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Phytoplankton Ice-edge Blooms in the Marginal Ice Zone at Princess Astrid Coast in Antarctica

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Abstract

Daily variation in sea surface temperature at the ice edge zone in Antarctic polynya during austral summer from 25th December 1991 to 25th February 1992, showed that the values did not exceed 0°C. Isotherms and isohalines showed vertically homogeneous profile during major part of the season. Nitrate, phosphate and silicate remained high. The ratio of SiO_3:NO_3:PO_4 was 5:12:1.The hydrographical features, the vertical profiles of nutrients and high SiO_3:PO_4 ratio suggest that the surface waters are continuously enriched by bottom silicates resulting out of vigorous mixing of different water masses in these coastal waters.

Chlorophyll *a* showed frequent occurrence of blooms with upto 3.68mg m^{-3} . The linear regression of chl *a* with NO_3, PO_4 and SiO_3 showed significant negative correlation suggesting active utilization of nutrients by phytoplankton. Size classification of phytoplankton showed that microplankton (>20 µm) populations dominated the bloom conditions and nanoplankton (5 to 20 µm) prevail the non-bloom periods while the picoplankton (<5 µm) constituted a minor fraction during most of the period.

Weekly changes in phytoplankton showed inverse relationship with zooplankton. Spiral and straight chains of *Fragilaria striatulla, F.cylindrus, Nitzschia closterium* and *N.seriata* were abundant during bloom. Copepods dominated the zooplankton. Increase in euphausiids on 31st December were responsible for reduction of the phytoplankton crop. Species distribution showed that herbivore zooplankters dominated the phytoplankton bloom periods while carnivores during non-bloom periods. The results suggest that while mixing processes are prominent the active growth of phytoplankton and zooplankton provide sufficient food for the proliferation of euphausiid crop.

Introduction

The abundance of krill populations *(Euphausia superba Dana)* are extremely variable in Antarctic waters (Priddle et al., 1988). Waters near Princess Astrid Coast have especially been productive as regards to the krill populations. Although many factors such as temperature, current flow, water mixing, etc.

may be important in determining the abundance of krill, the availability of food sustenance is a pre-requisite to maintain the vigorous feeding populations.

Since phytoplankton is the major food reservoir for krill, it is important to assess the biomass, size distribution and floristic composition. In some environments large content of algal cells are observed in bottom ice and ice-water interfacial assemblages which may be important as food resources for consumers in water column (Demers et al.,1986, Runge et al.,1991, Tourangean and Runge,1991). In both, the Antarctic (Garrison et al.,1987) and Arctic (Schandelmeir and Alexander, 1981) similarities between species from the ice and the water column have sometimes been observed which show possible role of ice algae in seeding phytoplankton spring blooms (Kuosa et al.,1992 and El-Sayeed,1988). In this communication the seasonal progression of phytoplankton patterns will be examined with regard to the prevailing hydrographic conditions in the polynya at Princess Astrid Coast, and the possible role of zooplankton organisms during austral summer - December 1991 to February 1992.

Material and Methods

Water samples for surface chlorophyll (Chl *a*), Phaeophytin (Phaeo) and temperature were obtained daily from. a single station near the ice edge in Antarctic polynya from 25th December 1991 to 25th February 1992. In the vertical water column, water samples were collected twice a week at series of standard depths upto 500 metres for nutrients, primary production and related parameters. Niskin sampler of 5 L capacity was used to collect sea water samples. Salinity was measured using Autosal. Nitrates, phosphates and silicates were estimated using standard methods described by Grasshoff (1976). Chi *a* and Phaeo were measured fluorometrically using Turner design Fluorometer (Strickland and Parsons, 1972). Primary productivity (PP) was measured using radioactive bicarbonate (Strickland and Parsons, 1972) in 1 ml quantities of 5pCi $NaH^{14}CO_3$ in 125 ml subsamples of sea water. Incubations were done in a flowing sea water deck incubator under natural light with neutral density filters to give appropriate percentages of surface light to the samples. Samples were incubated from 4 to 24 hours and filtered. Phytoplankton samples were collected in plastic bottles, preserved with formalin - lugols solution and counted under inverted microscope. Zooplankton samples were obtained by vertical haul from 150 m depth upto surface using Heron Tranter net of 0.25m mouth area. The samples collected were preserved in 5% formaldehyde. Biomass was determined by displacement - volume method. An aliquot of 10 to 25 % was examined for enumeration of common taxa. The number of organisms was calculated for the whole sample.

Results

Temperature in surface waters in polynya showed fluctuations in day to day values in December-January but remained steady for 2 to 3 days period in February (Fig 1). In general, the surface temperature did not exceed 0°C while the lowest recorded value was - 1.6°C (Table I). The water column was vertically homogeneous from surface to bottom (200 m depth) both in December and February while weak thermal stratification prevailed in January (Fig 2a). Temperature in the near bottom waters usually remained much lower than the surface waters with values of -1.3°C and below. Surface salinity fluctuated from a low of 33%*o* to a high 35.06%*o*. Low surface salinity was usually associated with the increase in temperature (Fig 2b). Isohaline in vertical column showed weak salinity stratification in January and February with an increase in values towards bottom.

Nitrate in surface waters was quite high ranging from 6.4 to 14.9 µM (Table I). The highest NO_3 concentrations were found around 13th January (Fig 2c). In the upper 5 metre water column, NO_3 values decreased sharply. However, below this depth the concentrations were uniformly high upto the bottom with patchy occurrence at some occasions. As seen with nitrate, the phosphate

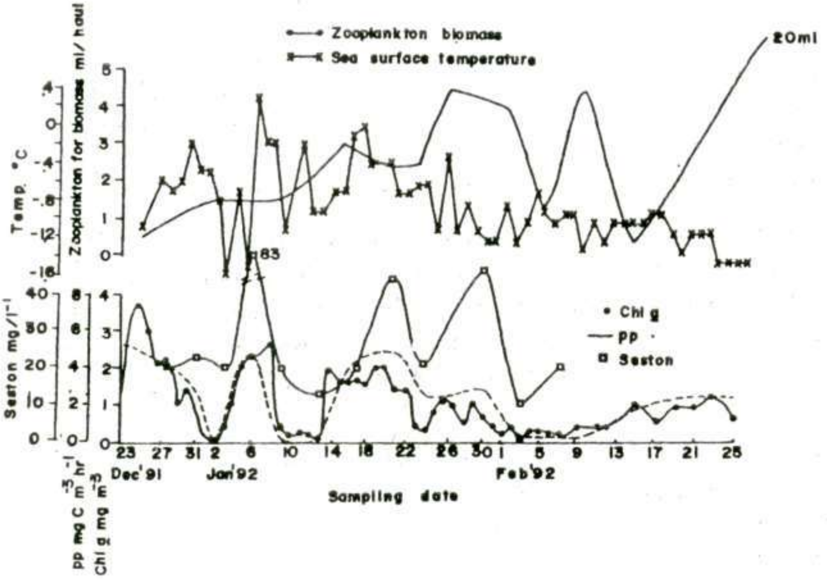

Fig 1 : Daily variation in sea surface temperature (°C) and chlorophyll a(Chl; mg^{-3}) in relation to primary productivity (pp; mg m^{-3} hr^{-1}), Seston (mg $[^{1}$) and zooplankton biomass (ml per haul; 150 m depth to surface) from December 23 J99J to February 25,1992 in Antarctic polynya.

