

Studies on the microzooplankton from the central and eastern Arabian Sea

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Numerical abundance and composition of microzooplankton in the upper 200 m were studied from the central and eastern Arabian Sea during three seasons. Protozoans, comprising of ciliates (loricates and aloricates), flagellates and sarcodines were dominant, ranging from 55% to 91%. Among metazoans, nauplii and copepodite stages were common. Microzooplankton abundance was generally higher in the upper 100 m water column during all the three seasons. The column values were from 69,000 m⁻² to 188,000 m⁻² (inter-monsoon), 7350 m⁻² to 56,350 m⁻² (winter monsoon) and 10,800 m⁻² to 139,150 m⁻² (summer monsoon). Seasonal averages were 700 l⁻¹, 130 l⁻¹ and 310 l⁻¹ respectively. A maximum of 5000 l⁻¹ was observed during summer at 5 m at a coastal station. Microzooplankton carbon in three different seasons ranged from a minimum of 4 µg C l⁻¹ during summer monsoon to a maximum of 36 µg C l⁻¹ during inter-monsoon and was higher than that of mesozooplankton. Peaks in population observed during inter-monsoon season, when phytoplankton productivity was low and relatively high bacterial abundance was observed, indicated a microbial loop.

As a part of the Joint Global Ocean Flux Studies (JGOFS-India), abundance and composition of microzooplankton were studied from the central and eastern Arabian Sea. They form a key component in cycling of carbon and other nutrients in marine surface waters^{1,2}. There is virtually no study on microzooplankton from this area. Microzooplankton are defined as the phagotrophic animal forms which pass through a 200 µm mesh netting³. They are taxonomically heterogenous comprising both protozoa and metazoa. It is known that the microplankton form a significant proportion of the plankton community in the epipelagic zone, in oceanic, coastal and estuarine waters⁴⁻¹³. In India, studies on the microzooplankton are limited to the work on tintinnids from the Vellar estuary, Pichavaram mangroves and the adjacent coastal areas along the east coast¹⁴⁻²⁰. We report here, for the first time, a study on the annual cycle of the microzooplankton abundance and composition from the Arabian Sea.

Materials and methods

Samples for microzooplankton were collected following the JGOFS protocol²¹. Water samples were ob-

tained from a CTD rosette sampler fitted with Go-Flo bottles (12 litre capacity, General Oceanics). The Go-Flo bottles were triggered during upcast at depths of 200, 150, 100, 50 and 5 m.

The collections were made during three seasons: inter-monsoon (April–May 1994), winter monsoon (February–March 1995) and summer monsoon (July–August 1995) onboard O. R. V. *Sagar Kanya* cruises (Figure 1). Samples were processed in the following manner: To quantify the larger (20–200 µm) microzooplankton, 10 litres of water from the Go-Flo bottle was filtered through 200 µm net into a bucket. This water was then slowly passed through a wide area of 20 µm net. The filtration was done carefully and slowly to avoid bursting of delicate forms due to pressure exerted while filtering. The filtered micro-zooplankton was then transferred to 500 ml GF/F filtered sea water and preserved with 1% Acid Lugol's solution, 1% EM hexam-

