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OBSERVATIONS ON PHYTOPLANKTON PIGMENTS, ZOOPLANKTON AND PHYSICO-CHEMICAL PARAMETERS IN SURFACE WATERS FROM SOUTHERN INDIAN OCEAN AND ANTARCTIC REGION

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ABSTRACT

Observations on distribution of chlorophyll *a*, phaeopigments, zooplankton and physico-chemical parameters in the Southern Ocean were carried out during IXth Indian Antarctic Expedition (1989-1990). The results indicated high phytoplankton biomass in terms of chl. *a*. The values of chl *a* and phaeopigment ranged from 0.51 to 6.4 and 0.05 to 0.62 mg m^{-3}, respectively. The zooplankton standing stock (biomass) values fluctuated between 3.1 and 62.2 ml 100^{-1} m^{-3} and showed an inverse relationship with chl *a* and phaeopigments. Copepods, euphausiids, decapods, polychaetes and chaetognaths were the major constituents of zooplankton community. The salinity values varied from 34.06 to 36.14 x 10^{-3}. Temperature fluctuations of the seawater were pronounced (-0.5 to 29.5°C) and seemed to influence the distribution and abundance of plankton. The nutrient concentrations at various stations were high.

Key-words: Phytoplankton pigments, physico-chemical parameters, zooplankton, Southern Indian Ocean.

INTRODUCTION

The food webs of the Southern Ocean have been characterized as high biomass systems (Smith and Nelson, 1985). The long and bright sunny days during the austral summer months trigger off the biological changes in the ecosystem. There is proliferation of phytoplankton population in the nutrient enriched waters resulting in high production at the primary level. This is followed by increase of herbivore zooplankters; the principal organisms being krill (*Euphausia superba*) which, in turn, is predated upon by squids, fishes, birds and whales. General characteristics and distribution of Antarctic plankton have been documented by Voronina (1968) and Voronina and Zadorina (1974).

Several studies were undertaken to evaluate production at different trophic levels since the launching of the first Indian Antarctic Expedition in 1981 (Goswami, 1983; Matondkar and Qasim, 1983; Parulekar and Matondkar, 1987; Mathew and Vincent, 1986; Goes, Fondekar and Parulekar, 1988). Information on chl. *a*, phaeopig-

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ments, environmental features and their relationship to the distribution and abundance of zooplankton is limited (Scientific Report, 1987). The results of the observations made during IXth Indian Expedition to Antarctica are presented in this paper.

MATERIALS AND METHODS

Surface samples were collected for determination of chlorophyll *a*, phaeopigments, zooplankton abundance and environmental parameters at 14 stations (Fig.1). Water samples were collected with Niskin samplers. For estimation of chl *a*, 500 ml of water sample was immediately filtered through millipore filter- paper (47 mm dia. and 0.45 µm poresize). The filter paper was kept in stoppered test tube with 8 ml of 90% acetone. The tube was covered with black cloth and kept in refrigerator for 24