concentrations were also high in surface waters ranging from 1.14 to 1.57 µM (Fig 2d). In the euphotic water column at 75 m depth, the PO_4 concentration was uniformly high with occasional patches of low and high content. Silica concentration was high throughout the course of sampling. The surface values fluctuated widely ranging from 26.28 to 53.02 µM (Fig 2e). The vertical distribution showed three distinct features. In the beginning of summer (December-January), the silicate isolines were patchy. These turned to be vertically homogeneous decreasing to low on 21st January. The SiO_3 values increased again to a high of 50 µM and above showing weak stratification in February.

Chlorophyll a showed highly pulsating values in the surface layers during December and January (Fig 1). The highest peak was observed on 25th December with Chl a concentration of 3.68 mg m^{-3} (Table I). The successive peaks decreased exponentially upto the end of January. The increase in Chl a was also evident in the second half of February after a short spell of steady low values. As in surface waters, the pulses of Chl increase were also seen in the vertical water column (Fig 3a). The higher Chl a was restricted to water column below surface between the depths of 10 to 50 m during December and January while in February, homogeneously low values prevailed. In the disphotic zone 200 m and below, Chl a was much lower than in the upper water column.

Phaeophytin in the surface waters was low with a mean value of 0.25 mg m^{-3} . This value was 4 fold lower than the chlorophyll content (Table I). The change in phaeophytin coincided with that of Chl a. Peaks of phaeo in the vertical water column followed those in the surface waters (Fig 3b). However, the higher values were generally restricted to subsurface depths.

The primary productivity (PP) values ranged from 0.1 to 5.2 mg cm^{-3} hr^{-1} during 3 months sampling period (Table I). The PP also followed the pattern of Chl a distribution with pulsating values in December-January and uniformly low levels in February (Fig 1). The changes in surface water were reflected well in the water column, the higher PP values being generally restricted between 5 to 25 m depth (Fig 3c).

Seston in surface water showed three peaks during December- January (Fig 1). The values ranged from 10.5 to 83.8 mg 1^{-1} . The highest seston content was seen on 6th January when Chl a and phaeo also attained peak level. During most of the sampling period, the vertical profile showed homogeneous values, except on 6th January, when high seston was confined to upper 25 m depth (Fig 3d). Phytoplankton cell counts in the surface waters ranged from (0.6 to 4.64) x 10^5 cells 1^{-1} (Table I). Fragilaria striatula, Nitzchia chlosterium were the dominant phytoplankton organisms during bloom as well as the rest of the period (Table II). The other forms such as Navicula sp., Rhizosolenia sp„

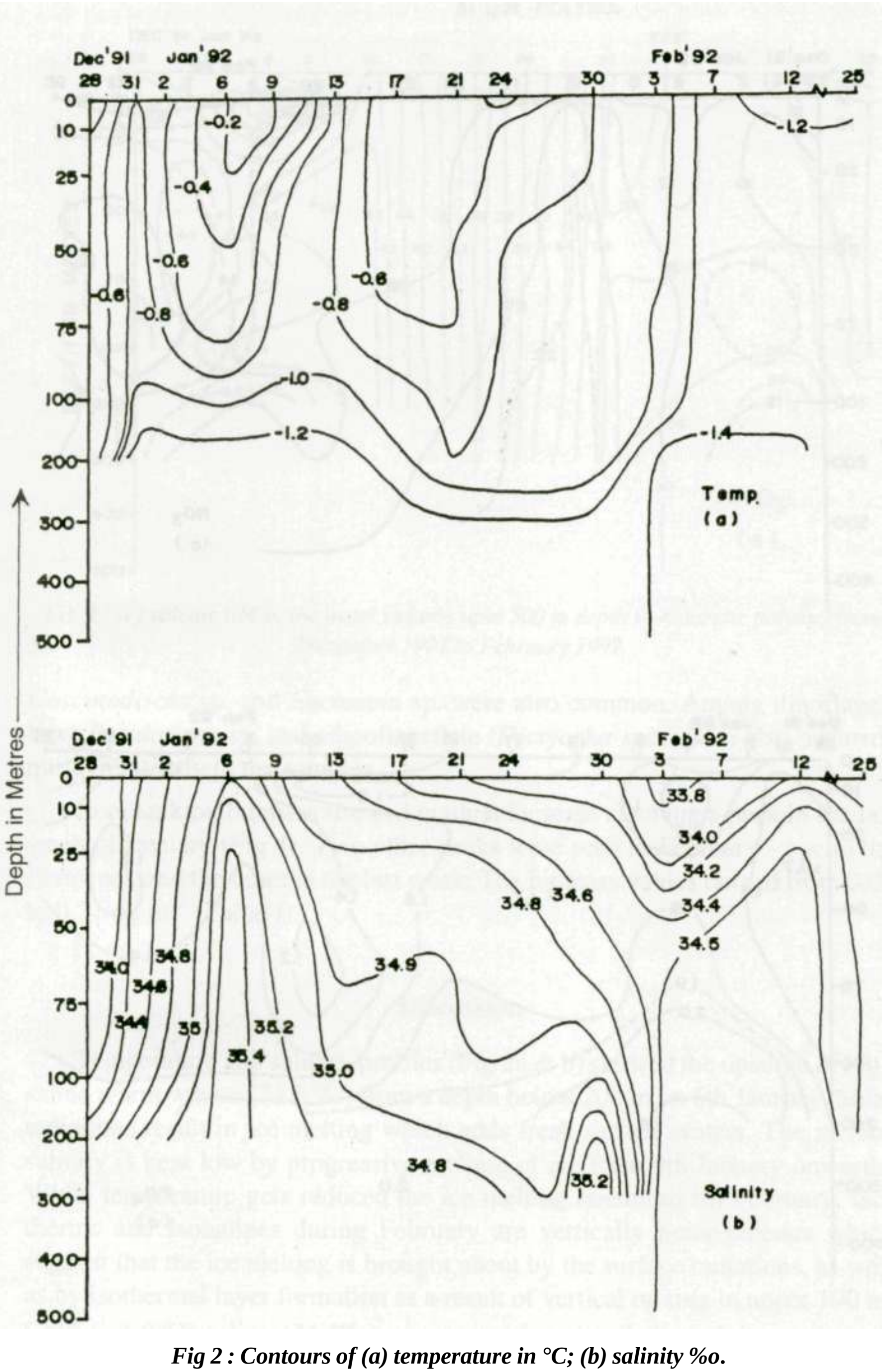

Fig 2 : Contours of (a) temperature in °C; (b) salinity %o.