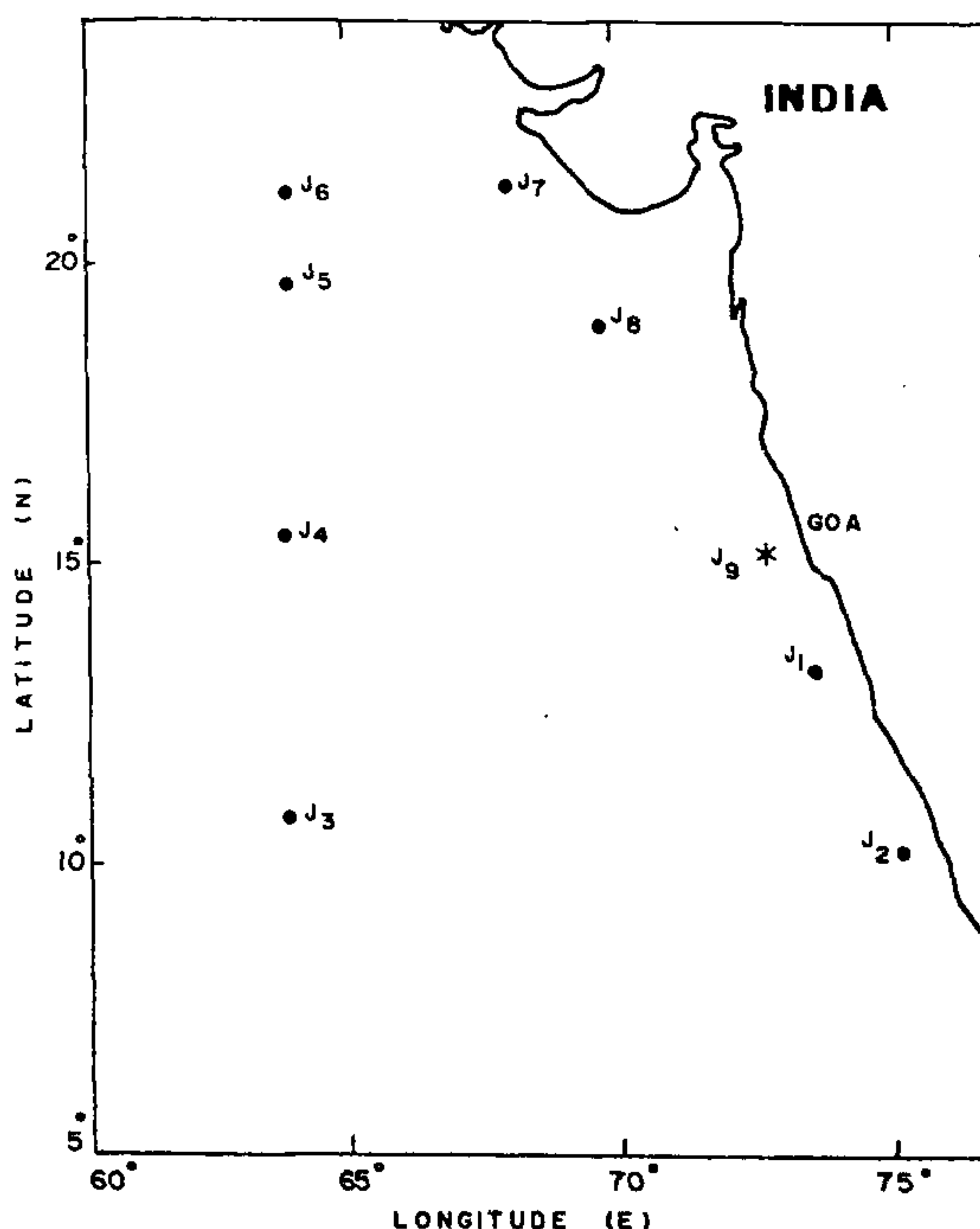


Figure 1. Station locations during three cruises. ●, stations sampled, *, additional station sampled during July–August 1995. Stations J2–J7, J1–J8 and J1–J4, J8, J9 were sampled during April–May, February–March and July–August respectively.

ine buffered formaldehyde and 2 mg/l of strontium sulphate. Samples were refrigerated in dark until analysed later in the laboratory. These samples were used for enumeration, identification and to measure the biomass.

