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The importance of nanoplankton within the pelagic Antarctic ecosystem

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Abstract

During the Second German Antarctic Expedition 24 stations were visited from January to February 1978 between Bellinghausen Sea and South Georgia. Samples were taken for the determination of phytoplankton composition and biomass as well as for protozooplankton biomass. Primary productivity was measured as ^{14}C-uptake for different size classes of the phytoplankton population (< 20, 20 – 100 and 100 – 300 μm) Remarkable was the distribution of biomass and primary production within the different phytoplankton size classes. At nearly all stations the major part of the biomass consisted of nanoplankton forms smaller than 20 μm which were responsible for about 90 % of the production. These tiny organisms were either diatoms (centric or pennate forms), μ-flagellates or dinoflagellates, thus representing the main phytoplankton groups. Protozooplankton cells were found at all stations, their biomass averaged about 16 % of the phytoplanktion biomass. The obvious importance of nanoplankton forms as a food supplier for the krill (*Euphausia superba*) as well as the importance of protozooplankton as a food source and a food competitor for the krill during the Australian autumn are discussed.

Introduction

Until recently the foodweb of the pelagic Antarctic ecosystem was considered to consist all the year round mainly of 'giants' with relatively simple relationships: huge whales feed on the large krill (*Euphausia superba*) which on the other hand is maintained by big diatoms (NEMOTO 1966, El-SAYED 1971, 1977, HOLM-HANSEN et al. 1977). With the use of improved methods during the last few years this picture had to be changed. In the course of the year the base of the foodweb proved to be more complicated. Seasonal existence and importance of small and very small phytoplankton and protozooplankton cells as well as the ability of the krill to feed on those tiny organisms became evident (FAY 1973).

Within this paper phytoplankton and some protozooplankton data from the western Antarctic region gathered during the Australian autumn are presented which give an impression of the distribution of phytoplankton biomass and productivity within different size classes as well as of protozooplankton biomass, thus showing the seasonal importance of small organisms as a food source and a food competitor for the krill.

Material and methods

During the Second German Antarctic Expedition 24 stations were visited in the western Antarctic region during January and February 1978. Locations of stations, station numbers and dates of sampling are shown in Table 1 and Figure 1. Samples were taken with 5 l bottles (Hydrobios Kiel) from different light depths (100, 50, 30, 10 and 1%). Light depths were calculated from Secchi disc readings.

Phytoplankton and protozooplankton cells were counted using an inverted microscope (UTERMÖHL 1958). Phytoplankton carbon (PPC) and protozooplankton carbon (PZPC) were calculated following the method described by STRATHMANN (1967) for different size classes (<20 μm, 20 – 100 μm and >100 μm) with conversion factors for different species and sizes given by SMETACEK (1975), SCHNEIDER (1980) and BRÖCKEL (unpubl. data).

Samples for productivity measurements were filtered through 300 μm gauze to avoid influences of larger zooplankton. Productivity measurements were carried out with the ^{14}C-method according to STEEMANN-NIELSEN (1952): 200 ml sample, 10 μCi of labelled carbon added, 4 hours simulated *in situ* incubation, beginning of the incubation period about noon. After incubation and prior to filtration on membrane filters samples were divided by gently filtering through 20 and 100 μm gauze. Thus the amount of labelled carbon incorporated by different size classes of the phytoplankton population (<20 μm, 20 – 100 μm and 100 – 300 μm) could be determined by Geiger-Müller counting.