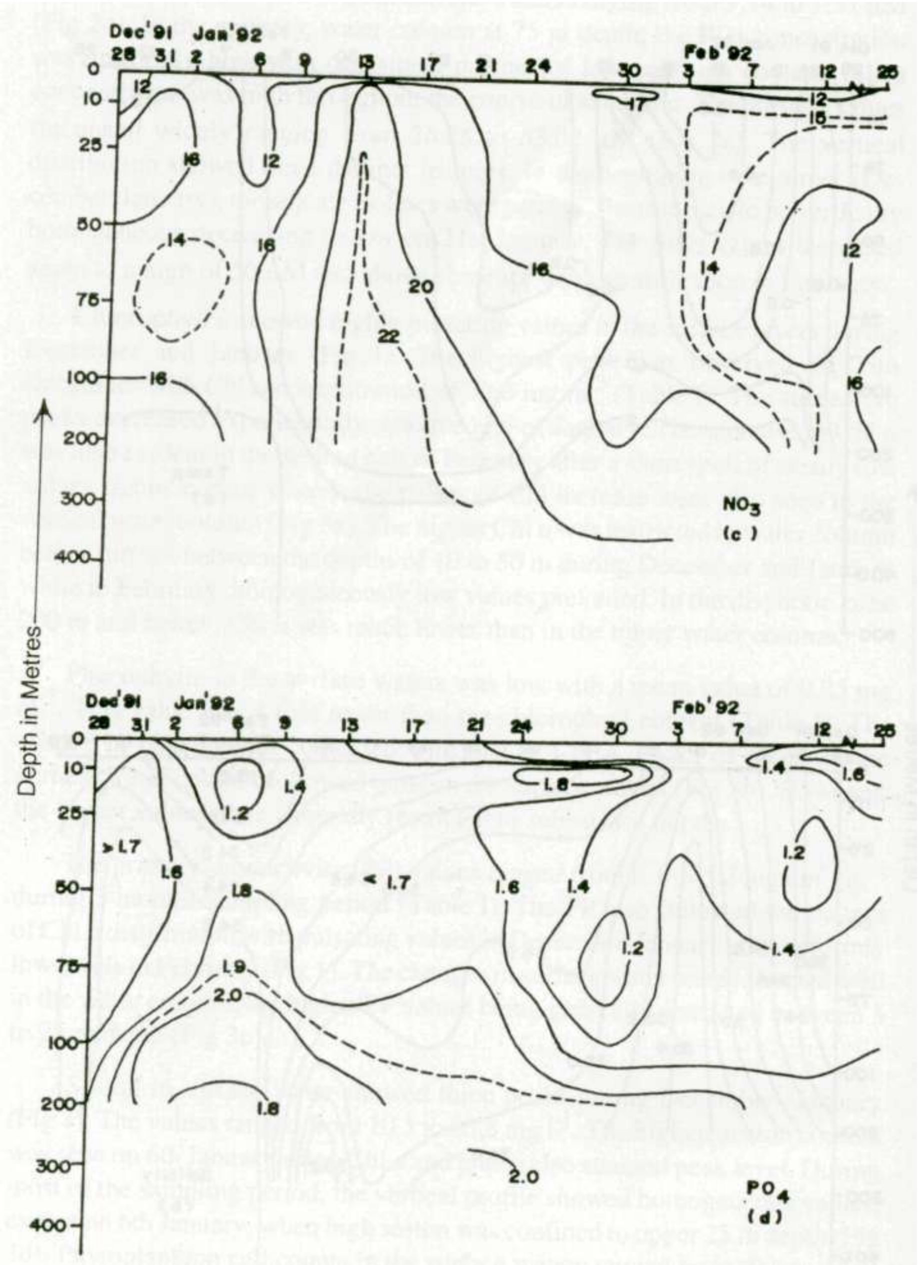

Fig 2 : (c) nitrate µM; (d) phosphate µM

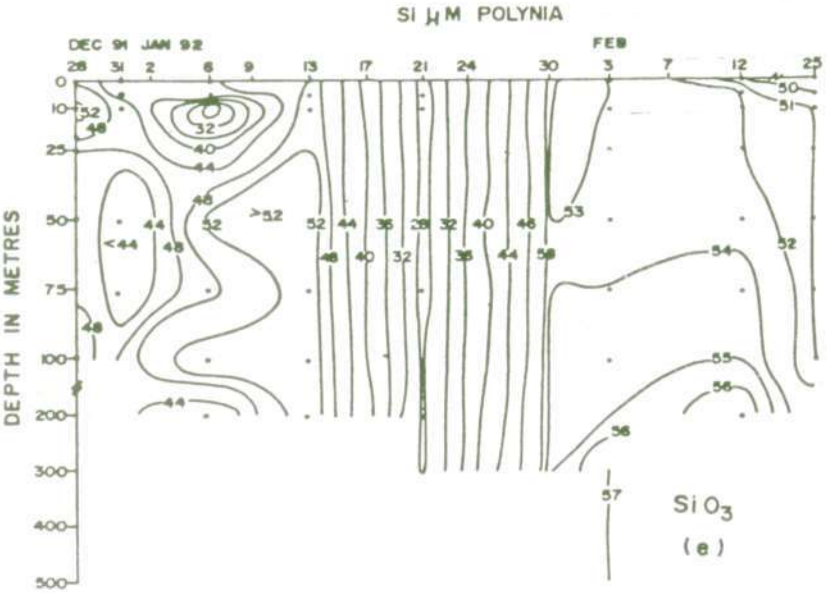

Fig 2 : (e) silicate µM in the water column upto 500 m depth in Antarctic polynya from December 1991 to February 1992.

Coscinodiscus* sp. and *Eucampia* sp. were also common. Among dinoflagellates *Peridinians* sp. and silicoflagellate *(Dictyocha speculum)* also occurred quite frequently in the samples.