In the laboratory these samples were left undisturbed and allowed to settle for more than 48 h. These were then concentrated to 50 ml by siphoning out the supernatant and observed under an inverted microscope with phase contrast optics⁷. Microzooplankton were identified to genus level based on literature²²⁻²⁶. They were assigned to the following five groups: metazoa, tintinnids, sarcodines, flagellates and aloricates. Metazoans were not counted during intermonsoon and cells were grouped as loricates and other protozoans. Cell dimension (μm) of protozoans was determined from microscopic measurements in order to compute the volumes. This was converted to carbon using a factor of $0.19 \text{ pg C } \mu\text{m}^{-3}$ for ciliates²⁷ and $0.14 \text{ pg C } \mu\text{m}^{-3}$ for dinoflagellates²⁸. A conversion factor of $16 \text{ ng C/individual}$ was used for metazoan microzooplankton²⁹. While computing the biovolume of protozoans 40% cell shrinkage due to preservation³⁰ was taken into consideration. The cell volume of tintinnine ciliates in the present study was assumed to be 50% of lorica volume. Mesozooplankton biomass (0–200 m depth) estimated as displacement volume³¹ was converted to dry weight (1 ml displacement volume = 0.075 g dry wt.) and to carbon (34.2%)³².

For studying the abundance of heterotrophic flagellates, 50 ml of fresh sea water samples from depths mentioned earlier was fixed in 2% glutaraldehyde (only during the winter and summer monsoon). These were then stained with DAPI (final concentration of $5 \mu\text{g/ml}$)^{33,34} and counter-stained with Proflavin and after 5 minutes concentrated onto $0.8 \mu\text{m}$ black Nuclepore filters of 25 mm diameter^{34,35}. These were stored at 5°C until observed under an epifluorescent microscope (Olympus) under UV excitation with a blue filter. Only unbroken well-defined organisms were counted.

Results

Composition

Protozoans were dominant at all stations during the three seasons. They mostly comprised of ciliates (both loricates and aloricates), sarcodines and flagellates. Tintinnids were represented by 30 genera. Among these 11 genera, *Tintinnopsis*, *Eutintinnus*, *Favella*, *Parundella*, *Amphorides*, *Codonellopsis*, *Rhabdonellopsis*, *Dictyocysta*, *Codonella*, *Tintinnus* and *Xystonellopsis* were present during all the three seasons. Other genera recorded were *Metacylis*, *Ascampbelliella*, *Parafavella*, *Coxiella*, *Dadayiella*, *Ormosella*, *Proplectella*, *Protorhabdonella*, *Rhabdonella*, *Epiplocyclis*, *Salpingella*, *Luminella*, *Stenosemella*, *Tintinnidium*, *Helicostomella*,

Leprotintinnus, *Daturella*, *Undella* and *Climacocylis*. Sarcodines were represented by radiolarians, acantharians and foraminiferans. Apart from these, flagellates consisted of *Peridinium*, *Ceratium*, *Dinophysis*, *Goniaulax*, *Noctiluca*, Silicoflagellates and *Prorocentrum*. Metazoans were mostly copepod nauplii, early copepodite stages, larval stages of appendicularians, polychaetes, chaetognaths and eggs of copepods and fishes.

Seasonal abundance of microzooplankton

Microzooplankton abundance during the three seasons in the central and eastern Arabian Sea is shown in Figures 2 a,b. Average cell concentration of microzooplankton was highest during inter-monsoon (700 l^{-1}) followed by summer (300 l^{-1}) and winter (130 l^{-1}) seasons and average integrated column values were $143,000 \text{ m}^{-2}$, $66,000 \text{ m}^{-2}$ and $24,100 \text{ m}^{-2}$ respectively. Protozoa contributed 55–91% to the total microzooplankton. Among protozoa, flagellates (avg. 47%) were abundant followed by loricates (27%), aloricates (21%) and sarcodines (5%). Copepod nauplii and early copepodite stages of copepods formed the major component of the metazoan microzooplankton. Higher abundance of microzooplankton was found in the upper 100 m compared to 100–200 m depth except at stations J5 and J6 during inter-monsoon period. Below 100 m flagellates and aloricate ciliates were usually more common compared to other taxa. Microzooplankton density was higher in open ocean waters during inter-monsoon and winter while it was more at coastal stations during summer. During inter-monsoon there was not much variation in abundance between northern (avg. 700 l^{-1}) and southern (avg. 716 l^{-1}) stations, but during winter and summer seasons southern areas showed more abundance (351 l^{-1} and 180 l^{-1} respectively) than north (78 l^{-1} ; 140 l^{-1}).

