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

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ABSTRACT

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

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

Introduction

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

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

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

The objectives of this study were :

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

Materials and Methods

Phytoplankton Sampling Survey, Cell Count and Identification

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

Species Diversity Indices

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

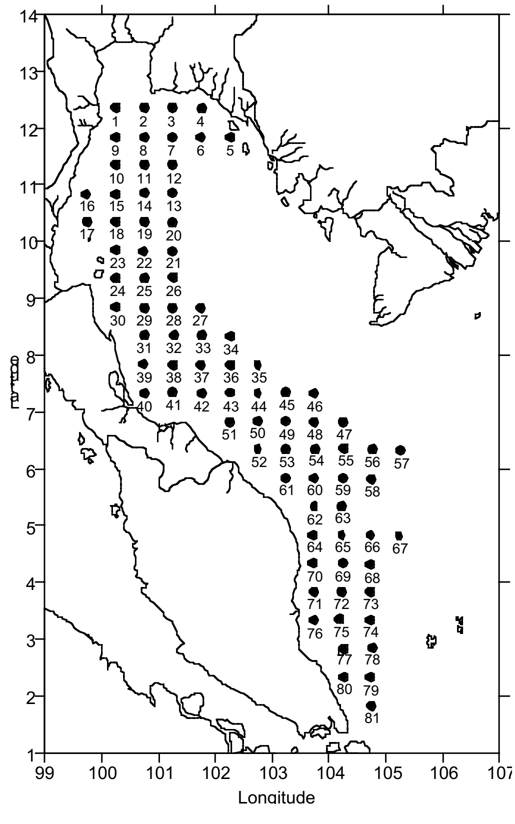

Fig. 1. Area and station of collaborative research survey in the Gulf of Thailand and east coast of Peninsular Malaysia.

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

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

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

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

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

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

Results

Identification

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

Abundance and distribution

Pre-monsoon season

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

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

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

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

Post-monsoon season

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

Table 1. The taxonomic list of phytoplankton identified :

Phylum Cyanophyceae (Blue green algae)

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

Phylum Bacillariophyceae (Diatom)

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

Table 1. (cont.)

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

Phylum Dinophyceae (Dinoflagellate)

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

Table 1. (cont.)

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

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

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

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

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

Occurrence of dominant species

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

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

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

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

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

Species diversity indices

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

Discussion and Conclusions

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

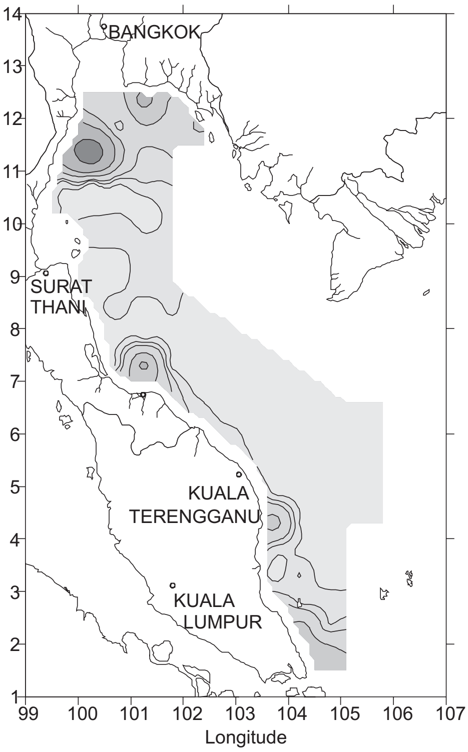

Fig. 2. Total phytoplankton in pre-NE monsoon season in the Gulf of Thailand and eastcoast of Peninsular Malaysia

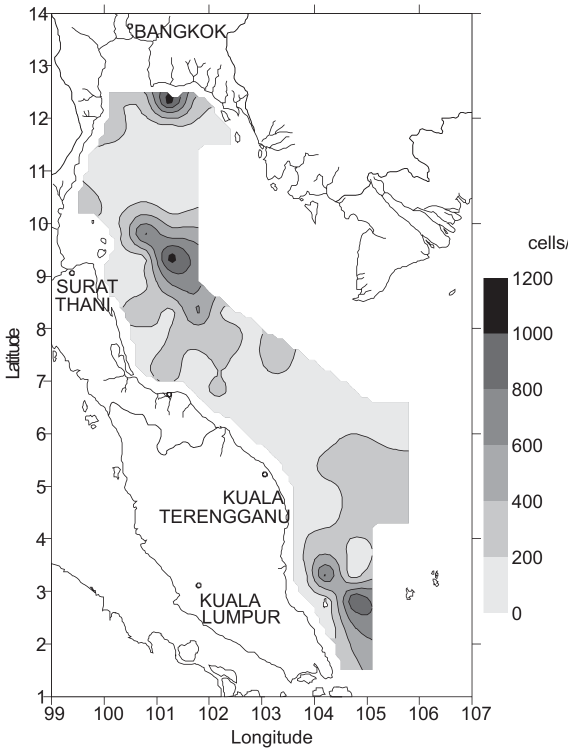

Fig. 3. Distribution of blue green algae in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

