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Studies on Antarctic Phytoplankton

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ABSTRACT

Ice-edge data from a single polynya station at 70°S 11°E over a 2-month period is assessed in relation to previously published work in similar environments. The phytoplankton community seems to be composed of 2 quite different elements, the first from ice-algae released by melting and the second consisting of planktonic algae. Biomass measured as chlorophyll a, ATP & cell counts is discussed in relation to primary production and doubling rates.

INTRODUCTION

Earlier studies in the Antarctic have suggested that ice-algae contribute substantially to biomass in these regions (Bunt and Wood, 1963). During spring blooms, Palmisano and Sullivan (1983), have shown that these biomass levels may be quite high and Bunt (1963) has suggested that ice-melt results in addition of this community to the marine environment leading to marked population increases.

The data presented here was collected during a 2 month stay at the ice-edge at 70°S 11°E from December, 1983 to March, 1984. The results suggest that two entirely different biotopes may be described in Antarctic ice-edge ecosystems, one comprising of ice-algae and the other of wholly marine phytoplankton with possibly quite different life cycles and physiology.

MATERIAL AND METHODS

Sea-water samples were collected using 51 Niskin samplers in series. The euphotic depth was calculated from the depth of disappearance of the Secchi disk at local noon. In most cases the euphotic depth was 30 m except on the 15th of January when it was 27 m. A minimum of three depths were sampled within the euphotic column at 100%, 60% and 1% of surface irradiance. Below this zone samples were collected at 40m, 50m, 75m, 100m, and 150m as time permitted. On several occasions, the 30% and 16% depths were also sampled within the euphotic zone.

Chlorophyll a, Particulate Oxidizable Carbon and ATP were determined on one litre each of sea-water filtered at a negative pressure not exceeding 50 mm Hg. Where filtration rates were slow, due to high particulate matter, less water was filtered. Sterilized Millipore(R) membrane filters of 0.45µ porosity were used for ATP determination. Whatman GF/C filters were used for chlorophyll and pre-fired filters of the same brand were used for POC determinations. The further processing of the samples was done according to Strickland and Parsons (1972). Chlorophyll *a* and phaeophytin were estimated on Turner(R) Fluorimeter. ATP was measured as photons emitted by the Luciferin-Luciferase system on an SAI(R) Photometer after extraction in Trisbuffer. POC was determined by wet oxidation with dichromate. The latter samples were assayed as a batch at NIO, Goa. All other estimates were made on board the ship.

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Carbon assimilation was measured using radioactive bicarbonate (Steemann Nielsen 1952 Strickland and Parsons 1972) in 1 ml quantities of 5µ Ci NaH^4C0_3 in 125 ml subsamples of sea water. Incubations were done in a flowing sea water (Maximum temperature - 1 0) deck incubator under natural I ght with neutral density filters to give appropriate percentages of surface light to the samples. The samples were incubated upto four hours and filtered. The 0 45 μ membrane filters used for the purpose of filtration were exposed to HCl fumes for two min and put into 4 ml of liquid Scintilla tion cocktail (Beckman Unisolv(R) for subsequent counting in a Packard(R). Scintillation counter Results are expressed as $mgC/m^3/nr$ or $gC/m^2/day$ Nitrite-N Nitrate N Phosphate-P and Silicate-Si were estimated according to the procedures given by Grasshoff (1976). Carbonate alkalinity was calculated from pH measurements and salinity was measured as conductivity. Temperature in the water column was measured using reversing protected and unprotected Golha(R) thermometers on the sampling bottles.

RESULTS

Chlorophyll *a*

Chlorophyll *a* ranged from 0 2µ g/l to 8 0µ g/l within the euphotic zone. The arithmetic mean of the column chlorophyll *a* content in the euphotic zone for the period 1 st January 1984 to 29th February 1984 is 39 15 mg m^2 and is substantially higher than the offshore mean value of 9 6 mg m^2 calculated from data collected on a north bound transect (Fig 1). In the ice edge region (table 1) the January average for chlorophyll *a* is 45 0 mg m^2 which is significantly higher than the February average of 26 8 mg m^2 chlorophyll *a.* The maximum concentration of chlorophyll *a* was generally found at 10 to 20 m depths at the ice edge station (approximately 25% lo) in the 30 m euphotic zone (Fig 2) although a substantial amount of chlorophyll *a* occurred below the 1% lo depth down to 100 m in the 210 m water column. Sub euphotic depth chlorophyll *a* in some case equalled the euphotic values (table 2) although the phaeophytin concentrations were higher.