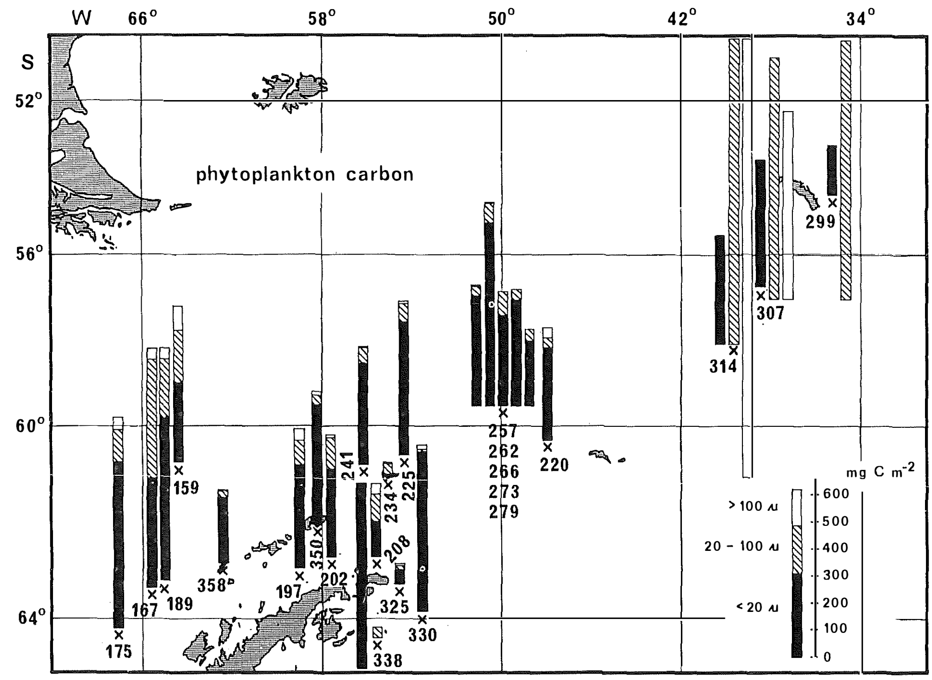

Figure 1

Phytoplankton biomass as phytoplankton carbon (PPC) within the euphotic zone for the different size classes at the stations as columns (Note: station 257 to 279 belonged to one time station, and columns for stations 299, 307, 314 and 338 had to be divided into several parts.)

Table 1

Station numbers, dates of sampling, total phytoplankton biomass as phytoplankton carbon (PPC) within the euphotic zone (as mg C m^{-2}) and PPC of different size classes as percentage of total PPC as well as protozooplankton biomass within the euphotic zone (as mg C m^{-2})

station	date	total PPC mg C m^{-2}	PPC of different size classes in % of total PPC <20 μm	20 to 100 μm	>100 μm	protozooplankton mg C m^{-2}
159	5. I.	576.7	51.7	34.1	14.2	76.8
167	6. I.	884.0	46.2	49.8	4.0	191.4
175	7. I.	779.2	79.4	13.7	4.5	88.4
189	10. I.	858.9	69.9	25.8	4.3	50.7
197	11. I.	514.3	74.9	15.7	9.4	139.2
202	12. I.	453.1	72.2	26.1	1.6	283.7
208	13. I.	267.8	49.0	38.3	12.7	86.5
220	16. I.	416.9	82.9	9.6	7.5	104.3
225	17. I.	570.1	86.1	10.8	3.2	36.3
234	18. I.	52.6	25.4	71.9	2.7	63.7
241	19. I.	435.8	85.9	13.3	0.8	41.6
257	22. I.	446.0	91.6	8.1	0.3	18.8
262	23. I.	751.5	90.2	9.6	0.2	30.7
266	24. I.	423.8	78.3	21.7	0	28.3
273	25. I.	429.9	91.6	8.4	0	15.4
279	26. I.	287.6	84.0	15.9	0.1	72.1
299	31. I.	1 141.2	16.3	83.7	0	62.3
307	1. II.	2 048.5	22.7	43.6	33.7	14.6
314	2. II.	3 148.4	12.7	36.0	51.3	324.5
325	6. II.	78.4	66.7	22.4	11.0	76.5
330	7. II.	613.6	96.3	1.4	2.3	36.4
338	8. II.	847.4	95.9	0.3	0.3	8.3
350	10. II.	489.6	90.9	7.0	2.1	349.5
358	12. II.	270.8	89.5	9.3	1.2	177.0
$\bar{x}$		691.0	69.6	23.5	6.8	109.0

Daily production per m² for each size class was calculated on the assumption that the relation of incident light and ^{14}C-uptake were equal during incubation period and total hours of incident light.

For the sake of comparison all data presented here are integrated values over 1 m² for the euphotic zone. Euphotic zone depths ranged from 20 to 60 m (Table 2). In general phytoplankton biomass found below the euphotic zone was very low.

Results

Total phytoplankton biomass (as PPC) as well as total and relative PPC of different size classes are presented in Table 1 and Figure 1. PPC values averaged about 700 mg C m^{-2} with a lowest value of 53 mg C m^{-2} occurring close to Elephant Island and high values with a maximum of 3.15 g C m^{-2} around South Georgia. Phytoplankton biomass belonged to nearly 70 % to cells smaller than 20 μm, only about 24 and 7 % of the PPC were supplied by phytoplankton cells in the size classes 20 – 100 μm and >100 μm respectively. These tiny organisms were mainly flagellates (either 5 to 10 μm in size or microflagellates about 2 μm small) and/or dinoflagellates (in the range of 8 to 15 μm).

Only on some occasions cells smaller 20 µm were either pennate diatoms about 15 µm in length (Stations 159, 299 and 307) and/or centric diatoms between 12 and 20 µm in diameter (Stations 208, 307 and 314).

