Southeast Asian Fisheries Development Center

Nanoplankton Distribution and Abundance in the South China Sea, Area III: Waters of Western

Lokman Shamsudin and Kartini Mohamad

Faculty of Applied Science & Technology, Universiti Putra Malaysia Terengganu
Mengabang Telipot, 21030 Kuala Terengganu, MALAYSIA

ABSTRACT

A collaborative cruise in the South China Sea in the waters of the South China Sea off the Western Philippines was conducted in the post-monsoon (April and May, 1998) periods on board MV SEAFDEC. The nanoplankton (including the smaller microplanktonic species) from 31 sampling stations consisted of more than 200 taxa comprising predominantly of nanodiatom (>150 species), Prymnesiophyta (>48 species), Dinoflagellata (>30 species) and Prasinophyta (>18 species). Among the minute plankton collected, three species of nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous Prymnesiophyta species were present. The dominant pennate diatom comprised of *Synedra parasitica, Fragilaria brevistriate, Diploneis crabro* and *Neodenticula* sp., all of which were <20µm in size. The central diatom comprised of *Cyclotella striata, C. meneghiniana* and *Stephenopyxis palmeriana*. The genera of *Synedra, Navicula, Fragilaria* and *Thalassiosira* contained a wide range of species; however, majority of these species were new records and have not been taxonomically identified. The dominant Prymnesiophyta species (mostly small flagellate cells) comprised genera of *Distephanus, Thalassomonas, Coccolithus, Protosphaera* and *Cryptochrysis*; while those of dinoflagellate consisted of a wide range of species of genera *Gyrodinium, Pyrodinium, Gonyaulax, Scrippsiella, Protoperidinium*, *Protoceratium, Ceratocorys* and *Alexandrium*. The genera of *Protoperidinium, Coccolithus, Minidiscus* and *Thalassiossira* had a wide range of species. The class Heptophyceae comprising of the three families namely; Prymnesiaceae (*Chrysochromulina* sp.), Coccolithaceae (*Oolithotus fragilis, Coccolithus pelagicus*) and Gephyrocapsaceae (*Emiliania huxlegi, Gephyrocapysa oceanica*) had high cell densities (ranging from 1 x 10^5 L^{-1} – 5 x 10^5 L^{-1}) especially in the nearshore waters. The total nanoplankton population (ranging from 3.1 x 10^5 to 2.47 x 10^5 L^{-1}) was dense in nearshore regions (especially around Subic and Manila bays) and tend to spread out in concentric semicircle into the open sea. The presence of the dinoflagellate species of *Protoperidinium* and *Alexandrium* were detected in considerable amounts at nearshore and midshore Philippines waters of the South China Sea. Blooms of *Pyrodinim bahamense* and *Protoperidinium* sp. (to a limited extend) occurred during the study period.

Key words : algae, dinoflagellate, nanoplankton, Philippines, South China Sea

Introduction

It is well know fact that nanoplankton study has not been emphasized and given priority due its minute size and difficulty in identifying; however, this should not lead to its neglect since in many waters it is responsible for more than 50% biomass carbon fixation and production in the ocean than the more immediate obvious microplankton whose size is much bigger.

Only a few studies of plankton (especially the minute nanoplankton) and other related parameters were carried out in the Malaysian waters in the South China Sea. Studies by Chua and Chong (1973) in the Malacca Straits showed that the distribution and abundance of pelagic species especially the small tuna (*Euthynus affinis*), chub mackerel (*Rastrelliger* sp.) and anchovies (*Stolephorus* sp.) were related to the density of phytoplankton. Qualitative studies of microplankton (20-200 μm in size) in the Malaysian coastal waters, especially the Malacca Straits have been conducted by Sewell (1933), Wickstead (1961) and Pathansali (1968). Primary productivity in the same location had been carried out by Doty *et al.* (1963); however, a detailed study of the species community structure, distribution and abundance of plankton in such waters had been lacking. Studies by Shamsudin *et al.* (1987) in the South China Sea around the coasts of Johore, Terengganu and Kelantan found that majority of the phytoplankton found were diatoms which comprise of numerous species of *Bacteriastrum, Chaetoceros, Rhizosolenia* and *Pleurosigma*. The blue green, *Trichodesmium erythraeum* was found in abundance in tropical waters (Chua & Chong, 1973). Studied on plankton (Chua & Chong, 1973; Shamsudin, 1987; Shamsudin & Baker, 1987; Shamsudin *et al.*, 1987; Semina, 1967; Markina, 1972) had raised questions about the qualitative and quantitative seasonal availability of these organisms as sources of food for those organisms higher up in the food chain and the relative production of these organisms in various study sectors of the South China Sea.

In the present study, the nanoplankton (including the lower size range of the microplankton having <50 μm) community structure has been analysed during the post-monsoon study period (April/May 1998) in the western Philippines waters of the South China Sea. The species communtiy structure patterns, distribution, composition and species abundance at various study sectors of the South China Sea were analysed.

Method

Study Area

The study area cover an area which extends from the northern tip of Philippines (19° 59.2' N; 119° 58.7' E) to the south near the Palawan island (11° 13.5' N; 118° 3.1' E) of the South China Sea. The estimated study area is ca 6000 nautical square miles covering the economic exclusive zone (EEZ) of Philippines sea of the South China Sea. The sea cruise track followed a zig-zag manner starting from the northern coastal Philippines waters and ended up at the southern end of Philippines waters covering a total of 31 sampling stations.

Sampling Method & Preparation

The research survey was carried out during the cruise survey in April/May 1998 covering thirty one stations. Water sampler (twin 10 L sampler, Jitts 1964) was used to collect water sample from the depth of the Maximum Chlorophyll Layer (MCL). The MCL was predetermined during the hydro-acoustic survey which is carried out simultaneously. The water sampel (5*l*) was first filtered through a 40 μm mesh-size filtering net; it was again subsequently filtered through a membrane filter paper (0.8 μm mesh-size) with square grid marks on its surface. The samples which had been fixed and preserved in 3% glutaraldehyde buffered with 0.01 M phosphate (pH = 7.8), were then mounted on (SEM) stubs with double-sided cellotape. The stubs with adhering samples were then coated with an alloy (gold with pelladium) before being observed under the scanning electron microscope (Barber & Haworth, 1981; Hallegraeff, 1984). For each stub, only 5 square grids (one grid having 20 fields of observation; one field measures 32.5 x 25 μm area) were considered whereby the organisms found on the grid were countered. The subsamples or subportions of original sample were preserved in 10% formaline and subsequently examined for species composition and abundance using an inverted microscope (Vollenweider *et al.*, 1974; Tippett, 1970; Shamsudin, 1987, 1993, 1994, 1995; Shamsudin & Shazili, 1991;

Shamsudin & Sleigh, 1993, 1995; Shamsudin *et al.*, 1987, 1997). Algal were identified with reference to Okada & McIntyre (1977), Gaardner & Heindel (1977) and Heimdal & Gaarder (1980, 1981).