Microzooplankton carbon ranged from 7 to $36 \mu\text{g C l}^{-1}$ (avg. $19 \mu\text{g C l}^{-1}$), 4 to $22 \mu\text{g C l}^{-1}$ (avg. $10 \mu\text{g C l}^{-1}$) and 4 to $25 \mu\text{g C l}^{-1}$ (avg. $12 \mu\text{g C l}^{-1}$) during inter-monsoon, winter and summer respectively. Southern stations showed comparatively higher biomass (avg. 3.96 g C m^{-2}) than the northern stations (1.96 g C m^{-2}). Microzooplankton biomass in terms of carbon was more than that of mesozooplankton in all seasons except in open ocean waters during winter monsoon when they were comparable (Table 1).

Discussion

Numerically, microzooplankton was dominated by protozoa which contributed on an average >75%. This is comparable to the results reported from Plymouth waters¹¹ where protozoa contributed to >97% of counts in

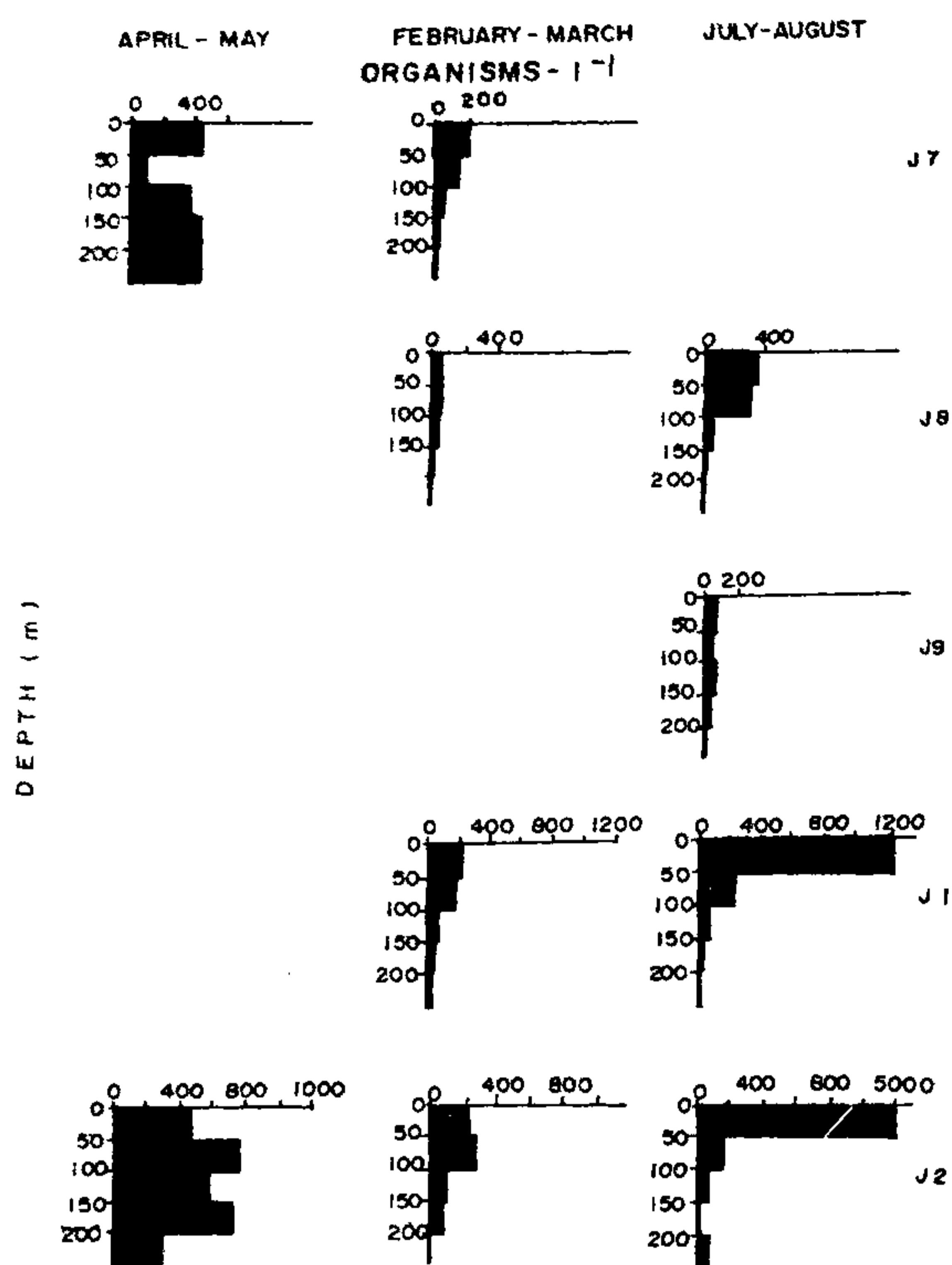


Figure 2a. Microzooplankton abundance during inter-monsoon, winter monsoon and summer monsoon at coastal stations (J1, J2, J7, J8 and J9).

the water column. Ciliates and flagellates dominated in the present study as reported¹¹.

An interesting finding of this study was the contribution of flagellates which ranged from 11 to 69% to the total microzooplankton. This suggests that they form an important group of microzooplankton in tropical waters similar to subtropical and temperate waters^{1,36-38}. Tintinnid population varied from 20 to 1060 l⁻¹ in the present study, is less than that reported during the north Atlantic bloom (300-1600 l⁻¹)² but higher than

Table 1. Average carbon content (g C m⁻²) of microzooplankton and mesozooplankton

	Inter- monsoon	winter monsoon	Summer monsoon
Microzooplankton			
Open ocean stations	3.1	1.8	2.3
Coastal stations	5.48	2.1	2.4
Mesozooplankton			
Open ocean stations	1.51	1.89	0.87
Coastal stations	0.92	0.90	1.00