TABLE 1

Euphotic column data for biomass and production at a single station on the Antarctic ice edge

Date of sampling 1984	*Chl a* mg/m^2	*ATP* mg/m^2	*PP* $gC/m^2/day$
1 Jan	51 6	35 3	1 85
2 Jan	49 0	57 1	0 4
5 Jan	43 5	14 0	0 94
7 Jan	13 0	13 5	1 13
9 Jan	34 4	49 1	0 26
11 Jan	21 0	89 4	0 06
13 Jan	19 0	45 4	0 36
15 Jan	118 8	99 7	2 3
27 Jan	32 5	24 0	0 31
31 Jan	15 0	10 0	0 11
6 Feb	17 0	19 0	0 66
8 Feb	45 2	45 9	1 48
12 Feb	26 1	55 4	1 1
16 Feb	37 8	18 3	0 34
29 Feb	7 9	1 5	0 01

Although the mean chlorophyll *a* concentration in January was greater than in February the standard deviations about these means were high (+75%) indicating considerable day to day variation in the samples during both months (Fig 3). Peak chlorophyll *a* concentrations occurred on the 15th January with a 20 m high of 7 8 µ g/l and on the 8th of February with concentrations upto 4µ g/l in the euphotic zone. On most other occasions the range was between 0 5 to 2µ g/l. The lowest value of 0 2µ g/l was recorded at the end of February.

Adenosine triphosphate (ATP)

ATP values ranged from 0 25 to 6 0µ g/l during the study near the ice edge. The fluctuations in ATP were similar to those of chlorophyll *a* (Fig 3) and there was a substantial amount of ATP from sub euphotic depths (Table 1). The regression of ATP on chlorophyll a was significant ($r = 0\ 61$ $n = 70$ $P < 0\ 001$) and it appears that most of the ATP was of phytoplankton origin.

