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

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ABSTARCT

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

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

Introduction

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

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

Materials and Methods

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

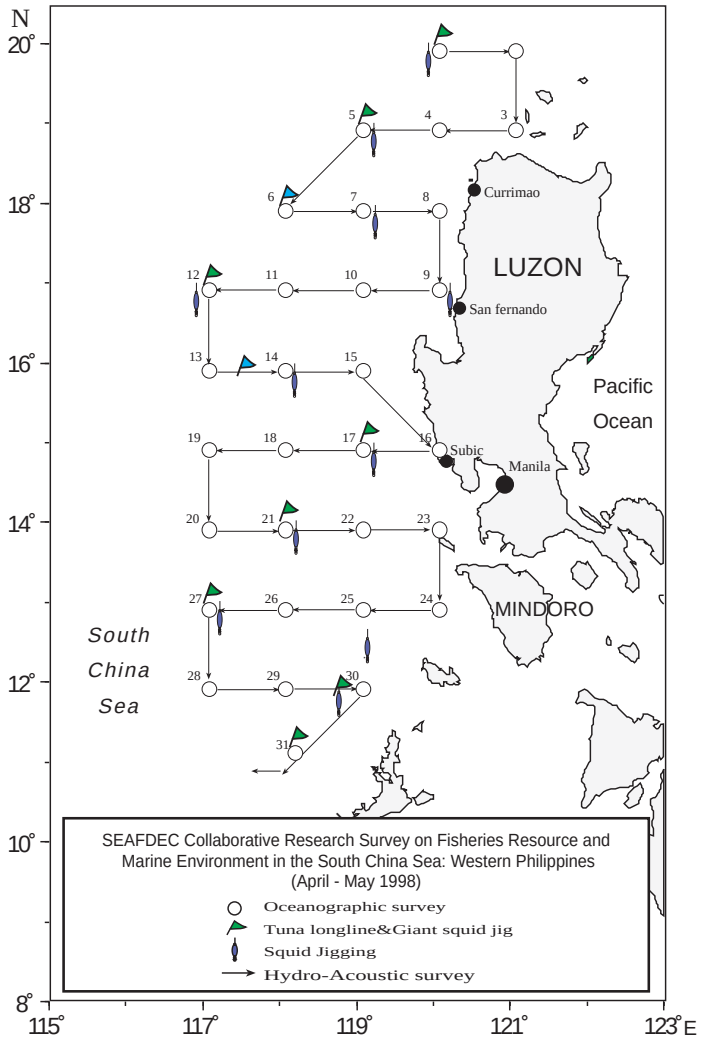

Fig. 1. Location of the sampling stations.

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

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

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

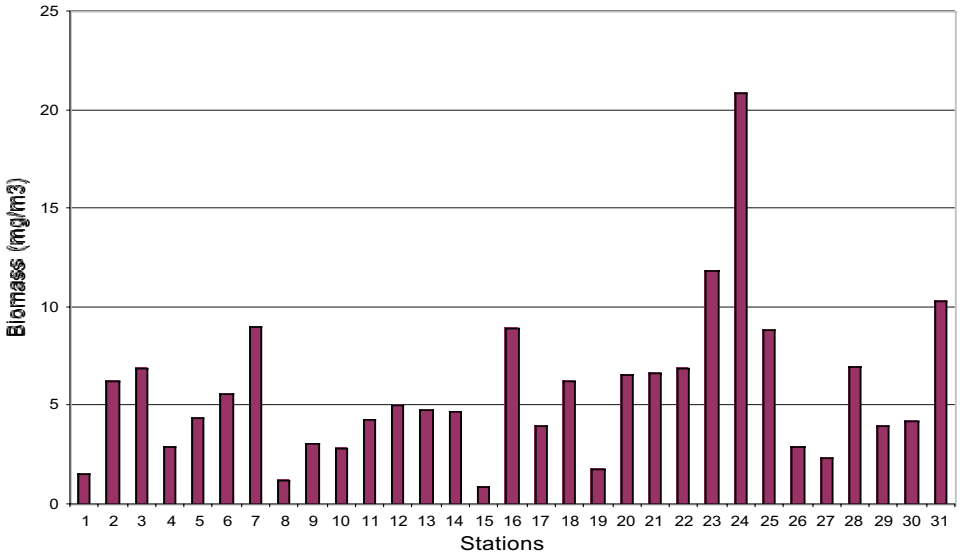

Fig. 2a. Zooplankton biomass.