Zooplankton biomass showed gradual increase reaching a peak in the last week of January (Fig 1). Two other peaks were seen in February - one in the first week and the other in the last week. The biomass values ranged from 0.02 to 0.21 ml m^{-3} (Table I).

Discussion

Temperature and salinity profiles (Fig 2a & b) showed the upsurge of high saline warm waters (34.6 %.) from a depth below 200 m on 6th January. Solar radiations result in ice melting which adds fresh surface waters. The surface salinity is kept low by progressive melting of ice from 9th January onwards. While temperature gets reduced the ice melting continues till February. Isotherms and Isohalines during February are vertically homogeneous which suggest that the ice melting is brought about by the surface radiations, as well as by isothermal layer formation as a result of vertical mixing in upper 100 m. Cold (-1.0°C) saline (34.6%o) waters are found in bottom layers on some occasions (Muench and Flusby,1986, Amos,1987 and Amos et al.,1990). Each

Table I: Maximum, Minimum and Mean of Different Physical, Chemical and Biological Parameters in Surface Water

	Minimum	Maximum	Mean	SD±	n
Temperature (°C)	-1.6	00.00	-0,75	0.39	53
Salinity *(%o)*	33.01	35.06	34.092	0.54	09
Nitrate (µM)	06.42	14.91	10.26	02.9	09
Phosphate (µM)	01.14	01.57	01.36	00.13	09
Silicate (µM)	26.28	53.02	45.02	07.9	09
Chlorophyll *a* mg m^{-3}	00.09	03.68	01.02	00.83	56
Phaeophytin (mg m^{-3})	00.00	00.72	00.25	00.2	53
PP(mg Cm^{-3} hr^{-1})	00.1	05.2	02.18	01.95	14
Seston (mg 1^{-1})	10.5	83.8	28.41	20.5	12
Zooplankton biomass ml m^{-3} of water	00.02	00.21	00.08	00.05	14
Phytoplankton cells x 10^5 l^{-1}	00.11	04.64	01.65	01.13	27

PP= primary productivity

of these water masses influencing the water column is reflected in the occurrence of nutrients. In December and the beginning of January, the circulation is sluggish and the nutrients are high in subsurface layer. However, during the rest of January and February, the vertical circulation was prominent giving rise to homogeneous nutrient patterns. This is well depicted by silicate (Fig 2e). The upsurge of nutrient rich bottom waters is seen by phosphate isolines on 6th January but the abundance of nitrates (Fig 2e) in the entire water column is an important phenomenon indicating active mixing processes.

Utilisation of nutrients by phytoplankton could also be reflected in the ratio of occurrence of nitrate, silicate and phosphate. The regression of NO_3 vs. PO_4 and SiO_3 vs. PO_4 were 11.8 and 4.9 respectively. Compared to Redfied; the higher SiO_3/PO_4 ratio could indicate the continuous replenishment of these nutrients from bottom waters and that the utilisation by siliceous diatoms was high (Verlencar et al.,1990).

Chl *a* values showed high correlation with surface temperature.