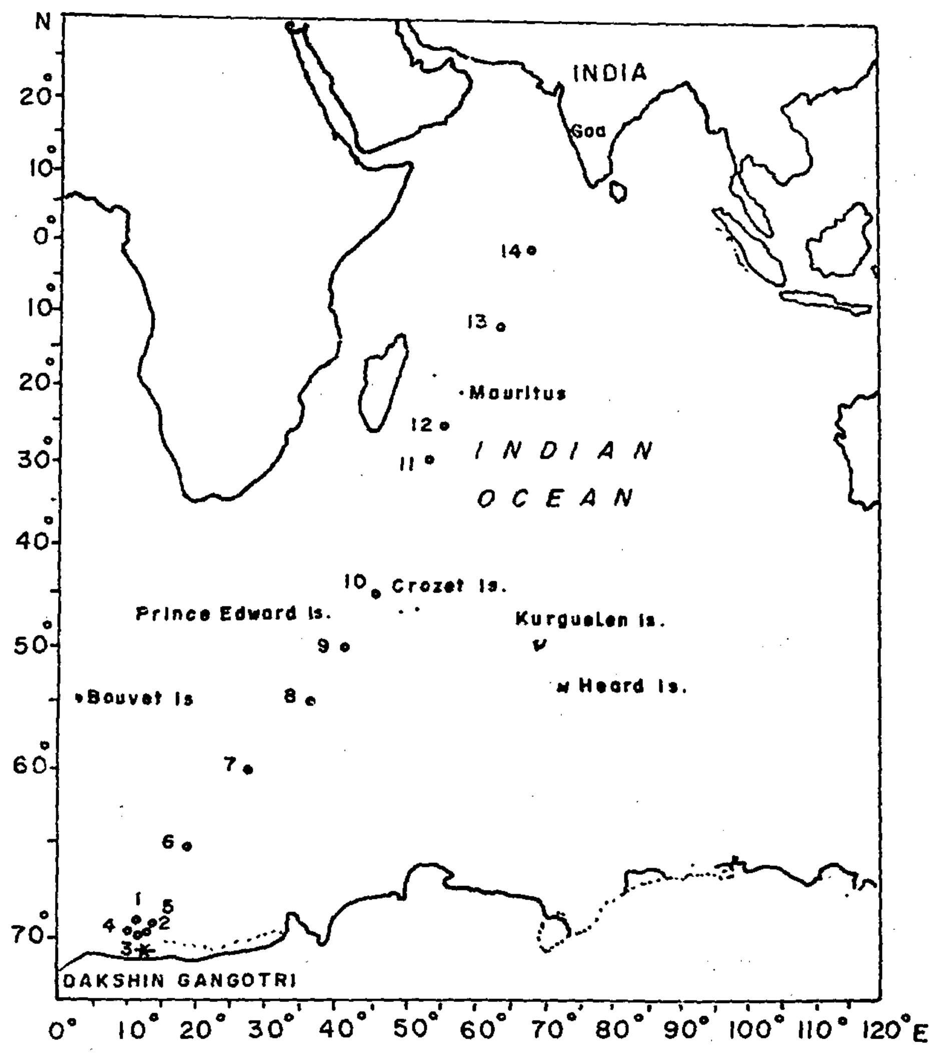

Fig.1. Locations of sampling stations.

hrs. After 24 hrs, 2 ml more acetone was added in the test tube. Observance for different wave lengths were read on spectrophotometer. The analyses of phytoplankton pigments and physico-chemical parameters were done following the standard methods (APHA, 1985). The phytoplankton standing crop was estimated by multiplying the chl *a* values by a factor of 67, assuming that chl *a* constitutes, on the average, 1.5% of the dry weight of organic matter of algae (APHA, 1985).

The zooplankton samples were collected with Heron Tranter net (mouth area 0.25 m^2, mesh size 330 µm) attached with a calibrated flowmeter. The samples were preserved in neutral 4% formaldehyde. Biomass was determined by displacement volume method. Major zooplankton taxa were sorted from aliquots (6-25%). The number of organisms was calculated for the whole sample and computed per 100 m^3. For comparative purpose, the area studied was arbitrarily divided into 3 regions: Polynya (stations 1-5), Antarctic oceanic waters (stations 6-10), and north of the Subtropical Convergence (STC) (stations 11-14).

RESULTS AND DISCUSSION

Hydrography

The surface water temperature increased northwards. The polynya region, near the continental shelf, showed the characteristics of cold (- 0.8 to 2.1°C) and low saline waters (34.10 to 35.57 x 10^{-3}) as a result of melting ice in the ice-edge areas. The Antarctic oceanic waters could be delineated by wider temperature range (- 0.5 to 10.5°C) and low salinity (34.06 to 35.19 x 10^{-3}). The north of Subtropical Convergence (STC) showed sudden rise in temperature (24.5 to 29.5°C) and increase in salinity (35.57 to 36.14 x 10^{-3}). Results in the present study agrees with those reported earlier (Goes, Fondekar and Parulekar, 1988). The surface salinity values obtained during the present study were slightly higher than those reported for the earlier Indian Antarctic Expedition (Matondkar and Qasim, 1983; Scientific Report, 1983; Pant, 1986 and Scientific Report, 1986). The Polynya region showed supersaturated oxygen conditions (9.78 to 11.0 ml l^{-1}) as were reported earlier (Fukuchi, Tanimura and Ohtsuka, 1985; Jehan and Traguer, 1985). The occurrence of high dissolved oxygen content was attributed to diatom bloom. The dissolved oxygen values in the other two areas ranged from 7.72 to 8.24 and 4.12 to 5.66 ml l^{-1} respectively (Table I). It was reported that the large scale upwelling and turbulent mixing in the upper water column in Antarctica kept the nutrients high in all seasons (Smith and Nelson, 1985). The nutrient concentrations, especially of nitrate, were observed to be high at all the stations. Significant correlation was found between the distribution of phosphate and nitrates. The average values of PO_4-and NO_3-N for the 3 regions studied were 4.38, 3.08 and 1.09 µmol dm^{-3} and 17.84, 17.14 and 15.65 µmol dm^{-3}, respectively. An average value of PO_4-P and NO_3-N of 1.63 and 21.0 µmol dm^{-3} for a period of 5 years

Table I – Chlorophyll, phaeophytin, zooplankton biomass and physico-chemical parameters of surface waters at different stations during IXth Antarctic Expedition, 1989-90.