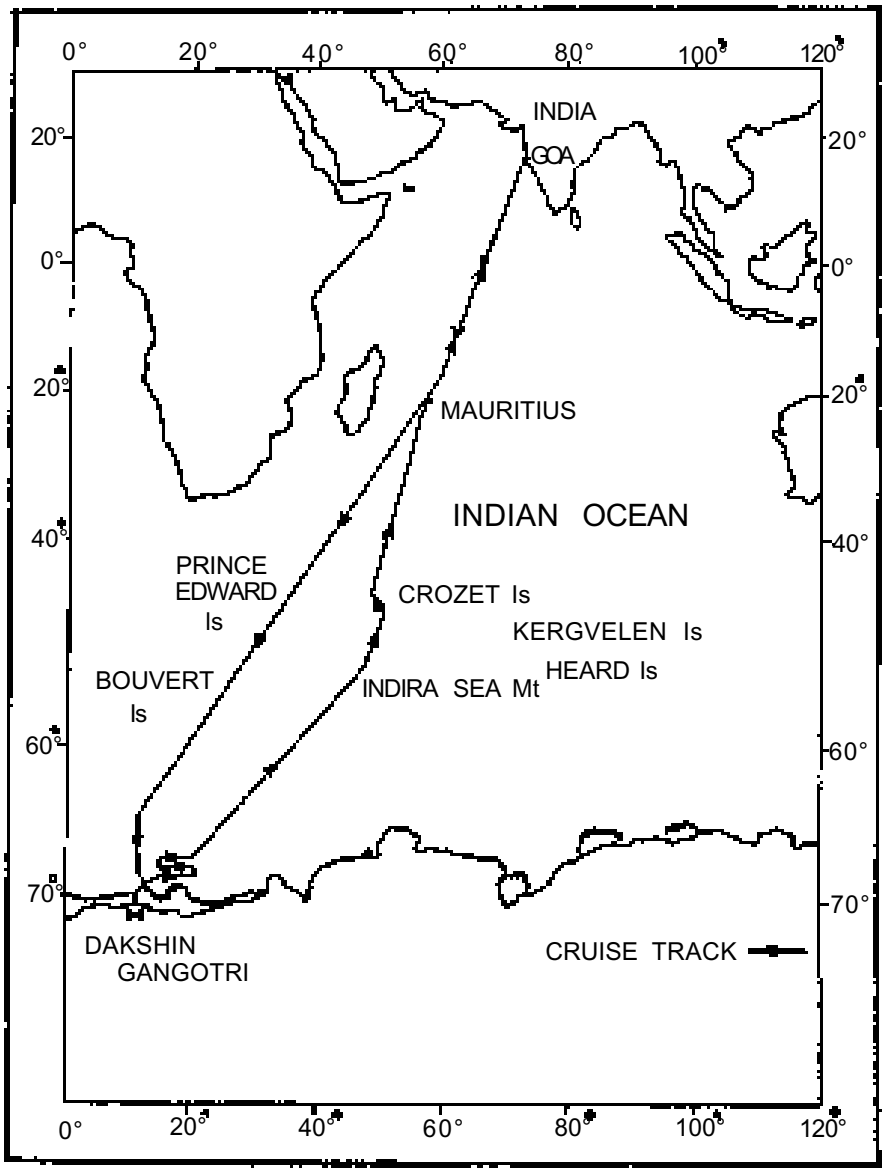

Fig 1 Cruise track

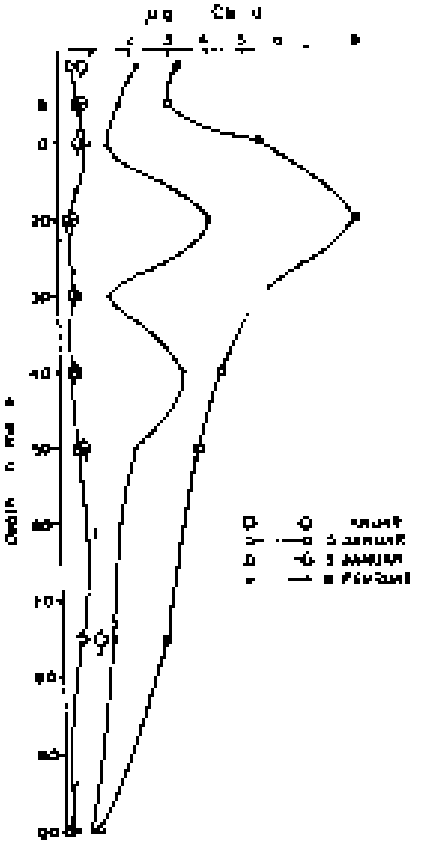

Fig 2 Chlorophyll distribution in the water column

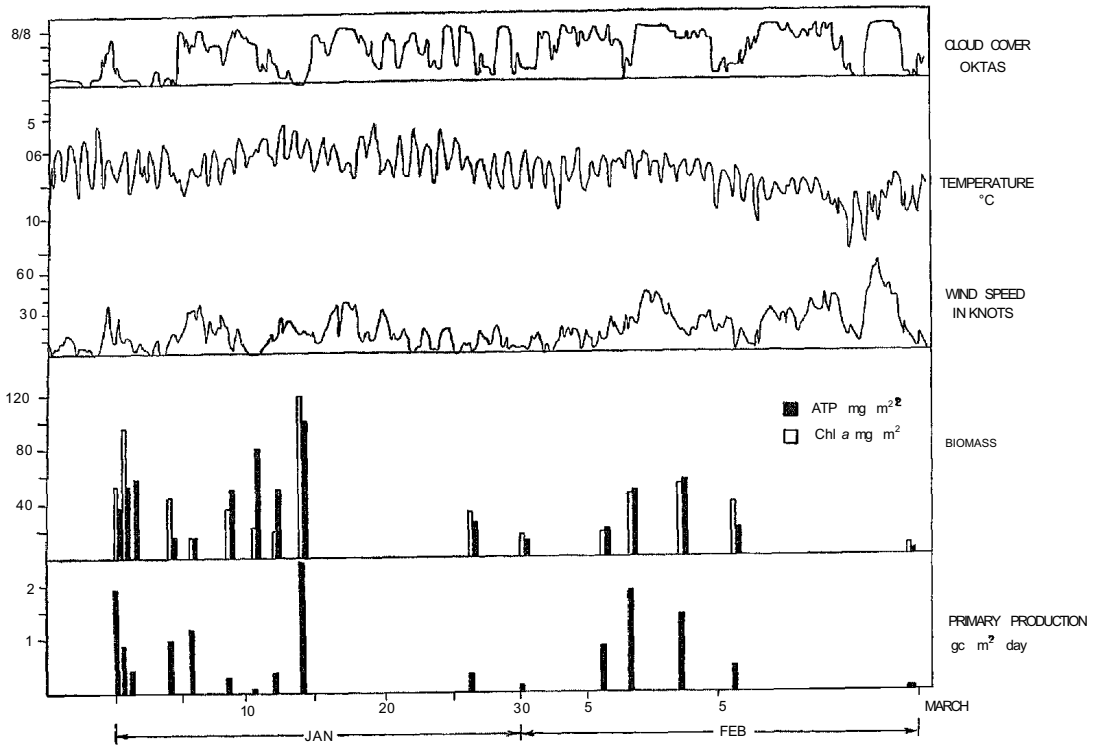

Fig 3 Biomass variations in the Euphotic Zone Primary Production and Meteorological Data Third Antarctic Expodition