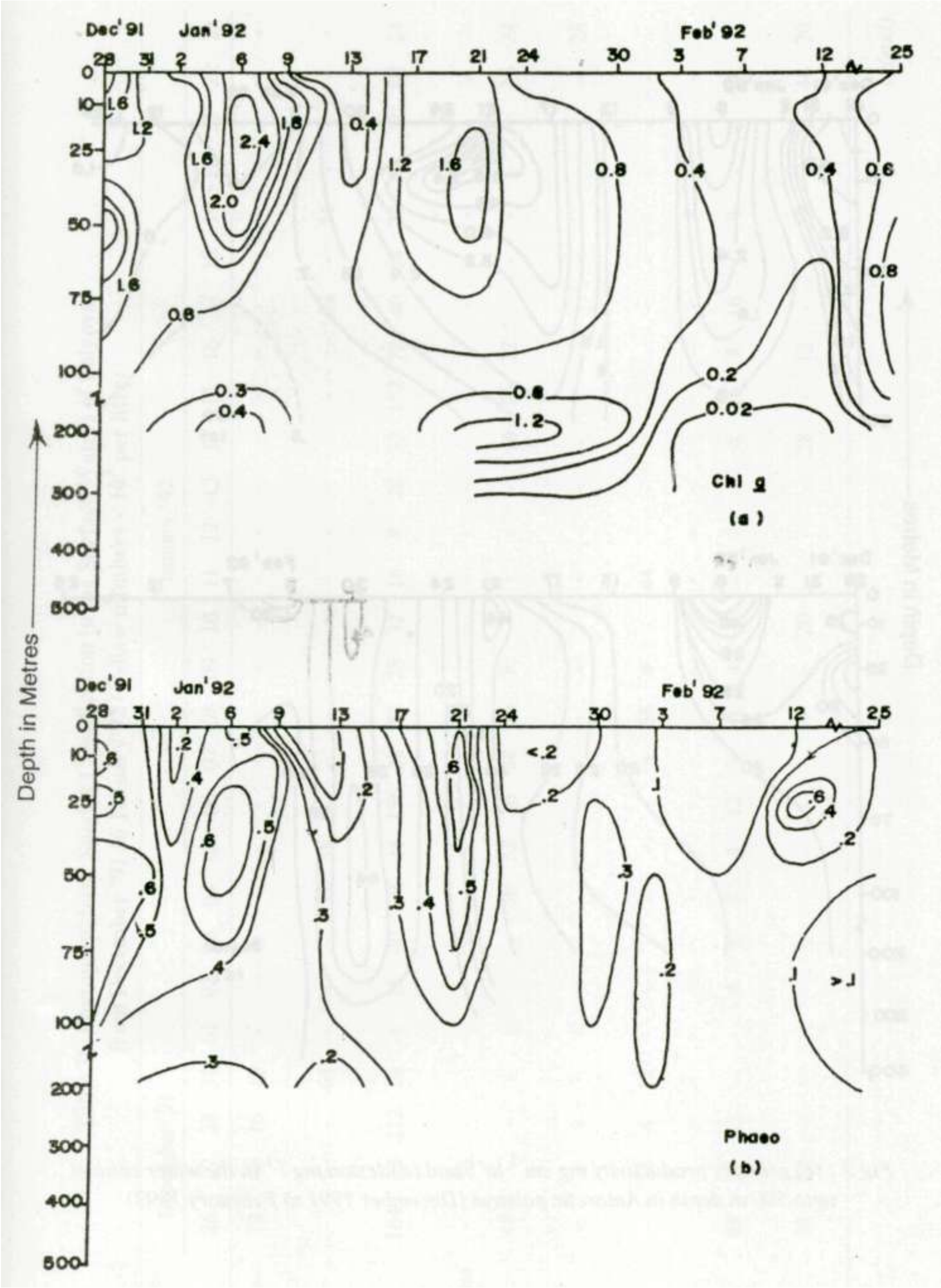

Fig 3 : Contours of (a) chlorophyll a mg m^{-3}; (b) phaeophytin mg m^{-3}

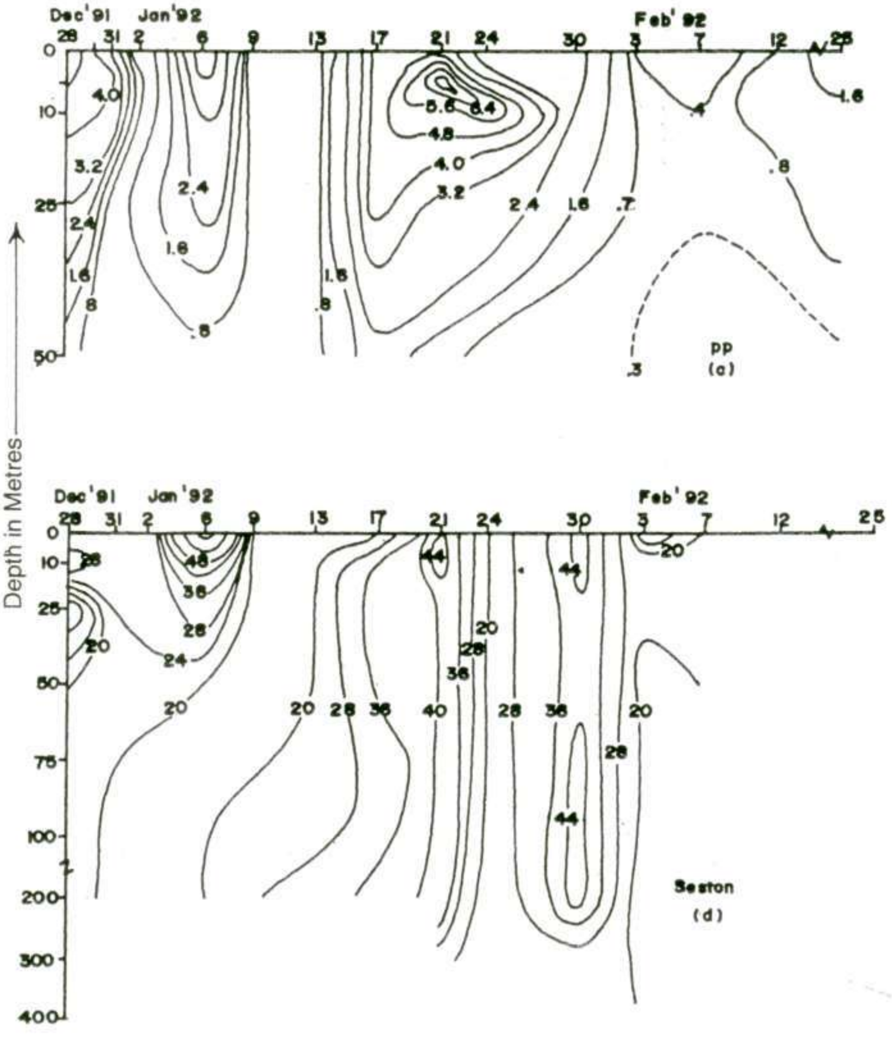

Fig 3 : (c) primary productivity mg cm^{-3} hr^{-1} and (d) seston mg [^{1} in the water column upto 500 m depth in Antarctic polynya (December 1991 to February 1992)

Table II: Phytoplanktonic Species Classification in the Surface Waters of Polynya from December '91 to January'92 (Cells = numbers x 10^3 per litre)

Month &	December '91				January '92																						
Date	26	27	28	31	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fragilaria crotonenses	72	40	16	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fragilaria islandica	-	-	-	68	-	-	-	32	38	-	-	-	-	-	-	-	-	-	-	-	32	-	56	-	-	-	-
Fragilaria striatula	104	32	112	16	4	16	40	128	24	156	28	52	28	32	16	8	20	32	152	72	40	68	24	48	32	68	24
Fragilaria nana	-	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fragilaria cylindrus	48	-	-	-	-	-	-	56	32	76	28	16	8	-	-	-	-	16	16	22	-	-	-	-	-	16	24
Fragilaria blandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28
Fragilaria sp.	-	28	4	12	-	-	-	-	-	-	8	36	4	-	44	-	-	-	-	-	-	-	-	-	-	-	-
Amphora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
Nitzschia clostarium	88	28	52	-	-	4	8	8	4	12	-	4	4	-	-	-	-	4	16	8	16	-	8	-	4	4	4
Nitzschia seriate	32	60	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	28	-	12	-	-	28	-	-	44	20

(contd).

Table II — *contd.*

Nitzschia sp.	4	20	4	4	-	-	-	4	-	-	4	-	-	12	-	16	4	-	-	4	4	-	2	8	12	28	4
Navicula vannoffeni	16	16	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.	8	12	4	4	0.4	-	4	16	4	4	8	8	8	4	8	4	4	8	8	8	8	12	8	8	4	8	4
Schroderella sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	4
Cosinodiscus granni	-	-	-	-	-	-	-	4	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cosinodiscus sp.	4	12	4	8	-	-	-	-	-	8	8	-	16	12	8	8	4	-	-	-	4	8	-	4	4	8	4
Cosinodiscus centralis	-	-	-	-	4	4	8	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thalassiosira sp.	16	8	8	4	-	4	4	4	-	-	12	-	16	-	-	4	-	4	-	-	-	8	4	-	4	4	-
Thalassiothrix sp.	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thalassiothrix frauenfeldii	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lauderia gracialis	16	16	40	-	-	-	-	8	-	-	-	-	-	-	-	-	-		-	-	-	-	-	16	-	-	-

contd.

Table II — *contd*

Leptocylindrus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	20	-	-	-	-	-	-	-	-	
Rhizosolenia cylindrus	8	16	108	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhizosolenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	-	-	-	-	-	-	4	
Chaetoceros curvicetus	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chaetoceros sp.	-	-	24	-	-	-	60	-	-	-	-	-	-	-	-	-	8	36	8	-	-	-	-	-	16	-	
Chaetoceros janischianus	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Corethron sp.	-	4	8	-	-	-	-	4	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	
Climacodium sp.	-	-	-	8	-	-	-	-	-	4	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Actinocyclus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	
Eucampia zodiacus	-	-	16	-	0.8	-	16	-	-	-	-	-	-	8	8	8	12	8	-	-	-	-	-	16	-	-	
Biddelphia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	

contd.

