philippines to test the feasibility of such an approach. Results of these studies have pointed to a number of factors that should be considered in the attempt to rehabilitate damaged reefs by coral transplantation. One such consideration is the life history of the species to be used as transplant material. Another factor to be borne in mind is the size of the coral colonies or fragments to be transplanted, since this has an implication for energy reserves crucial for survival. Other pointers are time and conditions of transplantation, and sensitivity of the corals to handling stress. All of these have a bearing on the ultimate success of the transplantation effort in effectively initiating the recovery of coral communities.

1. INTRODUCTION

The UNEP-sponsored project under the East Asian Seas Programme entitled "Study on coral resources and the effects of pollutants and other destructive factors on coral communities and related fisheries in the East Asian Seas region" was composed of several studies. One such study, implemented in the Philippines by the Marine Science Institute, was conducted in two parts. The first was an investigation of natural recovery processes in a reef area previously damaged by blast fishing, a common cause of destruction in Philippine reefs. The purpose of the research was to gain insights on how the coral reef ecosystem responds to physical damage of this type, including the likelihood of restoration to the original more productive state, and the time element and mechanisms involved if recovery does occur. It was considered that such an understanding was the key to elucidating the nature of important processes that affect present-day reefs, and should serve as a basis for measures aimed at mitigating negative impacts on such resources.

The second part of the project drew on findings from the first and from previous coral reef research carried out at the Institute. The nature of this study was in terms of attempts at active rehabilitation of damaged reef areas. Based on knowledge gained to date, a possible tool for coral reef restoration is the introduction of adult coral colonies or fragments thereof into a damaged area. The objective is to utilize these as seed material for the generation of new coral populations. The success of such an attempt obviously hinges on the existence of environmental conditions favourable for the re-establishment of coral communities approximating the original ones. The length of time involved in such a process is another key question.

The above studies are the first known attempts of the kind in Southeast Asia, focusing on coral reef resources and with an integrated purpose: to understand the nature of coral reef destruction and the processes involved in recovery (if the latter is at all possible in a given situation), and to examine possible means of actively restoring damaged habitats or accelerating their recovery. The aim is to contribute to possible management measures for protecting and conserving coral reef resources to assure their sustained productivity.

2. NATURAL CORAL REEF RECOVERY

This study was conducted on the reef flat of Cangaluyan Island, near Bolinao, Pangasinan in the northern Philippines, at 16°22'N and 120°00'E. Results have been published in Alino et al. (1985) and Yap and Gomez (1988).

As mentioned earlier, the purpose of the investigation was to look into processes that occur after physical damage on a reef. An area on the reef flat known to have been affected by recent blasting was identified as the experimental site. For purposes of comparison, a control station characterized by relatively healthy conditions was located about 1 km SE of the disturbed area. The control was designated as Site 1, and the experimental station as Site 2 (Fig. 1).

Recruitment of corals and associated organisms in both sites was monitored on two scales: the first involved a size range of microscopic to visible to the naked eye; the second scale was on the order of larger macro-organisms and fragments. In order to integrate these two scales, two methods of observation were utilized simultaneously. One technique made use of fossil coral tiles as settling plates to monitor the colonization of new organisms, and the other involved observations of recruitment in permanent 1-m^2 quadrats.

So as to take into account the succession of organisms starting immediately from the occurrence of the disturbance, the experimental site was further cleared of all visible living cover prior to the placement of the settlement tiles and the permanent quadrats.

2.1 Recruitment on a small scale

Recruitment substrates were laid out on the bottom of each study site in March 1983, immediately after clearing of the benthos. The tiles measured 2.5 x 7.5 x 15 cm. These were grouped into five patches arranged in a cross-shaped fashion, with one patch in the middle. There were 40 tiles in each patch in Site 1, arranged in 4 rows of 10, while Site 2 had 60 tiles in 5 rows of 12.

Each month, 5 tiles were collected from the control (Site 1), and 10 from the experimental site (Site 2). These were examined in the laboratory for settling organisms (details of procedures are given in Yap and Gomez (1988).

Both control and experimental stations were situated on what was generally considered the same reef zone. Surveys of Sites 1 and 2 revealed a similar degree of coral cover and community composition at the beginning of the study (Alino 1985). Presumably because of their location in the same reef zone, some broad similarities in organismal recruitment between the two areas were apparent.

The most obvious similarity between the control and disturbed sites was in the settlement of fleshy and filamentous algae (see Yap and Gomez 1988), here grouped in the category "fleshy algae". This component attained its greatest abundance on the settling plates at similar times in both sites, namely, starting at the relatively cool month of November and then declining towards May (the summer). Algal generic composition was also similar (Tables 1 and 2).

Table 1. Average frequencies of algal groups at the control station, Site 1, per sampling time.

ALGAL GROUP		YEAR	1983							1984				
		MONTH	APR	MAY-JUN	JUL	AUG	SEP	OCT	NOV-DEC	JAN	FEB	MAR	APR	MAY-JUN
		AGE(wks)	5	10	15	20	25	30	37	42	47	52	57	62
CHLOROPHYTA	Cladophora		12	1	7	4		10	7	2	1			
	Enteromorpha				1			2		5				
	Chaetomorpha				5									
	Acetabularia				1	1	1	4	6	15	4	11	6	16
	Caulerpa									2				
RHODOPHYTA	Gelidiella					1					5	6	6	1
	Polysiphonia		4		8			1		3	2	1	7	
	Herposiphonia												1	1
	Chondria									3	1			
	Champia					1					2			
	Ceramium		1							1	2	1		
	Centroceros		1								2			1
	Spyridia										8			
	Acanthophora										1			
	Laurencia										2			
	Griffithsia										1			
	Wrangelia							1			2			
	(Unidentified)							1						
PHAEOPHYTA	Sphacelaria		7			2			10	3	14	2	3	5
	Ectocarpus									2				
	Dictyota					2				6	1		23	3
	Padina											56		
OTHERS	Diatoms		7	3	3			17	64	51	2		1	
	Cyanobacteria				2									
	TOTAL GENERA		6	2	7	6	1	7	4	11	16	6	7	6
CORALLINES	Crustose									1		4		
	Articulated									3		2	9	

The significant difference between the two sites was with respect to the recruitment of coralline algae, and the subsequent settlement of corals. Corallines were abundant at the damaged area, and coral recruitment occurred much earlier there. The occurrence of corallines in significant quantities may be attributed to the absence of grazing fish due to the deterioration of the habitat.

In the light of previous evidence (e.g., Schuhmacher 1977), it is tempting to speculate that the corallines provided a necessary substrate for the early coral colonizers, pointing to a possibility of "preconditioning" by pioneer organisms before full-scale reef development could commence. Calcium carbonate in this case is very likely a preferred substrate.

After the initial settlement, coral recruitment at the damaged site then proceeded relatively more rapidly, indicating a gregarious pattern. As of January 1985, corals had colonized nearly half of the tiles remaining on the bottom (Alino et al. 1985). However, extreme losses due to mortality brought about by sedimentation and scouring were also documented.

2.2. Recruitment on a larger scale

The use of settling plates enabled the monitoring of planular recruitment. However, since colonization in the form of larger fragments, or even whole colonies, also occurred, it was necessary to adopt a second scale larger than that of the tiles, namely, permanent quadrats with an area of 1 m^2. These were positioned in between the patches of tiles and observations started in October 1983. Details of the procedures are given in Alino et al. (1985).

There appeared to be a relative increase in the total number of colonies at the disturbed site, while this parameter apparently levelled off at the control (Alino et al. 1985). The increase in coral settlers at the damaged site continued up till the end of the regular monitoring period. Such a trend may be characteristic of a community set back to an earlier successional stage by physical damage.

Despite the above pattern, the experimental site showed little signs of overall change when it was revisited 4 1/2 years after the disturbance. A full census one year after the experimental clearing revealed a mere 1-3% increase in living coral cover. The continual scouring and sediment impact associated with the loose rubble created by blasting is believed to be the main factor adversely affecting the survival and growth of coral recruits.

Table 2. Average frequencies of algal groups at the experimentally denuded area, Site 2 per sampling time.

ALGAL GROUP		YEAR	1983							1984				
		MONTH	APR	MAY-JUN	JUL	AUG	SEP	OCT	NOV-DEC	JAN	FEB	MAR	APR	MAY-JUN
		AGE(wks)	5	10	15	20	25	30	37	42	47	52	57	62
CHLOROPHYTA	Cladophora		16	4	1	2		2	37	15	9	1	1	
	Enteromorpha		6				2	1	1	1	3			
	Acetabularia				1	12	3	8	39	11	13	2	2	11
	Codium				3									
	Caulerpa										16			
	Neomeris										1			
	Boodlea										2			
RHODOPHYTA	Gelidiella		3	1	25	41	29	8	34	17	25	10	11	16
	Polysiphonia		15	1	3	5	5	4	6	6	4			
	Herposiphonia							1	12	3				
	Chondria			5						4				
	Champia							2	6	2				
	Ceramium					1					1			
	Centroceras									1				2
	Spyridia										4			
	Tolypiocladia				4									
	Laurencia						12				2			1
	Wrangelia								6	6				
	(Unidentified)													1
	Gonotrichium								1					
PHAEOPHYTA	Sphacelaria		30	25	8	18	3	26	67	68	165	119	23	13
	Ectocarpus		50	8		4	15			3	1	4	2	
	Feldmannia		10											
	Dictyota						12		48	112	196	129	23	69
	Padina			1						82	142	183	344	24
	Lobophora				8						10	12	29	
	Sargassum												12	1
OTHERS	Diatoms		2		1			1	7	29	9	1	2	
	Cyanobacteria			8										
	TOTAL GENERA		8	8	9	7	8	9	12	15	17	9	10	9
CORALLINES	Crustose		78	79	106	110	330	206	67	84	22	61	51	390
	Articulated							7			8	1		5

2.3. The nature of coral reef recovery

Based on the above findings on a Philippine reef, the earliest stages indicative of coral reef recovery, namely, the influx of the original framework builders (the hard corals), may be controlled by factors that are probably predictable. One would be the "preconditioning" of the substrate by pioneer organisms, such as the deposition of fresh calcareous layers by coralline algae.

However, a large aspect of coral reef recovery seems to be governed by chance, or by factors beyond human control. One of these is the nature of the surrounding community. In the present study, the latter was observed to deteriorate steadily (Alino 1985), due likely to widespread destructive human interference such as blast fishing. Then again, the original cause of damage generated an unstable substrate which probably hindered significant coral recruitment, at least by planular settlement. These factors together render the prospect of reef recovery in such a setting unlikely in the immediate future.

3. CORAL TRANSPLANTATION EXPERIMENTS: STUDIES ON REHABILITATION

It has been shown from the above discussion that natural recolonization of denuded reef substrates can proceed at a very slow pace (as low as 1-3 % coral cover per year). Since it appears that substrate preparation by early colonizers is needed before settlement by later groups, the slow process is also more prone to disturbances. An analogy can be made between this process and building of a tower out of playing cards. Upper levels cannot be erected without completing the lower levels, and any disturbance that affects the lower levels necessitates starting again from the very beginning.

One example of a disturbance would be silt and sand released from the reef by the denudation of its benthos. This hinders direct colonization of coral planulae thus necessitating preparation of the substrate by other organisms such as coralline algae.

Given such a situation, the most feasible option for accelerating the succession and regeneration process is coral transplantation, which would mean bypassing the sensitive larval stage. Transplantation involves the actual transfer of coral colonies, or fragments thereof, to the rehabilitation site. This takes advantage of the corals' ability to reproduce asexually using fragments. This method of coral reproduction is especially important in colonization of sandy or silty bottoms which are less favourable for larval settlement (Highsmith 1982). This author also mentions the importance of fragmentation in (1) reef extension, (2) initiation of patch reef formation, (3) development of monospecific coral thickets in major reef zones, and (4) possibly, avoidance of reef-bound competitors and predators.

Transplantation could be carried out via two ways. The first would involve actual attachment of fragments to the substrate (hereafter referred to as "fixed transplants"). Theoretically this would duplicate the corals' sessile habit and facilitate growth. Whether this is indeed so depends on particular characteristics of the species. What is obvious though is that transplantation using this mode will be costly as such an effort will entail some measure of substrate selection and preparation, and the use of a proper adhesive or bonding material.

However, there are species with a free-living habit (like fungiids) which are specialized for life on unconsolidated substrates. The use of unattached "free-fragments" as transplant material may be a more attractive option considering it requires a minimum of substrate preparation (or none at all), and no adhesive or bonding material.

3.1. Considerations for planning a coral transplantation effort

3.1.1. Size and shape of the transplant material

As a general rule, the larger the colony (or the transplant material), the greater the survivorship probabilities of the coral (Hughes and Jackson 1985, Done 1987). This may be due to the larger energy reserves available to bigger corals for coping with trauma caused by the transplantation process. The bigger size also allows the transplant to overtop potential competitors for light, and keep the live tissues away from scouring and smothering by bottom sediments.

For species that reproduce mainly by fragmentation (i.e. good "free fragment" transplant material) like Acropora pulchra, the three-dimensional structure of the branch may also be important. Preliminary work has shown that the greater the "branchiness" of a fragment or propagule, the better the survival rates since the branches keep portions of the colony above the sandy or silty substrate, minimizing the smothering of the coral's tissues (unpublished data). The branches also enhance the coral's resistance to wave- or current-induced rolling which can further aggravate smothering.

The use of large transplants complicates their collection, transport, and handling especially when large distances are involved. However, it is hoped that once a "critical mass" is achieved in a transplant area, regeneration would be self-sustaining.

3.1.2. Biology of the transplant species

A good knowledge of the basic biology of the coral species found in a given site is essential for any transplantation effort. Life-table information (e.g., recruitment, growth and mortality schedules) is especially important since this will figure in considerations like the choice of the species and the timing of the transplantation effort (when growth is fastest and mortality lowest; see also Yap and Gomez 1985).

A fast growth rate is always a preferred character for obvious reasons. It is to be noted, however, that a fast growing coral is not necessarily always good transplant material. Members of the genus Acropora have some of the highest growth rates among corals (see Gomez et al. 1985). However, transplant studies using A. hyacinthus and A. pulchra have shown these species to have some of the lowest survival rates (unpublished data), due perhaps to their greater sensitivity caused by high metabolic rates.

3.1.3. Site and environmental considerations

Aspects of the ecological relationships of the transplant species with their biotic and abiotic environment must also be considered especially when choosing specific sites for the transplantation effort. This involves considering the existing (or for damaged sites, the pre-existing) zonation and the dominant environmental gradients influencing the distribution of the reef benthos in the particular sites of interest.

Among others, the coral species dominant in the area must be the first ones considered as transplant material. Aside from ensuring a convenient source pool for transplantation into denuded areas, these species (depending on the level of disturbance or perturbation) can be expected to be better adapted to the conditions existing in a site. Introducing new species, if at all successful, may complicate the existing conditions by aggravating, for instance, competitive interactions. Though the degree to which competition influences community structure in reefs remains debatable (see Sheppard 1981, Bradbury and Young 1981), such interactions can be important at the scale at which transplantation is conducted.

Results of a preliminary transplantation study conducted in a silt-dominated coral community in the northwestern Philippines provide an interesting illustration of these concepts. Caryophiliids like Euphyllia and members of the poritid genera Goniopora and Alveopora are often encountered here as large, dispersed colonies or patches thereof. However, differences in small microhabitats within this area were not expected. Thirty-two (32) months after transplantation of both Goniopora and Euphyllia to a site about 800 m away from the source colonies, only the former genus remained in spite of the generally good growth rates of the latter in the early months. Apparently, the skeletal fragility of Euphyllia fragments was a disadvantage when sporadic strong waves hit the particular site. A large percentage of Euphyllia transplants broke off near the base of attachment.

Another unanticipated reaction was what appeared to be interspecific competition between two closely adjacent members of the two genera which resulted in polyp retraction (at the least) to partial to complete mortality. These two factors (microhabitat differences and competition) may have been the reason for the patchy nature of the distribution of the colonies in the area, something a good community structure survey could have detected.

This small study also brings out another point, namely, the importance of preliminary studies to determine feasibility of both the choice of the transplant, and the transplantation technique to be used. Preliminary trials may entail short term investment in cost and monitoring but will go a long way in ensuring success of the effort.

3.1.4. Transport and handling of transplants

The most prudent option is to minimize stress on the corals by maintaining ambient conditions during transport as close as possible to those existing where the coral is found.

For short and moderate distances and shallow depths, coral transplants can be moved by simply putting them in perforated plastic crates, and transporting them underwater. Care must be taken to prevent rolling in these rigid containers as this can result in the breakage of corallum parts like branch tips which will be essential for growth. Some sort of packaging material (like weighted plastic bags) can be used for this purpose so long as this is not too heavy or too hard.

Longer distance transport will require that the corals be put in containers of seawater and loaded into boats. This will help prevent possible scouring by swiftly-moving seawater as the boat moves. However, exposure of corals to air for long periods must be avoided. Also, deep water forms may require some measure of shading from ultraviolet rays (Jokiel 1980) or excessive light levels.

Perhaps a more important consideration is the maintenance of proper temperature which has significant effects on mortality rates (e.g., Yap and Gomez 1984). This may be accomplished by continually renewing water in closed containers.

3.1.5. Position and orientation of transplants

The manner by which the corals are positioned again depends on their natural habit, and microhabitat requirements mentioned earlier under Section 3.1.3. This is of obvious importance to fixed transplants since, for instance, shade loving species will survive better in nooks and crannies, rather than on top of rocks. Recruitment studies discussed earlier demonstrate a greater number of young corals on vertical and inclined substrates, possibly as a result of silt and grazing pressure. However, Euphyllia transplants on inclined concrete blocks accumulated silt at one side of the colony, leading to the smothering of the tissues and breakage of the skeleton. This serves as a reminder that different growth stages of corals will have different requirements.

Packing density of corals must also be considered. Competitive interactions between different coral species were discussed earlier and suggest the need for greater spacing between such transplants. For corals of the same species, higher packing densities will be more beneficial since they facilitate fusion. Within four years after transplantation 16 cm apart, fixed colonies of Pavona decussata fused into a large colony which probably has better survival chances (unpublished data). For "free fragment" transplants, fusion between branches enhances survivability since parts of the colonies are kept off the substrate to avoid smothering. Studies have shown that skeletal fusion between branches (in contact with each other) will occur regardless of the particular genetic identity of individual colonies of a species (unpublished data).

3.2. Other considerations and recommendations

Much remains to be learned about the biology and ecology of coral species useful for transplantation, and the processes involved in recolonization and recovery of damaged reefs.

Predation and grazing represent one area needing further work. Several experiments on A. pulchra had to be abandoned because of mass mortality of corals in the study area due to predatory drupellid gastropods. Periodic smothering by blooms of the branching sponge Callyspongia also contributed to these deaths.

Possible effects of the "short circuiting" of the reef recovery process by introducing adult colonies must also be investigated, in addition to the introduction of monocultures of corals in diverse, tropical reef environments. Parallels between coral transplantation and reforestation efforts could be expected to yield valuable insights.