St. No.	Date of Collection	Chl *a* (mg m^{-3})	Phaeo-phytin (mg m^{-3})	Zooplankton Biomass (100^{-1} m^{-3})	Temp (°C)	Oxygen (mg l^{-1})	Salinity ($x10^{-3}$)	PO_4-P (µmol dm^{-3})	NO_3-N (µmol dm^{-3})	NO_2-N (µmol dm^{-3})
1	31.12.89	4.75	0.15	-	2.1	9.78	-	-	-	-
2	12.1.90	4.20	0.42	-	1.9	11.0	-	-	-	-
3	31.1.90	6.40	0.32	4.0	-0.8	8.25	34.19	4.82	24.92	3.22
4	19.2.90	3.30	0.36	12.0	-	10.04	35.57	-	-	-
5	24.2.90	2.14	0.58	9.0	-	-	-	3.94	10.82	2.16
6	4.3.90	0.86	0.21	11.0	-0.5	8.24	34.06	3.80	15.18	7.98
7	6.3.90	0.51	0.10	19.0	-0.8	8.24	34.06	3.62	18.20	3.42
8	7.3.90	1.10	0.30	25.0	-	8.24	35.19	2.18	18.90	3.12
9	8.3.90	0.47	0.05	62.2	4.5	8.24	34.43	2.50	12.40	2.10
10	10.3.90	2.10	0.36	13.0	10.5	7.72	34.25	3.30	20.70	1.50
11	14.3.90	0.76	0.38	11.0	24.5	5.66	35.95	1.32	18.18	2.12
12	15.3.90	2.68	0.62	14.4	26.0	4.12	35.76	2.18	12.60	3.64
13	23.3.90	1.98	0.50	3.1	28.0	4.38	36.14	2.20	16.18	2.12
14	23.3.90	1.80	0.30	12.3	29.5	4.63	35.57	-	-	-

was reported by Parulekar and Matondkar (1987). Yet another work (Verlencar, Somasunder and Qasim, 1990) gave the mean values of PO_4-P and NO_3-N for the coastal and oceanic waters south of 67°S lat. to be 1.53 to 1.95 µmol dm^{-3}. Thus the nutrients were not limiting factors in phytoplankton production in the Antarctic waters.

In large part of the ocean including Antarctica it has been hypothesised that iron may be limiting in the standing crop (Pant, 1986; Sayed and Taguchi, 1981; Uribs, 1983, Heywood and Whitaker, 1984). The nitrate-nitrogen values ranged from 1.5 to 7.89 µmol dm^{-3} which observed to be higher, than those reported earlier (Fukuchi, Tanimura and Ohtsuka, 1985; Dhargalkar, 1988).

Chl a and Phaeopigment

Higher levels of chl *a* recorded in the Polynya region indicated very productive watermass near the ice edge.

The distribution of chl *a* showed a gradual decrease from the areas near the ice-zone towards the offshore regions. The concentrations of chl *a* ranged between 0.76 to 6.4 mg m^{-3} with higher values in Polynya near the ice-zone (2.14 to 6.4 mg m^{-3}). Earlier studies (Goes, Fondekar and Parulekar, 1988) indicated low range (0.6 - 3.49 mg m^{-3} for chl *a*). The phytoplankton bloom was mostly composed of *Nitzschia* spp. (Jiyalal, 1993, unpublished). Pant (1986) reported the occurrence of pennate forms, *Fragilaria islandica*, *Navicula* sp., *Thalassiosira* sp., *Biddulphia* sp., *Eucampia* sp., and *Corethron* sp. in the surface water. El-Sayed (1970) observed a massive diatom bloom in the melting pack ice of the western Weddell Sea. Stability of the water column is an important factor in controlling production and bloom formation in Antarctic waters (Sverdrup, 1953). However, the observed low salinity values associated with phytoplankton bloom suggest that the growth of phytoplankton might have been enhanced by the seeding with cells liberated from melting ice and resulting in very high values of chl *a* (Kopczynska and Ligowski, 1985). The concentration of phaeophytin in surface waters ranged from 0.05 to 0.62 mg m^{-3}. The ratio of chl *a* to phaeopigments in the 3 regions (Polynya, Antarctica oceanic waters and north of STC) was found to be 11, 9 and 7 respectively. The relatively higher ratio obtained for the Polynya region could be attributed to the healthy condition of phytoplankton cells.