Table II — *Contd.*

Guinardia flaccidor	–	–	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
***Nelosira* sp.**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–
***Ceratulina* sp.**	–	–	–	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	4	–	–
***Diplonsis* sp.**	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dinoflagelate Peridinium sp.	8	8	8	-	0.4	4	4	4	8	4	4	-	4	8	4	4	4	-	4	4	4	8	-	8	4	4	_
Unidentified	–	–	–	–	–	–	–	–	–	–	–	4	8	-	4	-	-	-	4	4	4	-	-	4	4	–	–
Silicoflagellate *Dictyocha speculum*	–	–	4	–	–	–	4	–	–	–	–	–	4	12	-	8	8	4	4	4	-	-	4	4	–	8	4
Blue green algae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–	–	–	–	–	–
Unidentified	8	12	12	12	1.2	4	-	12	12	-	-	8	4	16	12	4	8	4	12	4	8	8	-	12	20	8	12
Total	432	384	464	164	11	36	172	284	120	268	100	136	108	120	108	68	60	142	70	172	100	148	160	168	104	232	124

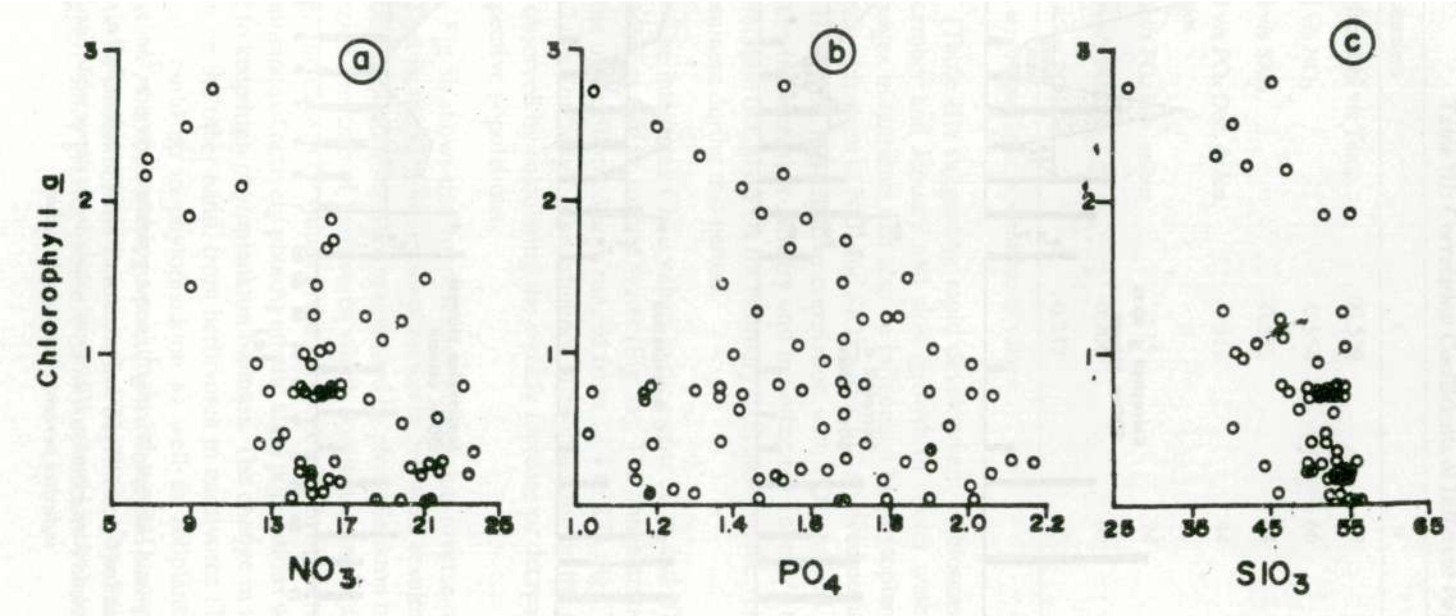

Fig 4 : Graph showing relation of chlorophyll a mg m^{-3} with (a) nitrate, (b) phosphate and (c) silicate in µM *in the euphotic water column upto 100 m depth*