An index of the composition of the plankton community in the aquatic habitat is given by calculating the diversity index (H) and evenness (J) of the community structure using the Shannon-Weiner index(1949). The formula for calculating Shannon-Weiner (diversity) index (H) is:

$$\mathbf{H = -\sum P_i \log_2 P_i}, \quad \text{where } P_i = n_i/N$$

n_i = The number of individuals of the i th species

N = The total number of individuals

The diversity index can measure species richness (H) and species evenness (J)

$J = H/\log_2 S$; where S is the number of species

Statistical Analysis

One way analysis of variance can be employed when comparisons are made between a number of independent random samples, one sample from each population. All counts must be classified in the same manner, but the number of counts in the various samples can be different (Elliott, 1977). Analysis of variance can be used to assess the relative importance of different sources of variation, e.g. between sites, between dates, etc., but it may be necessary to transform the data before analysis of variance tests are applied.

Coefficients of similarity are simple measures of the extent to which two habitats have species (or individuals) in common (Southwood, 1978). Essentially, such coefficient can be of two types, as given below, and both types reflect the similarity in individuals between the habitats.

(i) Jaccard $\mathbf{Cj = j / (a + b - j)}$

(ii) Sorensen $\mathbf{Cs = 2j / (a+b)}$

where a, b are the total individuals sampled in habitat a and b respectively, and j is the sum of the lesser values for the species common to both habitats (Southwood, 1978). In habitats where one or few species have high dominance the coefficients under-estimate the contributions of the moderately common species which may be more stable indicators of the characteristic fauna of an area while the rare species have little impacts (Southwood, 1978). It is apparent that Cs is greater than Cj and the inequality reduces as j approaches the magnitude of 1/2 (a+b). Subsequenthy the microplankton can be classified into species assemblages or associations in cluster analysis on species sampled from the nearshore and offshore stations according to their preference on environmental conditions using the Unweighted Pair Group Average (UPGA) Pearson Correlation Iindex (Pielou, 1984; Ludwig & Reyholds, 1988). The basic principle of UPGA is derived from comparing the coefficient of similarity between pairs of habitats in the community of various sampling stations under study.

Results

The nanoplankton (including the smaller microplanktonic species with the size range of 5 - 50 µm) from 31 sampling stations comprising of more than 200 taxa consisting predominantly of nanodiatom (>150 species), Prymnesiophyta (>48 species), Dinoflagellata (>30 species), Cryptophyta (>20 species) and Prasinophyta (>18 species) was collected from the Philippines waters of the South China Sea. Among the minute plankton collected were three species of nanodiatom (*Minidiscus comicus, M. chilensis, M. trioculatus*) and numerous Prymnesiophyta species (Table 1).

Dominant Nanoplankton Species Encountered

The three nanodiatom species of *Minidiscus* were centrale diatom while the other forms consisted of the genera *Navicula, Thalassiosira, Fragilaria, Diploneis, Synedra, Cyclotella, Stephosnopyxis, Pseudo-nitzschia* and *Chaetoceros* including those belonging to the minute species whose size range were between 5-50µm (Table 1). Some of the know *Navicula* species consisted of *Navicula grevileana, N. schonkenii, N. fucicola* and *N. pseudanglica* var. *signata;* while the *Thalassiosira* species comprised of *Thalassiosira tenera, T. climatosphaera, T. oestrupii* var. *ventrickae* and *T. pacifica*. Among the nanodiatom, 10 genera were new records in the Philippines waters during the study period.

The dinoflagellate consisted of a wide range of species of *Gyrodinium, Pyrodinium, Gonyaulax, Scrippsiella, Protoperidinium, Protoceratium, Ceratocorys, Oxytoxum* and *Alexandrium*; many of which were in the cyst forms found especially in the coastal waters (especially Subic Bay). The coastal and intermediate Philippines waters contained significantly higher cell concentrations of *Protoperidinium* sp. and *Pyrodinium bahamense*; these species have the potential to form blooms or red tides. The presence of the dinoflagellate species of *Ceratium, Protoperidinium* and *Alexandrium* were detected in considerable amounts at coastal and intermediate Philippines waters of the South China Sea.

Emiliania huxlegi and *Oolithotus fragilis* were found in considerable concentrations with values of 1.2 x 10^5 and 1.1 x 10^5 L^{-1} respectively. *Coccolithus pelagicus* and *Chrysochromulina* sp. were present in smaller quantities (<0.24 x 10^4 L^{-1}) (Table 2). Related genera belonging to Haptophyceae comprising of Prymnesiaceae (*Chrysochromularia* sp.); Coccolithceae (*Coccolithus pelagicus, Oolithotus fragidis*); Gephyrocapsaceae (*Gephyrocapsa oceanica*); Rhabdophaeraceae (*Discosphaera tubifira*); Helicosphaeraceae (*Helisosphaera carteri, H. pavimentum*), Rhabdosphaeraceae (*Acanthoica quattrospina, Discosphaera tubifera, Rhabdosphaera claviger*); Syracosphaeraceae (*Coneosphaera molischii, Syracosphaera pulichra, Umbellosphaera irregularis, U. tenuis*) and Halopappaceae (*Florisphaera profunda, Haloppapus* sp.) were also present.

Distribution and Concentration of Nanoplankton in Areal Sectors

The map from Fig. 1 shows the various sampling stations during the cruise survey in the Philippines waters of the South Chine Sea. The population in the offshore waters toward the north and western parts of the Philippines waters was sparse (3.1 x 10^4 to 1.03 x 10^5 L^{-1}) while the coastal waters ranged between 1.8 x 10^5 to 2.4 x 10^5 L^{-1} (Fig. 2a). The distribution of the different nanoplankton dominant species in the Philippines waters are also shown (Fig. 2b). Species of the genera *Gymnodinium, Oxytoxum, Emiliania, Minidiscua* and *Thalassiosira* were dominant in coastal waters (especially Subic bay); while species of *Fragilaria* and *Syracosphaera* were present in offshore waters. The minute pennate nanodiatom *Synedra* and *Fragilaria* were found in the western offshore waters (Stations 12, 13, 19) while the centrale diatom *Cyclotella* and *Thalassiosira* were dominant in nearshore and intermediate Philippines waters (Stations 8,

Table 2. The distribution and estimated cell density of the major species of Class Heptophyceae in the Philippines waters during the April/May 1998 cruise survey.

Class : Haptophyceae Family:	Taxanomic species	* Sectors in Philippines waters	Total cell x 10^5 density Nos. L^{-1}
1. Prymnesiaceae	*Chrysochromulina* sp.	North (midshore)	0.4
2. Coccolithaceae	*Coccolithus pelagicus* (Wallich) Schutter *Oolithotus fragilus* (Lohmann) Rainhardt	South West (nearshore)	0.7
3. Gephyrocapaceae	*Gephyrocapsa oceanica* (Kamptner) *Emiliania huxlegi* (Lohmann)	Subic Bay (nearshore)	1.6
4. Helicosphaeraceae	*H. helicosphaera carteri* Kamptner *H. pavimentum* Okada	North west (offshore)	1.1
5. Rhabdosphaeraceae	*Acanthoica quattrospina* Lohmann *Discosphaera tubifera* Ostefild *Rhabdosphaera claviger* Murray	North west (offshore)	1.2
6. Syracosphaeraceae	*Caneosphaera molischii* Gaarder *Syracosphaera nodosa* Kamptner *S. pulchra* Lohmann *Umbellosphaera irregularis* Poasche *U. tenuis* Paasche	Subic Bay (nearshore)	1.2
7. Halopappaceae	*Florisphaera profunda* Paasche	Western (offshore)	1.4

* Sectors containing more than 1 station.