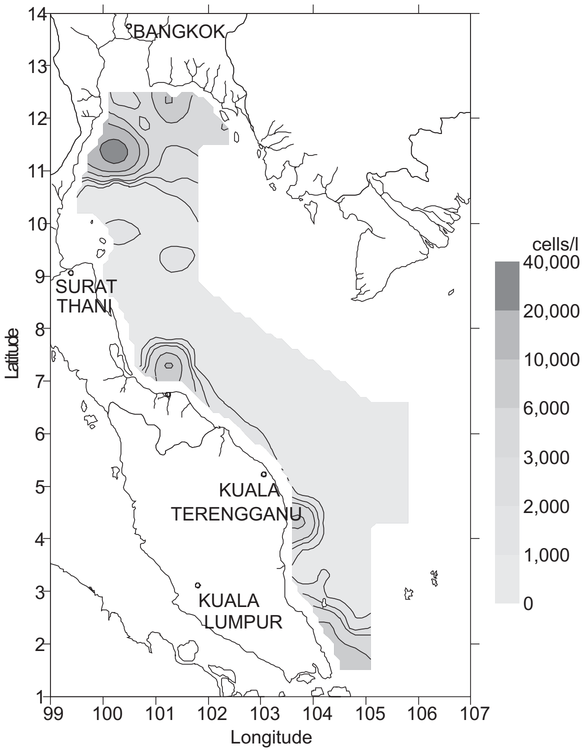

Fig. 4. Distribution of diatom in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

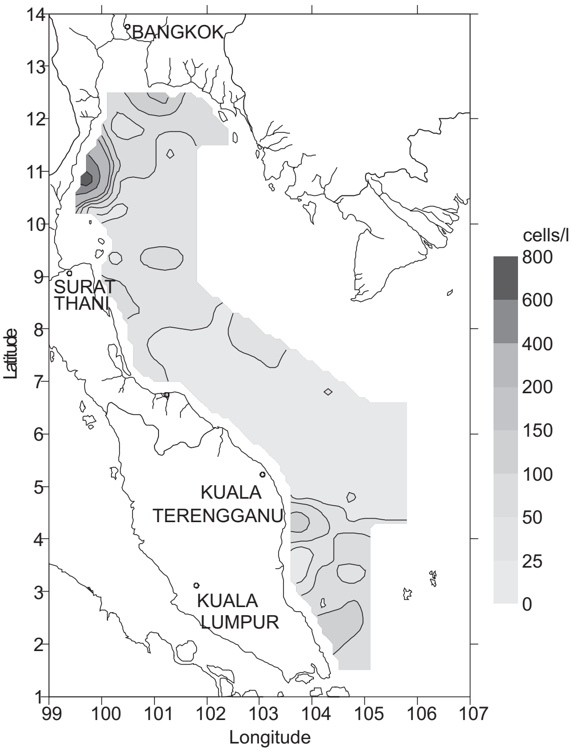

Fig. 5. Distribution of dinoflagellate in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

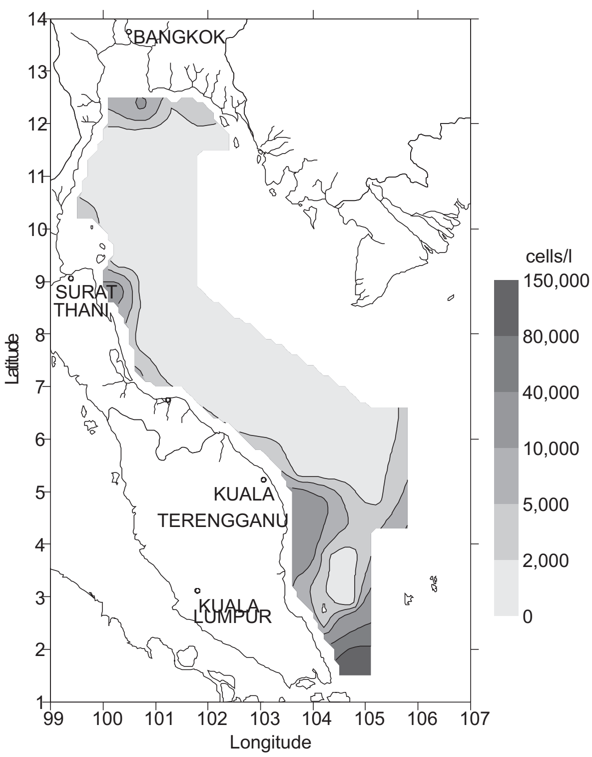

Fig. 6. Total phytoplankton in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

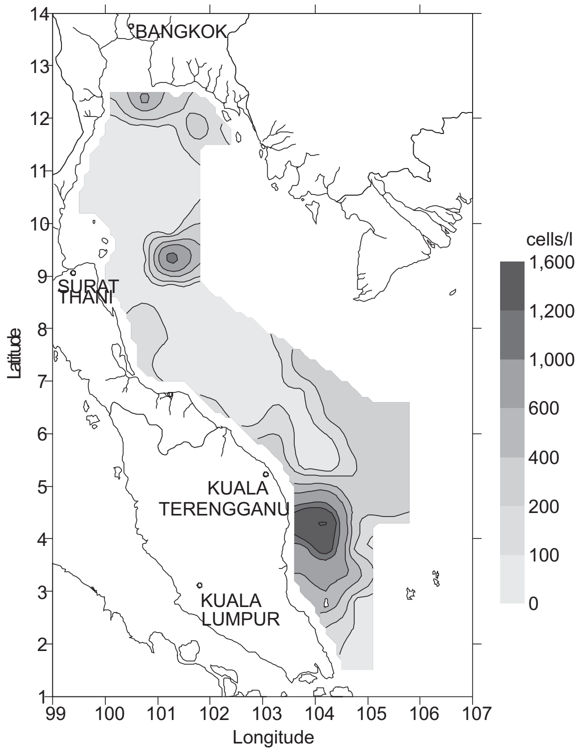

Fig. 7. Distribution of blue green algae in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