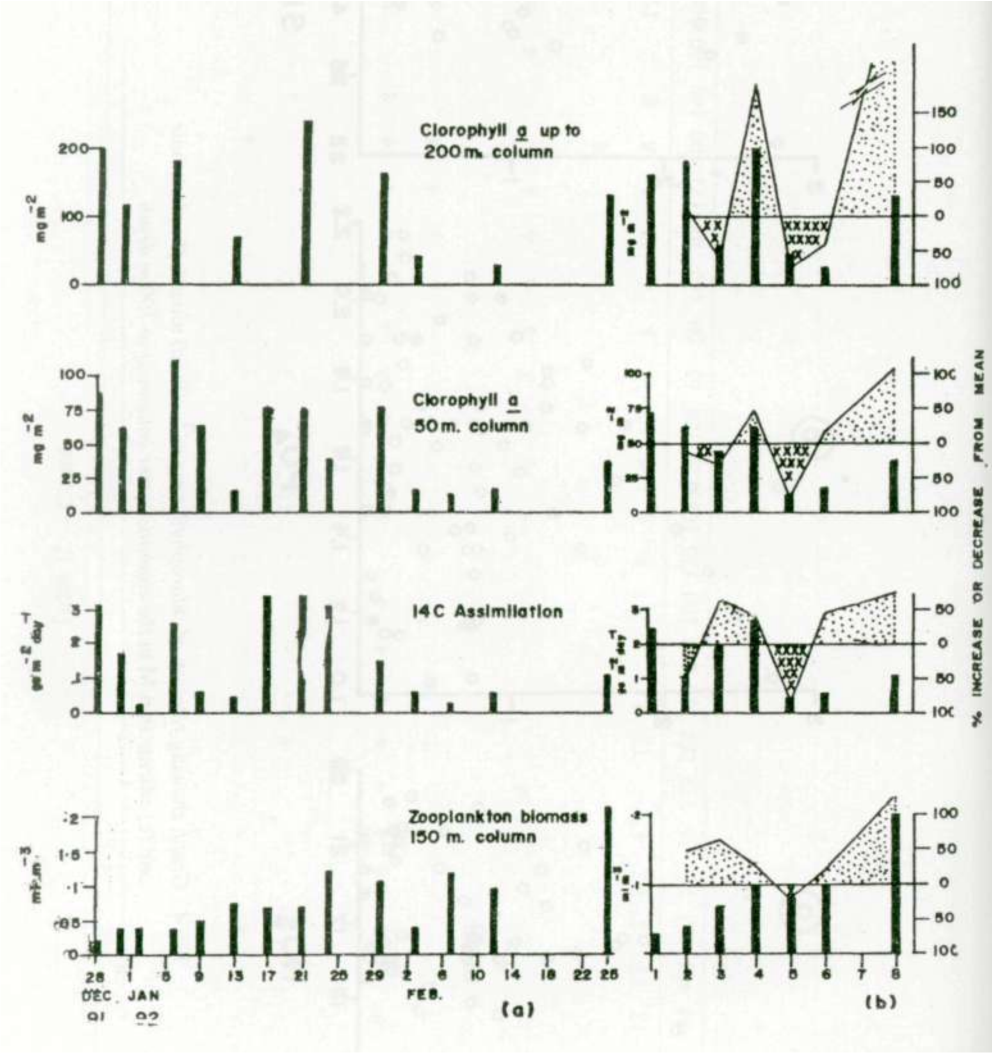

Fig 5 : (a) Integrated chlorophyll a (mg^{-2}); primary productivity (g cm^{-2} hr^{-1}) and zooplankton biomass (ml [^{1}); (b) Weekly increase and decrease in chlorophyll a, primary productivity and zooplankton biomass. Histogram values are as above while lined graph indicates percent change in the values

Table III: Correlation Coefficients of Different Parameters

Parameters	r	n	P<
Surface Chl v/s Temp.	00.529	49	0.001
Chl v/s NO_3	-0.554	66	0.001
Chl v/s $Si0_3$	-0.592	64	0.001
Chl v/s PO_4 Dec. & Jan. values	-0.511	44	0.001
Chl v/s $P0_4$ Feb. values	-0.15	24	NS
NO_3 v/s PO_4	0.706	65	0.001
$Si0_3$ v/s PO_3	0.232	65	0.1

NS = not significant; n = number of values

(Table III) suggesting rapid development of blooms in warm waters in December and January and slow growth in cooler waters during February. Changes in nutrients can also be influenced by phytoplankton crop. Thus the linear regression of NO_3 and SiO_3 with Chl *a* showed negative correlation (Fig 4). However, the negative correlation with PO4 showed two slopes- one for values in December-January and the other for February (Table III). The low correlation of Chl a/PO_4 for February indicates that the vertical mixing is more prominent during this period.

The integrated Chl *a* values in the upper 50 m and 200 m showed similar patterns as that of surface water (Fig 5a). The concentrations of Chl *a* and PP in the upper 50 m column ranged from 12.4 to 238 mg Chl *a* m^{-2} and 0.21 to 3.47 mg Cm^{-2} day^{-1} . The influence of zooplankton on the phytoplankton could be observed by calculating the weekly increase or decrease in biomass of the respective populations.

Fig 5b shows that zooplankton biomass has inverse relationship with Chl *a.* That is, the increase in zooplankton in 3rd week resulted in decrease in Chl *a.* Bloom conditions were maintained by phytoplankton organisms, in spite of grazing pressure of herbivores which dominated in the first 4 weeks. Moreover, increase in PP values in the 3rd week in spite of decrease in Chl a showed dominance of actively photosynthetic algal populations which were responsible to keep high phytoplankton biomass. The change in zooplankton population on the other hand, from herbivores to carnivores (Table IV), led to the steady build up in phytoplankton as well as zooplankton from 5th week onwards, thereby reaching a peak in the 8th week. Occurrence of phaeophytin peaks in December and January when herbivore population was high, further suggest heavy grazing pressure on phytoplankton. The low phaeopigments in

Table IV: Occurrence of Common Zooplankton Taxa (No. 1000 m^{-3}) in Polynya during Summer 1991-92

Date of Collection

	December' 91		January '92								February '92			
Groups	28	31	02	06	09	13	17	21	24	30	03	07	12	25
Medusae	27	27	27	00	160	160	53	27	81	54	27	83	160	1227
Siphonophores	00	00	00	00	00	00	53	53	80	27	53	80	427	160
Ctenophores	00	00	00	53	133	187	27	240	53	27	00	00	00	00
Polychaetes	27	80	27	53	320	853	1067	1146	1306	1413	1513	1890	2613	3467
Copepods	8642	9227	9893	10933	15200	16320	15680	14933	47493	53066	71466	84053	109333	137333
Euphausiids	267	826	53	27	53	00	00	00	82	133	53	160	213	186
Amphipods	00	00	00	00	00	00	00	00	00	00	27	81	00	133
Appendicularians	27	27	80	133	53	240	347	560	1413	1920	2613	3386	4026	4746
Gastropods	00	27	53	00	293	133	53	00	81	133	53	27	320	1653
Chaetognaths	00	00	00	00	53	133	133	107	240	80	133	27	53	107
Fish larvae	00	00	27	00	27	27	00	133	00	00	00	27	133	240
Others	53	27	81	53	27	27	53	27	81	107	53	133	187	53