Results

Zooplankton Biomass

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

Composition Abundance and Distribution of Zooplankton Community

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

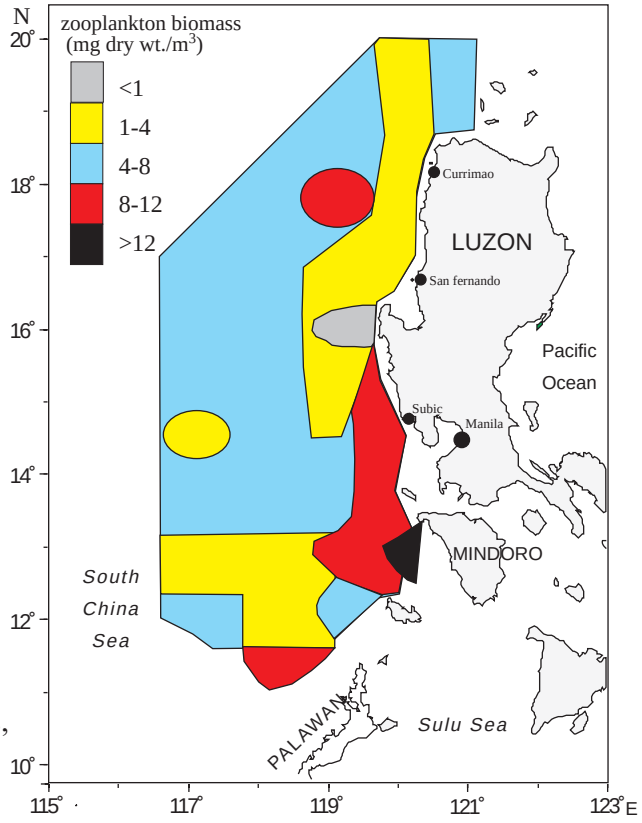

Fig. 2b. Distribution of zooplankton biomass, April-8-May9 1998.