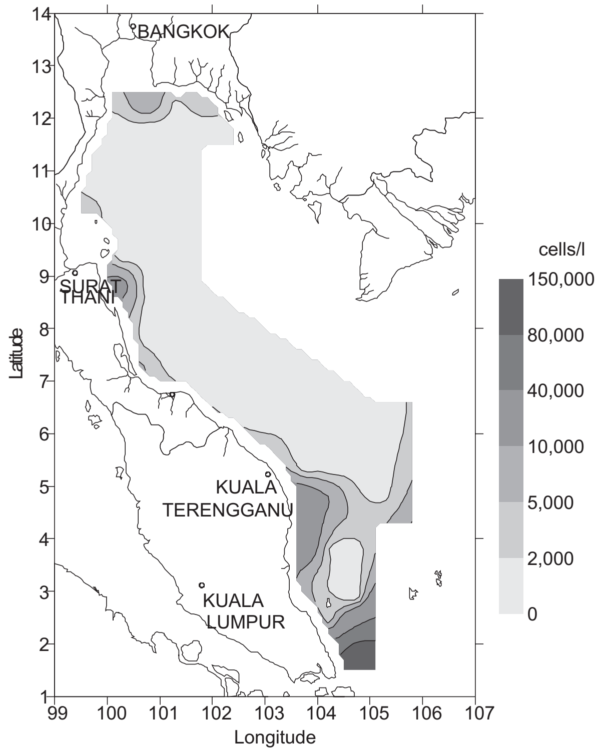

Fig. 8. Distribution of diatom in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

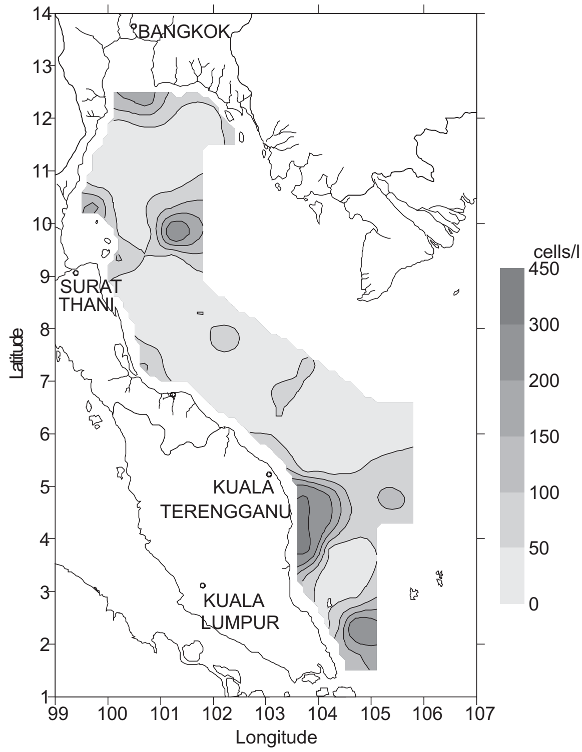

Fig. 9. Distribution of dinoflagellate in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia

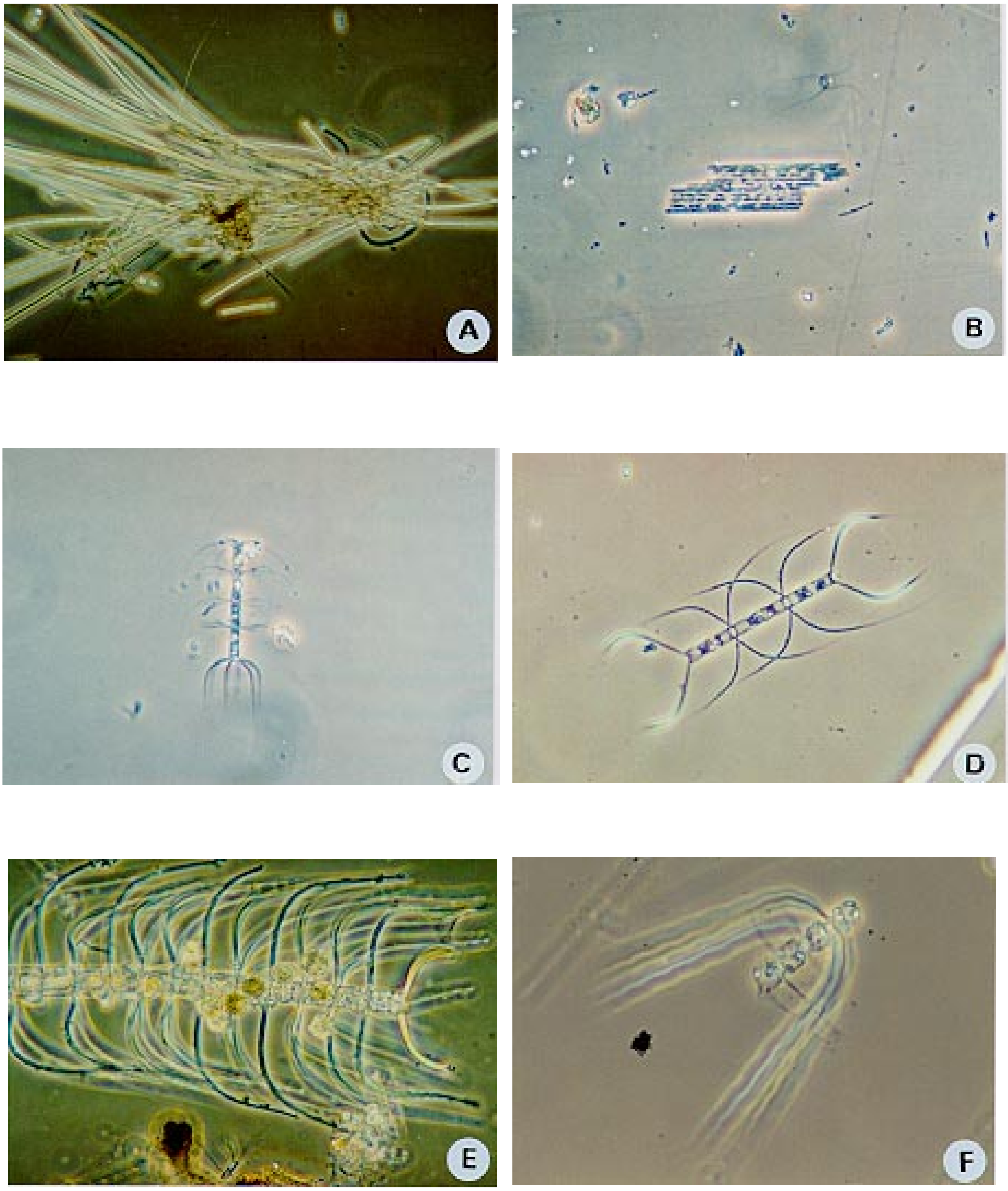

Fig. 10. Dominant phytoplankton species
(A) *Oscillatoria* (*Trichodesmium*) *erythraea*,
(B) *Bacillaria paxillifera* (O.F. Muller) Hendey
(C) *Bacterisatrum comosum* Pavillard
(D) *Chaetoceros affinis* Lauder (Ehrenberg) Kutzing
(E) *C. coarctatus* Lauder
(F) *C. compressus* Lauder