Considering the relative size-compositon of PPC the stations can be divided into three groups: (1) from the northern part of the Weddell Sea through the Bransfield Strait to the waters around the South Shetland Islands and in the eastern part of the Drake Passage PPC consisted mainly of organisms smaller than 20 µm. Here only small portions of organisms in the size classes of 20 – 100 µm and >100 µm could be found. (2) In the western and south-western part of the Drake Passage the portion of phytoplankton cells between 20 and 100 µm in size was considerably higher, although cells smaller than 20 µm still made up more than 50 % of the PPC. (3) Around and south of South Georgia a rather different situation was found. Here the major portion of PPC was formed by organisms larger than 20 µm. In the size class 10 – 100 µm these were mainly pennate diatoms (*Nitzschia* type) between 20 and 50 µm in length. Phytoplankton cells larger than 100 µm (only occurring at the stations south of South Georgia) were very big diatoms: different *Rhizosolenia* species (up to 770 µm in length), different *Corethron* species (up to 600 µm) and *Thalassiothrix antarctica* with the longest cells (up to 2300 µm in length with a width of only about 8 µm).

Total primary production as well as the production within different size classes are presented in Table 2 and Figure 2. Average production for all stations amounted to

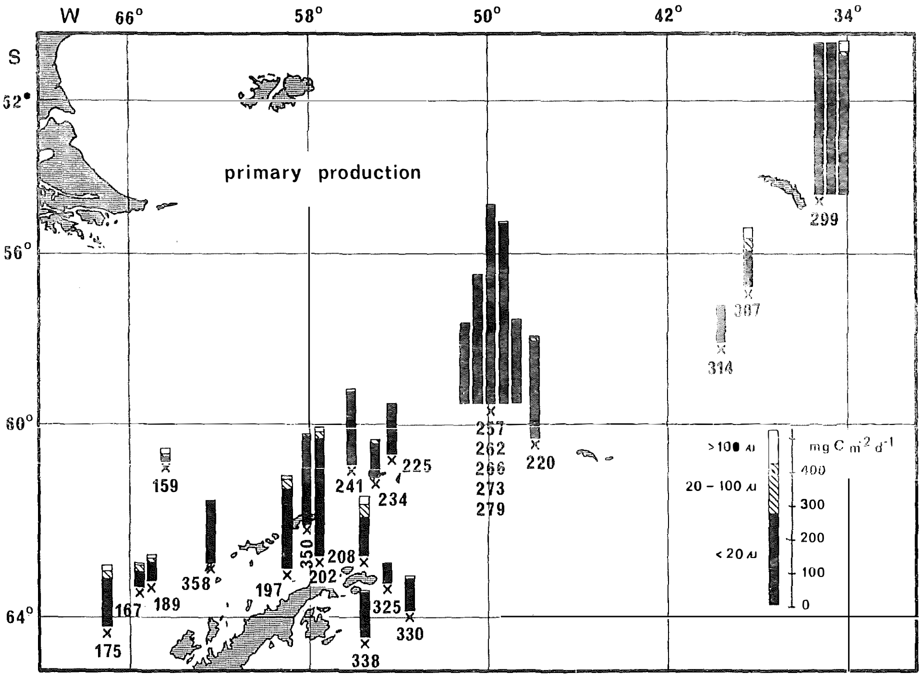

Figure 2

Primary production for the different size classes (as mg C m^{-2} d^{-1}) as columns (Note: station 257 to 279 belonged to one time station, and the column for station 299 had to be divided into three parts.)

Table 2

Station numbers, depths of euphotic zone, total primary production (as mg C m^{-2} d^{-1}) as well as the production within different size classes as percentage of total production

station	depth (m) of euphotic zone	total prod. mg C m^{-2} d^{-1}	prod. of different size classes in % of total production <20 μm	20 to 100 μm	100 to 300 μm
159	60	37.9	38.8	18.5	42.7
167	50	68.8	66.3	29.7	3.9
175	25	192.2	73.9	16.6	9.5
189	40	74.3	76.1	10.9	13.1
197	26	275.2	86.9	10.7	2.5
202	40	379.0	92.6	4.6	2.7
208	40	170.1	65.9	23.5	10.7
220	40	302.2	96.0	3.9	0.2
225	40	149.6	99.9	0.1	0
234	20	113.3	89.2	10.4	0.4
241	35	221.8	97.1	0.7	2.2
257	35	238.3	99.8	0	0.2
262	35	380.9	100	0	0
266	30	569.7	100	0	0
273	30	541.7	98.8	0	1.2
279	38	244.6	99.7	0.2	0.1
299	32	1 357.4	96.8	0.9	2.3
307	35	169.5	59.8	23.3	16.9
314	35	108.7	96.3	0	3.7
325	50	58.1	99.3	0.7	0
330	40	103.8	92.1	1.8	6.1
338	35	146.8	94.1	4.2	1.7
350	38	261.7	96.8	2.6	0.6
358	38	182.9	100	0	0
$\bar{x}$	35.5	264.52	88.18	6.80	5.03