Primary Production

The variation in primary production near the ice edge evidently depends on both biomass and ambient light as is to be expected under the experimental conditions. The average primary production near the ice edge is 0 66 gCm ^{2} day ^{1} as compared to 0 058 gCm ^{2} day ^{1} in the offshore areas. Although values as high as 1 8 gCm ^{2} day^{-1} have been recorded on two days both in January and February near the ice shelf production is not consistently high and values of 0 06 gC and 0 11 gCm ^{2} day^{-1} have also been noted (Table 1). The lowest primary production of 0 01 gCm ^{2} day ^{1} was recorded on the 29th of February underneath new platelet ice.

On bright days with less than 50% cloud cover production per unit chlorophyll *a* was highest at the 5 m depth (60% Io) within the euphotic zone and it appears that on these occasions there was surface inhibition of primary production by light (Table 3).

Samples from depths 1% Io greater than 30 m when incubated at surface light intensity show substantial primary production (Table 4) the chlorophyll *a* from these depths seems to be viable. When filtered through a 20 µ mesh net prior to incubation both chlorophyll *a* and primary production in the filtered samples formed 46% and 42% of total production. The percentage contribution to primary production of the smaller phytoplankton increases with depth (Table 5).

TABLE 2

Chlorophyll a and ATP data expressed as weighted means within and below the euphotic depth of 30 m

Date	Euphotic zone (1) 0 —30 m		Below euphotic zone (2) 30—70 m		Euphotic zone (1) 0—30m	Below euphotic zone(2) 30—70 m
	Chl a	Phaeo pigments	Chl a	Phaeo pigments	ATP	
7 Jan	0 515	0 55	0 69	1 41	0 54	1 22
15 Jan	5 48	1 13	3 3	1 9	3 13	ND
31 Jan	0 48	1 7	0 48	2 27	0 79	ND
8 Feb	2 27	1 09	1 52	2 7	1 76	1 05

$$\frac{Xb + Xa}{2} \qquad \frac{Zb - Za}{30} \qquad (1)$$

$$\frac{Xb + Xa}{2} \qquad \frac{Zb - Za}{70} \qquad (2)$$

TABLE 3

Surface inhibition of primary production

Date of sampling	Production / chl. a/hr 0 m	5 m	30 m
1 Jan.	1.3	2.98	0.14
5 Jan.	0.72	1.8	0.5
15 Jan.	0.36	1.21	0.6
8 Feb.	1.3	2.4	0.54
29 Feb.	0.05	0.07	0.03

TABLE 4

Primary productivity in sub euphotic depth samples All incubations at full surface light intensity

Depth	PP $mgC/m^3/hr.$			
	7th Jan.	15th Jan.	31st Jan.	8th Feb.
0	1.6	1.14	0.1	2.3
5	2.1	0.6	0.13	3.2
10	1.5	0.5	0.04	1.9
20	2.1	0.6	0.04	1.9
30	1.3	0.2	0.02	2.6
40	1.5	0.1	0.03	2.8
50	--	0.3	0.03	1.8
75	2.0	0.10	0.06	0.7
100	0.2	0.002	0.02	0.9

TABLE 5

Contribution of organisms less than 20 μ to phytoplankton assays in the neritic Antarctic

Date	Depth	Chl a μg/l		ATP μg/l		PP μgC/l/hr	
		Whole	20 μ mesh filtered	Whole	20 μ mesh filtered	Whole	20 μ mesh filtered
10-1-84	0	2 34	0 63	2 0	0 64	2 0	0 24
	5	3 69	1 1	1 9	0 5	1 8	1 2
	30	2 7	0 72	3 1	1 36	0 25	0 06
13-1-84	0	0 24	0 045	1 8	0 56	0 79	0 21
	5	0 18	0 18	1 7	0 5	0 61	0 31
	30	1 26	0 5	2 7	1 2	0 3	0 21
12-2-84	0	0 54	0 27	2 58	0 67	0 5	0 1
	5	1 35	0 36	1 6	0 22	2 3	0 3
	30	0 54	0 36	0 5	0 33	1 65	0 41