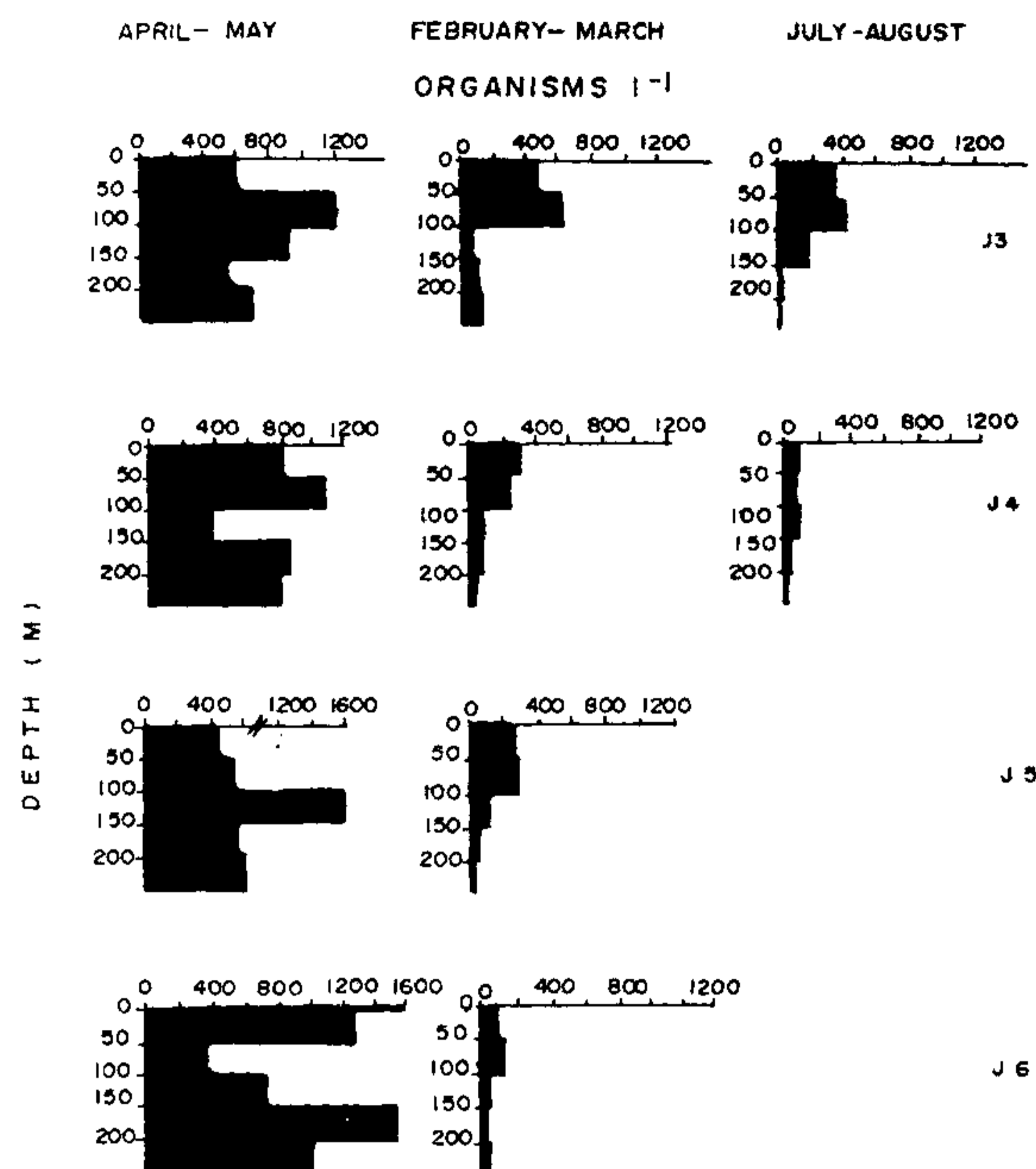


Figure 2b. Microzooplankton abundance during inter-monsoon, winter monsoon and summer monsoon at open ocean stations (J3-J6).

records from the Pichavaram Mangrove (4-13 l⁻¹)²⁰, South India. Similarly, microzooplankton biomass of this study (4-36 µg C l⁻¹) is comparable to that of Lancaster Sound 10, where microzooplankton (>35 and <200 µm) biomass varied from 1.33 µg C l⁻¹ to 48.7 µg C l⁻¹. The assumption of taking cell volume of tintinnids as 50% of lorica volume might have led to some over-estimation³⁹.

The physical and chemical environments during the three cruises were different. During February, winter cooling led to increased mixed layer depths and availability of nutrients in euphotic zone enhancing primary production in the northern region⁴⁰. During April-May, the entire study area was oligotrophic whereas in August enhanced production was noticed in coastal waters as a result of upwelling. Interestingly, maximum population of microzooplankton occurred during inter-monsoon season when primary production and chlorophyll were low, but bacterial population was high compared to other seasons⁴¹. It would seem that the microzooplankton population increased through a microbial loop during this season by actively feeding on bacteria⁴². Higher microzooplankton abundance below 100 m at some stations during inter-monsoon coincided with trends in distribution of bacteria. The higher population of microzooplankton in coastal waters during summer monsoon might have resulted from the fresh water plumes⁴³ due to river run-off.

The fact that microzooplankton biomass in terms of carbon usually exceeded that of mesozooplankton is a pointer that they dominate the food chain in grazing and thereby phytoplankton losses as reported from the Atlantic^{1,2}. Future studies should concentrate on this since this implies that it forms the largest sink for primary production.

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