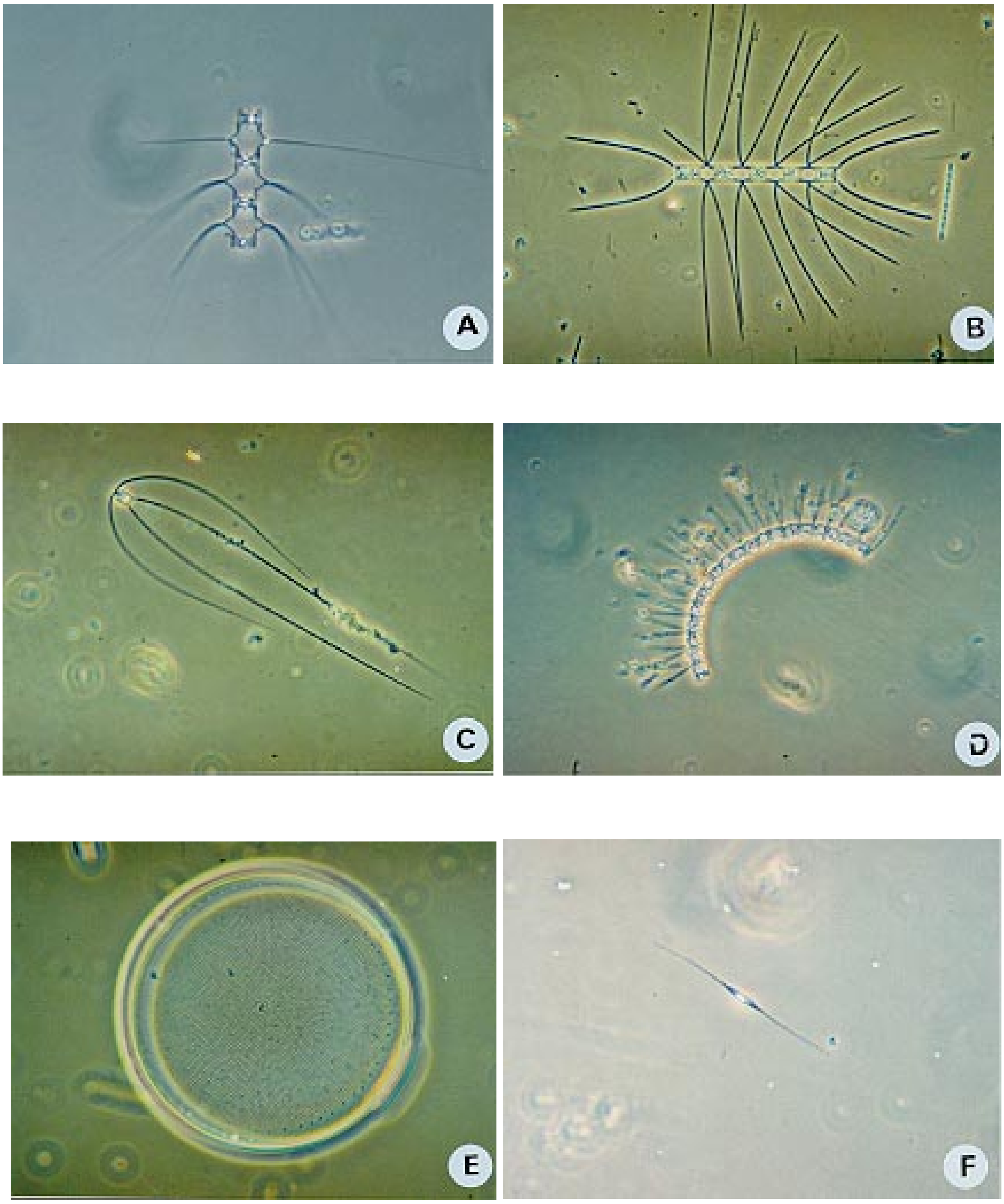

Fig. 11. Dominant phytoplankton species.
(A) *Chaetoceros didymus* Ehrenberg
(B) *C. lorenzianus* Grunow
(C) *C. peruvianus* Brightwell
(D) *C. pseudocurvisetus* Mangin
(E) *Cosinodiscus jonesianus* (Gaeville) Ostenfeld
(F) *Cylindrotheca closterium* (Ehrenberg) Reimann & Lewin

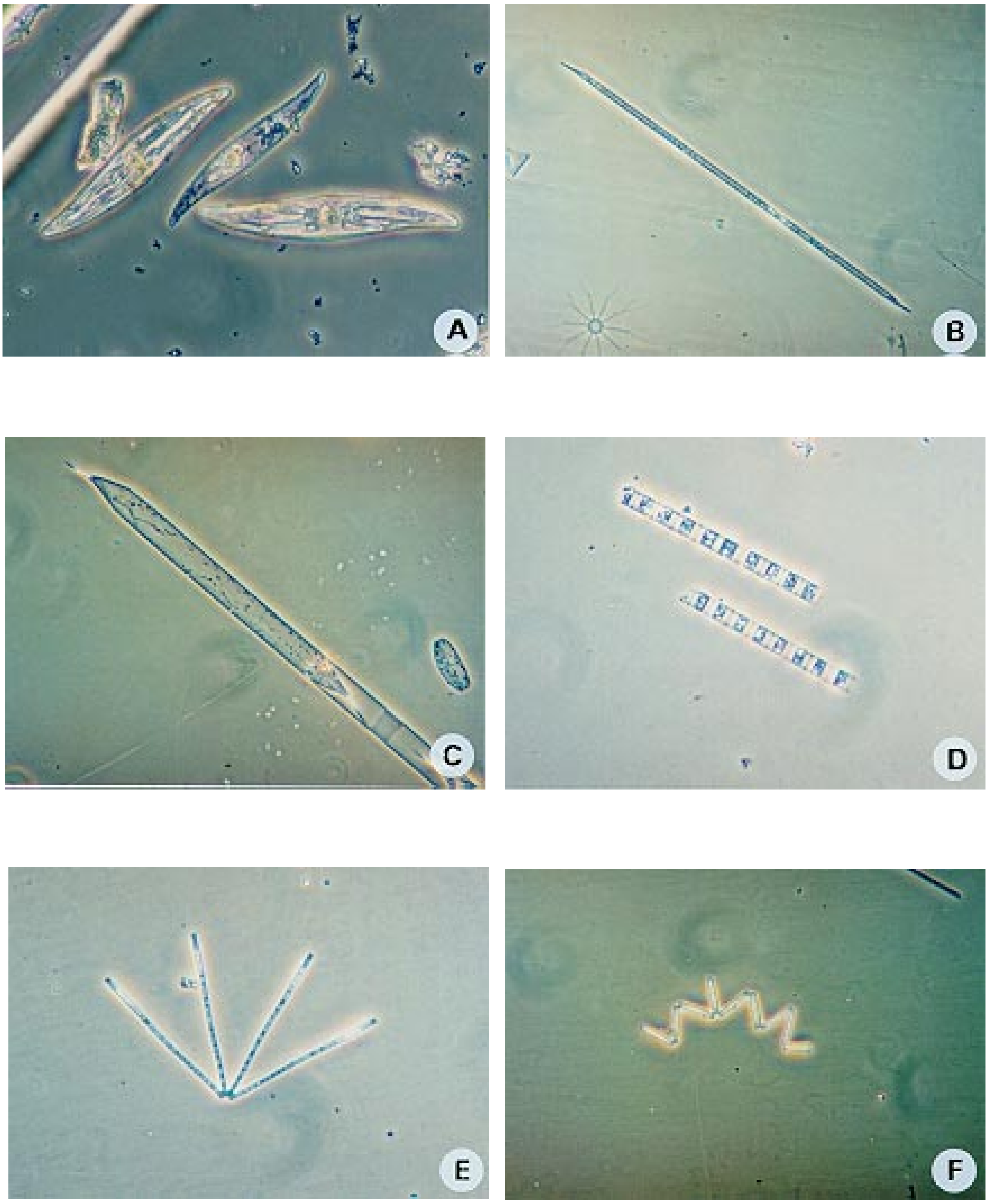

Fig. 12. Dominant phytoplankton species.
(A) *Pleurosigma* sp.
(B) *Proboscia alata* (Brightwell) Sundstrom
(C) *Pseudosolenia calcar-avis* (Schultz) Sundstrom
(D) *Skeletonema costatum* (Greville) Cleve
(E) *Thalassionema fruenfeldii* (Grunow) Hallegraeff
(F) *T. nitzschioides* (Grunow)Mereschkowsky

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

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

Table 2. (cont.)

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

Table 2. (cont.)