Cell counts

Microscopic examination of samples of vertical tows using a 20 μ mesh net showed that pennate forms *Fragilaria islandica* and *Navicula* sp were present in all the samples examined Slendoid diatoms *Thalassiosira* sp *Biddulphia* sp *Eucampia* sp and *Corethron* sp were also present in 500 ml sedimented whole water samples and the counts are given in table 6. Total cell counts varied from 3×10^5 cells/l on the 15th of January to 1×10^3 cells/l at the end of February. The increase in *Fragilaria* can be traced from the 7th to the 15th of January when it represented 92% of the population declining thereafter to the 31 st of January when it formed about 2% of the total samples. In early February net samples *Thalassiosira* sp was dominant.

Nutrients

Nutrient concentrations near the ice shelf were high during both January and February. No_3-N ranged from 19 6 to 20 9 μg-at/l $P0_4$-P from 1 6 - 2 3 μg-at/l and $Si0_4$-Si from 56 7 to 58 1 /ug-at/l. It is unlikely that these nutrients at least limited phytoplankton production and growth in the study period. There was a slight decrease in nitrate concentrations from the surface to 20 m congruent to the subsurface chlorophyll *a* maximum. The euphotic depth calculated from the depth of disappearance of the Secchi disk was 30 m except on the 15th January. The biomass of phytoplankton was high on this date and the euphotic depth shallowed to 27 m. On the few occasions that it was possible to invetigate T-S profiles ♂t varied between 27 4 to 27 7 from the surface to 200 m there was no marked thermocline or pycnocline.

TABLE 6

Cell counts and major species in euphotic depth

Date	*Depth*	*Log_{10} cells/l*	*Fragilaria islandia*	*Thalassiosira sp.*	*Navicula sp*	*Remainder*
1	*2*	*3*	*4*	*5*	*6*	*7*
01-1-84	0	3 4770	7%	23%	3%	67%
	5	3.4770	47%	23%	9%	21%
	35	3.7000	38%	27%	9%	24%
02-1-84	0	4.7800	50%	28%	2%	20%
	5	4.7000	72%	7%	15%	6%
	30	3.0000	NR	36%	9%	55%
05-1-84	0	4.4100	82%	7%	14%	4%
	5	3.6000	37%	13%	37%	13%
	30	3.9000	69%	27%	NR	4%
07-01-84	0	3.4800	NR	21%	NR	79%
	5	3.3000	6%	NR	6%	..
	30	3.6000	7%	47%	2 5%	43%
09-1-84	0	4.5180	36%	1%	45%	18%
	5	4.0400	72%	4%	7%	20%
	30	4.2000	55%	NR	13%	32%
13-1-84	0	4.7600	87%	3%	4%	6%
	5	4.1800	74%	8%	5%	13%
	30	3.9500	57%	21%	1%	21%
15-1-84	0	5.5200	92%	6%	1%	1%
	5	5.2200	83%	4%	12%	1%
	30	4.5300	98%	1%	NR	1%
27-1-84	0	3.9000	69%	16%	NR	15%
	5	3.4100	58%	38%	NR	4%
	30	No sample	-	.	..	
31-1-84	0	4.0800	23%	49%	2%	26%
	5	3.8400	10%	33%	NR	57%
	30	3.7000	4%	31%	4%	61%
16-2-84	0	3.3000	35%	25%	10%	30%
	5	3.0000	46%	8%	NR	46%
	30	3.3000	32%	32%	NR	36

DISCUSSION

The average biomass of phytoplankton near the ice edge is 42 mg m ^{2} ATP three times higher than off shore values of 14 mg m ^{2} ATP in the euphotic zone south of the convergence. There is a four fold difference in chlorophyll *a* values in the two environments. The average primary production is 0 76 gC m ^{2} day ^{1} as compared to an oceanic average of 0 058 gC m ^{2} day ^{1} measured on the north bound track. Values reported here are usual for ice edge and near shore primary production during austral summer (El Sayed and Mandelli 1965 Home Fogg & Eagle 1969 El-Sayed and Taguchi 1981) when there is no localized bloom of phytoplankton.

Within the euphotic layers in the polynya there was a sub surface maximum in both biomass and production at 5 m about 60% lo. However as reported earlier (El-Sayed 1970 El-Sayed and Weber 1982) in Antarctic waters phytoplankton biomass occurs well below the euphotic depth (Table 1) down to 150 m in the 215 m water column.