16, 23) (Fig. 2.1a & b).

The pennate diatom *Synedra* (especially *S. parasitica* A. Boyer) was present in considerable quantities (ca 9 x 10^4 L^{-1}) in the south west offshore waters while the pennate *Fragilaria* (especially *F. brevistriata* A. Boyer) was concentrated in the western offshore Philippines waters of the South China Sea. The centrale diatom *Thalassiosira* (*T. tenera, T. punctigera, T. oestrupii* var venrickae)) and *Cyclotella* (*C. striata*) were dominant in the coastal waters adjacent to the Subic bay (Fig. 2.2a & b). The dinoflagellate, *Gymnodinium* sp. (especially *G. maguelomense*) and *Pyrodinuim bahamense* were especially important along the coast of western Luzon and the adjacent waters of Subic bay respectively (Fig. 2.3a & b). The diatom *Navicula* sp. and the dinoflagellate *Oxytoxum mileri* were distributed toward the north of Subic bay (Fig. 2.4a & b). The centrale nanodiatom species of *Minisdiscus* (*M. comicus, M. childensis, M. trioculatus*) were concentrated in the vacinity of the Subic bay while *Cryptochrysis* species were found in coastal regions especially toward the Southern part of the Philippines waters (Fig. 2.5a & b). Other minute diatom (*Coscinodiscus* sp., *Diploneis crabro, Stephanopyxis palmeriana*) and the

Table 3. Species assemblage or association in the Philippines waters of the South China Sea during the cruise survey (April/May 1998).

	Species association		
Group	**Diatom**	**Coccolithophoridaceae**	**Dinoflagellate**
A	***Synedra parasita***	***Oolithotus fragilus***	***Protoperidinium* sp.**
B	***Diploneis crabro*** ***Navicula* sp.** ***Cyclotella striata*** ***Manidiscus* sp.** ***Thalassiosira* sp.**	-	***Gymnodinium* sp.**
C	***Stephanopyxis palmeriana***	***Penthospahera* sp.** ***Chrysochromulina* sp.** ***Florisphaera* sp.**	**Gonyaulax sp.**
D	***Fragilaria* sp.**	***Discosphaera* sp.** ***Caneosphaera* sp.** ***Acanthoica* sp.**	-
E	-	***Emiliana* sp.** ***Helicosphaera* sp.** ***Umbellasphaera* sp.** ***Syracosphaera* sp.**	-
F	-	-	***Alexandrium* sp.** ***Pyrodinium bahamense***

flagellate (*Thalassomonas* sp., *Tetraselmis* sp.) were distributed along the coastal areas. The dinoflagellate *Protoperidinium, Gonyaulax* and *Alexandrium* species were also encountered in the coastal regions around Subic bay and Manila bay during the cruise survey.

The Gephyrocapsaceae (especially *Emiliana huxlegi*) and the Syracosphaeraceae (mostly *Syracophaera nodosa*) belonging to the class Haptophyceae were present in the western offshore waters with mean values of 1.7 x 10^5 and 1.2 x 10^4 cells L^{-1} respectively (Fig. 2.6a & b).

3.3 Nanoplankton Assemblage and Association

The dendrogram from Fig. 3.1 (Table 3) illustrates that the nanoplankton species during the cruise survey comprised of at least six species assemblages or associations in cluster analysis on species sampled from the nearshore, midshore and offshore stations according to their preference on environmental conditions using the Unweighted Pair Group Average (UPGA) Pearsons Index analyses. The species assemblages consisted of group A (*Synedra parasitica, Protoperidinium* sp., *Oolithotus fragilus*); group B (*Diploneis crabro, Navicula* sp., *Cyclotella striata, Minidiscus* sp., *Gymnodinium* sp., *Thalassiosira* sp.); group C (*Stephanopyxis palmeriana, Penthosphaera* sp., *Chrysochromulina* sp., *Gonyaulax* sp., *Florisphaera* sp.); group D (*Discosphaera* sp., *Caneosphaera* sp., *Acanthoica* sp., *Fragilaria* sp); group E (*Emiliania* sp., *Helicosphaera* sp., *Umbellasphaera* sp., *Syracosphaera* sp); group F (*Alexandrium* sp.,

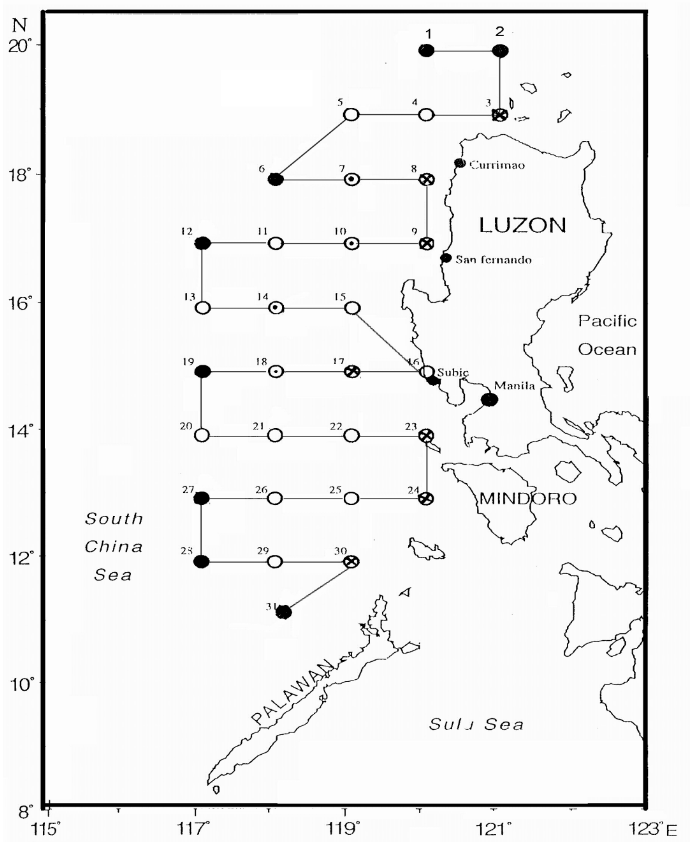

Fig. 1. The map showing the sampling stations in the Philippines waters of the South China Sea.

Pyrodinium bahamense).