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

Table 2. (cont.)

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

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

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

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

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

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

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

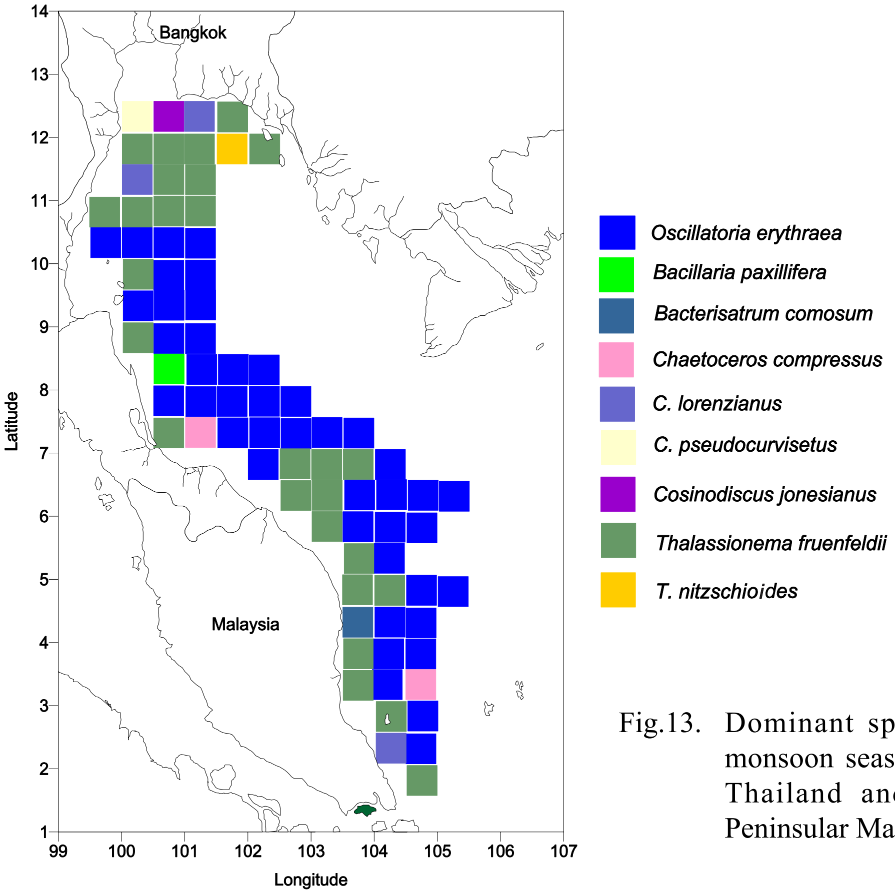

Fig.13. Dominant species in pre-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia.

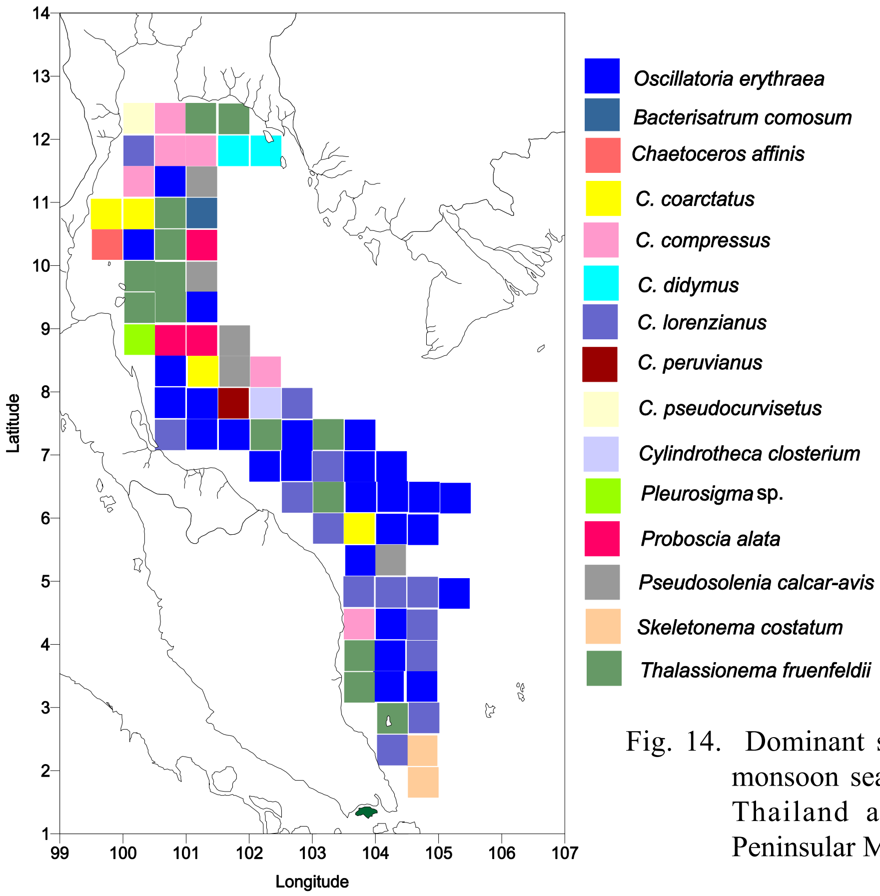

Fig. 14. Dominant species in post-NE monsoon season in the Gulf of Thailand and east coast of Peninsular Malaysia.