The biomass contributed by organisms less than 20 µ in size (nannoplankton) varied from 20 to 40% of the total in terms of chlorophyll *a* and ATP (Table 5). In terms of primary production the contribution of these organisms is slightly higher about 50% of the total carbon fixed. Nannoplankton appears to be a fairly important component of phytoplankton in the Antarctic waters. Although the values reported here are lower than those of Brockel (1985) who found that an average of 70% of production was due to organ sms < 20 µ Ronner *et al* (1984) showed that there was great variability in nannoplankton biomass in the Scotia Sea. On the basis of the cell counts reported here (Table 6) a certain overlap between size fractions is expected considering that pennate diatoms formed a sub stantial part of the phytoplankton community.

Although the average values for near ice edge production and biomass are high there is a good deal of day to day fluctuation. Chlorophyll *a* for example varies from 118 mg m ^{2} to 15 mg m ^{2} ATP and cell counts show similar differences (Fig 3) during the 2-month period. The apparent growth in biomass from the 13th to 15th January (Fig 3) cannot be explained on the basis of the calculated doublings per day (Eppley 1972) based on ^{14}C-$NaHC0_3$ uptake and chlorophyll *a* standing stock. The average μ in these samples is 0 64 ± 0 4 (n = 16) a generation time of about 2 days using a C. Chl *a* ratio of 30 ± 10 (Steele 1962 Eppley 1972) for nutrient rich waters. As discussed earlier by El Sayed and Taguchi (1981) the use of ATP-Carbon results in a much lower apparent µ of 0 15 ±0 12 n=16 and may be due to the over estimation of phytoplankton carbon as pointed out by Karl (1978) and the contrbution of microzooplankton and bacteria.

Thus the fluctuations in biomass are probably caused by the melting of fast ice and consequent release of ice algae and the dispersal of organisms both vertically due to wind mixing and horizontally due to lateral flows of water away or along the ice shelf. The fluctuations in biomass can be traced to at least 100 m (Fig 2) from 7th January to high values on the 15th to a 31 st January low and a sub sequent peak in organisms on the 8th February.

Taken in conjunction with meteorological data periods of calm weather (wind speeds < 25 knots) are related to h gher biomass in the euphotic zone. However the variations in wind speed and cloud cover are so rapid that it is doubtful if the phytoplankton with calculated specific growth rates (μ) of 0 6 doublings per day can adequately utilize optimum conditions for substantial biomass in crease. As pointed out by Jaques (1983) the phytoplankton do not appear to be well-adapted to this environment and holophytoplanktonic blooms such as found by Mandelli and Burkholder (1966) and El-Sayed (1971) appear to be rare events.

Biomass added to the marine system by ice melt of the kind between 13 to 15 January reported here does not seem to act as seed for pelagic communities as pointed out by McConville Mitchell &

Wetherbee (1985) from their work on ice edge communities. One conclusion of the work reported here is that any estimation of standing stock biomass is composed of at least two components the first is algae released from ice which may or may not be physiologically active but will certainly contribute to food chain dynamics. The second is holoplanktonic plants with possibly quite different life cycles whose biomass must also contribute to the food chain.

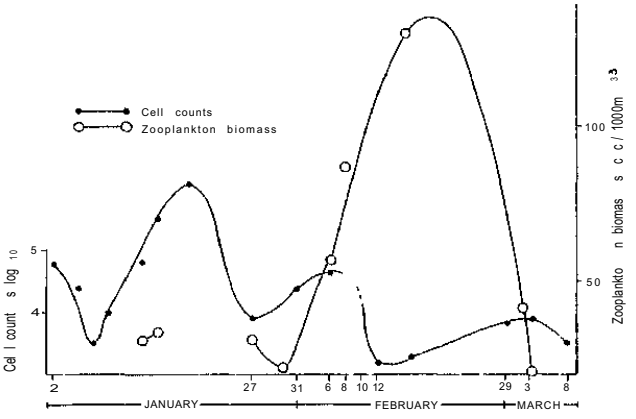

Fig 4 Relationship between Phytoplankton and Zooplankton-Zooplankton data (Courtesy KJ Mathew CMFRI)

As suggested by Fig 4 zoop lankton biomass at the same station, consisting largely of Euphausids, (Mathew, personal communication) increases in February following the algal peak From the data presented here it appears that the growth of krill along the ice-edge, ecosystems of the Southern Ocean may be influenced by the release of ice-algae into the marine system rather than the autochthonous growth of marine holoplankton. A study of the physiological differences between the two groups should prove rewarding for the better understanding of energy transfer mechanisms within the ecosystem.

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