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

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

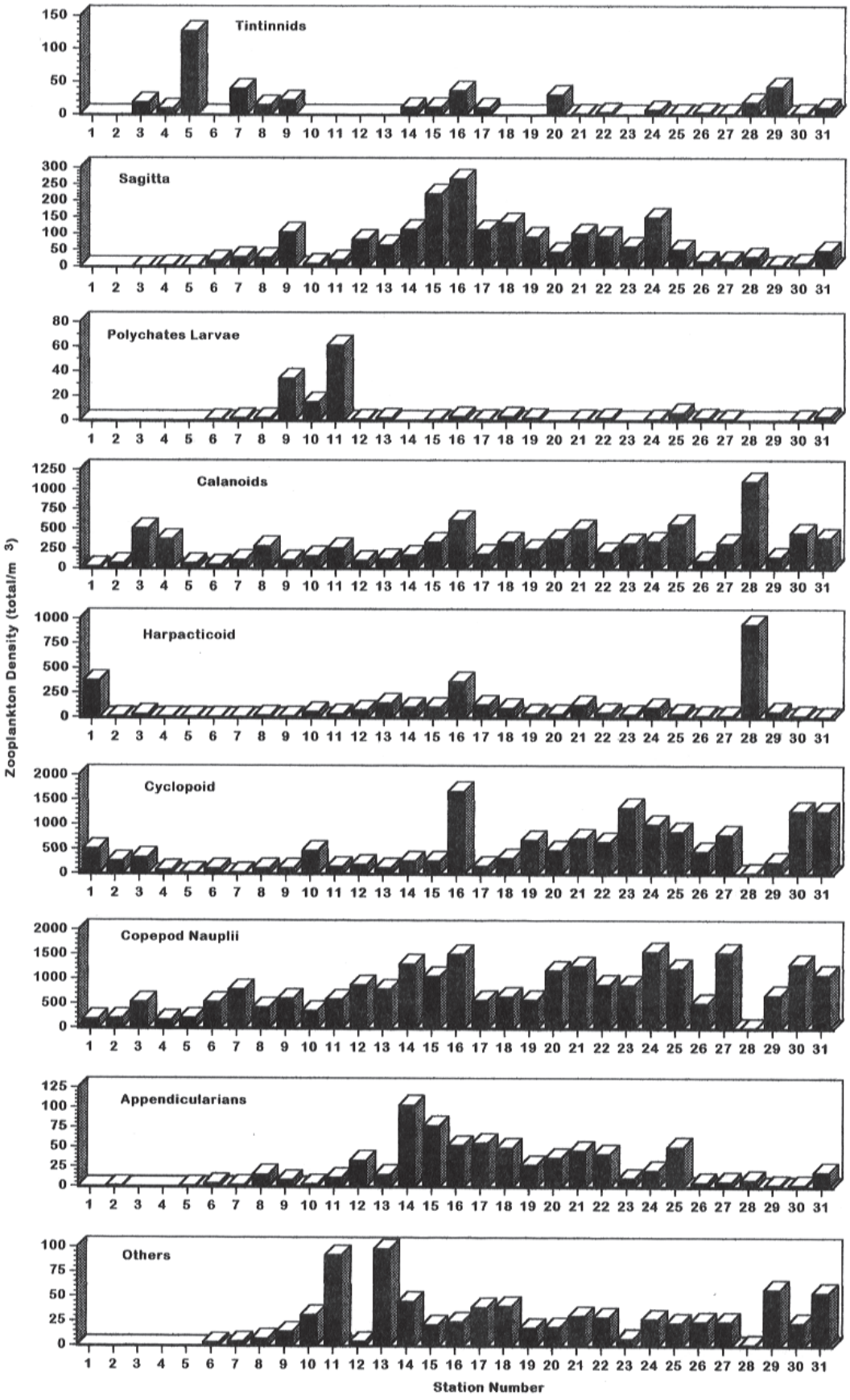

Fig. 3. Population density of the dominant zooplankton groups per station in the SCS, western Philippines (April 18 – May 9, 1998).