Zooplankton

The zooplankton biomass in the 3 regions were between 4.0 and 12.0 (Polynya), 11.0 and 62.2 (Antarctic oceanic water) and 3.1 and 14.4 ml 100^{-1} m^{-3} (Subtropical waters) indicated higher zooplankton biomass in the Antarctic oceanic water. As per earlier report (Voronina and Zadorina, 1974) the standing crop of zooplankton ranged from 12 to 17 ml 100^{-1} m^{-3} in the Antarctic zone, whereas the highest density (62.4 ml 100^{-1} m^{-3}) was earlier reported (Goswami, 1983) at the Antarctic convergence. Verlencar, Somasunder and Qasim (1990), indicated that the zooplankton biomass in the region south of 67°S lat. varied from 10.8 to 72.0 and 16.0 to 26.8 ml 100^{-1} m^{-3} at the coastal ice-edge and oceanic stations, respectively. The zooplankton standing stock displayed a negative correlation with surface chl *a* and phaeopigments (Table II) which was similar to earlier findings (Pant, 1986), in the Polynya region. Twenty one zooplanktonic taxa were observed in the surface collections taken at various stations.

Table II – Correlation matrix between zooplankton and other parameters.

Parameters	Zooplankton	Chl *a*	Phaeophytin	Temp.	DO	Salinity	PO_4-P	NO_3-N	NO_2-N
Zooplankton	1.0								
Chlorophyll *a*	-0.463	1.0							
Phaeopigments	-0.608*	0.354	1.0						
Temperature	-0.220	-0.118	0.437	1.0					
Dissolved oxygen	0.295	0.080	-0.696***	-0.446	1.0				
Salinity	-0.372	0.286	0.628*	0.676**	-0.346	1.0			
Phosphate-phosphorus	-0.064	0.223	-0.085	-0.523	-0.053	-0.580*	1.0		
Nitrate-nitrogen	-0.069	0.124	-0.093	-0.218	0.149	-0.264	0.775***	1.0	
Nitrite-nitrogen	-0.048	-0.161	-0.169	-0.320	0.126	-0.452	0.611*	0.475	1.0

* significant at 5% level; ** significant at 2% level; *** significant at 1% level.

Table III – Occurrence of common groups of zooplankton (no. 100^{-1} m^{-3}) in surface hauls at different stations.

Groups	STATIONS											
	3	4	5	6	7	8	9	10	11	12	13	14
Copepods	407	531	1301	1204	1025	8370	14259	4679	4537	6883	2324	4136
Euphausiids	0	0	0	0	0	3037	3210	346	123	29	10	0
Decapods	49	110	824	56	217	1037	1383	110	111	186	18	74
Chetognaths	0	0	0	10	25	296	1383	25	543	67	25	12
Polychaetes	0	358	839	100	117	49	494	37	49	37	12	110
Ostracods	0	0	0	0	6	0	1679	37	25	123	10	10
Gastropods	49	12	12	12	10	49	456	148	25	111	46	10
Amphipods	0	37	49	46	10	49	148	148	222	86	6	25
Salps Doliolids	12	37	0	123	0	0	49	0	10	12	0	210
Siphonophores	0	0	0	0	6	0	23	46	25	284	0	37
Hydromedusae	12	45	77	0	0	0	124	0	0	10	0	46
Others	112	49	148	30	46	308	1728	43	46	62	31	25
Total Population	641	1179	3250	1581	1462	13195	24936	5619	5716	7890	2482	4695