Sampling stations can be grouped into at least 5 sectors with respect to their similarities in species composition using cluster analyses by mean of the Unweighted Pair Group Average (UPGA) Pearson Index analyses (Fig. 3.2). The identified sectors in the Philippines water of the South China Sea comprised of a) Eastern nearshore waters, b) Intermediate midshore waters, c) western offshore waters, d) Northern Philippines waters and e) Southern Philippines waters. The mean population densities at various stations of the 5 sectors (data from various stations from each sector were pooled together) were significantly high along the nearshore region during the study period with values ranging from 1.1 x 10^5 to 2.2 x 10^5 L^{-1}. Subic bay coastal waters sector had the highest values. The trend in the mean densities at the 5 sectors was inversely proportional to the distance from the coast; the values were much lower furthest away from the coast ranging from 0.05 x 10^5 to 0.2 x 10^5 L^{-1}. The diversity index H values ranged from 0.42 to 2.94 with high values in the region around the nearby and offshore stations (St. 14 to St. 21) of the Subic bay during the study period (Fig. 4). The J evenness index values were usually directly proportional to the H values.

Discussion

Semina and Tarkhova (1972) recorded close to 1000 species of phytoplankton, mainly of diatoms and dinoflagellates in the Pacific Ocean. The only other conspicuous marine microplanktonic forms are the spherical green cells belonging to the Prasinophyta (*Halosphaera, Pterosperma*) and the bundles of filaments of the Cyanophyte genus *Trichodesmium* (*Oscillatoria*): both of these groups tend to float to the surface, the former buoyed up by oil globules and the latter by gas vacuoles in the cells. The nanoplankton is almost entirely composed

Table 1. The distribution and estimated cell density of dominant nanoplankton in the Philippines waters during the April/May 1998 cruise survey.

	Species	* Sectors in Philippines waters	Total cell x 10^5 density Nos. L^{-1}
1. Centrale Diatom	*Minidiscus* sp. *M. comicus* Takano *M. chilensis* Rivera et Koch *M. trioculatus* Hasle	Subic bay (nearshore)	1.7
	Thalassiosira sp. *T. oestrupii* Hasle *T. punctigera* Hasle	Subic bay (nearshore)	2.4
	T. tenera Proschkina- Lavrenko *Cyclotella* sp. *Cyclotella striata* Grunow *C. meneghiniang* Kutzing *Stephanopyxis palmeriana* Kutz *Chaetoceros* sp.	Northern (offshore)	2.1
2. Pennate Diatom	*Synedra parasitica* A. Boyer	Subic bay (nearshore)	0.9
	Fragilaria brevistriata A. Boyer *Diploneis crabro* Ehr. *Neodenticula seminae* Akiba *Pseudo-nitzschia multistriata* Takano	Western (offshore)	0.9
	Navicula sp. *Navicula fucicola* Taasen *N. grevilleana* Hendey *N. pseudainglica* var. *signata* Hustedt	Subic Bay (South)	1.2
3. Dinoflagellate	*Gymnodium maguelomense* Biecheler *Gyrodonium* sp.	Subic Bay	4.2
	Pyrodinium bahamense Plate	Subic Bay	1.9
	Protoperidinium sp.	Subic Bay	1.1
	Protoceratium sp. *Ceratium* sp.	Subic Bay	1.2
4. Flagellate	*Gonyaulax* sp. *Scrippsiella* sp. *Ceratocorys* sp. *Alexandrium* sp.	Subic Bay	0.2
	Oxytoxum sp.	Subic Bay	1.6
	Crypochrysis sp. *Thalassomonas* sp. *Tetraselmis* sp.	Subic Bay	1.7

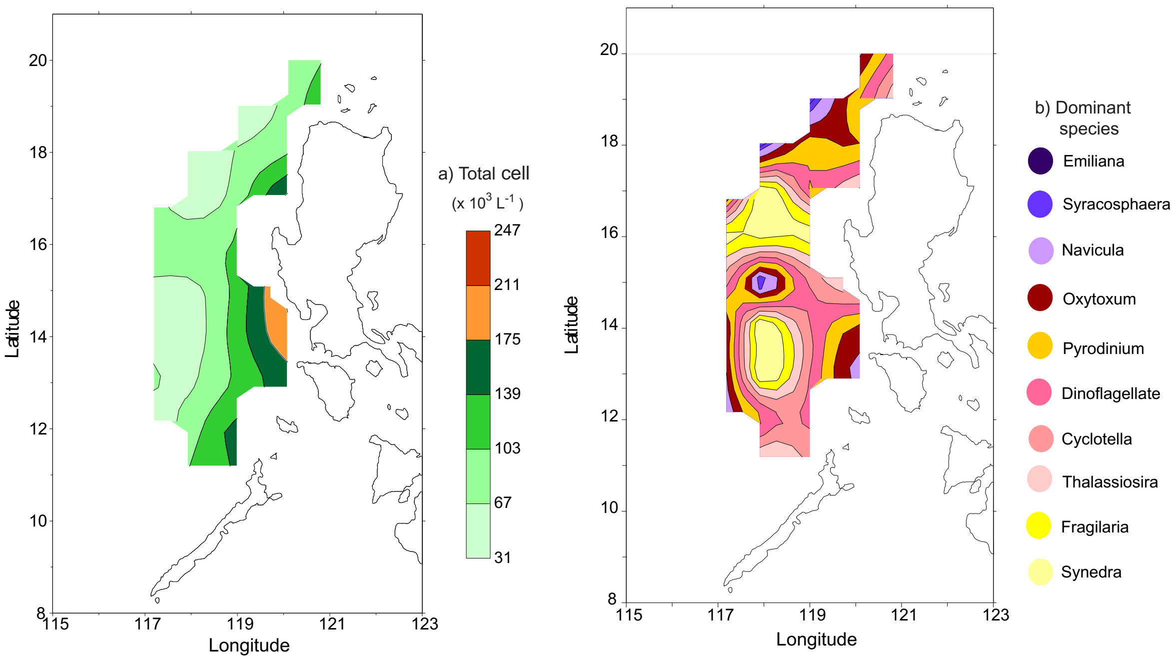

Fig. 2. a) Total cell density (x 10^3 L^{-1}) and b) Dominant nanoplankton species (10^4-10^5 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