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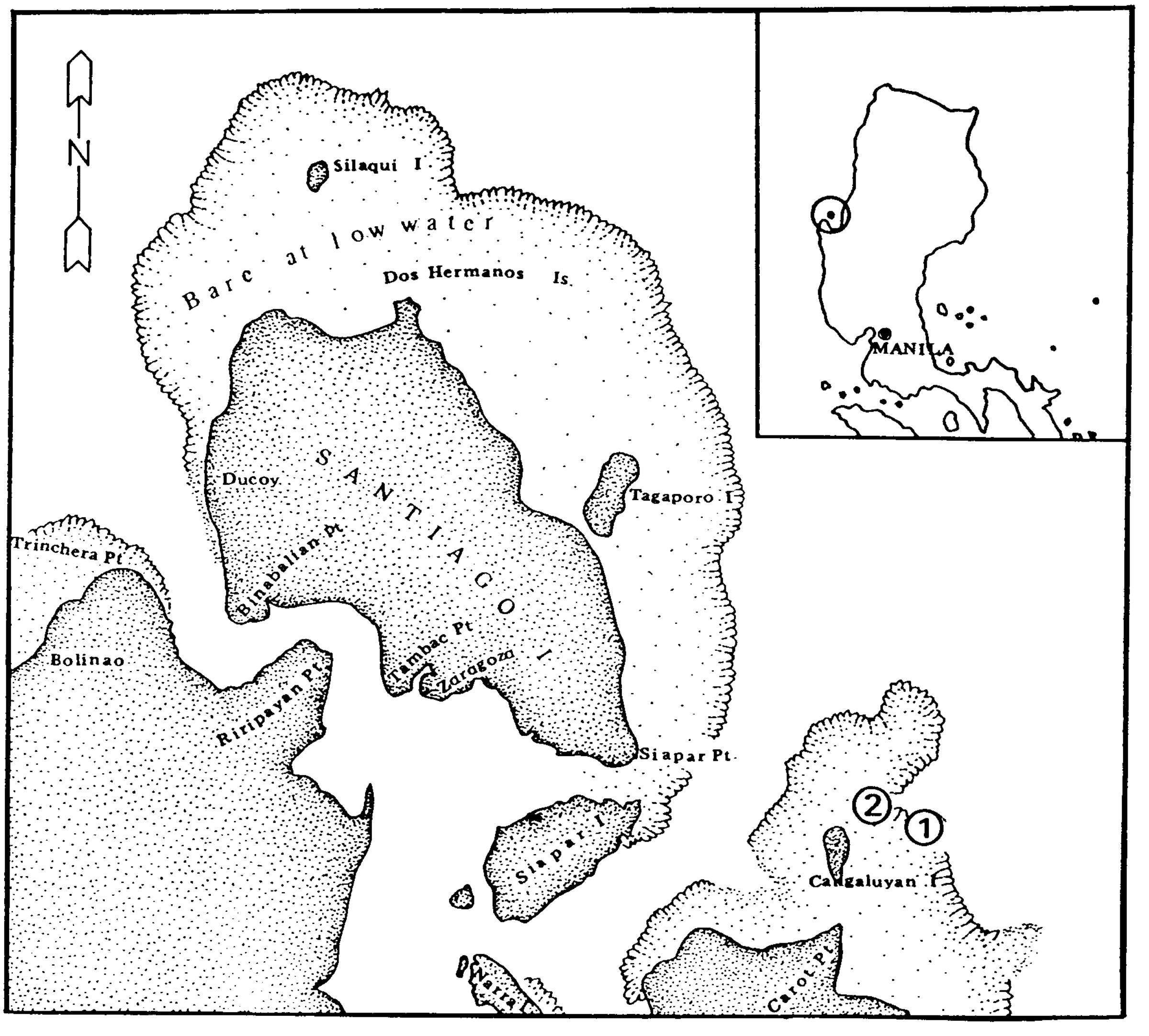

Fig. 1. Control (Site 1) and experimentally denuded (Site 2) areas on a reefflat at Cangaluyan Island, Pangasinan for the study of coral reef recruitment.

CORAL REEF CONSERVATION IN SINGAPORE: THE SINGAPORE REEF SURVEY AND CONSERVATION PROJECT

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ABSTRACT

Recent quantitative studies of some coral reefs in Singapore showed that the upper reef slope zone supported a high diversity of corals as well as a high percentage of live coral cover, in contrast to the accepted view that the country's reefs have been devastated by high sediment levels caused by extensive land reclamation programmes. This provided the impetus for three non-governmental organizations, the Republic of Singapore Yacht Club, the Singapore Institute of Biology and the Singapore Underwater Federation, to pool their resources together and launch a Singapore Reef Survey and Conservation Project in early 1988 which will see the surveys of the majority of reefs completed before the end of 1989, and the publication by 1990 of a book containing results and recommendations. This paper describes in detail the project from its early inception to the present, highlighting its aims and achievements to date.

1. INTRODUCTION

Almost all of the coral reefs in Singapore waters are located south of the mainland as fringing reefs of the offshore islands or as patch reefs (Fig. 1). Massive land reclamation programmes both on the mainland as well as on some of the offshore islands since the mid sixties have increased the sediment load of the waters, reducing average visibility from the original 8 m to the present 2 m. Concern for the reefs was expressed then (e.g., Hill 1973) but remained largely ignored. However, it had the effect of creating the belief that the coral reefs were deteriorating rapidly and gave the mistaken impression that the reefs were devastated to a hopeless condition. This view was further reinforced by the poor water clarity which obscured reef life from non-swimmers looking down from boats or from non-experienced snorkellers who have difficulty in submerging. With SCUBA diving as a fast-growing activity, most trainees intent on having their outings recognized as qualifying dives descend to more than 10 m where the bottom seafloor offers hardly anything exciting save for a few colonies of seafans and seawhips.

Recent quantitative surveys of some of the reefs revealed that coral cover and reef life were surprisingly good and diverse at the shallower depths (Chou and Koh 1986). These surveys, carried out under the ASEAN-Australia Coastal Living Resources Project and funded by the Australian International Development Assistance Bureau, showed that the upper reef slope zone supported live coral cover of up to 62% and coral generic diversity of 44 per 100 m line transect. These results provided the basis for the realization that the established impression of dying reefs was a total misconception.

2. ORGANIZATION

In the later half of 1987, representatives of three non-governmental organizations, namely, the Republic of Singapore Yacht Club (RSYC), the Singapore Institute of Biology (SIB) and the Singapore Underwater Federation (SUF), held a series of informal meetings to examine the possibility of a reef conservation project which will draw attention to the condition of the reefs and present results to convince policy makers that these reefs warrant some management measures.

The Reef Conservation Project Committee was formed in December 1987, comprising members from each of the above organizations. The Committee aimed at educating sea-sport enthusiasts on how to enjoy Singapore's coral reefs without destroying them so that future generations could benefit from these resources. It was also concerned that divers hack up corals or remove reef organisms as souvenirs, thereby depleting the already limited stocks in the natural environment.

The Committee agreed to undertake a project to be officially known as the "Singapore Reef Survey and Conservation Project" and the terms of reference for the project were finalized. The three organizations will implement the project and receive the support of the Singapore Sea Sports Liaison Committee. The ultimate aim of the project is to recommend selected reefs for conservation for the wholesome recreation of citizens and visitors, the furtherance of scientific research and education, and the enjoyment of future generations. The project was officially inaugurated on 23 September 1988.

The responsibilities of each of the three participating organizations fitted in naturally with their expertise. The Underwater Federation would encourage and co-ordinate the volunteer divers, the Institute would train the divers on how to conduct reef surveys, and the Yacht Club would provide the boats for the survey trips.

3. TRAINING

The Committee agreed to adopt the survey methodology that was being used in the ASEAN-Australia Coastal Living Resources Project which was relatively quick, simple and, most significantly, able to be carried out by non-specialists. The method involved the laying of a 100-metre tape measure along a specific depth of the reef slope (in this case, at the crest and at 3 m) following closely the contour of the slope. All lifeforms transected by the tape were recorded as pre-determined codes together with the length intercepted. The lifeform categories used enabled non-biologists to participate in the surveys (Table 1).

Training courses were organized for the qualified divers. Instructors from the Institute gave theory lessons on the survey techniques and on how to recognize the lifeform to the correct category. These instructors have been fully involved with the ASEAN-Australia project and are biology graduates. Qualified SCUBA instructors from the Underwater Federation handled the pool training mainly to test the participants' SCUBA diving skills, particularly that of buoyancy control. Emphasis was placed on maintaining neutral buoyancy as sediment was easily stirred up in the field and contact with the substrate had to be kept minimal. Each training course consisted of three theory, two pool and two outdoor hands-on sessions. Audio-visual aids were used intensively to familiarize the participants with the lifeforms. Teaching aids and materials have now been standardized for use in all future courses. Tests are conducted in the classroom as well as in the field to ensure that only participants found to be competent enough to carry out the surveys are allowed to participate.

The first training course held in the early part of 1987 was given for 14 certified SCUBA instructors who were subsequently given a refresher course in the later part of the year. Three other courses have been conducted and a total of 38 participants have completed them satisfactorily. Monthly training courses have been scheduled for the rest of this year. Participants who have completed the courses were awarded a certificate issued jointly by the three organizations (Fig. 2) and were assigned to a survey team. To date four survey teams have been formed and representatives from the three organizations accompany each team on survey trips to ensure that the surveys are properly conducted.

Underwater video footage showing the lifeforms as well as divers laying the transect and recording data has been recorded and is in the process of being edited for instructional use.

4. SCHEDULE AND RELATED ACTIVITIES

Approximately 90 sites (2 transects per site, at the crest and 3 m depth) spread over 48 reefs have been targeted for survey. When completed, the results will give a comprehensive picture of the state of most of the coral reefs in Singapore (except those lying within the restricted military zone). This will enable the Committee to recommend the better reefs for conservation. It is envisaged that the survey programme will generally be completed in the early part of 1990. A full report containing the results and supported by colour photographs will be prepared and published shortly after the completion of the surveys. A presentation will then be made to the relevant authorities. Meanwhile, the Committee has the task of raising funds and will during this year approach potential sponsors.

An educational pamphlet showing representative lifeforms on Singapore reefs (Chou and Lim 1988) was published by the Singapore Institute of Biology this year and the Committee agreed to meet half the publication cost. The pamphlet was distributed widely to draw attention to the diversity of organisms prevalent on Singapore reefs. More of such educational materials, including the production of a video tape, are being planned.

Table 1. List of lifeforms and their associated codes.

Category			Code
Hard coral			
	Dead coral (recent)		DC
	Dead coral with algal covering		DCA
	Acropora	Branching	ACB
		Encrusting	ACE
		Submassive (digitate)	ACS
		Tabulate	ACT
Non-_Acropora_ coral		Branching	CB
		Encrusting	CE
		Foliose	CF
		Massive	CM
		Submassive (digitate)	CS
		Mushroom	CMR
		Millepora (fire coral)	CME
		Heliopora (blue coral)	CHL
Other Fauna			
	Soft coral		SC
	Sponges		SP
	Zoanthids		ZO
	Others (Ascidians, Anemones, Gorgonians, Giant Clams)		OT
Algae			
	Algal assemblages		AA
	Coralline algae		CA
	Halimeda		HA
	Macroalgae		MA
	Turf algae		TA
Abiotic			
	Sand		S
	Rubble		R
	Silt		SI
	Water (fissures deeper than 50 cm)		WA

5. CONCLUSION

While reef conservation or management was unheard of in Singapore in the past, the Committee's action is considered timely in the light of recent quantitative studies which show reef life on the upper slopes to be diverse and abundant. The reefs deserve some form of management in order to prevent their complete elimination from Singapore waters. Current plans to develop some of the southern islands for industry or recreation should take into consideration the surrounding reef resource.

All personnel involved with the project are doing so purely on a voluntary basis and without such support, the project would not have been able to be implemented even to this day.

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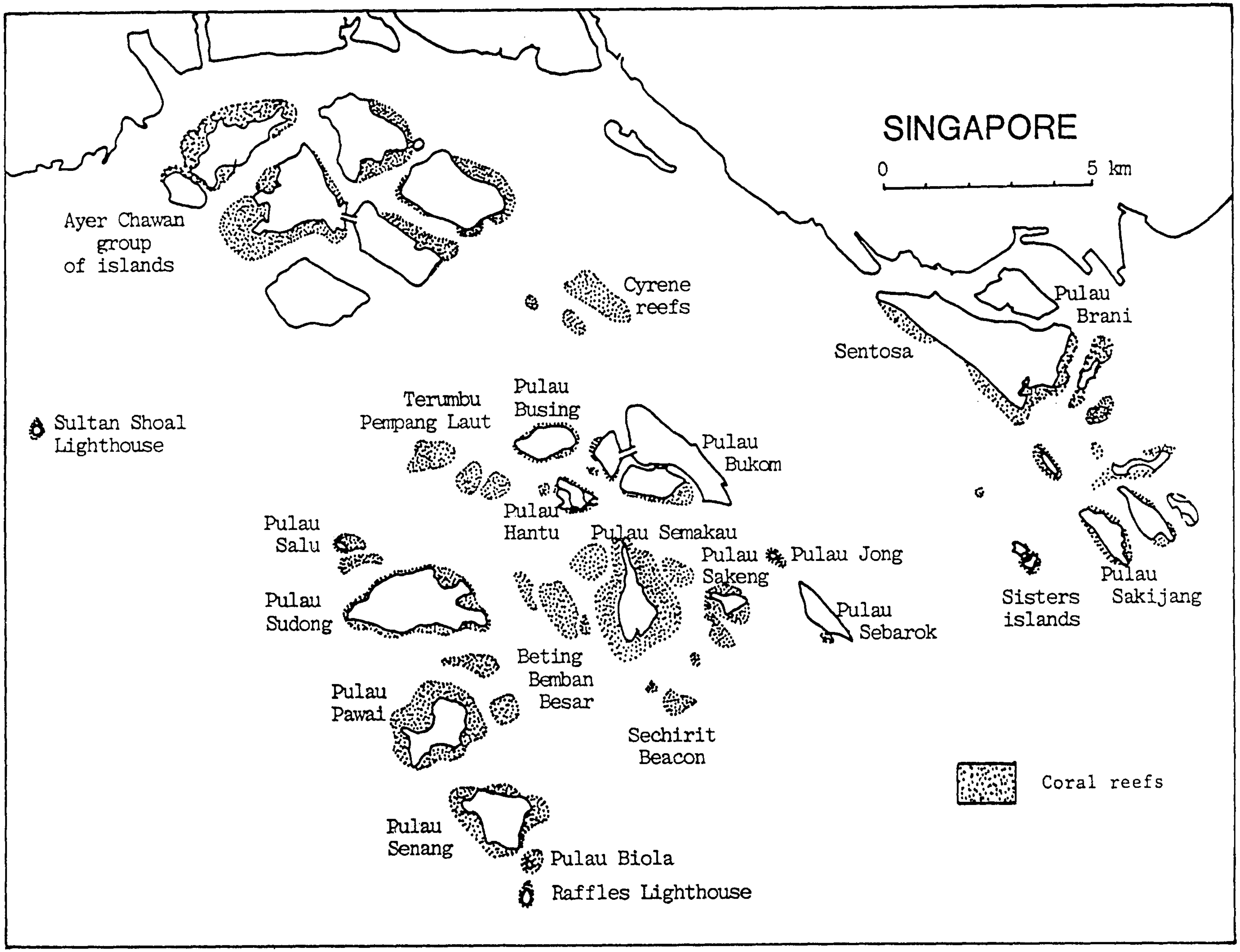

Fig. 1. Map showing offshore islands and their reefs.

This is to certify that

....

has satisfactorily completed the

Reef Ecology Research Specialty Course

as a

Research Diver/Specialty Instructor

....

under the sanction of and subject to the rules

stipulated by The Reef Survey and Conservation Project Committee

under the auspices of

The Republic of Singapore Yacht Club

Singapore Underwater Federation

The Singapore Institute of Biology

....

Date of Certification

....	....	....
Commodore Republic of Singapore Yacht Club	President SUF Singapore Underwater Federation	President Singapore Institute of Biology

Fig. 2. Certificate awarded to successful participants.

SEAGRASS RESOURCES OF EAST ASIA: RESEARCH STATUS, ENVIRONMENTAL ISSUES AND MANAGEMENT PERSPECTIVES

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ABSTRACT

Despite the high diversity and abundance of seagrass communities in the East Asian Seas region, little is known about their bio-ecology and much less is documented about their utilization and role in the marine habitat. Fortunately, compared to coral reefs and mangroves, the seagrass habitats of the region are not yet as disturbed or destroyed. The last decade, however, has seen the rapid increase in pressure on these resources.

Countries in the East Asian region have no management policies specific for seagrass ecosystem resources and their uses. Recent surveys and scientific investigations, however, point to a wide spectrum of uses (both at the component and ecosystem levels) of seagrasses and their associated flora and fauna. This fact alone makes it even more compelling for the region's governments to formulate policies, and implement and sustain activities that would ensure the proper utilization and protection of the seagrass resources of East Asia.

A multi-disciplinary approach is required for the effective management of such multiple use resources as seagrass beds.

1. INTRODUCTION

Despite their known uses both at the component and ecosystem levels, seagrass beds in East Asia are probably the least studied among the communities of the marine environment of the region. This prevailing attitude is due largely to three reasons: (1) the training of the local ("traditional") marine scientists who usually view the ocean as a deep water mass, hence, the shallow-water plants are not usually included in the investigations; (2) perhaps the people think that seagrasses are unimportant, especially in relation to marine fisheries; and (3) those who consider that they are important are faced with the difficulty of evaluating the plants' economic uses and potential. In a region where environmental imperatives are often sacrificed in the name of economic development, even the most obvious sources of income and livelihood of the majority of the inhabitants need first to be given dollar values before these are considered priorities for research and development. The question may be asked: Is there a need to determine the money equivalent of seagrass fisheries which are directly consumed, or of a resource whose biological richness is indisputable?

2. DOES EAST ASIA POSSESS SEAGRASS RESOURCES WORTHY OF MANAGEMENT CONSIDERATION?

From taxonomic, ecological and resource-use points of view the need arises to manage the seagrass resources and their uses in the East Asian Seas region. The Indo-West Pacific region has long been known to be the major centre of generic richness and distribution of seagrasses in the world. In the region, 16 taxa have been recorded from the ASEAN countries (Fortes 1986), one species short of the world's greatest number of seagrass species recorded for a region (Western Australia). This fact alone implies the enormous ecological and economic use and potentials of the habitat and its components.

The region houses about 30% of the coral reefs of the world with which seagrasses are closely associated (IUCN/UNEP 1985). These plants cover much more area on many fringing reefs than do corals (McManus 1988). Vast seagrass meadows are often found between coral reefs and the coastal fringes that support most of the region's mangroves. In this transition zone characterized by soft, sandy-muddy bottoms, the plants have colonized all environmentally suitable areas.

In Indonesia, seagrass beds are habitats for young fish, dugong, turtles and wading birds (Hutomo and Martosewojo 1977 in Soegiarto and Polunin 1982). At the Ancol Oceanarium in Jakarta, dugongs are fed with the seagrass, Syringodium isoetifolium. Seventy-eight species of fish, including some priced groups like Siganus, Apogon and Gerres have been found in large numbers in Pari Island. In some parts of Indonesia, the fruits of Enhalus acoroides are eaten as diet supplements. In Thailand, dugongs reared in captivity are fed Halophila ovalis (Chansang 1985).

In the Philippines, 54 species from 25 fish families have been identified and found abundant in seagrass beds (Vergara and Fortes, in press). Fish and prawn catches yielded densities at least three times greater than those from non-seagrass areas. The fruits of E. acoroides are eaten by some coastal residents, and together with the leaves, are chewed and the spat mixture placed over wounds to check profuse bleeding (Aliño et al., unpublished report). Drinking the soup from the boiled fruits is believed to cause temporary or permanent sterility. Crude protein levels from leaves of E. acoroides and Thalassia hemprichii point to the great potential of the species as cheap and indigenous sources of fodder and fertilizer.

Mapping of seagrass beds as a prerequisite to resource management has been successfully initiated in the Philippines. As a result of digitizer analysis of Landsat imageries, and low altitude photography aided by ground truth surveys and planimetry, six study sites in the country are now known to harbour 50.88 sq. km of seagrass beds:

Bolinao Bay	37.00 sq. km
Pagbilao Bay	1.89
Puerto Galera	1.14
Ulugan Bay	2.97
Banacon Is.	7.81
Calancan Bay	0.07
TOTAL	50.88 sq. km

There is a significant coincidence between the shrimp exploitation areas in the East Asian Seas (IUCN/UNEP 1985) and the known occurrence of seagrasses in the region (Fig. 1). Similarly in Indonesia, there is a high coincidence between the areas where dugong (Compost 1980) and turtle (Kajihara 1973) sightings have been made and those where seagrasses are reported.

Seagrasses grow as fast as cultivated corn, rice, hayfields, or tall grass prairies (Phillips 1978). The production rate of E. acoroides in the Philippines (1.08 gm carbon/sq. m/day (Estacion and Fortes 1988)) is fairly comparable with that of cultivated crops (e.g., wheat, corn, rice, hay) on a world average basis (Odum 1959, McRoy and McMillan 1977). Interestingly, seagrasses attain these rates without the use of energy subsidies like fertilizers and modern cultivation techniques.