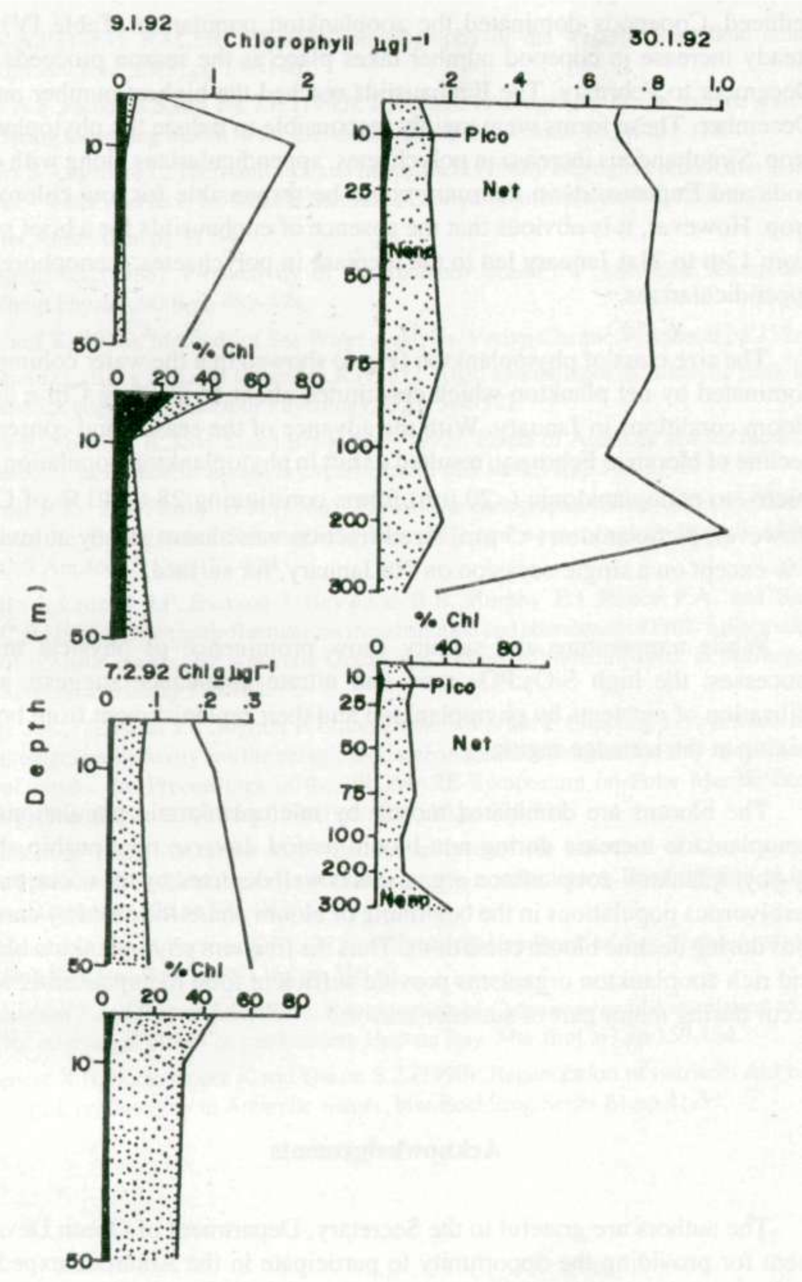

Fig 6 : Size classification of phytoplankton biomass (chl a) at different depths in mg m-3 and percent fractions 20 µM, microplankton, 5 to 20 µM, nanoplankton and 5 µM, picoplankton.

February is in support of the fact that the herbivores activity was relatively reduced. Copepods dominated the zooplankton population (Table IV). The steady increase in copepod number takes place as the season proceeds from December to February. The Euphausiids reached the highest number on 31st December. These forms were mainly responsible to reduce the phytoplankton crop. Simultaneous increase in polychaetes, appendicularians along with copepods and Euphausiids in February could be responsible for low chlorophyll crop. However, it is obvious that the absence of euphausiids for a brief period from 13th to 21st January led to the increase in polychaetes, ctenophores and appendicularians.

The size class of phytoplankton (Fig 6) showed that the water column was dominated by net plankton which constituted about 56 to 93 % Chl *a* during bloom conditions in January. With the advance of the season and consequent decline of bloom in February, resulted a shift in phytoplankton population from micro- to nanoplanktonic (<20 µm) forms constituting 28 to 40 % of Chl *a*. However, picoplankton (<5 µm) sized fraction was almost steady at less than 6 % except on a single occasion on 9th January, for surface.

While temperature and salinity show prominence of physical mixing processes, the high $Si0_3$:P04 ratio and nitrate abundance suggests active utilisation of nutrients by phytoplankton and their replenishment from bottom mixing at the ice edge region.

The blooms are dominated mostly by microplanktonic populations and nanoplankton increase during non-bloom period. Inverse relationship shown by phytoplankton-zooplankton organisms is well depicted by the occurrence of herbivorous populations in the beginning of bloom phase followed by carnivorous during decline bloom conditions. Thus the frequent phytoplankton blooms and rich zooplankton organisms provide sufficient food to euphausiids which occur during major part of summer season.

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References

Amos A.F(1987): RACER : Physical oceanography of the western Bransfield strait. U.S.Ant.Jour.,22(5),pp 137-140.

Amos A.F.,Jacobs S.S.and Hu J.H.(1990): RACER : Hydrography of the surface waters during the spring bloom in the Gerlache strait. U.S.Ant.Jour.,25,pp 131-134.

Demers S.,Legendre L.,Therriault J.C. and Ingram R.G.(1986): Biological production at the ice - water interface. In: Marine Interfaces Ecohydrodynamics (ed.J.C.J.Nihoul).

Elsevier,Amsterdam,pp 31-54.

El Sayeed S.Z.(1988): Productivity of the Southern Ocean : a close look. Comp.Biochem.Physiol,,90:B,pp 489-498.

Grasshoff K.(1976): Methods of Sea Water Analysis. Verlag Chemie,Weinheirn,pp 317.

Garrison D.L.,Buck K.R.and Fryxell G.A.(1987): Algal assemblages in Antarctic pack ice and ice edge plankton. Jour.Phycology,23,pp 564-572.

Kuosa H.,Norrman B.,Kivi K.and Brandini F.(1992): Effect of Antarctic sea ice biota on seeding as studied in aquarium experiments. Polar Biol., 12,pr, 333-339.

Muench R.D. and Flusby D.M.(1986): Physical oceanographic observation, Antarctic Marine Ecosystems Research in the ice edge core program,March 1986. U.S.Ant.Jour.,21,pp 127-128.

Priddle J.,Croxall J.P.,Everson I.,Heywood R.B.,Murphy E.J.,Prince P.A. and Sear C.B.(1988): Large scale fluctuations in distribution and abundance of krill - a discussion of possible causes. In: Antarctic Ocean and Resource Variability (ed. D.Sahrhage). Springer,Berlin,pp 170-182.

Runge J.A.,Therriault J.C.Ingram R.G.and Demers S.(1991): Coupling between ice microalgal productivity and the pelagic food web in southeastern Hudson Bay: a synthesis of results. In: Proceedings of the PROMARE Symposium on Polar Marine Ecology ,Trondheim 12-16 May 1990,Polar Res., 10,pp 325-338.

Schandelmeir L.and Alexander V.(1981): An analysis of the influence of ice on spring phytoplankton population structure in the southeastern Bearing Sea. Limnol.Oceanogr., 26,pp 935-943.

Strickland J.D.H.and Parsons T.R.(1972): A Practical Handbook of Sea Water Analysis. Bull.Fish.Res.Bd.Can.,No.l67,pp 310.

Tourangean S.and Runge J.A.(1991): Reproduction of *Calanus gracialis* in relation to an ice microalgal bloom in southeastern Hudson Bay. Mar.Biol.,63,pp 159-164.

Verlencar X.N.,Somasunder K.and Qasim S.Z.(1990): Regeneration of nutrients and biological productivity in Antarctic waters. Mar.Ecol.Prog.Series 61 ,pp 41 -59.