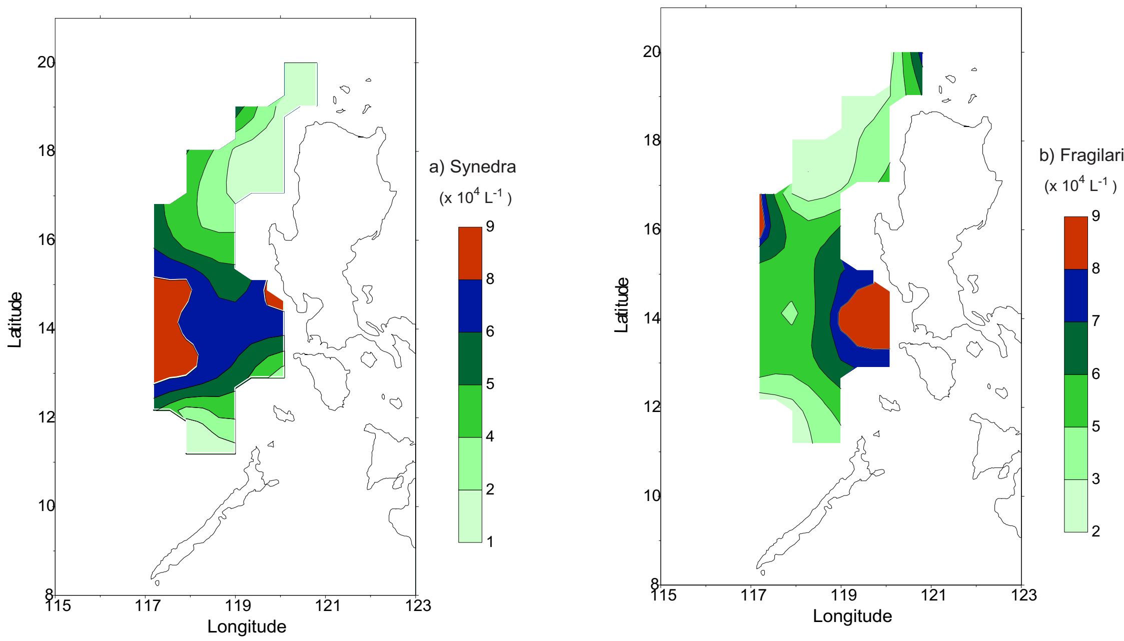

Fig. 2.1. Distribution of the genera (a) *Synedra* (x 10^4 L^{-1}) and (b) *Fragilaria* (10^4 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

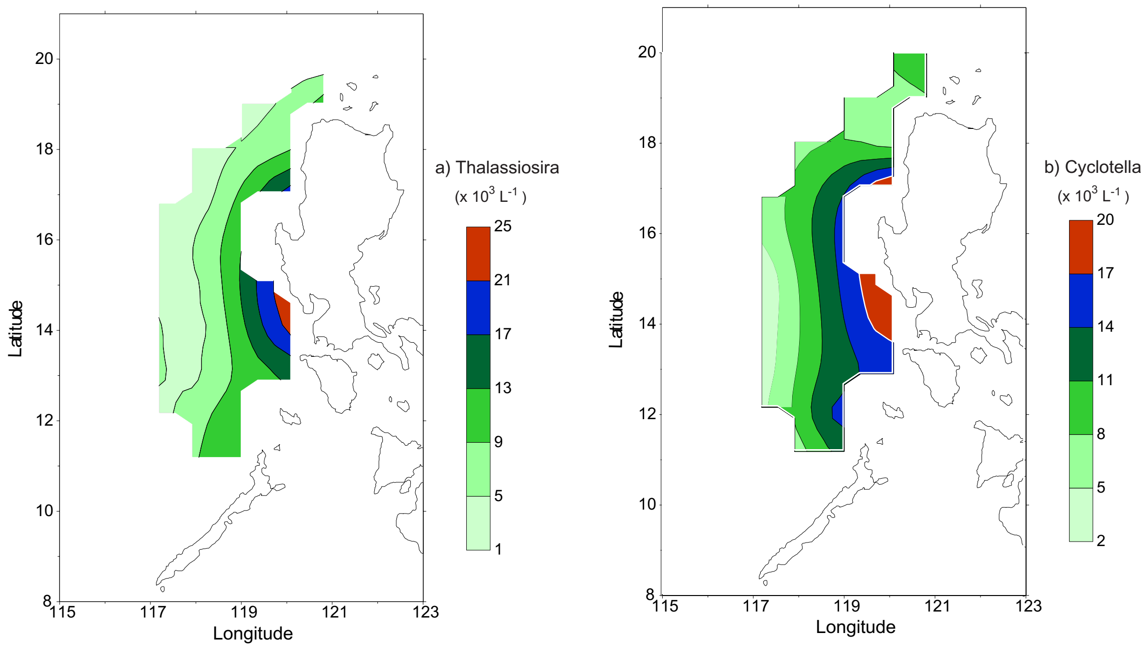

Fig. 2.2. Distribution of the genera (a)Thalassiosira(x 10^2 L^{-1}) and (b) Cyclotella(10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

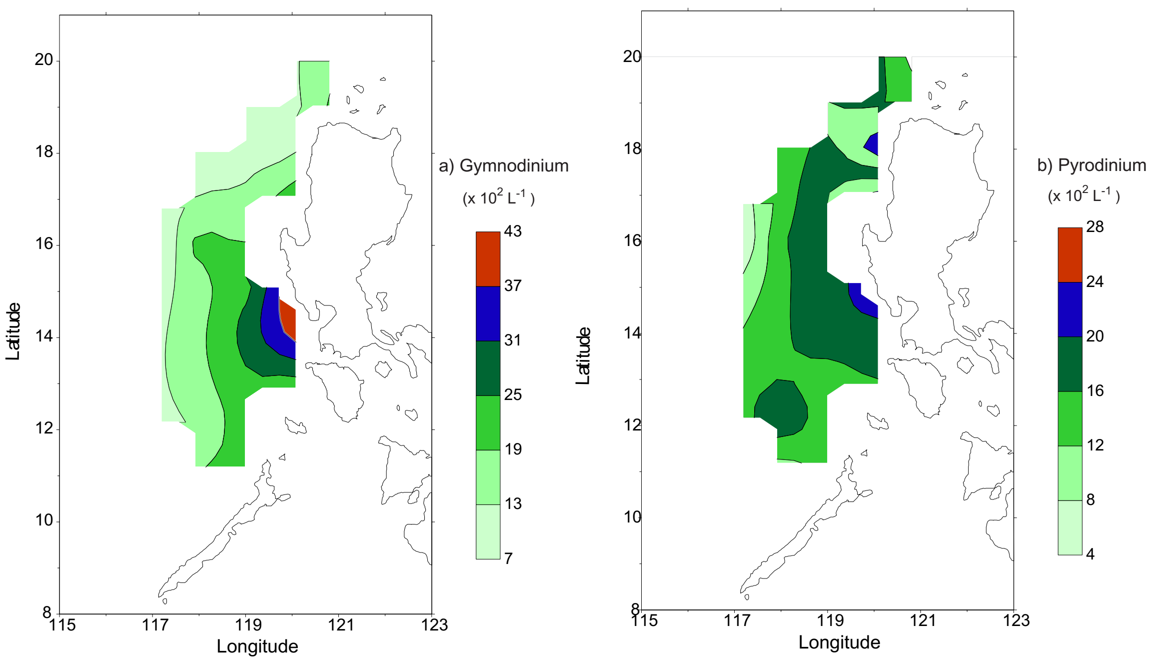

Fig. 2.3. Distribution of the genera (a) Gymnodinium (x 10^2 L^{-1}) and (b) Pyrodinium(10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