The dense beds at Bolinao Bay produce at least 18,900 kg carbon/day, assigning to a square meter area of the plants' habitat a production rate of 8,635 calories daily or roughly 20% of the daily caloric requirement per kilogram weight of an ordinary individual (Fortes, in press). Bolinao Bay is comparatively richer in seagrasses. But if these data are considered in relation to the total seagrass areas in the East Asian Seas, and considering the fact that ASEAN countries have about 60,583 km of coastline that borders areas known to be richly inhabited by seagrasses, the meadows, as nutrient providers, might very well be the most important marine ecosystem in the region.

3. STATUS OF SEAGRASS RESEARCH AND UTILIZATION IN EAST ASIA

On 17-22 January 1989, the First Southeast Asian Seagrass Resources Research and Management Workshop (SEAGREM 1) was held in the Philippines. Among others, it discussed the status of research and utilization of the plants in the region, focusing attention on the priority areas for developmental activities.

Table 1 lists the taxa of associated biota documented from seagrass beds in the region. Quite clearly, groups which command direct economic benefit to people (e.g., fish, molluscs, crustaceans) have received relatively more attention. As clear, however, is the fact that the ecosystem yet remains an untapped source of biological and ecological information.

Table 1. Number of species (except where indicated) of associated biota documented from seagrass beds of Southeast Asia. X = information inadequate.

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	THAILAND
1. Bacteria		X	X		
2. Fungi		X	X		
3. Algae	X	X	>50	X	X
4. Protozoa		X	X		X
5. Sponges/Bryozoa		X	X		X
6. Cnidaria/Ctenophora			X	X	X
7. Non-polychaete worms			X		X
8. Polychaetes	25		X	X	X
9. Crustaceans	28	X	>14	X	X
10. Insects/Arachnids			X		
11. Molluscs	10	X	6-7	X	X
12. Echinoderms	3		>12		X
13. Ascidians			X		X
14. Fish	ó100	X	>55	X	>20*
15. Reptiles	X		5		X
16. Birds			>10		
17. Mammals	1	1	1		X

*Families

Current research efforts and other activities on seagrasses in East Asia can be viewed at two levels: national and regional. At the national level, these activities are as yet unique to each country, dictated by specific concerns and priorities. These activities include:

- Mapping, using Landsat/SPOT imageries
- Survey of plant resources of seagrass beds
- Studies on land-based impacts
- Proximate constituent analysis
- Artificial enhancement of fish stocks
- Fodder and fertilizer studies
- Seagrasses as pollution indicators
- Pilot coastal rehabilitation using seagrasses

At the regional level, the following research efforts and activities are being undertaken by most if not all of the countries in the region:

- Ground truth surveys
- Fishery resources of seagrass beds

- Seagrass beds as nurseries for fish and fauna
- State-of-the-art
- Workshops
- Regional co-operation
- Identification and analysis of existing legislation which concerns seagrass habitats

SEAGREM 1 similarly emphasized the extent of utilization of the seagrass resources in Southeast Asia. Among the potentially sustainable uses of the plants and their habitats, their role as sources of fish, crustaceans and shellfish has received more attention (Table 2). Surprisingly, the ecosystem is slowly being recognized as a useful source of educational information as well as a key to preservation of critical portions of the marine environment.

Table 2. Potentially sustainable uses of seagrasses in Southeast Asia.

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	THAILAND
1. Food and drinks	W1	-	L1	-	-
2. Fertilizer	X	-	W2	-	X
3. Fodder	X	-	L1	-	-
4. Medicine	-	-	X	-	-
5. Paper	-	-	-	-	-
6. Construction purposes	-	-	1	-	-
7. Textiles	-	-	-	-	-
8. Children's toys	-	-	X	-	-
9. Footwear	-	-	X	-	-
10. Fish source	W1, 2	-	W3	-	LW
11. Crustacean source	W1	-	W2	-	LW
12. Shellfish source	L1	-	W3	-	LW
13. Utilization of other mammals	L1	-	W3	-	L2
14. Recreation	X	-	W3	-	-
15. Education	L1	W2	L1	-	L1
16. Preservation	L3	X	L1	L1	L1
17. Shoreline protection	X	-	W3	-	X

KEY: L = use is localized; W = use is widespread; 1 = a minor use; 2 = A moderate use; 3 = A major use; X = not known

Seagrass habitats in Southeast Asia are being rapidly destroyed or removed to give way to other coastal uses (elimination uses). In the ASEAN countries, the habitat is continually being disturbed mainly for conversion into aquaculture ponds (for fish, crabs, prawns), industrial and urban centers, ports, airports, recreation and mining areas (Table 3).

Unfortunately, few people realize that many of the beds are ancient and can only be partially restored in our lifetime. The consequent impacts of this long-term recovery on the values that society places on seagrass beds such as coastal stabilization, water column filtering, and as fishery habitats are virtually unevaluated. Fortes (1988) has sufficiently discussed the nature and effects of natural and human-induced stresses to which seagrass beds in the region are subjected.

4. ENVIRONMENTAL USES OF SEAGRASS BEDS

The small number of seagrass species greatly underestimates the ecologic importance of the plants. Due largely to their enormous quantities, forming dense beds which cover large areas in coastal waters, they perform a wide spectrum of environmental functions in the marine ecosystem. These functions include:

- Sewage filtration
- Pollution sinks
- Coastal stabilization
- Habitat for fish and invertebrates
- Alternate feeding sites for commercial and foraging organisms
- Export of nutrients to nearby ecosystems
- Dynamic physical interactions with coral reefs and mangroves in water energy reduction and flow regulation

It should be noted that the applied uses of seagrasses are mainly based on studies and observations from non-tropical ecosystems. Many, if not all, of these functions, while undoubtedly applicable under East Asian conditions, are as yet to be realized.

Table 3. Elimination uses of seagrasses in Southeast Asia.

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	THAILAND
1. Aquaculture ponds for					
Fish	X	-	L1	-	L1
Crabs	X	-	L1	-	L1
Prawns	X	-	L1	-	LW
2. Rice fields	-	-	X	-	-
3. Sugarcane fields	-	-	X	-	-
4. Palm plantations	-	-	X	-	-
5. Other types of agriculture	-	X	X	-	-
6. Pasture	-	-	X	-	-
7. Solar salt		-	L	-	-
8. Industrial Dev't.	X	L	W2	W3	-
9. Urban development	X	W	L2	W3	-
10. Ports	X	-	W3	W3	-
11. Airports	X	-	L1	L3	L1
12. Recreation areas	X	W	W2	W2	L2
13. Mining	X	X	L3	-	L1
14. Waste disposal	-	W	W2	-	-
15. Flood runoff engineering	-	-	L2	-	-
16. Boat traffic	L	-	W2	W2	L1

KEY: L = use is localized; W = use is widespread; 1 = a minor use; 2 = a moderate use; 3 = a major use; X = not known

5. SEAGRASS MANAGEMENT PERSPECTIVES

Compared to the coral reef and mangrove ecosystems in East Asia, the region's seagrass beds and their resources are not yet as disturbed or exploited. The last decade, however, has seen an increasing pressure on these resources. This fact makes it even more compelling for national governments in the region to formulate policies and implement and sustain activities that would ensure the proper utilization of the region's seagrass ecosystems.

In East Asia there exist no management policies specific for seagrass ecosystem resources and their uses. Existing regulations relate to specific country priorities. Indonesia, Malaysia, the Philippines, Singapore and Thailand include the study and protection of seagrasses but only when these are associated with coral reefs, mangroves, and fisheries. Currently, mention of seagrass ecosystems is becoming more widespread and audible as a component of environmental impact assessment activities in these countries. At this point, the question may also be raised: Is there a need for management measures specific for seagrass resources and their uses?

6. A PROPOSED MANAGEMENT SCHEME FOR SEAGRASS RESOURCES AND THEIR USES

The proposed program of management given below primarily incorporates inputs from the proposed National Seagrass Program of the Philippines. This program was formulated by representatives from the Marine Science Institute of the University of the Philippines and the Environmental Management Bureau of the Department of Environment and Natural Resources. At SEAGREM 1, the program was, in principle, unanimously adopted by the participating countries.

I. RESOURCE MAPPING AND SURVEY

A. Project 1: Mapping
B. Project 2: Ground truth surveys

II. RESEARCH AND DEVELOPMENT

A. Basic Aspects

1. Project 1: Plant resources of seagrass beds
2. Project 2: Fishery resources of seagrass beds
3. Project 3: Seagrass beds as nurseries for fish and fauna
4. Project 4: Seagrass ecosystem dynamics
5. Project 5: Land-based impacts on seagrass beds
6. Project 6: Seagrass ecosystem oceanography
7. Project 7: Natural products chemistry of seagrasses
8. Project 8: Interactions between seagrass beds, coral reefs and mangroves

B. Applied Aspects

1. Project 1: Artificial enhancement of fish stock in seagrass beds
2. Project 2: Fodder, fertilizer and paper from seagrasses
3. Project 3: Seagrass transplantation

III. INFORMATION DISSEMINATION, EDUCATION, TRAINING AND PUBLICATION

A. Project 1: State-of-the-art
B. Project 2: Bibliography
C. Project 3: Newsletter and technical reports
D. Project 4: Workshops
E. Project 5: Short-term training
F. Project 6: Graduate degree training
G. Project 7: Study tours
H. Project 8: Regional cooperation

IV. ENVIRONMENTAL MANAGEMENT

A. Project 1: Identification and assessment of impacts and polluting industries and the types of pollutants
B. Project 2: Seagrasses as pollution indicators
C. Project 3: Pilot rehabilitation using seagrasses
D. Project 4: Socio-economic aspects

V. POLICY AND LEGISLATION

A. Project 1: Identification and analysis of existing legislation
B. Project 2: Incorporation of seagrass management into existing legislation

7. CONCLUSION

The strategic position of East Asia within the centre of the world's seagrass distribution endows the region with enormous potentials for varied uses of the resource. Unfortunately, past ignorance, wastefulness and complacency on the part of governments are causing the ultimate diminution of areas colonized by seagrasses. Despite this negative, historically rooted attitude, however, much of the resource in East Asia still remains intact. But it is a fast disappearing frontier which urgently calls for rational development in harmony with sound ecological principles. More importantly, a marked change in attitude and outlook in the region has occurred, reflecting in part, a greater awareness of the vital function and intrinsic values of the seagrass ecosystem. The future well-being of our seagrass resources lies in achieving an increased understanding of their interacting physical, chemical, and biological processes and how these processes are affected by specific human activities.

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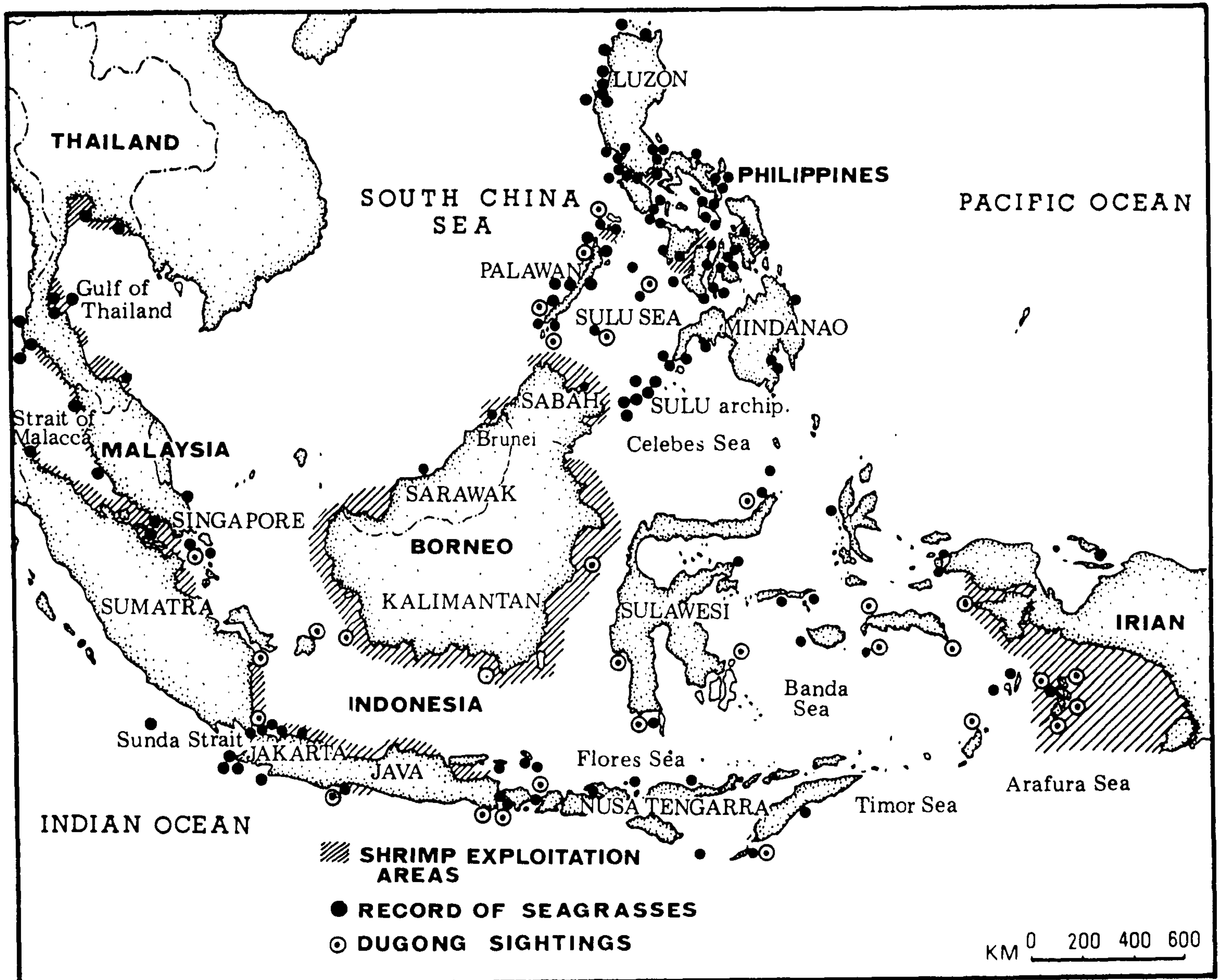

Fig. 1. Map of the East Asian Seas region showing shrimp exploitation areas, locations of dugong sightings and seagrass occurrence.

CORAL REEFS AND SEAGRASS BEDS URGENTLY REQUIRE MANAGEMENT PLANS FOR ECONOMIC REASONS*

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ABSTRACT

The data gathered under the auspices of the ASEAN-Australia Coastal Living Resources Project (CLRP) show that the coral reefs in the ASEAN region are now being threatened by various impacts. Pristine reefs can still be located and those areas should be preserved. Seagrass beds which are very important as nursery grounds are now deteriorating. Not enough attention has been given to the protection of the seagrass beds because very little information concerning them is available. With the ASEAN-Australia CLRP, more information has been gained on these resources. With rapid change occurring at present, effective management plans should be drawn up and urgently executed. Economic gains from some aspects of resource management using an example from Thailand are discussed in this paper.

* This paper was also presented at the ASEAMS symposium. However, a full manuscript was not submitted for publication. Ed.

ENVIRONMENTAL CHANGE AFTER THE SEVERE FLOODING IN NOVEMBER 1988 IN SOUTHERN THAILAND

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ABSTRACT

On 22 November 1988, heavy rainfall caused landslides on the deforested mountains at Nakhon Si Thammarat, Suratthani and Songkhla Provinces. The water from the rain and rivers flooded many villages and towns of about 14 southern provinces. The sediment and trees flowing with the river runoff destroyed housing and irrigation land. The Tapi River has changed course. The coastline also has been altered. The flood devastated the shrimp and oyster farms along the coastal area. This paper is a review of the environmental changes after the flood involving forests, landforms and the coastline. It is an example of the damage caused by deforestation. This damage was estimated to cost more than US$300 million and the loss of more than 400 human lives.

1. INTRODUCTION

The east coast of the southern peninsula of Thailand is a fertile and scenic area, especially Nakhon Si Thammarat and Suratthani Provinces. It undergoes minor flooding nearly every year during the NE monsoon season. However, the catastrophic flood on 22 November 1988 was an extraordinary one. It caused damage to property costing more than US$300 million and the loss of more than 400 human lives. The purpose of this study is to investigate the causes of the catastrophic flood and the environmental changes after that. It is an example of the consequences of deforestation.

2. CAUSES OF THE CATASTROPHIC FLOOD

2.1 Sea level history

From geological evidence, at about 17,000 B.P. (the last ice age) the sea level was lower than the present by approximately 130 m. The whole Gulf of Thailand was land and the western coast was located more than 100 km from the present coast (Loeffler et al. 1983). When the ice melted in the late ice age (10,000 B.P.), the sea level rose above the present coastal level by about 4-5 m. Then by about 6,000 B.P. sea level was lowered to the present level and sandy beaches prograded to form the extensive coastal plain. The datings from peat and shale in the sediment along the eastern shore are less than 6,000 years. This new land has an average height of 4 m above sea level. Some places are only 1-2 m high and are flooded from heavy rain of 200 mm a day, especially along the alluvial valleys of various streams.

2.2 Major coastal types

2.2.1 Mangrove forests

The west coast of Peninsular Thailand is covered with more extensive mangrove forest than the east coast (Pitman 1985), particularly between Satun and Phang-nga in association with broad tidal mud flats, and north of Takua Pa to Ranong. In the Gulf, they are found near Narathiwat, Pattani, Songkhla, Nakhon Si Thammarat and Surat Thani.

These mangroves reach their maximum development on the submergent Andaman seacoast, where individual trees may be 40 m high. Beyond the seaward fringe of the mangroves are extensive mud flats with gradients <1%. Inland, these estuarine deposits merge into extensive alluvial deposits 5.3 m above sea level.

Mangroves are being cleared for construction and charcoal while "nipa" is used for roofing. Current estimates are that more than 75% of the mangrove areas have been converted for shrimp and oyster mariculture.

2.2.2 Sandy beaches

While the western peninsular coast is dominated by mangroves and mudflats, the Gulf coast is predominantly composed of alternating sand beach ridges, planted with coconut palms and fruit trees, which contrast sharply with the paddy cultivation of the mud-filled depressions between the ridges (Pitman 1985). It is particularly noteworthy that the major areas of these ridges are in the southern peninsula and in eastern Thailand. Lagoons and beach barriers are common at these locations and rivers at the coast are deflected by longshore drift. This gives rise to a distinctive pattern of drainage parallel to the coast, with major rivers often emerging behind rocky outcrops, as at Narathiwat. The larger depressions are often peat and muck filled, forming convex domes up to 10 m high.

Beach sediments are being actively mined for detrital tin along the southwestern coast, especially the Thai Muang Beach of Phang-nga Province, and silica sand is being extracted from beach ridges at Songkhla, Chumpon and Rayong.

The lowland of the coastal plain from Narathiwat to Prachuap Khiri Khan has been flooded during the rainy season (the NE monsoon) nearly every year.

2.3 Rivers

The features of high central ranges and small coastal plains reflect on the relatively short and small rivers in southern Peninsular Thailand. Numerous short streams drain to both southern coasts, while the medium and larger streams all (except the Trang River) flow into the Gulf of Thailand. The medium-sized streams from Chumphon downward are the Khlong Tha Tapao (Tha Sae), Lang Suan, Pak anang, U-Taphao (flowing to Thale Sap Songkhla), Sakom, Thepa, Sai Buri and Sungai Golok. The large rivers are Tapi and Pattani (Fig. 1).

The drainage area of Tapi River covers 19,134 km^2. It has two branches: Tapi River (5,287 km^2) and Pumduang River (13,847 km^2) (Donner 1978). Table 1 shows the characteristics of the hydrology of some rivers in the south. The maximum monthly dishcarge (m^3/s) is as follows:

Chumphon River	-	August (31)
Tapi River (Surat Thani)	-	November (262)
Na Thawi (Songkhla)	-	November (17)
Pattani River	-	December (223)

This means that most rivers in the east coast of Peninsular Thailand have maximum or high water discharges in November (see also Figures 2 and 3). The river floodplain along these numerous streams is also inundated during the rainy season. Owing to the short course of rivers and the low-lying coastal plain, with high slopes from nearby mountains, flooding normally occurs relatively quickly.