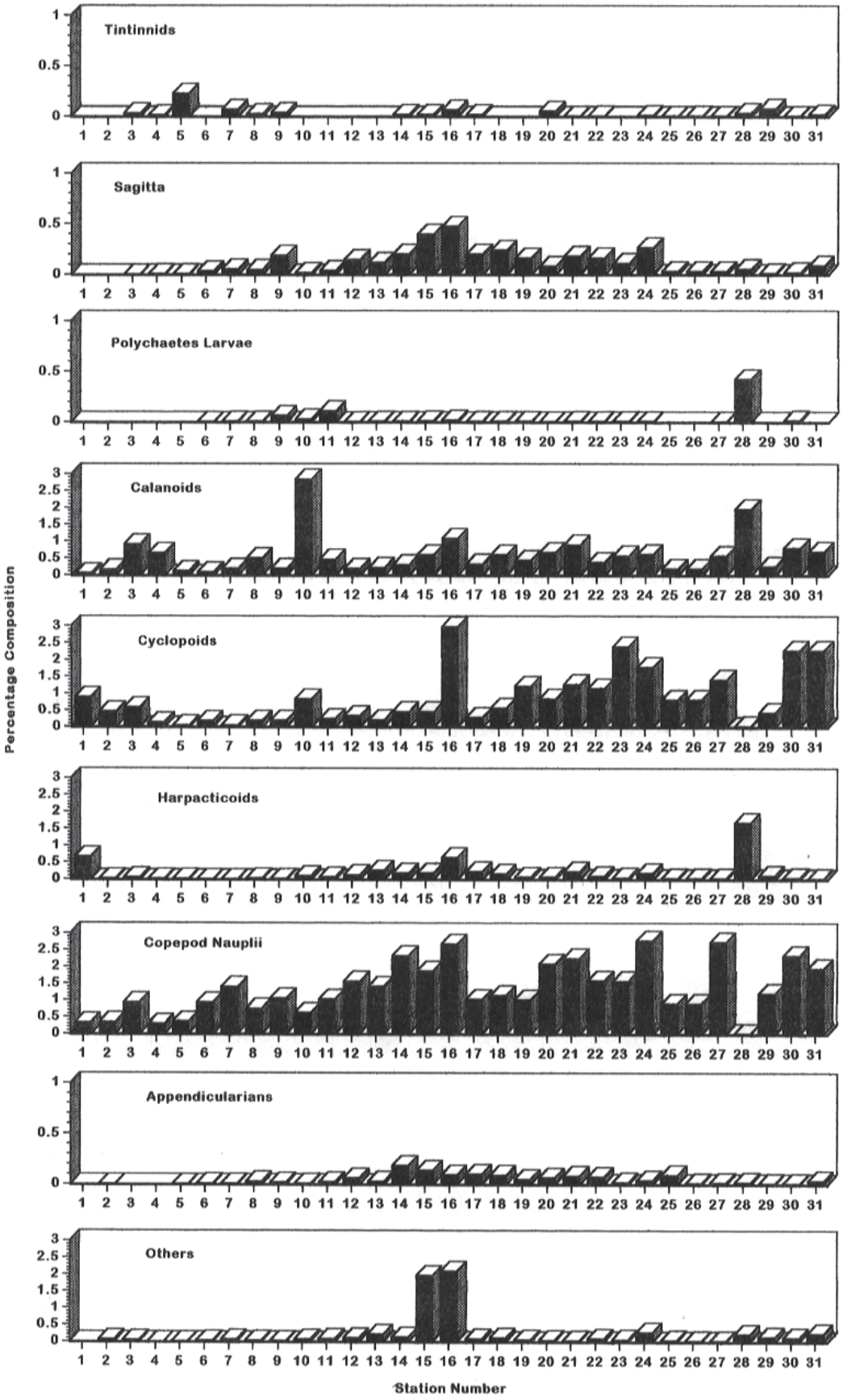

Fig. 4. Percentage composition of the dominant zooplankton group per station in the SCS, Area III: Western Philippines.

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

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

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

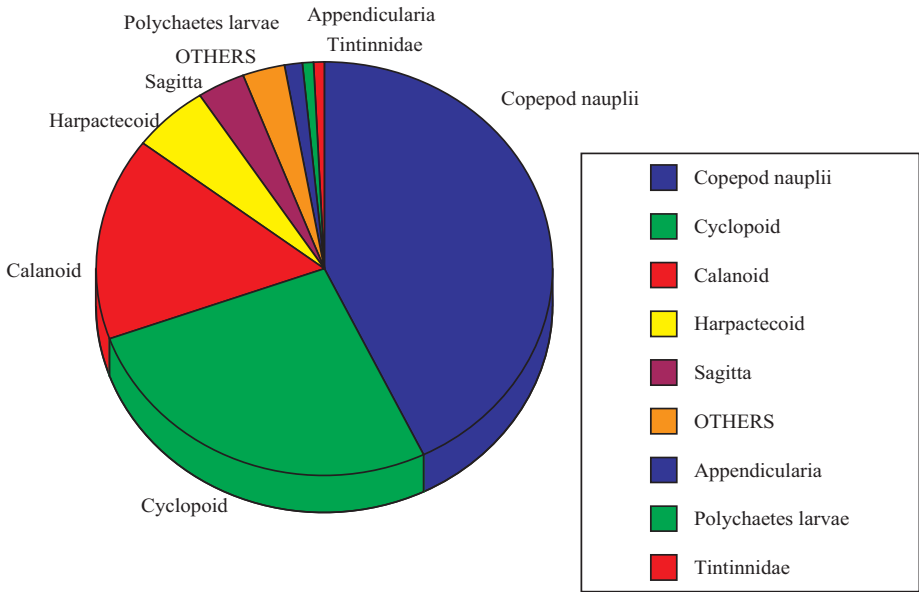

Fig. 5. Percentage composition of different zooplankton groups in the SCS, off western Philippines (April 18 – May 9, 1998)

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

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

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

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

Discussion

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

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

Table 2. List of Zooplankton Observed in the Study Area

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

Table 2. Continue

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

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

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

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

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

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

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

The plankton analyzed by Alvariño (1981) also showed that copepods were the dominant group in almost 80% of the collections made in the waters of California. Interestingly, this also conforms well with the present study wherein copepods constituted 87.37% of the total zooplankton in the entire sampling area. Alvariño (1981) further observed that the maximum

abundance of copepods occurred in areas where there was an abundant anchovy larvae but never from localities with no anchovy larvae. Thus, it seems specially true for zooplankton to play a role as important link in the grazing food chain in marine ecosystem [Day *et al.,* (1989)]. Zooplankton production depends on primary and secondary production and is important in the estimation of the productivity of fish species and the fishery resources since zooplankton are fish food and can control fish recruitment and stocking success.

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