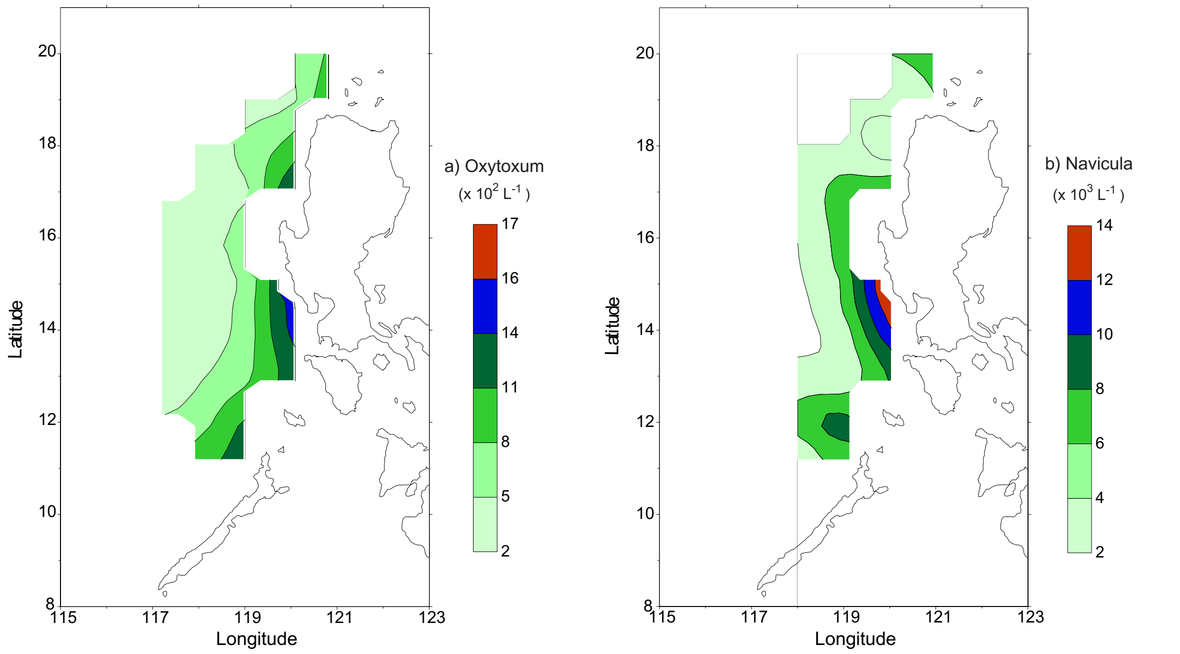

Fig. 2.4. Distribution of the genera (a) Oxytoxum (x 10^2 L^{-1}) and (b) Navicula (10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

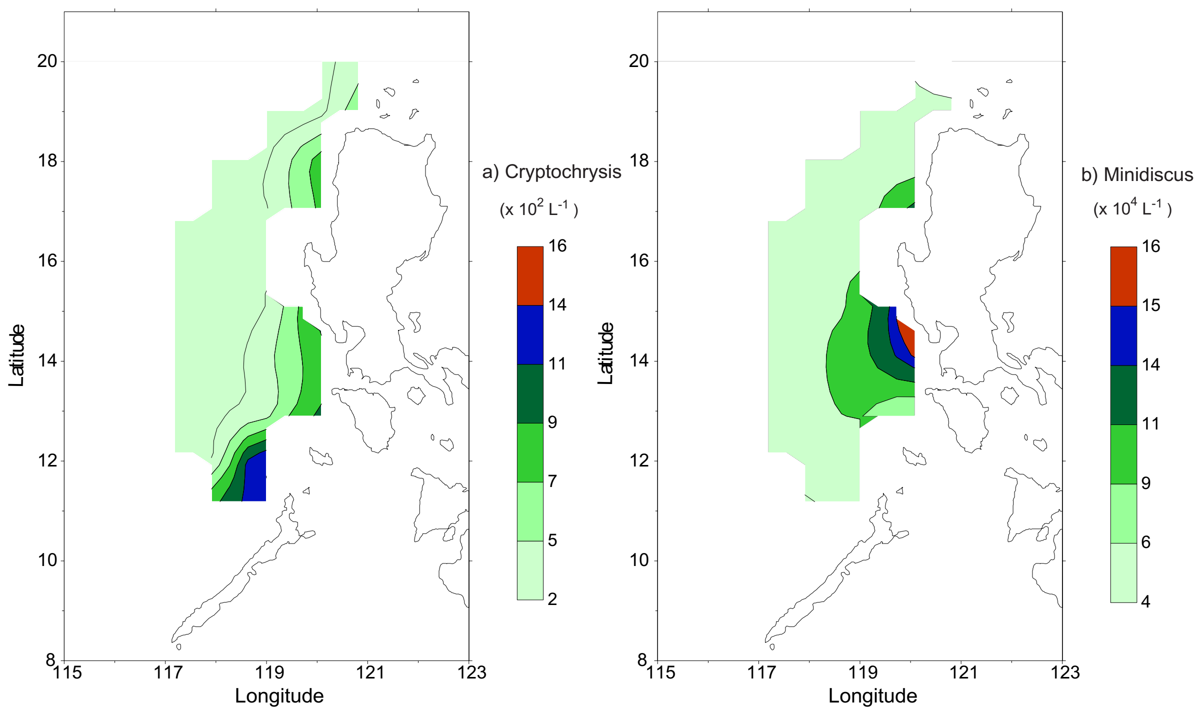

Fig. 2.5 . Distribution of the genera (a) Cryptochrysis (x 10^2 L^{-1}) and (b) Minidiscus (10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