Table 1. The hydrological characteristics of some rivers in the southern part of Peninsular Thailand (from Donner 1978).

Name of river, Gauging station (m), Period of record	Catchment area at gauging station (km^2)	Difference between high and low water level (m)	Discharge in m^3/second			Ratio min./max.	Annual runoff (million m^3)	Drainage m^3/km^2 in 1 year
			Mean	Min.	Max.			
(A) Small coastal rivers								
Khlong Rattaphum Ban Kamphaeng Phet (5) 1967-70	272	3.00	5.62	0.61	87.0	1:143	177	650,730
Khlong Tam Tambon Khuan Lang (n.a.) 1967-70	127	4.50	2.75	0.063	72.1	1:1,202	72.7	368,500
Khiong Wat Ton Nga Chan (114) 1954-70	71	0.78	0.82	0.22	8.68	1:39	25.7	361,970
Khlong La Ngu Satun (247) 1966-70	80	3.10	4.61	1.14	73.3	1:69	145	1,817,500
(B) Medium-sized rivers								
Khlong Ta Sae Ban Ta Ngo (50) 1963-8	352	3.00	5.47	0.77	109.5	1:142	171	437,210
Khlong Lang Suan Khao Chum Sang (10) 1963-70	1,240	7.00	50.8	4.93	486.7	1:99	1,604	1,293,220
Khlong Sai Buri Sakor (100) 1965-70	1,020	6.00	76.0	20.4	707.0	1:35	2,400	2,352,940
(C) Large rivers								
Mae Nam Ta Pi Tambon Thung Luang (11) 1969-70	5,201	5.00	108	13.0	544	1:42	3,742	719,470
Khlong Phum Duang Ban Yan Lon (16) 1964-70	2,690	10.00	153	8.76	1,934	1:221	4,835	1,797,390
Mae Nam Pattani Amphoe Muang (14) 1964-70	3,296	5.00	86.8	14.6	1,110	1:76	2,743	832,220
Mae Nam Trang Ban Pradu Tai (10) 1966-70	1,801	6.00	46.8	5.17	294	1:57	1,477	820,090

Source: Royal Irrigation Department, National Energy Authority

2.4 Rainfall

Generally, November is the wettest month for the east coast of southern Thailand (Table 2), since before reaching the coast, the cool and dry air passing over the great continental area of Asia has a long sweep over the South China Sea. Thus, the air becomes warmer and more moist which results in heavy to very heavy rainfall. Exceptions are Hua Hin and Prachuap Khiri Khan because their coastlines are parallel to the prevailing wind direction (Table 3). From Chumphon Province southward, the amount of rainfall increases gradually and in Narathiwat is two times greater than in October. The highest precipitation ranges from 341 mm in Surat Thani to 639 mm in Narathiwat, the southernmost province of Thailand. Normally, November is the month with the second highest frequency of tropical cyclones passing Thailand (Fig. 4).

Table 2. Mean monthly rainfall recorded at the Meteorological Station, Amphoe Muang, Nakhon Si Thammarat, from 1984 to 1988.

Month	Rainfall (mm)					Mean
	1984	1985	1986	1987	1988	
January	192.9	46.6	56.5	196.8	233.7	145.30
February	96.7	50.9	4.1	2.7	52.6	41.40
March	29.1	88.2	10.7	4.5	19.8	30.46
April	94.3	117.2	43.2	28.2	109.3	78.44
May	208.8	182.4	328.7	154.7	228.7	220.66
June	113.6	111.6	156.4	75.5	103.7	112.16
July	225.4	137.9	87.9	70.2	126.1	129.5
August	36.6	34.3	55.6	253.8	151.9	106.44
September	168.3	247.8	220.2	193.8	134.6	192.94
October	291.6	260.3	477.7	212.5	209.5	290.32
November	904.4	558.2	617.5	346.5	1,640.5	813.42
December	436.9	559.6	229.7	838.1	198.6	452.58
Total	2,798.6	2,395.0	2,288.2	2,377.3	3,209.0	2,613.62

Table 3. Rainfall in November (mm) averaged for the period 1951-1980 for the east coast of southern Thailand (data from the Meteorological Department).

Province	Monthly rainfall	Greatest in 24 hours
Hua Hin	174	429
Prachuap Khiri Khan	193	222
Chumphon	355	264
Surat Thani	341	457
Nakhon Si Thammarat	610	414
Songkhla	583	329
Pattani	432	226
Narathiwat	639	366

The heavy rainfall which caused the severe flood started on 19 November 1988 and reached a maximum at Nakhon Si Thammarat on 21 November (at night), at Surat Thani on 22 November (day time), and at Narathiwat on 20 November (Fig. 5). These data and NOAA satellite images from the Meteorological Department show that the low pressure area from Malaysia moved northwestward, passing southern Thailand, and then went into the Andaman Sea and caused the storm surge in Bangladesh. The quantity of rainfall in one day at Nakhon Si Thammarat (from the half day of 21 to the half day of 22 November) was 669.9 mm. At 10 pm on 21 November the rate of precipitation was 50 mm/hour and in the morning 80 mm/hour. This is the highest rainfall ever recorded in 38 years in Thailand.

2.5 Tides

November is also the month of maximum mean sea level on the east coast of southern Peninsular Thailand (Table 4).

Table 4. Monthly mean sea level (MSL) in m in November along the east coast of southern Thailand (from Siripong 1985).

Station	MSL in November	Yearly Mean	Tidal Range	Type of Tide
Chumphon River (1973–1983)	2.632	2.480	0.762	1.042 mixed-semidiurnal
Ko Mattaphon, Chumphon (1957-58, 60-68, 73, 78, 80-84)	3.042	2.806	0.793 (1983)	2.012 mixed-diurnal
Lang Suan, Chumphon (1982-1983)	2.805	2.520	1.140 (1983)	0.779 mixed-diurnal
Ko Prap, Surat Thani (1974-1984)	2.840	2.544	0.886 (1983)	1.234
Thathong Harbor, Surat (1976-80, 1983)	2.865	2.553	0.955	0.916 mixed-semidiurnal
Pak Nakorn (1977-1983)	2.383	2.453	0.606	0.757 mixed-semidiurnal
Pak Phanang (1971, 73-83)	2.771	2.560	0.445	1.028 mixed-semidiurnal
Songkhla (1968-1983)	2.732	2.479	0.309	0.679 mixed-semidiurnal
Pattani (1978-1983)	2.922	2.545	0.457	0.519 mixed-semidiurnal
Narathiwat (1978-1983)	2.793	2.585	0.388	0.632 mixed-semidiurnal

The flood from heavy rain and river discharge combined with the high sea level caused the coastal villages, especially Pak Phanang and Ban Don, to be inundated longer than the villages in the mountain valleys.

2.6 Deforestation

The effect of large-scale deforestation is two-fold. The first concerns regulation of local climate. In general, forests return moisture to the atmosphere, so that a loss in forest cover may lead to a decrease in precipitation over the long-term. The second effect of deforestation is failure of the soil to retain moisture which leads to increased runoff, and therefore erosion, during rainfall. These are discussed in detail in the following.

In the eastern part of Thailand, the rate of deforestation has been very high from 1961 to 1963, with forest loss about 10.39%, and was highest from 1973 to 1982. The amount of rainfall decreased from 2400 mm in 1955 to 1900 mm in 1985, or at an average of 16.6 mm per year (Sudara 1989). For both sides of southern Thailand, the rainfall decreased at about 10 mm per year. In 1961, forests covered about 53% of the whole country. In 1988, there was only less than 19% of forest area left in Thailand. The government decided to close down all concessions in 1989. However, this is not an optimum solution to recover the forest area, and to prevent flooding.

The influence of tropical forests on climate is generally accepted but many contradictions and gaps in knowledge remain as regards the relationship between the clearing of tropical forest lands and local climate. If deforestation leads to a reduction in water returned to the atmosphere, it is likely that the effects vary according to the size of the area cleared.

A possible effect of the clearing of large areas of forest (>100 km^2) would be an increase in albedo and consequently a reduction in rainfall. The reduction in rainfall immediately downwind, if focused, could result in a complete change in the structure of the adjacent forest. Essentially, such deforestation would trigger a process that would slowly but continuously eat away at forest downwind.

In Thailand, the agricultural use of tropical forests has been accelerated by the influx of poor people following the opening up of forests by logging contractors and by highway construction. These migrants know little about tropical forest land. They cut down the big trees even on the mountain tops where they should be preserved as a watershed. Later the people grow rubber and fruit trees which have roots too shallow to protect the soil from erosion when heavy rain falls. This is also a major cause of the catastrophic flood in November 1988.

3. THE ENVIRONMENTAL CHANGES AFTER THE SEVERE FLOOD IN NOVEMBER 1988

Because of local climate change due to deforestation, in the long run the land became drier. Kathun Basin of Nakhon Si Thammarat turned into a desert covering an area of thousands of km^2 (Fig. 6). But in November of 1988, the rainfall was the heaviest ever recorded in a human life span.

The lands on the slopes of many mountains were eroded severely, as shown in Figure 7. The granitic rocks are a major source of sand which converted the fertile soil in the lowland into a desert. The landslides caused by heavy rain also uprooted big trees which swept down everything in front of them (Fig. 8).

The heavy sediment runoff changed the course of old streams and cut into new terraces (Figs. 9 and 10).

The flood destroyed the paddy field at Kathun (Fig. 11), famous rambutan orchards at Na San (Fig. 12), rubber plantations (Fig. 13), housing (Fig. 14), highways (Fig. 15), bridges (Fig. 16), cattle and human lives.

Sediment still covers Ban Na San town more than 2 months after the flood (Fig. 17). This may cause lung diseases among the inhabitants.

The flood devastated shrimp and oyster farms and discharged sediment heavily into the river mouth. The inlet is unnavigable. The shore has prograded rapidly.

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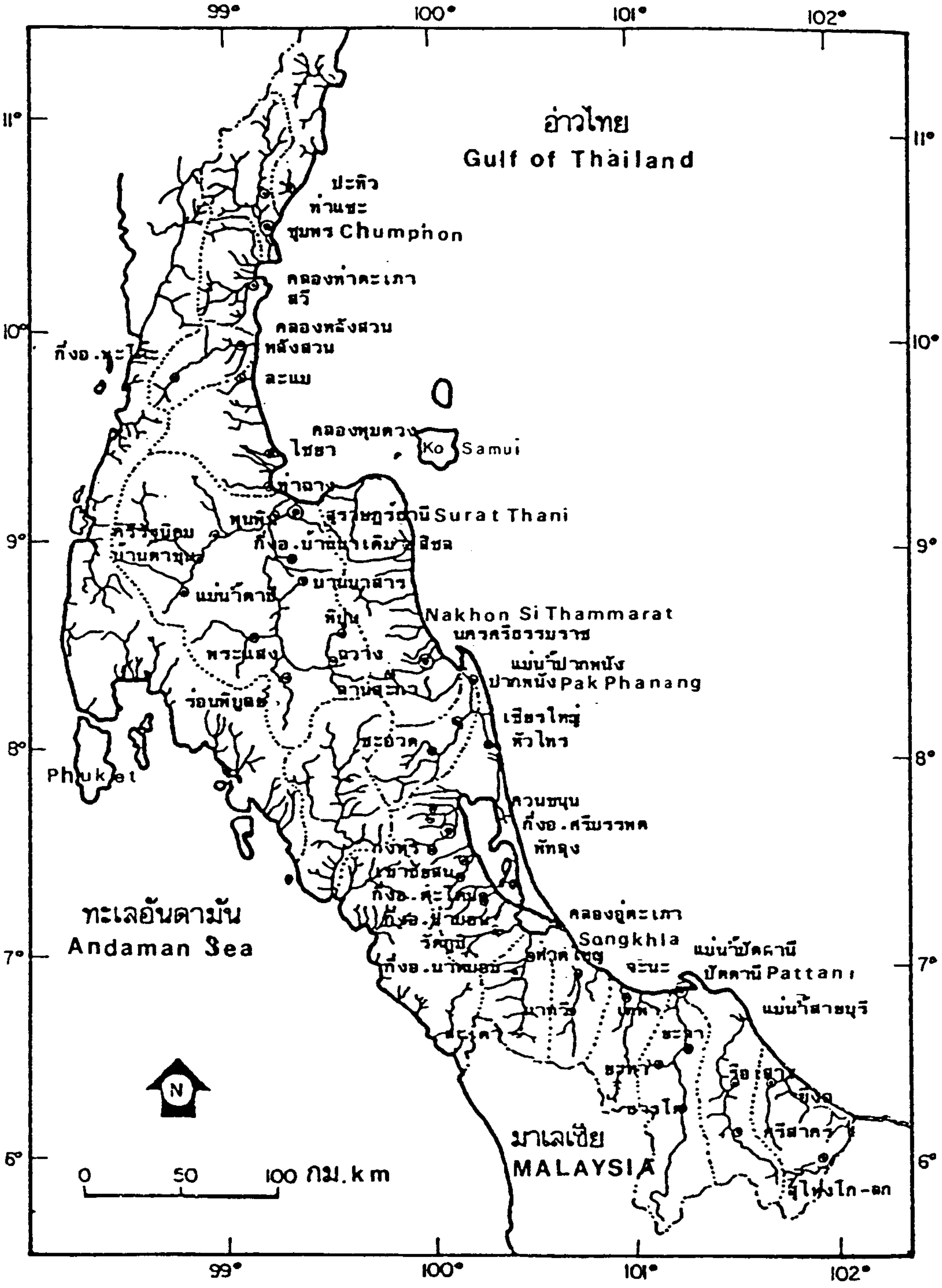

Fig. 1. Map of drainage pattern in southern Peninsular Thailand (from Nutalaya and Soponsakulrat 1989).

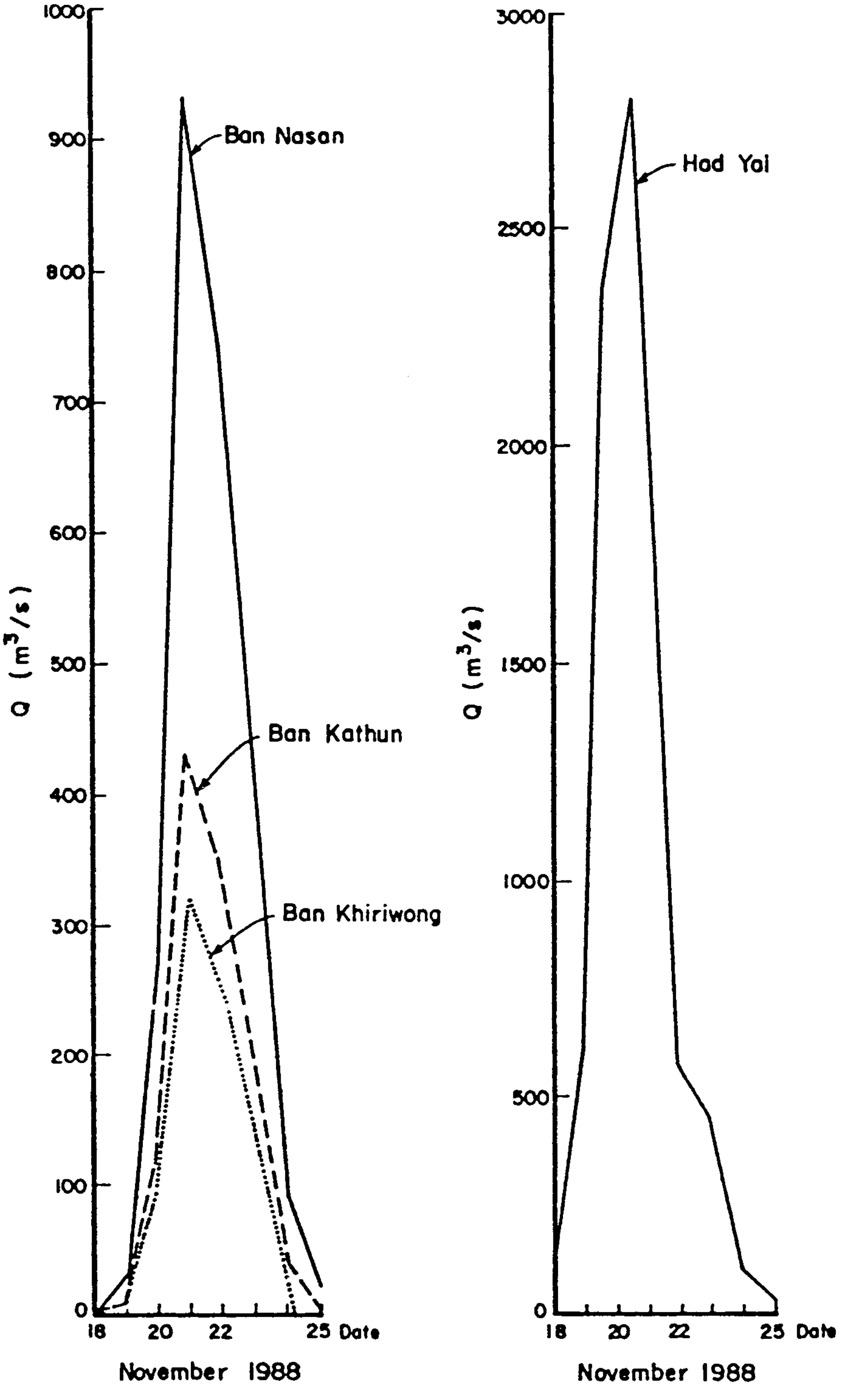

Fig. 2. Computed discharges of four critical basins during the flood of November 1988 (from Vongvisessomjai 1989).

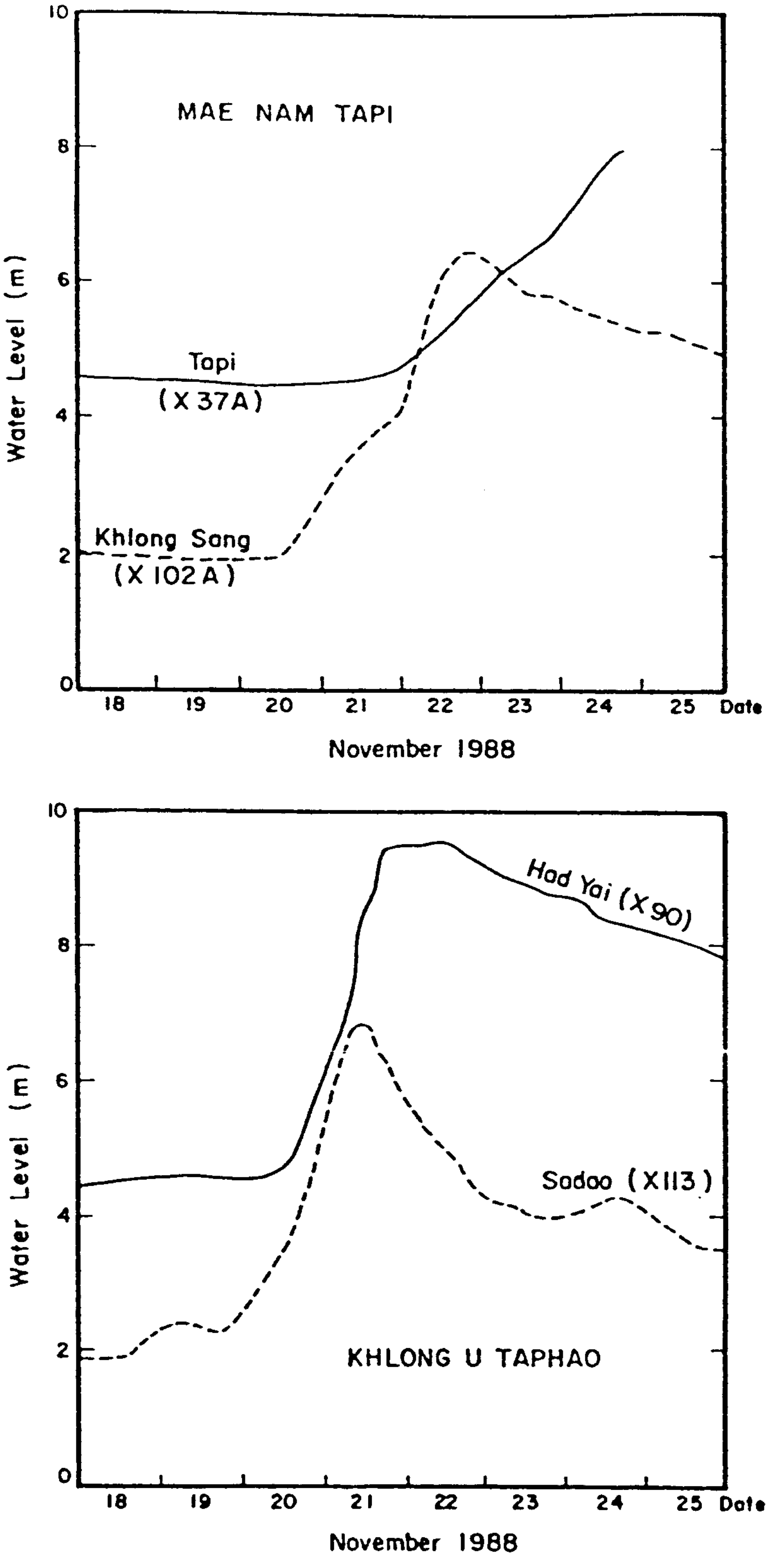

Fig. 3. Water levels recorded by the Royal Irrigation Department of Thailand in November 1988 at 4 stations (from Vongvisessomjai 1989).