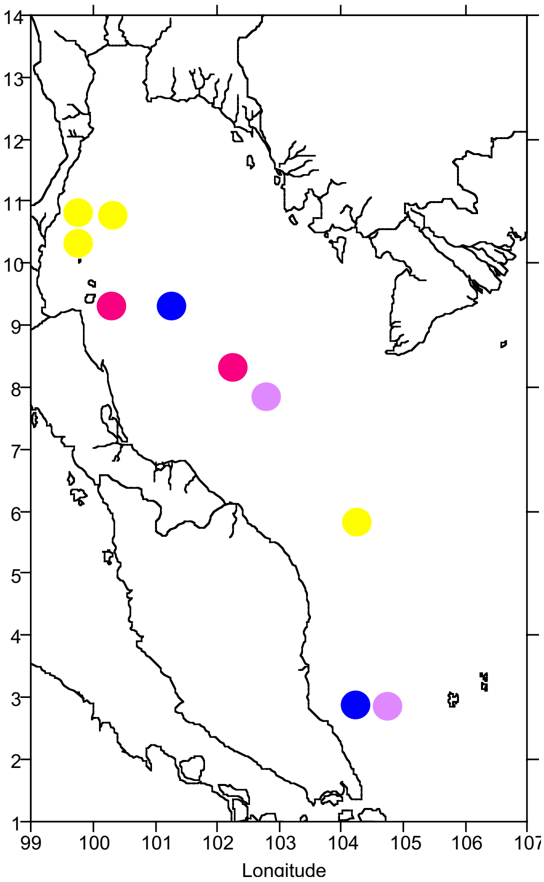

Fig. 15. Occurence of *Alexandrium* in pre-NE monsoon season (1-17 cells/l).

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

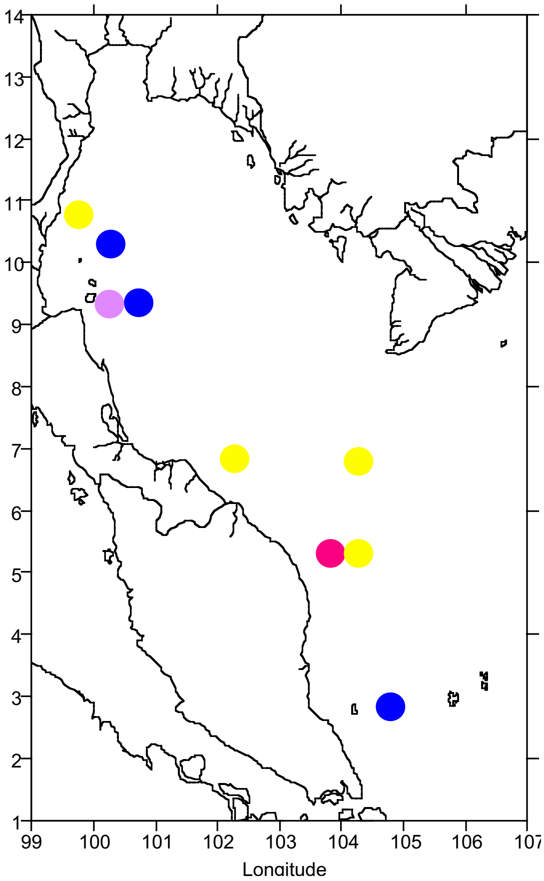

Fig. 16. Occurrence of *Alexandrium* in post-NE monsoon season (1-8 cells/l).

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

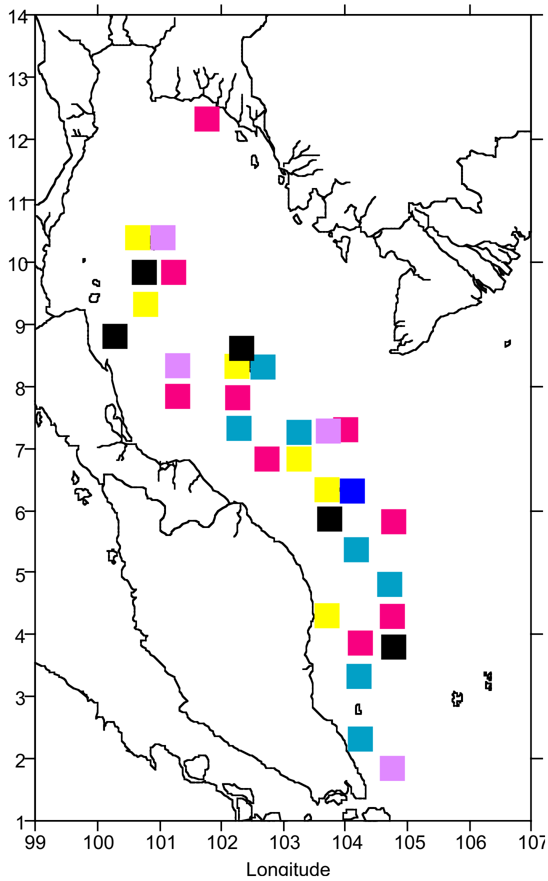

Fig.17. Occurrence of *Gonyaulax* and *Lingulodinium* in pre-NE monsoon season (1-13 cells/l).