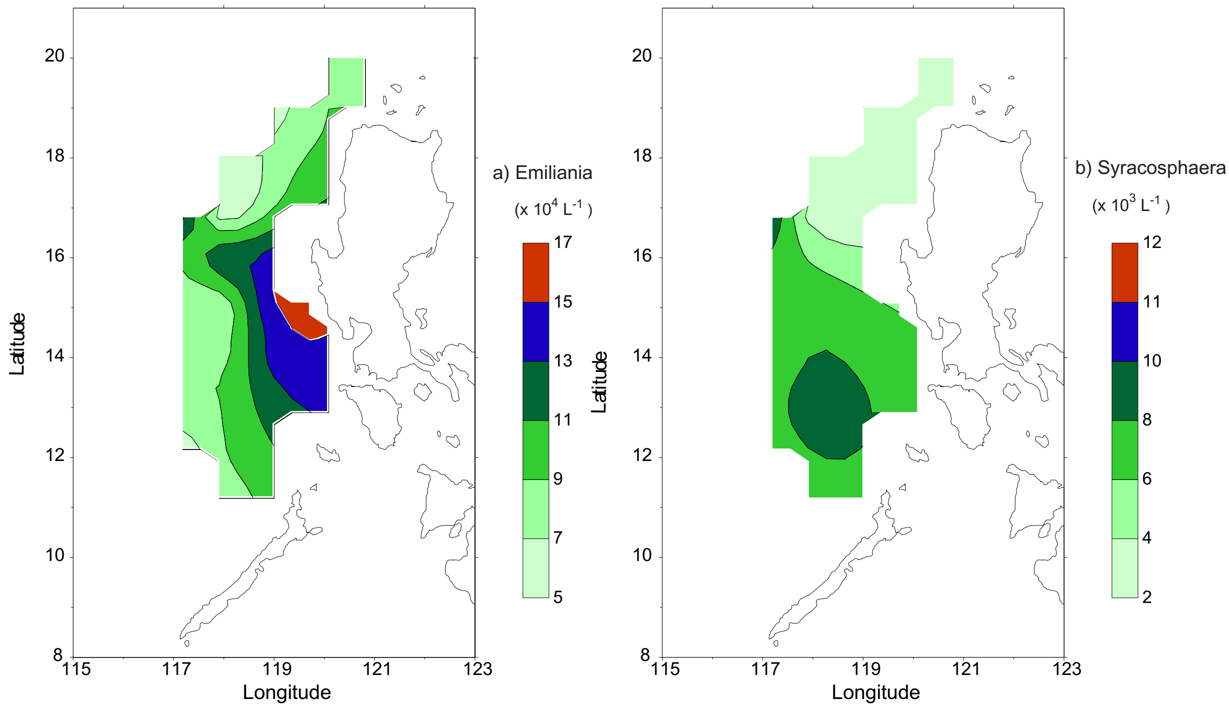

Fig. 2.6. Distribution of the genera (a) Emiliania (x 10^2 L^{-1}) and (b) Syracosphaera (10^2 L^{-1}) in the Philippines waters of the South China Sea (April/May 1998 cruise survey).

of small flagellate cells belonging to the Prymnesiophyta. They possess two flagella with a haptonema. This group now contains the genera of the *Prymnesiales* (= Coccolithophoridaceae) since many of these have been shown to possess a haptonema. Some are delicate and are assually damage beyond recognition or are destroyed by preservatives (formalin, is not an ideal preservative for phytoplankton) and their numerical abundance is rarely determined. Prymnesiophyta bearing calcareous plates (coccoliths) are more easily damage than the delicate forms bearing organic scales (*Chrysochromulina*), but the latter can make up a considerable amount of the biomass in some seas. An increase in the diversity value of the nanoplankton population could be *due to an increased* number of species or even distribution of individuals per species as described by Gray (1981). In reality, such community organisation is constantly acted on by biological and physical factors in many different ways to produce, perhaps a different organisation in the future as a response to such environmental changes. When a bloom occurs, only a few microplankton species will predominate and thus effect or influence the number of species or the even distribution of individual species. A few small diatoms, dinoflagellates and other groups (e.g. *Dictyocha*) occur in the marine nanoplankton but detailed studies are still needed. During the present survey *Dictyocha* sp. was not encounted; however, Coccolithophoridaceae was well represented.

Nanoplankton species tend to occur in groups throughout natural communities and it ought to be possible to distinguish associations of species in the plankton. Observations from some detailed surveys and from the continuous plankton recorded certainly suggest that there are discrete associations. These associations appear to be linked with geographical zones (currents, water masses) rather than with subtle differences in water chemistry. The present cruise survey shows that the bulk of the nanoplankton comprised of nanodiatom, dinoflagellate and flagellate; all of these organisms reach a value of close to 200 taxa, many of which are yet to be carefully identified.

The fact that the nanoplankton is small should not lead to its neglect since in many waters it is responsible for more carbon fixation than the more immediately obvious microplankton.

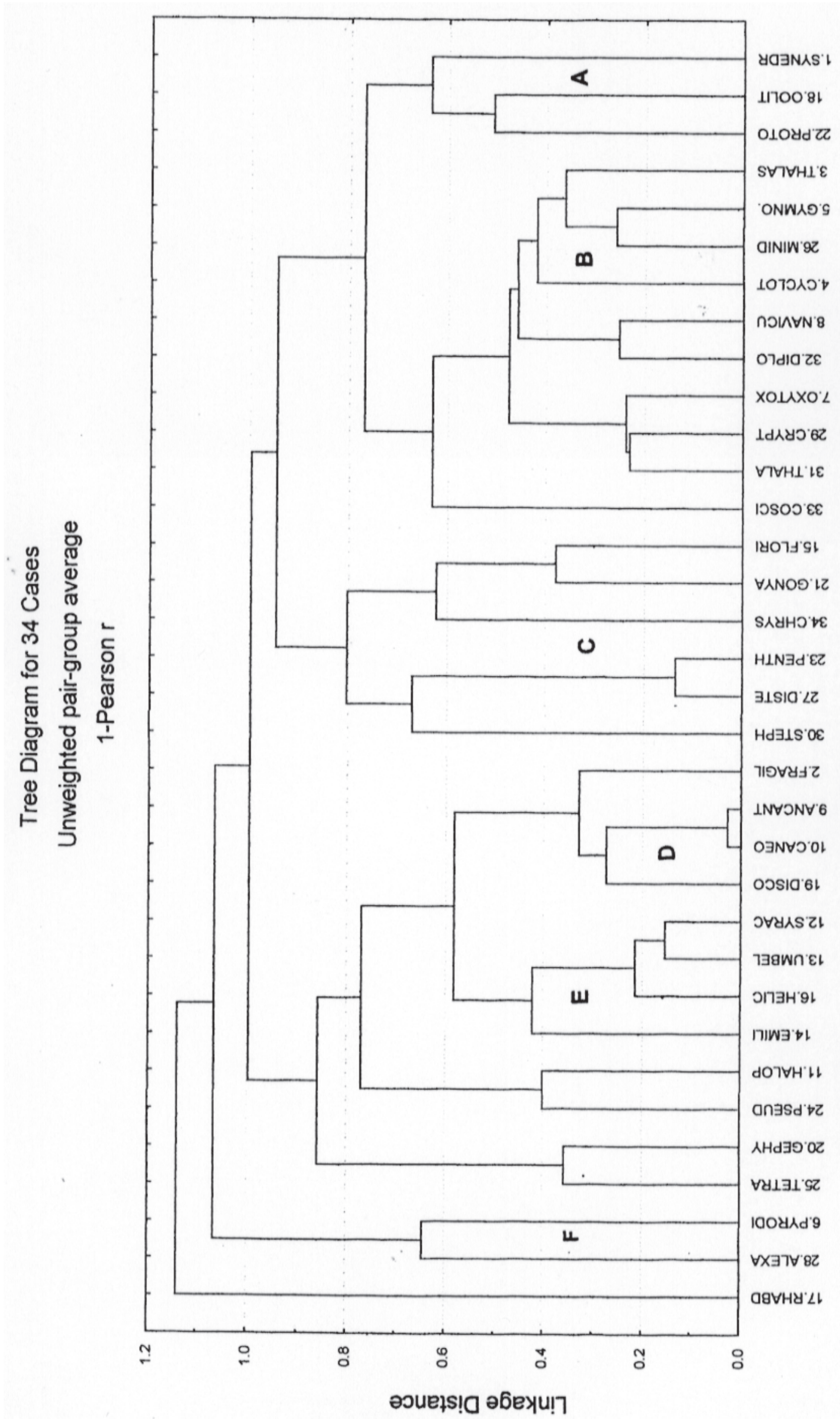

Fig. 3.1 The dendrogram showing the aggregation & association of nanoplankton species in the Philippines waters of the South China Sea (April/May 1998)