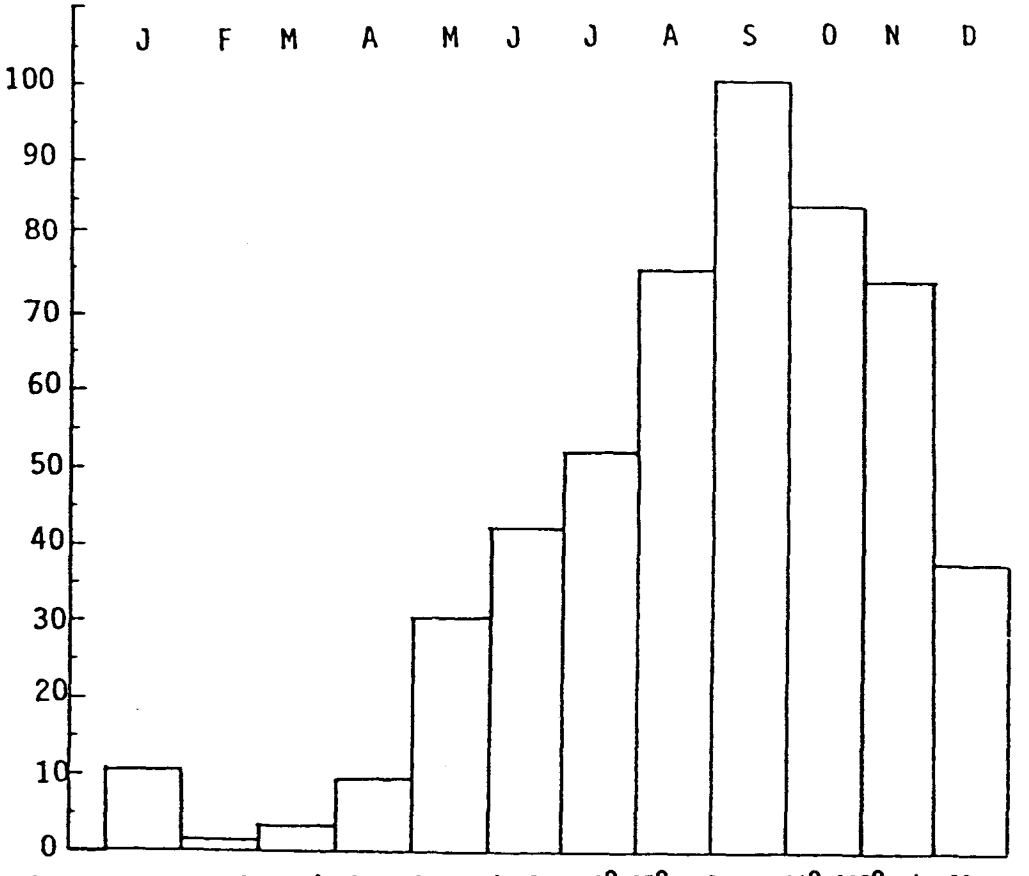

Fig. 4a. Number of tropical cyclones in lat. 0°-25°N, long. 90°-115°E in 33 years (1947-1979) (from Siripong 1985).

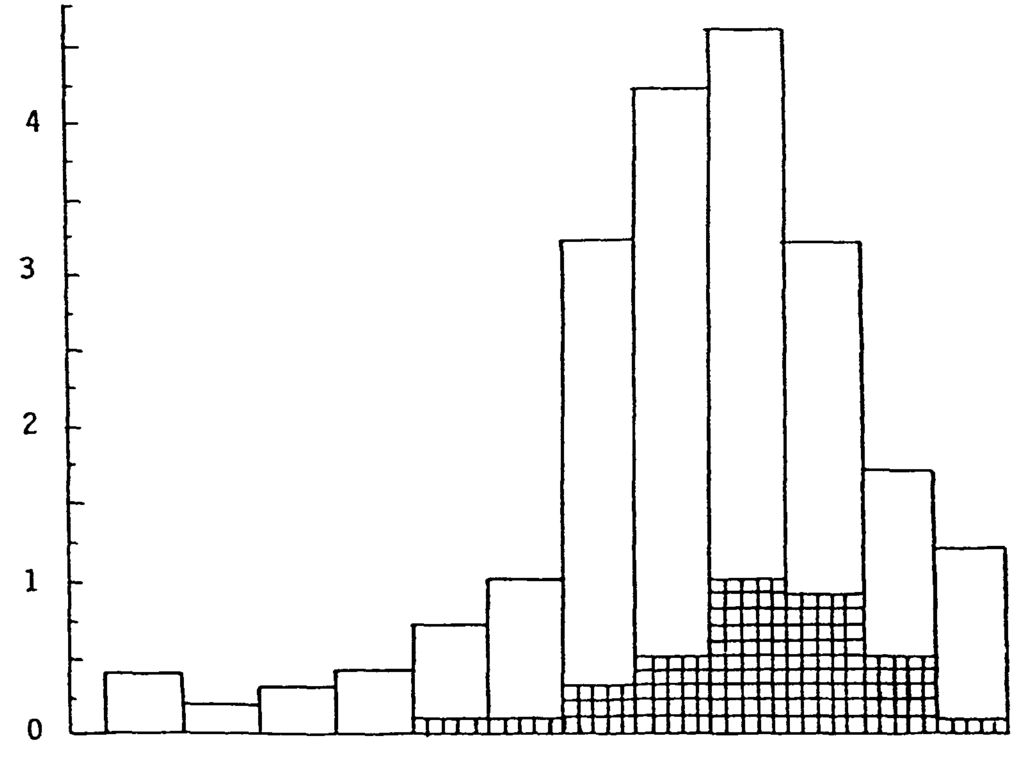

Fig. 4b. Monthly frequency of occurrence of tropical cyclones in the North Pacific Ocean. The grid area indicates those which passed Thailand (from Siripong 1985).

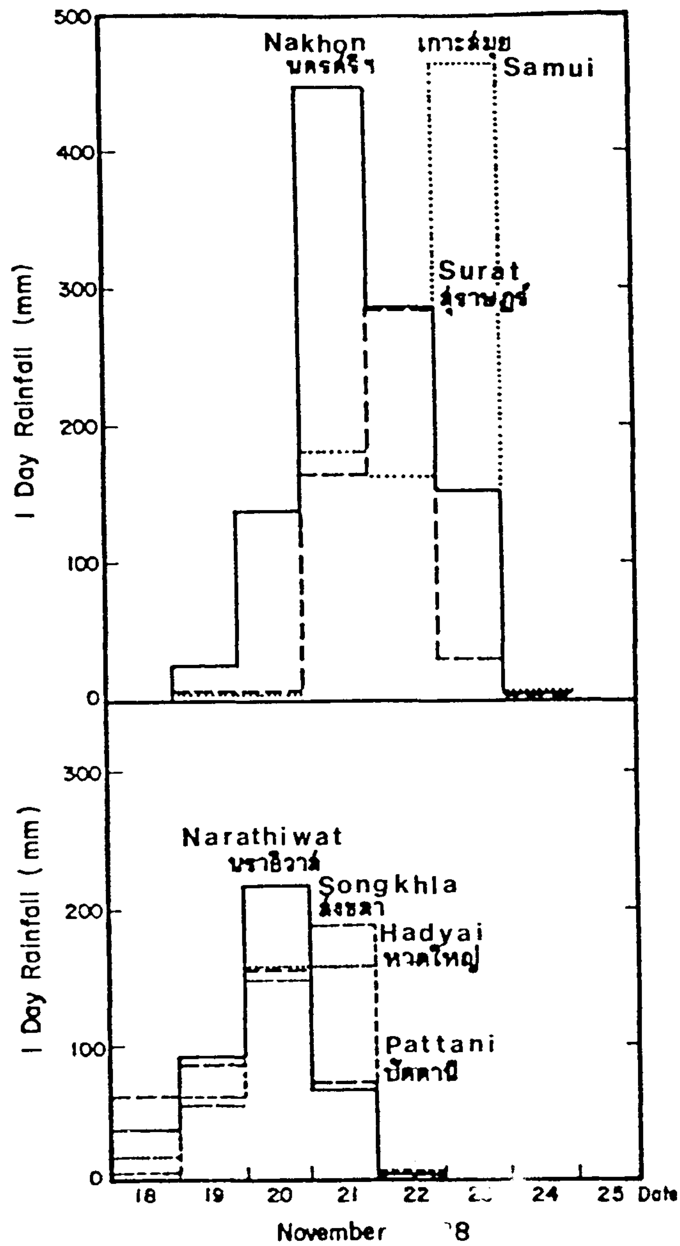

Fig. 5. One-day rainfall in the south during the 1988 flood (from Vongvisessomjai 1989).

Fig. 6. The new desert at Kathun Basin, Amphoe Phi Pun, Nakhon Si Thammarat Province on 25 January 1989 after the flood.

Fig. 7. The hill slopes were eroded severely on the mountains at Huei Go, Amphoe Phi Pun, Nakhon Si Thammarat.

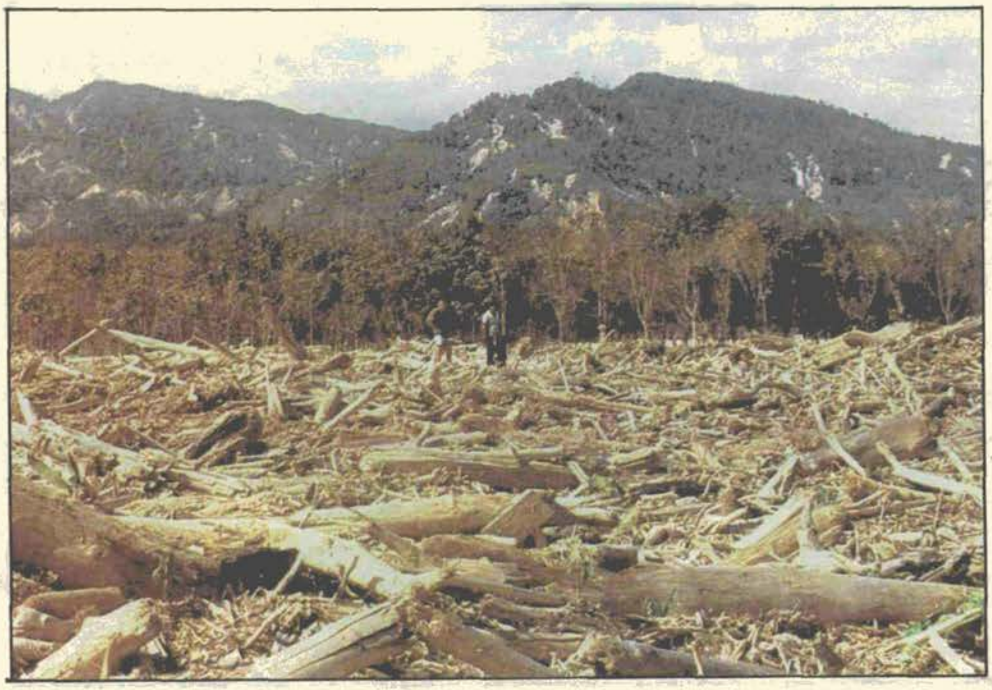

Fig. 8. The big trees were uprooted and swept down at Huei Go.

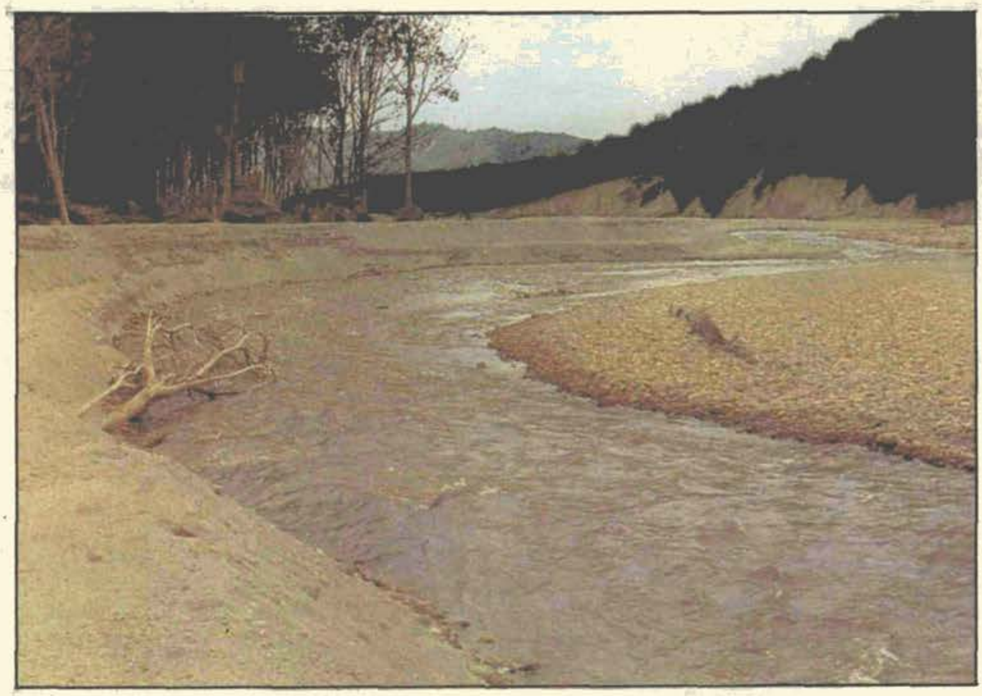

Fig. 9. The heavy sediment laden runoff overflowed the lower land at Kathun Basin.

Fig. 10. The flood changed the course of the old stream and cut into new terraces. One level of terrace means one flood. There were 3 floods in one day on 22nd November 1988.

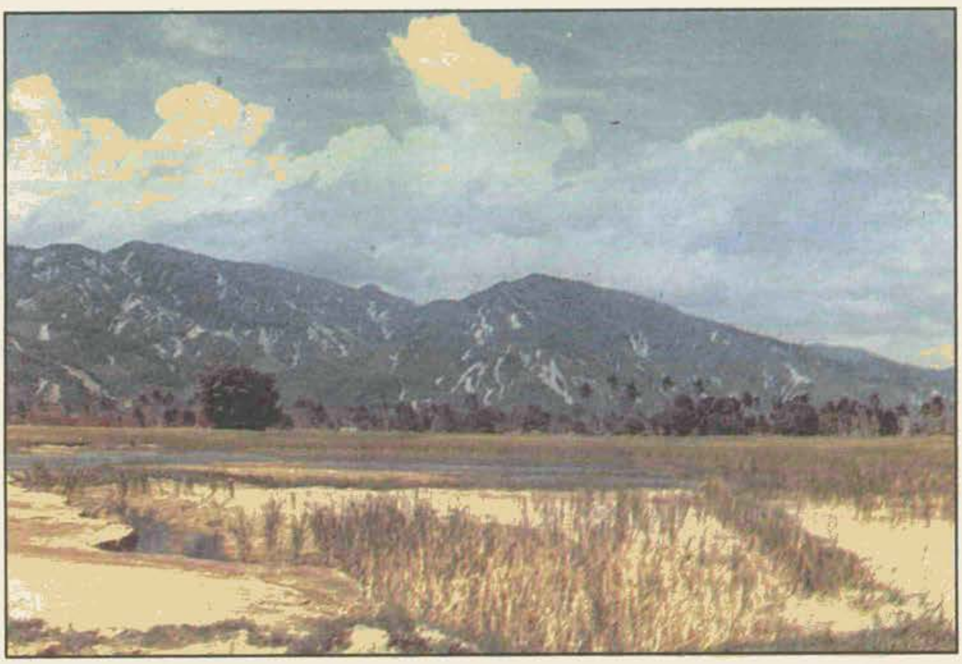

Fig. 11. The flood destroyed the paddy field at Amphoe Phi Pun.

Fig. 12. The flood destroyed the rambutan orchards

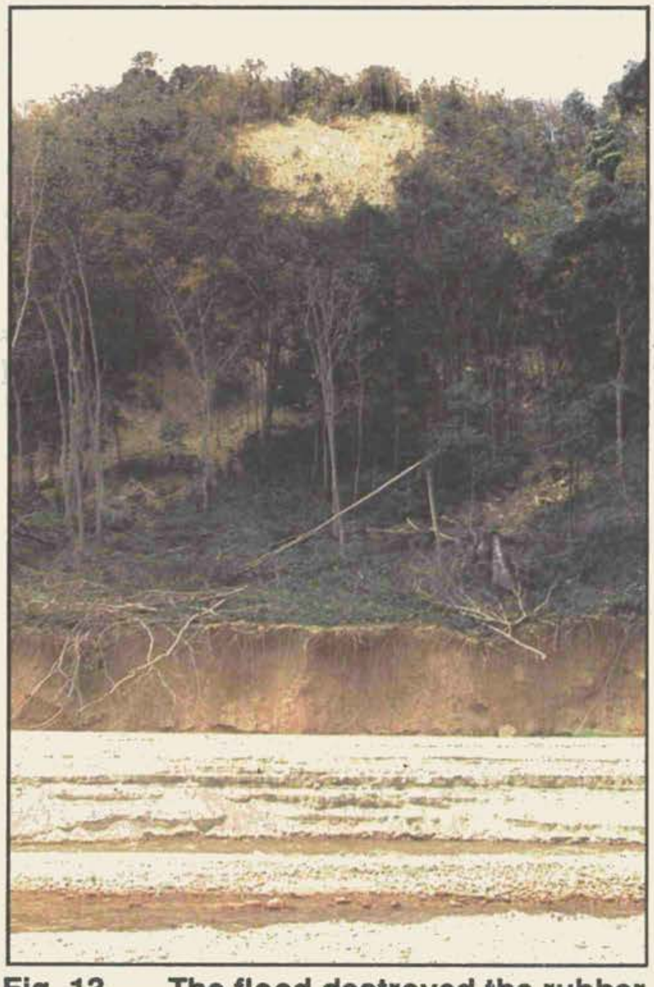

Fig. 13. The flood destroyed the rubber plantation.