The copepods were numerically the most abundant (68.38%) followed by euphausiids (9.30%) and other groups. The distribution of the most common groups at various stations (Table III) indicated the higher abundance of euphausiids at St. 8 & 9. The faunal groups which occurred sparsely were grouped together and given as others. These groups were foraminiferans, cirripede, cladocerans sergestids, pteropods, appendicularians, phyellosomes, stomatopods, fish eggs and fish larvae. Copepods were reported (Fukuchi, Tanimura and Ohtsuka, 1985) as the dominant taxon of zooplankton community in Antarctica. On the other hand, the radiolarians were reported to be outnumbered the copepods in the Antarctic convergence region. The euphausiids formed a major constituent of the zooplankton with the dominance of krill (*E. superba*) (Mathew and Vincent, 1986), in the Southern Ocean south of the Antarctic Convergence. The chaetognaths were moderately represented but the polychaetes were invariably present in all the samples collected. Polychaetes occurred in large numbers in Polynya which was also supported by earlier reports (Mathew and Vincent, 1986). Amongst the other groups, the appendicularians, fish eggs and fish larvae were quite common, albeit obtained in small numbers. The appendicularians showed gradual increase in population at stations located in the Polynya region. The fish eggs and fish larvae were comparatively more abundant in Antarctic Oceanic waters. Their maximum abundance was recorded at St. 9. Highest population density of copepods (1.4×10^4 individuals 100^{-1} m^{-3}) was also recorded at this station. Twenty five copepod species were observed in the collections (Table IV). The copepod species diversity was lowest in Polynya and the zooplankton samples comprised mostly of copepods of *Calanus* sp., *Eucalanus* sp. and *Oithona* sp. The occurrence of copepods indicated the initial increase and growth phases of copepods. The calanoid copepods, *Paralabidocera antarctica* is endemic to Antarctic coastal waters (Fukuchi, Tanimura and Ohtsuka, 1985) and played an important role in energy transfer in these waters. The number of copepod species increased in Antarctic oceanic waters. The calanoid copepods such as *Calanus simillimus, Calanoides acutus, Rhincalanus gigas, Clausocalanus* sp. and *Oithona* sp. were common. The copepods population towards north of STC consisted mostly of tropical species of *Eucalanus, Euchaeta, Lucicutia, Candacia, Pleuromamma* and *Oncaea*. The absence of euphausiids in Polynya region was probably due to their avoidance of dense diatom bloom. However, they were invariably present in the samples from the other two regions. Maximum population

Table IV – Distribution of copepod species at different stations.

	STATIONS											
Species	3	4	5	6	7	8	9	10	11	12	13	14
Calanus simillimus	-	-	-	-	+	+	+	+	+	-	-	-
Calanus species	+	+	+	+	-	-	-	-	-	-	-	-
Calanoides acutus	-	-	-	+	+	+	+	+	-	-	-	-
Eucalanus elongatus	-	-	-	-	-	-	-	-	-	-	-	-
E. species	+	+	-	+	+	-	+	+	-	+	+	+
Rhincalanus gigas	-	+	-	-	+	+	+	+	-	-	-	-
R. nasutus	-	-	-	-	-	-	-	-	-	-	-	+
Microcalanus species	-	-	+	-	-	-	-	-	-	-	-	+
Clausocalanus species	-	-	+	+	-	+	+	+	-	-	-	+
Spinocalanus species	-	-	-	-	-	-	-	-	-	+	-	-
Pseudocalanus species	-	-	-	-	-	-	-	-	+	+	-	+
Centropages calaninus	-	-	-	-	-	-	-	-	-	-	-	+
Haloptilus species	-	-	-	-	-	-	-	-	+	+	-	+
Calanopia species	-	-	-	-	-	-	-	-	-	-	-	+
Scolecithrix species	-	-	-	-	-	-	-	-	-	+	-	+
Luciculia species	-	-	-	-	-	-	-	-	+	+	-	-
Euchaeta species	-	-	-	-	+	+	+	+	+	-	-	-
Candacia species	-	-	-	-	-	+	-	-	-	+	+	+
Metridia species	-	-	-	-	-	-	-	-	-	+	-	-
Pleuromamma indica	-	-	-	-	-	-	-	-	+	+	-	+
P. abdominalis	-	-	-	-	-	-	-	-	+	+	-	+
P. gracilis	-	-	-	-	-	-	-	-	+	+	-	+
Oncaea species	-	-	-	-	-	+	+	+	+	+	-	+
Oithona similis	-	-	-	-	-	-	-	+	+	+	-	-
Oithona species	+	-	-	-	+	+	+	+	+	+	-	-

– Absent; + Present.

Table V – Average values of various factors at the different regions studied.

Region	Chl *a* (mg m^{-3})	Chl *a* / Phaeophytin	Standing crop (mgC m^{-3})	Zooplankton Biomass (ml. $100^{-1} m^{-3}$)	No of Zooplankton Taxa
Polynya	4.16	11	279	8.33	9
Antarctic Oceanic waters	1.01	9	68	26.04	21
North of Subtropical Convergence (STC)	1.80	7	121	10.2	18

density was in the Antarctic Oceanic waters, contributing to the higher average zooplankton biomass values (Table V). The larvae of *Euphausia superba* were common (Hubold, Hempel and Meyer, 1988). The krills alone wouldn't solve the mysteries of the Antarctic ecosystem (Hubold, 1967). The detailed studies on energy flow through pico-nanoplankton, microzooplankton, larger zooplankton including krills and carnivores would go a long way towards a better understanding of Antarctic marine ecosystem.

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