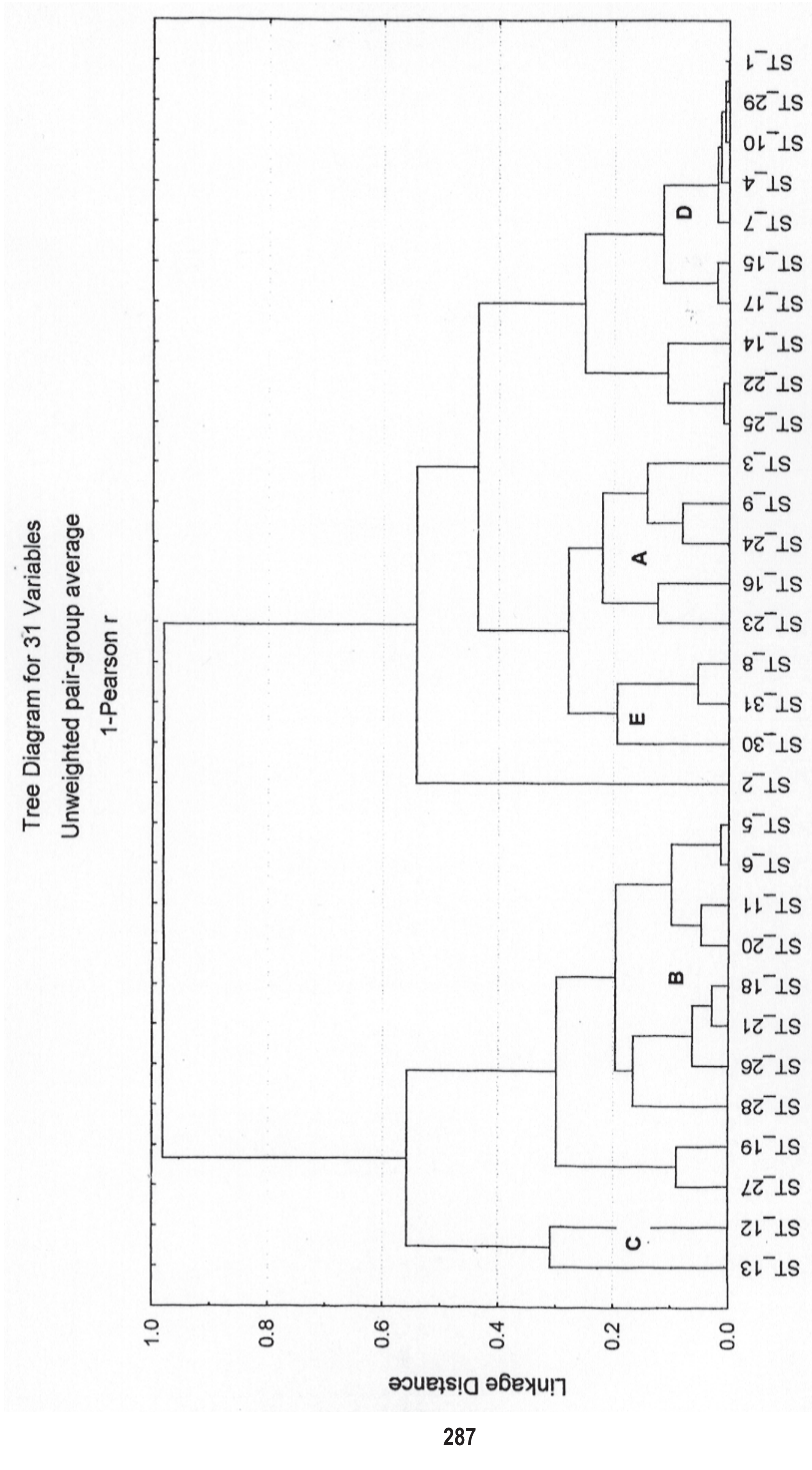

Fig. 3.2 The dendrogram showing the aggregation & association of sampling stations with similar community structure in the Philippines waters of the South China Sea (April/May 1998)

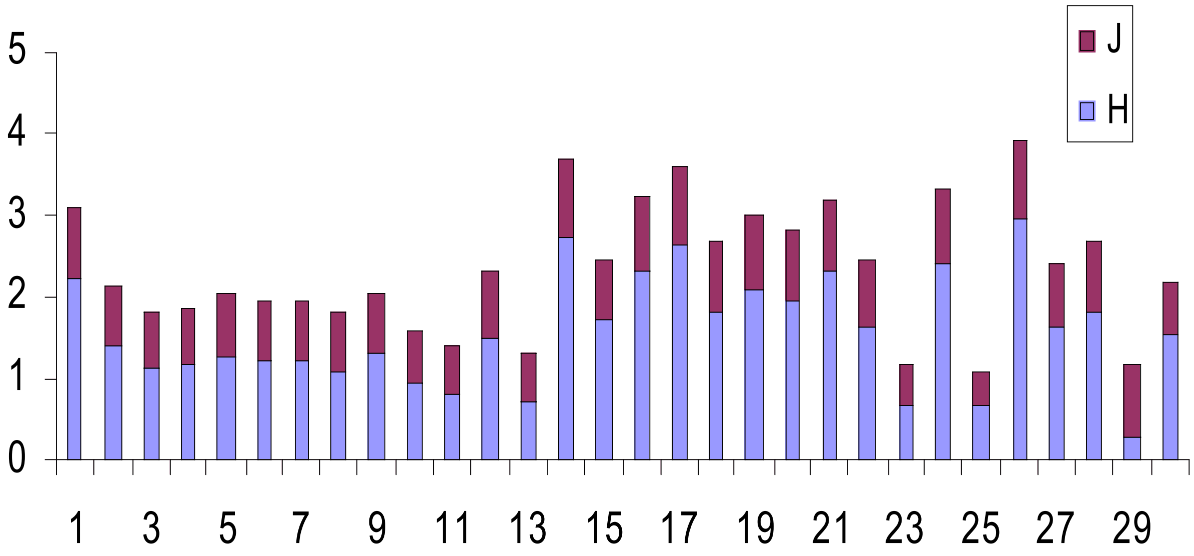

Fig. 4. The diversity (H) and eveness (J) indices of various station in the Philippines waters of the South China Sea during (April/May 1998).

On an annual basis 70-80% (total carbon 78 – 82 g C m^{-2}) was attributed to the nanoplankton. McCarthy *et al.*(1974) found that over a two year study in Chesapeake Bay the nanoplankton (in this case species passing through a 35 µm mesh net) was responsible for 89.6% of the carbon fixation. In the open ocean, especially in oligotrophic regions, the nanoplankton are often the most abundant organisms (Hulbert *et al.*, 1960). Pomeroy (1974) gives a table which shows that over 90% of total fixation is by forms smaller than 60 µm in diameter. It is necessary to measure cells and to calculate cell volumes if more detailed information of the biomass of individual species species is required. The nanoplankton together with the Coccolithophoridaceae were present in significant quantities and many of these organisms are minute having the size range between 5 to 50 µm; these organisms have been shown to contribute >50% in total biomass and productivity in the sea (MeCarthy *et al.* 1974, Hulbert *et al.* 1960).

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