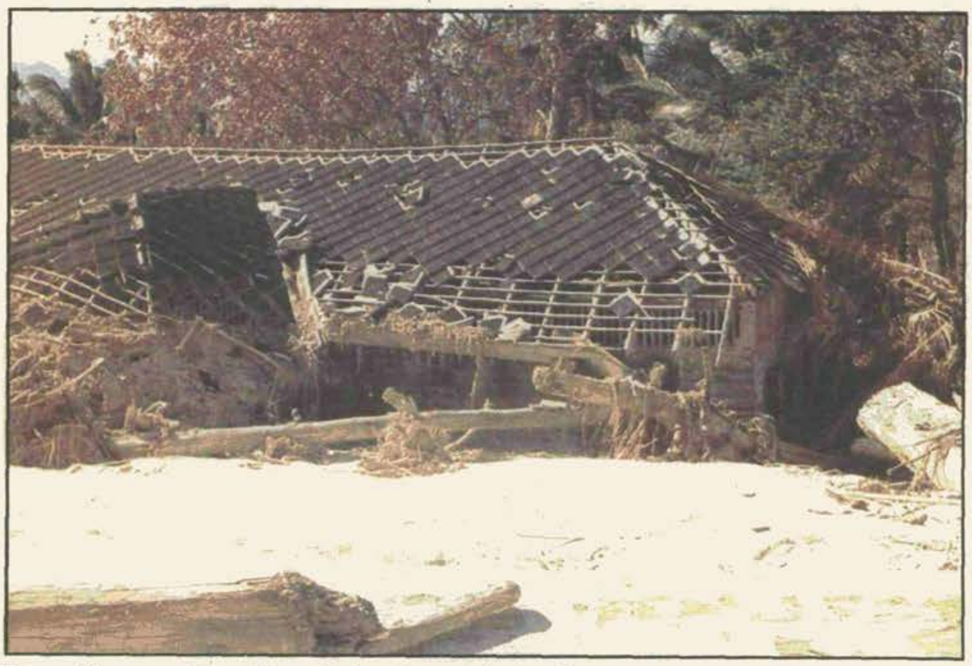

Fig. 14. The flood destroyed the houses.

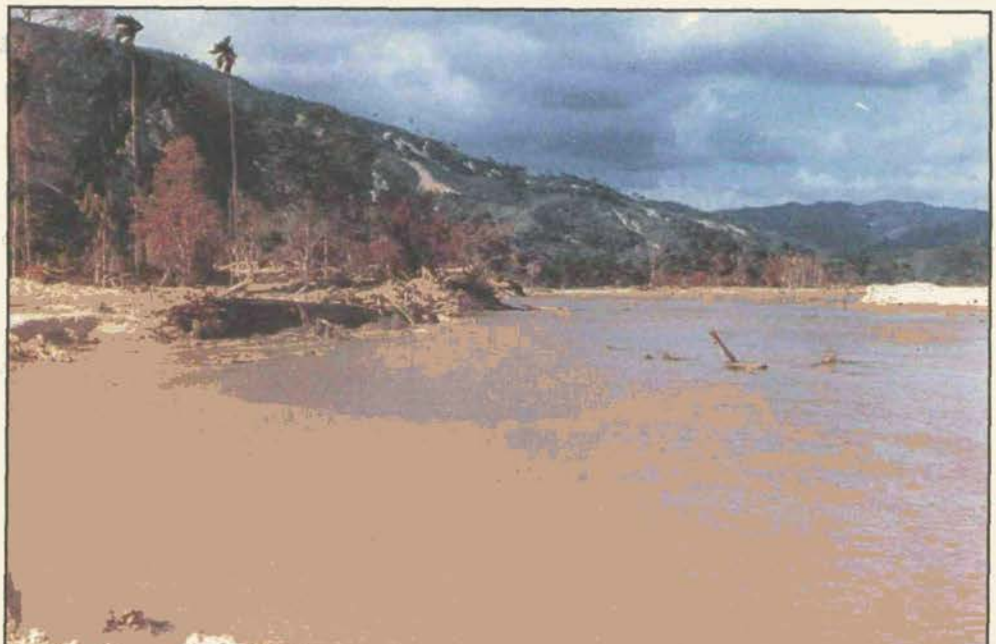

Fig. 15. The flood destroyed the road.

Fig. 16. The flood destroyed the bridge.

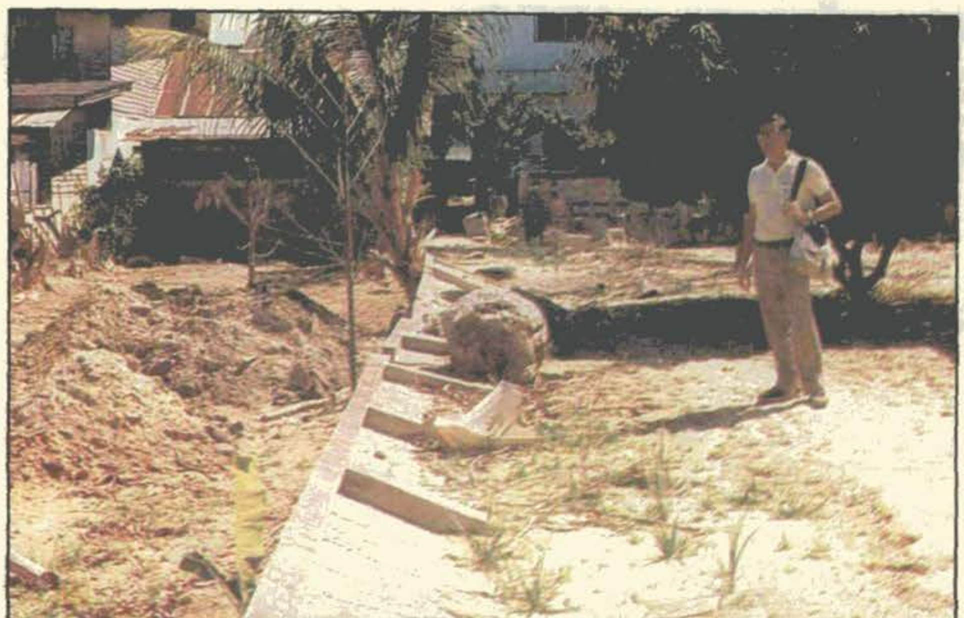

Fig. 17. The dirty town of Ban Na San, Surat Thani Province.

SOME NOTES ON OIL SPILL CONTINGENCY PLANNING IN INDONESIA

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ABSTRACT

Technical, institutional and legislative aspects are described to explain oil spill contingency planning with special reference to the Indonesian waters and their surroundings. These are considered within the framework of the ASEAN regional research programmes, and requirements for future formulation and implementation of an ASEAN oil spill contingency plan for oil spill control and clean-up.

1. INTRODUCTION

Oil spills can have serious economic impacts on coastal activities and those who exploit the resources of the sea. In most cases, such damage is temporary and caused primarily by physical properties of oil creating nuisance and hazardous conditions. More than ten years ago the oil tanker "SHOWA MARU" grounded in the Malacca-Singapore Straits, releasing some 5,000 tons of crude oil, and thus provided the first concrete example of the types of environmental damage that oil spills can create. Although precautions have been taken to prevent further such accidents in the region, this has proven to be difficult.

Several similar accidents have occurred in the waters of Southeast Asia causing a variety of stresses on the marine environment. With the increased number of ships passing through Southeast Asian waters, and given that most sea-lanes are located in the waters of ASEAN member countries, it has become imperative to give high priority to an overall Oil Spill Contigency Plan. Such an activity needs to address oil spills originating from both offshore oil production/exploration and operations from tanker traffic. Thus, for the first time, many countries, especially in ASEAN, have realized that a National Oil Spill Contigency Plan is now a necessity and that the national efforts should be backed up by international co-operation. Major oil spills could affect more than one country and combating of major oil slicks would in most cases exceed the capability of one single coastal state.

Recognizing that (oil) pollution knows no natural or political boundary, ASEAN member countries have been emphasizing the need for close co-operation in the protection and conservation of the environment, pollution control, and safety of petroleum operations. The need is greatly felt in the ASEAN region due to the geographical proximity of neighbouring states and the similar characteristics of their coastal and marine environment.

The archipelagic state of Indonesia, situated between 94°45' and 141°05'E longitude, and from 06°08'N to 11°05'S latitude, stretches 5,110 km from west to east and 1,888 km from north to south, consisting of 17,508 islands, over one-half of which are unnamed. Approximately two-thirds of the country's territory is covered by tropical oceans, with a total area of 5.8 million km^2, which consist of 0.3 million km^2 of territorial sea, 2.8 million km^2, of archipelagic waters (perairan Nusantara) and 2.7 million km^2 of Exclusive Economic Zone. The length of coastline is about 81,000 km.

The Indonesian waters have been of great economic importance for the people for centuries due to the rich and diversified life and resources they contain, including minerals and hydrocarbon resources in the shallower parts of the seas. The waters also sustain other types of activities such as inter-island, regional and international trade and communication, recreation and tourism. Unfortunately, as a result of strong economic development of the country in almost all sectors, the marine and coastal resources have been subjected to severe pressures, both direct and indirect.

Some concerns are the increasing number of incidents of pollution, and the degradation of certain coastal areas and ecosystems, including coral reefs. The evaluation of these problems and implementation of solutions are being carried out in accordance with the Act of the Republic of Indonesia No. 4 of 1982 concerning Basic Provisions for the Management of the Living Environment. In part the Act states that management of the living environment should be based upon the sustenance of the capability of a harmonious and balanced environment to support continued development for the improvement of human welfare. In order to fulfill these requirements, development and management steps should address policy statements, legal implications, institutional aspects, manpower, co-ordination efforts, and monitoring activities in the country.

2. LEGISLATIVE AND INSTITUTIONAL DEVELOPMENTS RELATED TO THE MARINE ENVIRONMENT IN INDONESIA

Current environmental legislation originated from principles adopted under the Stockholm Declaration (1972), and a more complete Basic Act for Management of the Living Environment was promulgated in 1982, providing for further environmental legislation suited to Indonesia's particular situation. The formulation of appropriate institutional and legislative frameworks for implementing guidelines and standards for environmental management has received high priority.

Utilization and management of the environment in Indonesia is protected by the Constitution. Every five years, the National Assembly, as the highest political authority, evaluates the provisions and promulgates the broad outline of environmental policy. The State Ministry for Population and the Environment is responsible for co-ordinating national implementation, and each Provincial Governor is designated as the Environmental Administrator, assisted by the local Bureau for Population and Environment. The main legislative provisions on the living environment in Indonesia issued by the State Ministry for Population and the Environment are as follows:

(1) ACT OF THE REPUBLIC OF INDONESIA No. 4 of 1982 (concerning BASIC PROVISIONS FOR THE MANAGEMENT OF THE LIVING ENVIRONMENT) (see discussion above).

(2) GOVERNMENT REGULATION No. 29 of 1988 (regarding the ANALYSIS OF IMPACT UPON THE ENVIRONMENT) - prescribes an Environmental Impact Assessment (EIA) process involving seven types of reports following a number of guidelines issued in 1987 on the execution of EIA studies. In the same year, a Ministerial Circular letter was also issued which set out the Ministerial interpretation of the 1982 Act regarding sanctions for environmental damage and pollution.

(3) MINISTERIAL DECREE (STATE MINISTER FOR POPULATION AND THE ENVIRONMENT) No. Kep - 02/MENKLH/I/1988 (concerning GUIDELINES ON ENVIRONMENTAL QUALITY STANDARDS, including the Quality Standards for Sea Water) - was divided into 6 categories under three large groups, namely:

(a) For recreational and tourism purposes, constituting standards for bathing, swimming and diving in one group, and general use and aesthetics in another;

(b) Concerning the marine biota, and consisting of fish mariculture standards in one group and marine park and conservation uses in another;

(c) For mining and energy purposes, consisting of standards for cooling systems.

3. NOTES ON OIL SPILL CONTINGENCY PLANNING IN INDONESIA

Marine pollution can be caused by oil and non-oil substances. Different pollutants require different patterns of action against the pollution. Multi-disciplinary and cross-sectoral operations are usually needed. This calls for the involvement of various institutions which should have an integrated system and be constantly on alert.

Firstly, pollution may occur due to routine activities. Secondly, it may occur as a result of an accident. In the first case, a routine action should be performed in order to protect the area against pollution. The second case requires emergency action under an Emergency National System to Protect Against Marine Pollution (Sisnas PDPL = Sistem National Penanggulangan Darurat Pencemaran Laut).

The implementation of the operational mechanism of "Sisnas PDPL" is based on the utilization of existing institutions. There are 2 aspects of action:

(1) Physical prevention where the operation is co-ordinated by the Department of Transportation, the Directorate General of Sea Transport, and the Head of the Regional Office of Sea Transport which is responsible for the field activities;

(2) Protection from the negative impact of the pollution and rehabilitation measures.

The ultimate co-ordination of the activities is by the State Minister of Population and Environment.

Action against marine pollution can be carried out both at the national and regional levels. This will depend on the ability of the regional officer. In every operation, experts in the field of ecology participate in measuring the extent of waste distribution and its impact on the environment.

For practical purposes, a distinction is made between the open sea and the coastal area. The vulnerability of a coastal area is indicated by the Index of Environmental Sensitivity which is determined through an ecological approach. The lowest index number is 1 (one) which indicates that the area concerned is an ecosystem with the highest tolerance towards an oil spill and the highest potential rate of recovery. The highest index number is 8 (eight) which indicates a sensitive ecosystem, with the lowest tolerance towards an oil spill and the lowest potential rate of recovery. This is admittedly a general categorization. The Indonesian government uses the Index of Environmental Sensitivity to estimate the level of activity needed to overcome an oil spill.

From the middle of the seventies the development of national and international contingency plans has accelerated considerably both with regard to effective execution and the development of new combating techniques. However, the proper tool for deciding on reasonable combat measures was still not utilized.

This tool-risk analysis is being used today to a large extent and forms the basis for re-evaluation of the various contingency plans. It should also form the basis of all future contingency arrangements dealing with pollution of the sea by oil and other harmful substances as it has proven to be extremely effective both for decision-making and training. It involves determining or predicting the frequency of incidents, the characterization of incidents, the evaluation of ecotoxicological effects and effects on amenities, and the effectiveness of emergency measures. More detailed techniques exist, for example, for:

- predicting the frequency of accidents, using shipping loss statistics and various mathematical models;

- analyzing the effect of various navigational improvements on risk;
- predicting the spread and dispersion of oil and chemicals in and on the water;
- predicting ecotoxicological effects and ecological costs of losses; and
- calculating a probability spectrum of loss rates.

The risk analysis will thus enable the responsible authority to:

- identify sources of pollution;
- estimate frequency and sizes of releases;
- identify sensitive areas;
- estimate the probability that the pollution reaches a given target; and
- assess damage.

The outcome will then form the basis for the re-evaluation of proposals for a contingency plan including administrative framework, procedures, spill control strategies, location of spill bases, and type and amount of clean-up equipment.

Realizing that exercises can never simulate the experience of a real incident, it must, however, be stressed that they form a very important part of every contingency arrangement, both nationally and internationally, to keep the various components of the plans in a high degree of readiness.

4. CONCLUSION

Although several efforts are being made to combat and control oil spills, there is still limited capability in the East Asian Seas region to handle them. Therefore, a considerable number of activities will be undertaken, including the formulation of an INDONESIAN OIL SPILL CONTIGENCY PLAN, to meet requirements for oil spill control and clean-up in the region.

It is also recommended that all the governments and national agencies in the region should:

- develop national and, where appropriate, regional oil spill response plans;

- establish strong liaisons with local industry and international industrial organizations in evolving oil spill response measures as necessary additions to existing systems; and

- draw upon, as appropriate, expertise and technical advise from ASEAN, UNEP, IMO and other relevant international organizations in developing oil spill contingency plans and preventing marine pollution.

It can therefore be seen that, with its ASEAN partners and other international agencies, Indonesia is seeking to promote effective regional co-operation in environmental management and protection.

TRANSNATIONAL POLLUTION AND ITS LEGAL ARRANGEMENT IN SOUTHEAST ASIA

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ABSTRACT

As reported by the ASEAMS to the Second Meeting of Experts on the East Asian Seas Action plan in 1987 at Bangkok, one of the most serious problems besetting the MARINE ENVIRONMENT OF SOUTHEAST ASIA is pollution (sewage, industrial, and oil). "Pollution originating in one country and affecting another country's environment through natural media" is called "TRANSNATIONAL POLLUTION" (TNP). Other people prefer to call it "TRANSFRONTIER POLLUTION" (TFP) with a slight difference.

After the grounding of the Japanese supertanker "SHOWA MARU" on January 6, 1975 before the harbour of Singapore, we have learned so much in controlling and abating MARINE POLLUTION through REGIONAL ARRANGEMENTS. Through the "TRIPARTITE ARRANGEMENT" between the three border states of the STRAITS OF MALACCA (Indonesia, Malaysia, and Singapore) which has been endorsed by the General Assembly of the Inter-Governmental Maritime Organization (now International Maritime Organization) through Resolution A. 375 (X) of November 14, 1977, we have developed an efficient mechanism to control and combat marine pollution. This involves establishing integrated and co-ordinated TECHNICAL, SCIENTIFIC AND RESEARCH, AND LEGAL AND ADMINISTRATIVE arrangements. The technical arrangement has been further developed into our present CONTINGENCY PLAN for the Straits of Malacca.

In addition, the ASEAN Council on Petroleum (ASCOPE) has established in 1980 the ASCOPE Plan for the Control and Mitigation of Marine Pollution (APCMMP) which focuses on the prevention and abatement of marine pollution originating from offshore platform refineries close to the coast, and from other production facilities. Almost at the same time discussions have been held leading to the establishment of a Sub-regional Centre for Shipping Pollution Countermeasures at Davao for the Sulawesi Sea Area, which was later on more commonly known as the OIL SPILL COUNTER-MEASURES IN THE LOMBOK/MACASSAR STRAITS AND SULAWESI SEA".

Before the establishment of the abovementioned arrangements, a REGIONAL ENVIRONMENTAL GROUP was formed in 1973, known as the "ASEAN Marine Pollution Experts Group" (AMPEG), which established in 1975 an ASEAN Contingency plan (ASEAN CONPLAN). But it has been reported by Coutrier (1988) that CONPLAN "has been dormant for some time".

By studying the abovementioned pollution arrangements, it has been observed that all our efforts and attention have been restricted up to now to the control and abatement of pollution caused by navigational hazards and especially oil exploitation. For all other kinds of pollution the required arrangements are still lacking.

Taking into consideration the MANILA DECLARATION ON ENVIRONMENT of April 30, 1981, the ASEAN-member Countries have already proclaimed their political will to strengthen "REGIONAL CO-OPERATION AND COLLABORATION IN THE FIELD OF ENVIRONMENT" by adopting the objective: "To ensure the protection of the ASEAN environment and the sustainability of its natural resources so that it can sustain continued development with the aim of eradicating poverty and attaining the highest possible quality of life for the people of the ASEAN countries".

Knowing the situation and condition of the CONPLAN at present, and realizing the limited scope of purpose and operation of the existing arrangements in the control and abatement of pollution in the ASEAN environment, would it not be an excellent occasion to invite the ASEAMS to consider the above proclaimed objective of the MANILA DECLARATION - 1981 and initiate the study of its realization? It would really be an honoured attitude and devotion of the ASEAMS if after the adoption of its Charter on February 6, 1989, it might be willing to inaugurate its PROGRAMME OF ACTION with the study on the problems and their solutions, among others by re-activating the CONPLAN and developing more effectively its arrangements regarding the technical and scientific research as well as the legal-administrative aspects. Special attention should be devoted to developing an awareness and insight concerning the problem of protecting and preserving the ASEAN ENVIRONMENT against all kinds of pollution, including TRANSNATIONAL POLLUTION both in its unidirectional as well as in its reciprocal aspects.

1. INTRODUCTION

Perhaps no marine region in the world presents more diverse problems of environmental management than the East Asian Seas. Gulfs and peninsulas, sluggish estuaries coupled with teeming and narrow straits, indented land masses and clusters of islands large and small, all contribute to a physical configuration of unequalled complexity. Peopled by teeming populations with widely varying cultures, ideologies, and socio-economic systems, this East Asian Seas region offers a formidable challenge to resource diplomacy and the making of environmental policy. Few would deny that the "EAST ASIAN SEAS PROGRAMME" is the most audacious of designations under the "Regional Seas Programme" of the United Nations Environment Programme (UNEP).

To reduce the problem to manageable size, it was recommended at an early stage that the region should be divided into a number of "sub-regions", such as: (i) the Bay of Bengal; (ii) the Straits of Malacca; (iii) the Gulf of Thailand; (iv) the South China Sea; (v) the Sea of Japan; (vi) the Yellow Sea; (vii) the East China Sea; and (viii) the Eastern Archipelago, as has been attempted at the Penang Workshop in 1976. But it seemed that even with such a division, the region still proved to be very complicated.