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

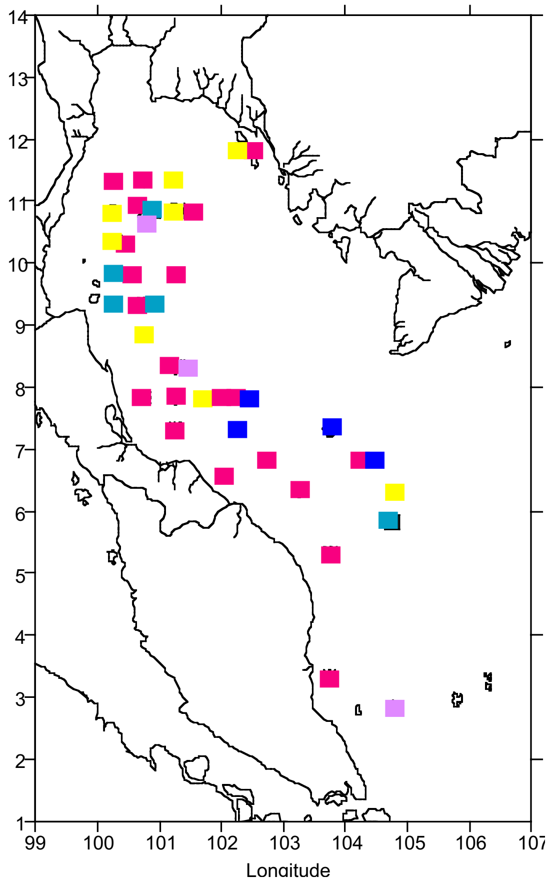

Fig. 18. Occurrence of *Gonyaulax* and *Lingulodinium* in post-monssoon season (1-13 cells/l).

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

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

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

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

Table 3. (cont.)

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

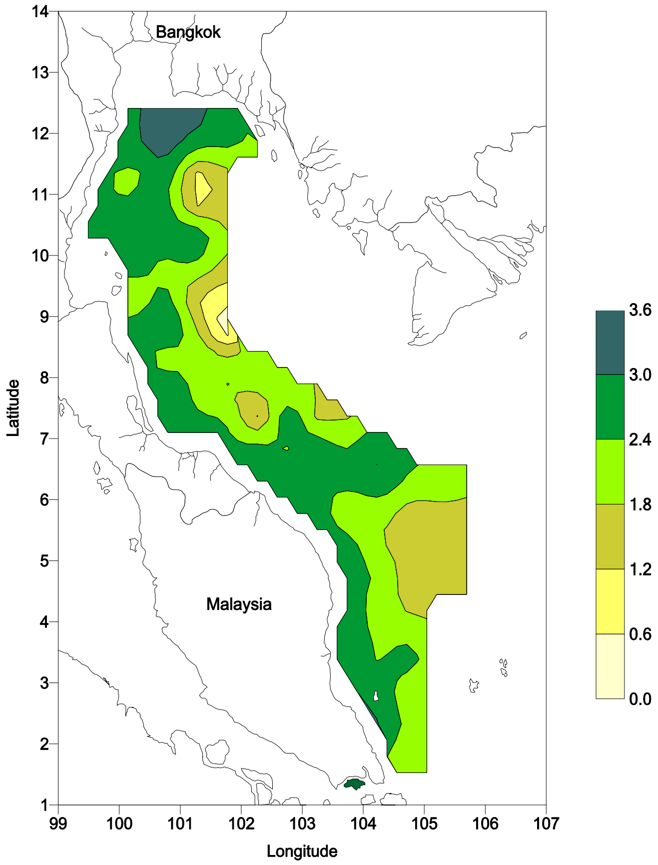

Fig. 19. Diversity indices of phytoplankton in pre-NE monsoon season.

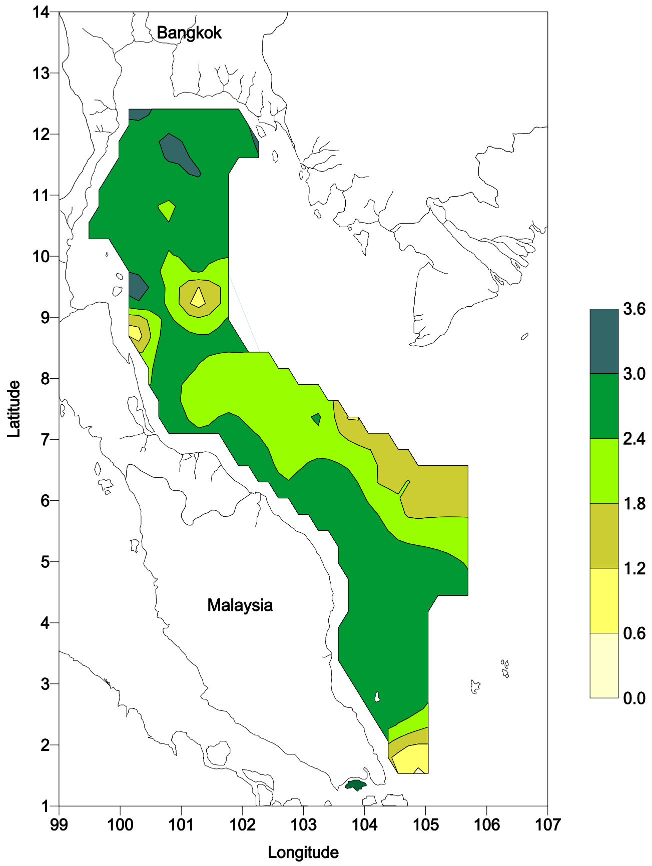

Fig. 20. Diversity indices of phytoplankton in post-NE monsoon season.

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

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

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

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

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

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