For these reasons one shifted to the idea of developing a single "sub-regional seas programme" covering: (i) The South China Sea; and (ii) the adjacent waters, known as "the Southeast Asian Sub-regional Seas Programme". As in other Regional Seas Programmes, for the East Asian Seas a special interest has been taken in combating the dangers of oil pollution in general as well as the special threat to the fragile mangrove ecosystems of the region. As early as April 1976, at the Penang Workshop, oil pollution was identified as a first priority concern, particularly in the "ship-congested area of the Straits of Malacca and Singapore" (Danusaputro and Kusumaatmadja 1978).

2. THE ASEAN SUB-REGIONAL SEAS PROGRAMME

In March 1979 UNEP formulated its first draft Action Plan for the Southeast Asian region (UNEP 1980). The document stated that:

> "The Southeast Asian Region has been recognized by the Governing Council of the United Nations Environment Programme (UNEP) as a "concentration area" in which UNEP, in close collaboration with the relevant components of the United Nations system, will attempt to fulfill a catalytic role in assisting the developing States of the Southeast Asian Region to formulate and implement, in a consistent manner, a commonly agreed upon Action Plan."

But even Southeast Asia proved too large and complex a "sub-region" to deal with. Accordingly the scope of the draft Action Plan had been further reduced, at least for "the purpose of the initial stages of the Action Plan", to the marine environment and coastal areas of the countries of the Association of Southeast Asian Nations (ASEAN). Recognizing the sensitivity of political and juridical issues with respect to the seas in the region concerned, the drafters of the first Action Plan were careful to add:

> "The geographic limitation of the marine environment and coastal areas to be considered as part of the region will be identified by the Governments concerned on an ad hoc basis depending on the type of activities to be carried out as part of the Action Plan."

More optimistically, the draft concluded:

> "Further extension of the region to comprise the marine environment and the coastal areas of all the States bordering the entire South China Sea is considered desirable."

As we have seen, the above mentioned ASEAN countries constitute but a part of Southeast Asia, bordering the South China Sea. Politically, it will not be very easy to extend the Action Plan to the other countries for conservation or other environmental purposes.

3. POLLUTION PROBLEMS

One of the initial activities of ASEAMS was to undertake an inventory of the most serious problems besetting the marine environment of Southeast Asia based on consultations with the region's scientists. The perceived problems are presented as follows in their probable order of severity (using a scale of 1 = Most severe, to 7 = Least severe) (UNEP 1987):

PROBLEM	IMMEDIATE	SHORT-TERM	LONG-TERM
Destruction of support ecosystems, specifically coral reefs and mangroves	1	1	1
Sewage POLLUTION	2	3*	3
Industrial POLLUTION	3	2	2
Oil POLLUTION	4	5	-
Fisheries over-exploitation	5	-	-
Siltation and sedimentation	6	3*	5
Coastal erosion	7	6	6
Coastal area development	-	7	7
Rise in sea level and other natural hazards	-	-	4

*Tied for third rank.

Pollution ranks among the serious problems besetting the marine environment of Southeast Asia. "POLLUTION" is usually defined as: "The entry or introduction of living organisms, matter, energy and/or other components into the environment, and/or change in the environmental system due to man's activities or natural processes resulting in the decline of the environmental quality to such a level which causes the environment to function insufficiently or to lose its proper function."

4. THE PROTOCOL CONCERNING CO-OPERATION IN COMBATING POLLUTION

At the Baguio Meeting of Experts on 17-21 June 1980 (UNEP 1980), a draft Protocol concerning co-operation in combating POLLUTION in the East Asian Seas region which was prepared by the Inter-Governmental Maritime Consultative Organization ("IMCO"; now the International Maritime Organization, "IMO") was submitted. The draft Protocol dealt with pollution by oil and other harmful substances in cases of emergency, 1/ a subject which had been discussed already very intensively by the ASEAN Experts on the proposed CONTINGENCY PLAN. 2/ The Meeting of Experts was of the opinion that the planned IMCO (=IMO)/UNEP international workshop in the Philippines which would study the PREVENTION, ABATEMENT AND COMBATING of pollution from ships in the East Asian waters should consider the feasibility of developing an INDEPENDENT REGIONAL ARRANGEMENT AND AGREEMENT that would address the issues related to co-operation in cases of pollution emergency, taking into consideration the existing ASEAN Contingency Plan. 3/

1/ The first serious oil pollution incident in ASEAN waters was the spilling of 3,600 tons of crude oil into the Straits of Malacca and Singapore by the Japanese tanker "SHOWA MARU" in January 1975. The next two relatively minor spills were: (i) In August 1976 a Philippine tanker "DIEGO SILANG" collided with another vessel in the Straits of Malacca and spilled about 6,000 gallons of Kuwait oil; (ii) A larger spillage of 590,000 gallons resulted from an earlier collision in the Gulf of Thailand in April 1974, when a coastal vessel "VISA HAKIT", loaded with fuel oil, was hit by a freighter.

2/ The terms of reference of the ASEAN Expert Group Meeting on Marine Pollution are:

(a) To lay down the fundamental obligations of the ASEAN member countries to preserve the marine environment through the implementation of appropriate anti-pollution measures, taking into account international conventions;

(b) To consider further national, regional or international measures for the discharge of the fundamental obligation;

(c) To recommend broad principles for dealing with certain regional or international questions relating to jurisdiction, compensation for damage and settlement of disputes, and also technical assistance schemes; and

(d) To conduct fact-finding activities in the ASEAN region concerning marine pollution.

3/ The Contingency Plan provides for:

(a) An effective reporting system to alert the member countries in case of a major oil spill;

(b) A programme of identification and exchange of information on existing anti-pollution operational capabilities within member countries; and

(c) A system of providing assistance to a member country in the event of a large oil spill which it alone cannot cope with, and/or which threatens a neighbouring country.

Cf. with Proposed ASEAN Sub-Regional Environment Programme (ASEP) 1977.

5. OIL POLLUTION CONTROL MEASURES

Following the grounding of the "TORREY CANYON" at Seven Stones Reef, UK in 1967, concern was expressed over the possibility of a similar incident occurring in the important Straits of Malacca. In early 1970, the three coastal states bordering the Straits of Malacca, Indonesia, Malaysia and Singapore, took measures to improve navigation through the Straits. On November 16, 1971, these states issued a Joint Statement declaring that "the safety of navigation in the Straits of Malacca and Singapore is the responsibility of the three Coastal States". A "Traffic Separation Scheme" (TSS) was organized to ensure safety of navigation through the Straits.

Following the grounding of the Japanese super-tanker "SHOWA MARU" at Buffalo Rocks on January 6, 1975, the Foreign Ministers of Indonesia, Malaysia and Singapore signed on February 24, 1977:

(i) An AGREEMENT on Safety of Navigation in the Straits of Malacca and Singapore;
(ii) A JOINT STATEMENT on Safety of Navigation in the Straits of Malacca and Singapore; and
(iii) GUIDELINES for Senior Officials and Technical Experts on Safety of Navigation in the Straits of Malacca and Singapore.

A routing system was compiled and forwarded as a proposal to the IMCO. By mid-1980 all provisions had been settled and the results were reported to the 43rd Meeting of the MSC (Maritime Safety Commission) of the IMCO which declared that the routing system for the Straits of Malacca and Singapore should be implemented as of May 1, 1981 at 00.01 GMT.

In view of the potential threat of a major or disastrous oil spill from vessels larger than 200,000 dwt. (VLCC = Very Large Crude Carriers) in the Straits of Malacca and Singapore and the Straits of Lombok and Macassar, several CONTINGENCY PLANS were established for the area. They are usually grouped into National and Regional Contingency Plans.

"National Contingency Plans" (NCP's) have been designed for the three states, Indonesia, Malaysia, and Singapore, particularly to co-ordinate local pollution response for coastal zone waters and shores. Regional co-operative efforts in navigational safety and marine pollution were initiated in 1971 by the establishment of the COUNCIL ON SAFETY OF NAVIGATION AND CONTROL OF MARINE POLLUTION in the Straits of Malacca and Singapore, also called "The Tripartite Committee" (=Indonesia, Malaysia, and Singapore). This group was later developed to become "The Malacca Straits Council" which was responsible for the management of the "Malacca Straits Revolving Fund".

In 1973 a "Regional Environmental Group" was formed in Manila, called the "ASEAN Marine Pollution Experts Group" (AMPEG), which established in 1975 the "ASEAN Contingency Plan" (ASEAN CONPLAN). The latter has the purpose to control and mitigate marine pollution in the ASEAN region. It is envisioned that this "ASEAN CONPLAN" will:

(i) Institute prompt measures for control of oil pollution;
(ii) Mitigate associated environmental effects;
(iii) Co-ordinate and integrate the action and efforts of the member countries in combating the said discharge of oil; and
(iv) Provide information on operational anti-pollution facilities and equipment so as to facilitate response operation.

Ten years after its inception in 1985, experience has shown that the ASEAN CONPLAN is too ambitious to be fully successful. It has been reported that, in practice, the ASEAN CONPLAN has in fact been dormant for some time.

This, among others, was the reason why the members of ASCOPE (ASEAN Council on Petroleum) agreed to establish the "ASCOPE Plan for the Control and Mitigation of Marine Pollution" (APCMMP). In ASCOPE the members of the ASEAN countries are represented by their respective

Petroleum Authorities or National Oil Companies, e.g., PERTAMINA for Indonesia, PETRONAS for Malaysia, PNOC for the Philippines, SNOC for Singapore, and PTT for Thailand. To avoid duplication with other regimes or institutions, the APCMMP focused on the prevention and abatement of marine pollution originating from offshore platform refineries close to the coast and other production facilities.

Meanwhile, efforts are being made to simplify regional oil spill contingency planning. Some of the major international oil companies have studied the capabilities of oil spill response in the region. They concluded that no single country would be able to abate a major oil spill of, say 10,000 tons, be it from a leaking tanker or an offshore blowout. For this reason, five major oil companies, BP, CALTEX, ESSO, MOBIL, and SHELL, established in 1985 the "TARC capability system" with the objective to stockpile enough equipment to augment the capability of the area in the event of a major oil spill. The "TARC system" is based upon 3-levels/tiers of response based on the size of the oil spill.

The Straits of Malacca and Singapore are perceived as the primary area of interest for TARC. The TARC equipment can be mobilized from its base in Singapore beyond the primary area, provided it is available and can be returned to the base within 24 hours. The most significant feature of the TARC system is <u>its mobility</u>, including air transportation of the equipment to the pollution site, and equipment for aerial spraying of dispersants over oil slicks. Preliminary permits have to be obtained from the respective countries before entering their air space.

A sub-regional arrangement involving a centre for shipping pollution countermeasures was established at Davao, the Philippines in 1980 after Indonesia, Malaysia and the Philippines agreed to accept a UNDP project known as the Project for Strengthening of the Network for Oil Spill Countermeasures in the Lombok/Macassar Straits and Sulawesi Sea. Later on, consensus was also reached among the member countries for the operation of the Sulawesi Sea Oil Spill Network, which is to be incorporated into the National Contingency Plans of the three member countries and within the ASEAN Contingency Plan (Coutrier 1988).

6. TRANSNATIONAL POLLUTION PROBLEM

6.1 Nature of transnational pollution

Based upon the definition of "pollution" stated above, such a process may affect not only the domestic environment, but may even transcend national frontiers. "Pollution originating in one country and affecting another country's environment through natural media" is called "transfrontier pollution."

Transfrontier pollution creates "transnational environmental problems" which need transnational arrangements leading to the creation of agreements which are usually formulated into legal stipulations affecting the birth of "transnational pollution law". In fact, the above stated definition concerning "Transfrontier Pollution" does not encompass all cases of exported pollution, since pollution can also be exported by MOVEMENT OF GOODS AND SERVICES.

Moreover, transfrontier pollution may be (i) unidirectional and (ii) reciprocal. "Unidirectional transfrontier pollution" occurs when one country pollutes other countries. "Reciprocal transfrontier pollution" is developed when the countries mentioned above pollute each other. Cases of reciprocal transfrontier pollution can be considered conceptually as the "sum of two cases of unidirectional transfrontier pollution occurring simultaneously."

In this connection, it may be accepted that if a general solution and agreement to unidirectional transfrontier pollution problems could be found, all problems of transfrontier pollution could in principle be solved. This might be the desired basis for "transnational arrangements" and "transnational agreements" concerning the prevention and combat of transfrontier pollution.

6.2 Economic aspects of transnational pollution

Most of the economic literature on pollution is concerned with "externalities" or the "unintended response" of one firm's production (or one person's leisure) to the activity of others. This approach, drawn from the Law of Torts and Damages, is useful because it integrates well with the rest of economic analysis. As Anthony Scott of the University of British Columbia lectured, in the best known examples concerned with "foundries" and "laundries", the firms are unrestrained users of the atmosphere which carries undesired smoke away from the foundry and alters the fresh air desired for drying wet clothing. The foundry has private marginal costs and extra social or external marginal costs of production that spill over from it to add to the private cost of the other industry. In other examples, the external effects are felt within the same industry, but by other firms, such as in fishing, petroleum, and ground-water drilling.

Therefore, the approach which might be recommended is that it is usually less costly to reform the management of the common property resource over which the firm's activity spills than it is to intrude into the management of the firms and their costs.

6.3 Transnational pollution and international law

For the "Symposium on Environmental Research and Coastal Zone Management Problems in the Straits of Malacca" on 2-4 October 1985, organized by the University of Sumatera-Utara (USU) in co-operation with the EMDI (Environment Management and Development in Indonesia) of Canada, the present author submitted a paper entitled "Transnational Issues and their Required Legal Arrangement in the Eco-Development of the Coastal Zone of the Straits of Malacca."

As already known, the Straits of Malacca are bordered by more than one state, viz., Indonesia, Malaysia and Singapore. Moreover, the Straits of Malacca are a "strait used for international navigation" which has its special *regime* as is stipulated in PART III: Articles 34-45 of the UN Convention on the Law of the Sea (1982).

Taking into consideration these two characteristics of the Straits of Malacca, it might become an appropriate example within the marine environment of Southeast Asia in which issues can be studied concerning transnational pollution in its relation with international law. Particularly, there is a special reason for the bordering states to be aware of their rights and obligations according to the new Law of the Sea.

In developing and enhancing such friendly co-operation in the execution and implementation of the rights and obligations of the bordering states, understandably there are a lot of issues of transnational character which obviously need to be arranged in advance by the states concerned before they will be confronted with the outside foreign users. Besides, there are also many issues of transnational character which are very important for internal sub-regional intercourse so that the three states should feel it necessary to consult each other. The transnational issues in this field will predominantly relate to the arrangement of the proper management of shared resources within the realm of the Straits of Malacca. In this respect, there are indeed many transnational issues which deserve adequate attention, preferably on a joint co-operative basis as already experienced with the Joint Hydrographic Survey before 1970 and the Tripartite Arrangement in combating the marine pollution effects caused by the grounding of the Japanese supertanker "SHOWA MARU" in 1975 (Danusaputro and Kusumaatmadja 1978).

Contemplating particularly transnational pollution within the Straits of Malacca, we immediately will be confronted with "International Law" or the "Law between States". According to several global and regional treaties, states have assumed legal obligations to prevent transnational pollution. Understandably, only the states which are parties to these treaties are bound by such obligations.

6.4 In search of a general rule of international law

Taking into consideration the above stated information, the question has been put forward whether there exists any GENERAL RULE of International Law under which it is incumbent upon States to stop transnational pollution.

Contemplating the growing interdependence of States, the ever growing development of industrial production, the ever mounting risks of pollution, the growing rise in consumption and the steady increase in population, it is possible that the application of the principle of "good neighbourly relations" has developed into "a prohibition in international law against transnational pollution" (Bramsen 1974, cf. Danusaputro 1978).

The Law of NEIGHBOURLY RELATIONS known from "MUNICIPAL LAW" was invoked in an international context as early as 1941 in the well-known "Trail Smelter Case" submitted for arbitration by the United States and Canada. In this case the United States claimed compensation from Canada for damage caused by emission of fumes from a Canadian factory. In its famous consideration, the Tribunal held that:

> "Under the principle of International Law as well as the Law of the United States, no State has the right to use or permit the use of its territory in such manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, where the case is of serious consequence and the injury is established by clear and convincing evidence."

Another precedent was the "Corfu Channel Case" in 1949. In this case the International Court of Justice (ICJ) referred to:

> "Every State's obligation not to allow knowingly its territory to be used for acts contrary to the rights of other States."

The above stated consciousness and juridical conviction is in full accordance with "THE DUTY OF NON-INTERFERENCE" established by CUSTOMARY INTERNATIONAL LAW. It is usually stated in the maxim:

> "SIC UTERE TUO UT ALIENUM NON LAEDAS:.
> (Use your own property so as not to injure your neighbour's.)

In the context of modern environmental management, the abovementioned principle has been proclaimed in the "Stockholm Declaration", paragraph 21 which states:

> "States have, in accordance with the Charter of the United Nations and the principle of International Law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and <u>the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction</u> (UN 1973)."

By taking into consideration this existing principle of International Law, it is quite right to understand that it is the PERTINENT DUTY AND OBLIGATION of the three coastal states of the Straits of Malacca to prevent and combat transnational pollution. Contemplating the present state of national development of Indonesia, Malaysia and Singapore with their extensive programmes of industrialization, the possibility of occurrence of transnational pollution is real. This is the more so if we consider the rapid industrialization of Sumatera's east coast, the Malayan Peninsula, Singapore, and the Riau Archipelago development with its special Batam island industrial complex. A JOINT CO-OPERATIVE ACTION PLAN by the states concerned is therefore called for.

6.5 Transnational pollution caused by navigational hazards

As has been pointed out above, the Straits of Malacca are used for international navigation. With this characteristic they have a special regime as regulated in PART III: Articles 34-45 of the United Nations Convention on the Law of the Sea (CLOS). With the birth of these legal provisions there is now applicable an "international regime for the navigation through the Straits of Malacca" which needs to be implemented adequately and strictly for the sake of the

protection and preservation of the marine and coastal environment along with the interest of the international shipping community.

According to the provision of Article 34 of CLOS, the regime of passage through the Straits of Malacca shall not in other respects affect the status of the waters forming the Straits of Malacca as well as the exercise of the States bordering the straits of their sovereignty and jurisdiction over such waters and their air space, sea bed and the subsoil thereof. On the other hand, the sovereignty and jurisdiction of the States bordering the straits is exercised subject to the provisions of this part of CLOS and other rules of International Law.

According to Article 38 of CLOS, within the Straits of Malacca all ships and aircraft enjoy the right of transit passage which shall not be impeded, except that if the Straits are formed by an island of a State bordering the Straits and its mainland, transit passage shall not apply if a high seas route or a route in an EEZ (Exclusive Economic Zone) of similar convenience with respect to navigational and hydrographical characteristics exists seaward of the island.

Transit passage is the exercise in accordance with this provision of the freedom of navigation and overflight solely for the purpose of continuous and expeditious transit of the straits between one area of the high seas or an EEZ and another. However, the requirements of continuous and expeditious transit do not preclude passage through the straits for the purpose of entering, leaving or returning from a state bordering the straits, subject to the conditions of entry to that state. Any activity which is not an exercise of the right of transit passage through a strait remains subject to the other applicable provisions of CLOS.

The citation of Articles 34 and 38 of CLOS above provides but an example of the judicious regulation of transit passage through a strait used for international navigation with the purpose of protecting it against navigational hazards such as pollution.

The great importance of the Straits of Malacca lies in the fact that they are the most used sea-link between the Indian and the Pacific Oceans so that they may be overused!! This reflects on one hand the need for protection against growing deterioration and pollution, while on the other hand it reflects the emerging competition and resulting tensions among the user states for maximum benefit from use of the Straits.

The crucial question is whether and to what extent "ENVIRONMENTAL PROTECTION" and "ECONOMIC INTERESTS, SECURITY AND POLITICAL REQUIREMENTS" of the littoral States converge or are at variance with similar interests of the User-States. This is evident in the position adopted by the littoral states on the one hand, and by the user-states on the other, on the question of the "PROTECTION OF THE STRAITS OF MALACCA AGAINST THE GROWING DANGER AND THREATS OF POLLUTION, SPECIFICALLY THE TRANSNATIONAL POLLUTION CAUSED BY NAVIGATIONAL HAZARDS."

In recent years several accidents have occurred at sea in Southeast Asia, posing serious hazards to the coastal populations. The alternative sea-route through the Strait of Lombok and Macassar has been recommended by the Government of Indonesia in order to guarantee the safety of navigation, particularly for supertankers of over 200,000 dwt. Although it has been recommended for their own safety of transit, many supertankers still prefer to sail through the Straits of Malacca, ignoring the dangers and risks of shallowness and narrowness of the waters in the Straits.

7. TOWARDS ECO-DEVELOPMENT OF THE ASEAN ENVIRONMENT

7.1 The Manila declaration of environment of 1981

The dangers and threats of pollution of diverse kinds such as oil as well as sewage and industrial in the Straits of Malacca provide an example of the vulnerability of the marine environment of Southeast Asia, being at the CROSS-ROADS OF WORLD NAVIGATION. Besides, the marine environment of Southeast Asia also constitutes a marine basin of specific importance since it is surrounded by countries which are all moving towards industrialization.

This problem was clearly expressed during the first ASEAN Ministerial Meeting on Environment in Manila on April 30, 1981. The ASEAN Ministers of Environment also unanimously voiced their deep concern with the overall challenges of POVERTY and UNDERDEVELOPMENT besetting the people of the ASEAN countries. POVERTY in itself constitutes a major cause of ENVIRONMENTAL DEGRADATION.

To overcome poverty it is essential that the ASEAN countries continue and even accelerate their development processes. Unwisely planned and executed development will also endanger the environment. Considered basic to ASEAN's continued success is the principle that the stability and security of the ASEAN region are the responsibilities of the ASEAN States jointly and co-operatively. Regional security should be perceived in its broadest meaning and pertains to POLITICAL, ECONOMIC, and SOCIAL stability as well as to DEVELOPMENT within the region.

The protection and safeguarding of the common ASEAN ENVIRONMENT should likewise be a collective ASEAN responsibility. This is a responsibility of EACH NATION towards its own NATIONAL ENVIRONMENT and towards the environment of OTHER NATIONS. Ultimately, it is a responsibility towards the TOTAL GLOBAL ENVIRONMENT.

Each nation should therefore refrain from willfully undertaking actions and activities that are detrimental to its own environment or to the environment of other nations. Overly destructive and unsound ecological practices of resource exploitation should not be tolerated, even if such practices appear to be justifiable because of the need for employment creation and income-generation.

Not all countries have been able to enact measures to protect their environment. The exercise of such a sense of responsibility would be essential in preventing such anomalies as THE EXPORT OF POLLUTION and THE RAPE OF FOREST AND OCEANIC RESOURCES. The seriousness of poverty and its related problems have long been recognized and an understanding of the nexus between DEVELOPMENT and the ENVIRONMENT should further heighten the perception of the magnitude of those problems.

Based upon these considerations, the first ASEAN Ministerial Meeting on Environment solemnly declared the agreement to strengthen REGIONAL CO-OPERATION and COLLABORATION in the field of environment by adopting the following:

a. Objective:

To ensure the protection of the ASEAN ENVIRONMENT and the sustainability of its natural resources so that it can sustain continued development with the aim of eradicating poverty and attaining the highest possible quality of life for the people of the ASEAN countries.

b. Policy Guidelines:

(1) Foster a common awareness among the people of the ASEAN countries of the biological and physical resources and their vital significance for sustained development;

(2) Ensure, as far as practicable, that environmental considerations are taken into account in development efforts, both ongoing and future;

(3) Encourage the enactment and enforcement of environmental protection measures in the ASEAN countries; and

(4) Foster the development of environmental education programs.

By this declaration, the ASEAN First Ministerial Meeting on Environment has endorsed the implementation of the adopted ASEAN ENVIRONMENTAL PROGRAMME (ASEP) and recommended the establishment of an ASEAN COMMITTEE ON ENVIRONMENT in the context of the restructuring of ASEAN.

This political commitment of the ASEAN countries in the "MANILA DECLARATION - 1981" of adopting and realizing the existence of a common ASEAN ENVIRONMENT really heralds a turning point in history and the growth and development of the environmental awareness of mankind. Never before has any region in the world had the courage and progressiveness to proclaim the existence of a "REGIONAL ENVIRONMENT". The proclamation of the ASEAN Ministers on Environment on April 30, 1981 in Manila was indeed the first evidence in history.

7.2 Implementation of the Manila declaration for the control of transnational pollution

The "Manila Declaration of April 30, 1981 concerning the ASEAN Environment" really heralds a new phase in the development of awareness of the environment for the countries and people of ASEAN. Following this declaration, everyone in ASEAN should take the necessary initiative and endeavour to implement the content of this declaration in order for it to become a reality.

For the purpose of organizing and framing that implementation set-up, the declaration itself already provides the framework of thinking as stipulated in the Declaration's OBJECTIVE and POLICY GUIDELINES. Based thereupon, would it not be a proper basis and guideline for ASEAMS in inaugurating its ACTION PROGRAMME, after its Charter has been adopted at its first Assembly on February 6, 1989?

If this is the case, the idea of constituting a "PROGRAMME OF ACTION" for the ASEAN environment should be broadened and completed with the inclusion of the Programme on the Control and Abatement of TRANSNATIONAL POLLUTION in Southeast Asia, since it has not yet been taken-up in the diverse existing programmes. The inclusion of the latter is really very urgent for the purpose of protecting the ASEAN basin.

As already explained above, taking into consideration the present stage of industrialization of all the littoral states of the ASEAN basin (South China Sea), it will not be difficult to assume that the threat of TRANSNATIONAL POLLUTION in Southeast Asia will immediately become very pressing. A similar situation has been experienced in the United States on the Atlantic Coast about midway between New York and Washington, D.C. before the establishment of the well-known "Delaware River Basin Commission" as has been studied very intensively by Herbert A. Howlett in his presentation under the title of: "a basin agency and the joint exercise of sovereign powers" (1972). By studying the US P.L. 87-328 of September 1961, Howlett was able to submit an example of an ARRANGEMENT which has been created to implement policies on the Control and Abatement of Transfrontier Pollution within a basin.

A more advanced example is presented by the Agreement of Copenhagen of 1967 concerning the combat and control of pollution, including transfrontier pollution, of the marine environment bordered by Denmark, Finland, Norway and Sweden. And the most modern and sophisticated arrangement concerning the Control and Abatement of Pollution of the Sea, is perhaps the "BONN AGREEMENT OF 1969" for the protection and preservation of the North Sea. In 1972 the OECD organized a Seminar on "problems in transfrontier pollution" of which the result may serve as a reference for ASEAMS in framing its programme.

By submitting this idea of constituting an Action Programme for the Control and Abatement of Transnational Pollution within the ASEAN MARINE ENVIRONMENT, the hope may be expressed that the ASEAMS might be willing to respond immediately to this pressing need. By studying the existing examples from all over the world, ASEAMS will easily find the needed components to constitute its own model and design.

Moreover, after the conclusion of UNCLOS-III in 1982, the UN Convention on the Law of the Sea is already available which may provide the desirable guidelines and components. The legal principles and stipulations of the UN Convention on the Law of the Sea should be integrated with the Stockholm Declaration on the Human Environment of 1972 together with its 109 Recommendations and their implementation in several Conventions.

If the ASEAMS is willing to inaugurate its Action Programme with the launching of this "Arrangement of the Legal Regulation of Transnational Pollution within the ASEAN Marine Environment", it may give the desirable push to constitute the start of the "ASEAN PROGRAMME OF ACTION" starting from 1989 on to re-activate the ASEAN CONPLAN. By developing this "ASEAN PROGRAMME OF ACTION", a legal arrangement will be provided to support the further development of the Malacca Straits Contingency Plan, the APCMMP, and the Sulawesi Sea Oil Spill Network Action Plan which will be incorporated into the ASEAN CONPLAN.

8. CONCLUSION

In conclusion, the hope may be expressed that after the adoption of its Charter, ASEAMS may be willing to initiate its Programme of Action with the desirable endeavour to give real content to the ASEAN PROGRAMME OF ACTION by implementing the Manila Declaration of April 30, 1981 together with the launching of a campaign to develop a LEGAL ARRANGEMENT FOR TRANSNATIONAL POLLUTION.

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MARINE ENVIRONMENTAL LAW: PROPOSAL FOR A LEGAL FRAMEWORK FOR THE EAST ASIAN SEAS ACTION PLAN (EASAP)

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1. INTRODUCTION

Environmental law is defined as that set of legal rules addressed specifically to phenomena, whether natural or man-made, which potentially affect the quality of the environment. It consists of international and national laws relating to the protection and enhancement of the environment and encompasses both "hard law" (i.e., international treaties and national legislations) and "soft law" (i.e., guidelines, procedures, etc.). Its elements are derived from various subject areas, e.g., air, marine and inland water, soil, energy, living resources and others. It is a component of environmental protection which should be implemented by other functional tasks such as environmental impact assessment, development plans, conservation strategies and institutional and technical support.

Marine environmental law, therefore, encompasses laws and regulations that may be needed for pollution control, the offshore oil and gas industry, production of energy from the water, navigation, laying cables and pipelines, fishing, scientific research and customs control. Likewise included are sea regulations and traffic separation schemes which may be required to control the passage of oil tankers and ships carrying dangerous substances.

Despite the diversity of legal cultures and systems, the countries of the ASEAN sub-region have succeeded in introducing marine-related environmental legislation. Subjects range from assertion of sovereign rights over territorial waters, contiguous zones and exclusive economic zones, to licensing procedures for offshore drilling operations, to combating pollution from vessels and land-based sources. Some legislative measures are designed for planning purposes, e.g., laws on zoning and the imposition of building regulations on the acquisition of land as methods of controlling urban development in coastal areas. Some are designed to deal with critical situations in certain sections of the coast, particularly because of tourism. Laws to establish marine parks and sanctuaries or to prevent oil pollution are examples of this type. Still others are designed to satisfy financial and institutional arrangements, either requiring better co-ordination among existing administrative units or establishing a central co-ordinating body to ensure consistent implementation of decisions by all agencies concerned.

Be that as it may, rarely could the legislative response be considered as truly comprehensive. The latter means sufficient detailed regulations and standards with implementation and enforcement capabilities as well as adequate manpower, laboratory equipment and other facilities. The legislative measures so far taken specifically for the development of marine resources in particular remain scanty. Where such measures have been taken, they are largely single-purpose or piecemeal. A systematic approach has yet to emerge. In the countries where some form of resource planning or management exists, it is usually with reference to a narrow strip along the shoreline and coastal waters.

Furthermore, the ASEAN countries (except Singapore), being developing countries, have manifested reluctance to resort to regional conventions. This is quite evident where pollution is concerned. The latter has to compete for recognition against other, allegedly higher priorities. The reluctant states may be won over only after watering down proposed convention commitments to general, vague, or non-mandatory language, or after an assurance that memberships in a proposed organization will not become onerous. This explains the variation in the number of countries that have ratified or acceded to international conventions dealing with particular problems like pollution.

2. THE EAST ASIAN SEAS ACTION PLAN (EASAP)

The Regional Seas Programme was initiated by the United Nations Environment Programme (UNEP) in 1974. Since then, the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

A similar strategy was adopted by UNEP for each region aimed at tackling the causes as well as the consequences of environmental damage in coastal areas. This strategy encompasses: (1) an Action Plan setting out activities for scientific research and co-operation, including assessment and management; (2) a legally binding Convention embodying general commitments; (3) technical and specific Protocols to deal with individual issues such as dumping, co-operation in pollution emergencies, land-based pollution sources, and conservation; and (4) financial and institutional arrangements that provide the back-up for the other three components.

Work on the East Asian Seas Action Plan (EASAP) has an exceptionally long preparatory phase. Scientific meetings began as early as 1976 but the Action Plan was not adopted until five years later in order to incorporate the results of several initial pilot projects, e.g., research into the dangers to tropical and sub-tropical marine species from chemicals used to disperse oil, the impact of pollution on mangrove life, and a study of land-based pollution sources.

The main components of the East Asian Seas Action Plan are environmental assessment, environmental management, co-ordinating means in lieu of a legal component, and the institutional financial arrangements.

Priority projects for the first phase of the Action Plan, approved in Manila in April 1981, cover basic oceanography, control of coastal pollution, protection of mangroves and coral reefs, and waste management.

While the programme is sub-regional in extent involving only the five original Association of Southeast Asian Nations (ASEAN) member countries (Brunei Darussalam's participation is in an observer capacity), the ASEAN countries explicitly state that this is "without prejudice to its future extension to all coastal states in the East Asian Seas". The EASAP could then act as the core for a wider programme.

A new long-term (ten-year) strategy for EASAP was adopted in 1987 designed to guide activities until the year 1996. This was approved at the sixth meeting of the Co-ordinating Body for the Seas of East Asia (COBSEA) based on UNEP's evaluation of the development and achievements of EASAP over the last ten years, and the recommendations of the first meeting of experts on the EASAP. Among others, the new strategy focuses on the following:

(1) The most important issues requiring solution by regional co-operation will be the focus of future Action Plan projects. The Plan will thus concentrate on activities to control pollution from petroleum hydrocarbons and from the disposal of urban, industrial and agricultural wastes, all of which have been identified by governments as primary threats to the marine and coastal environment of the region;

(2) A regionally applicable methodology for the assessment of environmental risk from major pollutants and suitable environmental impact assessment procedures will be developed;

(3) A region-wide monitoring system will be launched to provide continuous and comparable information on levels and trends of marine pollution. This will also serve as an early warning system for changes which may require national or regional action;

(4) Management plans for the protection, rehabilitation and utilization of endangered coastal and marine living resources such as mangroves, coral reefs and seagrass beds will be formulated and applied;

(5) In order to intensify the involvement of regional experts and to benefit from their independent technical advice in the implementation of the Plan, a non-governmental organizational network should be set-up through which scientists in the region can contribute to the Action Plan;

(6) A data management system will be established and operated as part of the Action Plan;

(7) Each of the Action Plan's member states will establish a national co-ordinating mechanism under the chairmanship of their respective national focal point to ensure the timely and effective implementation of projects;

(8) UNEP will continue to function as the Action Plan's secretariat and be responsible for the overall technical co-ordination of project activities and the management of the East Asian Seas Fund; and

(9) The feasibility of adopting a regional convention and protocols to provide the legal framework for the Action Plan is to be explored at the seventh COBSEA meeting.

3. THE NEED FOR A LEGAL COMPONENT FOR THE EASAP

The report of the meeting of experts to review the draft action plan for the East Asian Seas (Baguio, 17-21 June 1980) reads in part:

> "50. The meeting agreed that it was appropriate to include among the objectives of the action plan the development of a regional Convention for the protection of the marine environment and related protocols. However, it was not considered feasible to adopt a regional legal agreement concurrently with the action plan. Rather, it was recommended that the action plan should be adopted formally by Governments as soon as practicable and that the negotiation of a regional convention be considered after further consideration at the expert level".

As mentioned above, the 1986 meeting of experts on the EASAP analyzed the preliminary findings of an evaluation exercise on the results of the EASAP since its inception and made recommendations for a future long-term strategy. After revising UNEP's draft in-depth evaluation of all activities carried out since the Action Pl was launched, the meeting recommended that future Action Plan activities should be strengthened and made more efficient through the adoption of a regional convention and related protocols, thereby providing the necessary legal framework and reaffirming the member countries' political commitment to the Plan's goals.

Effective legislation is vital in other to ensure success of the various projects under the Action Plan. Primarily, the legal component of the Action Plan calls for a review of existing legislation and, when necessary, the overhaul, updating and strengthening of current procedures.

A legislative formula used successfully in other UNEP Regional Seas Programmes is a sort of "umbrella" regional convention supported by specific protocols which elaborate standards of management and control for environmental protection. Depending on the current economic, social and political climate of participating governments, this formula will allow them to immediately accept a general obligation to co-operate in the protection of the marine and coastal resources through the Convention while letting them assume more specific commitments successively by means of the Protocols. In short, the "umbrella" regional convention, elaborated by specific technical protocols, provides a legal framework for co-operative regional and national actions. The legal commitment of Governments clearly expresses their political will to manage individually and jointly their common environmental problems.

Legal agreements are negotiated to strengthen co-operation among States in managing the identified problems. They also provide an important vehicle for national policy-makers to implement national control activities. Management activities aimed at controlling existing environmental problems and preventing the development of new ones are one of the means by which States fulfill their treaty obligations. Co-ordinated assessment activities then continue to assist Governments by providing scientific information by which to judge whether the legal agreements and management policies are effective.

The success of an Action Plan rests precariously on collaborative and interdependent efforts in each sector, i.e., environmental assessment, environmental management, legislation, institutional and financial arrangements. The large cast of legal agreements, management and assessment activities, and co-operative alliances among States all share the same fate - each intimately linked to the overall effectiveness of the programme.

Thus, adoption of a complete Action Plan will build a sturdy framework within which to promote new patterns of development, patterns that are not only sensitive to the natural quality of the region but to the needs of the indigenous governments and peoples.

The area encompassed by the East Asian Seas is probably one of the most complicated regional seas in the world. The ASEAN sub-region has one of the largest fractions of the world's population and represents a great diversity in terms of geography, population, races and environment. The political and economic atmosphere of each state likewise varies. As a consequence, the problems relating to the protection of the marine environment wherein international co-operation is indispensable have not received adequate total attention. An example would be the wastes of one country easily affecting the coastal waters of another inasmuch as winds and water currents recognize no national boundaries.

It is a fact that political and economic reasons are major obstacles to the conclusion of a sub-regional legal agreement on the marine environment. However, lessons could be learned from the experience of the Mediterranean Sea. The Mediterranean consists of industrialized and developing countries, Israel and the Arab countries. It has been a scene of conflict and remains so. However, these difficulties were overcome by efforts for comprehensive protection of the marine environment.

At the Conference of Plenipotentiaries of the Mediterranean Sea held in Barcelona on 2-16 February 1976, the Mediterranean countries adopted the following three treaties: Convention for the Protection of the Mediterranean Sea against Pollution, Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, and Protocol concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency. The texts were drawn upon such precedents as the 1972 Oslo and London Conventions for the Prevention of Marine Pollution by Dumping from Ships and Aircraft, the 1973 IMCO Convention for the Prevention of Pollution from Ships, the 1974 Convention of the Protection of the Baltic Sea Area, and the guidelines for the Mediterranean Sea developed by the FAO consultations in 1974. The framework convention for the Mediterranean Sea, therefore, is the legal "umbrella" providing a general obligation to protect it from all sources of pollution. The protocols provide more specific obligations to control pollution from particular types of sources.

4. CONCLUSION

As could have been gleaned from the above, existing international conventions do not constitute a comprehensive approach to the preservation of the marine environment. They deal with only a few aspects of the marine pollution problem and in a piecemeal manner. The existing legal order must be reformulated on the basis of environmental consideration, the limits of national jurisdiction notwithstanding. To attain that end, the preservation of the marine environment must be considered in the global perspective. Since the nature of environmental problems differ considerably among regions, a special effort is needed at the regional levels.

Insofar as the Law of the Sea is concerned, its role in the development of marine environmental law is restricted to the formulation of an "umbrella" treaty which means the enunciation of general principles. In order to meet different regional conditions, regional agreements are required. Steps towards this direction have already been made. Out of the ten regional seas programmes (Wider Caribbean, South-East Pacific, West and Central Africa, Mediterranean, Red Sea and Gulf of Aden, Kuwait Action Plan, Eastern Africa, South Asian Seas, East Asian Seas, South Pacific), only two (South Asian Seas and East Asian Seas) are without a regional convention. As aptly stated by the Executive Director of UNEP, "together these regional arrangements can form bands of environmental protection woven into the fabric of a new world order in the oceans".

In terms of economic, social, health and cultural values, the marine environment of the East Asian Seas and all the living organisms it supports are of utmost importance to the people of ASEAN. The latter have an interest in ensuring that this environment is managed in such a way that its natural quality and resources are conserved. If only for this reason, there is an urgent need to reach agreement on a convention for the protection of the marine environment and natural resources of the East Asian Seas.

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