about 265 mg C m^{-2} d^{-1}, highest values were found around South Georgia (up to 1.36 g C m^{-2} d^{-1}) and the lowest value occurred in the northern part of the Weddell Sea with only 58 mg C m^{-2} d^{-1}. Of this production 88 % orginated from cells which passed through a 20 μm gauze, whereas only about 7 and 5 % were due to the activities of cells in the size classes 20 – 100 μm and 100 – 300 μm respectively (Table 2).

The differences which can be seen from figure 1 and 2 comparing the portions of phytoplanktonbiomass PPC) and phytoplankton production within the different size classes can be attributed to some extent to the different methods used for fractioning. Most diatoms larger than 300 μm were eliminated when filtering the productivity samples through a 300 μm gauze prior to incubation. Thus the productivity data are not correct when noticeable amounts of big diatoms (>300 μm) occurred. Specially the productivity data for stations 307 and 314 are too low and give a false impression.

Differences between the two size classes of organisms smaller than 20 μm and between 20 and 100 μm most probably originate to some extent from dinoflagellates slightly larger than 20 μm and pennate diatoms longer but thinner than 20 μm. They will at least partly pass through a 20 μm gauze and thus appear in the size class of 20 – 100 μm regarding biomass, but in the size class of smaller than 20 μm regarding production.

Keeping these methodological errors in mind, it can not be concluded from the data presented above that the relation of production to biomass (carbon produced per biomass carbon) varies between the different size classes.

In Table 1 protozooplankton biomass (as protozooplankton carbon – PZPC) from cell counts is presented. These organisms were mainly ciliates of which some belonged to the group of tintinnids, with lengths averaging 50 to 60 μm (ranging from 10 to 120 μm). Average PZPC amounted to about 110 mg C m^{-2} with the lowest value of 8 mg C m^{-2} in the northern part of the Weddell Sea and a highest value of about 325 mg C m^{-2} south of South Georgia. Compared to phytoplankton biomass, protozooplankton biomass (PZPC) expressed as a percentage of PPC averaged about 16 % with a very high value of 121 % close to Elephant Island and a rather low one (< 1 %) in the northern part of the Weddell Sea.

No relation could be found between total amount of PPC and production and relative portion of the different size classes regarding these two parameters. And no relation could be found between stations with high krill abundance (Stations 257 to 279) and stations where almost no krill was caught (Stations 299, 325 to 338).

Discussion

Although the data presented above are limited in time (Australian autumn) and space (Bellinghausen Sea to South Georgia), they show clearly that the pelagic Antarctic ecosystem can seasonally depend to a big extent on organisms smaller than 20 μm in size as a food supply for herbivorous organisms of which the most important is the krill (*Euphausia superba)*.

Photographical examinations of the distances between the different setae of the krill (KILS, pers. comm.) show interspaces down to 2 μm for the 2nd-degree-setae and gaps of less than 1 μm width for the 3rd-degree-setae, hence displaying the ability of the krill to filter even very tiny organisms (< 5 μm) out of the water.

Naturally the unarmoured cells of dinoflagellates and flagellates can not be found during stomach investigations. Thus, up to now, only phytoplankton and zooplankton cells with skeletons such as diatoms, silicoflagellates, tintinnids and others are reported as krill food (BARKLEY 1940, NEMOTO 1966). But it seems to be obvious that the krill feeds on other small organisms too.

The Antarctic ecosystem, although rather far away from any human settlement, is much influenced by human activities. Specially when regarding the part of the pelagic food web which consist of phytoplankton – krill – baleen whales. At the beginning of the century heavy whaling started which resulted in drastically reduced whale numbers. With the whales gone the grazing pressure towards the krill decreased, thus most probably increasing the amount of krill to some extent. This growth of the krill population had to be supported by the phytoplankton community which is the main producer of particulate organic material within the Antarctic ecosystem. This increasing grazing pressure towards the first link of the food web might have influened compositions and/or successions of the phytoplankton population. During some seasons only smaller sized cells with rather short turnover rates might now be able to support the bigger krill population. More research on the relation of krill abundancy and the composition of phytoplankton populations during the course of the year is necessary. The phytoplankton composition is of special interest shortly after the ice retreat, when the influence of krill grazing might still be rather low.

Moreover, protozooplankton data as presented above show the relevance of an important part of the food web which was neglected during most of the recent quantitative studies. The importance of the protozooplankton biomass becomes obvious when compared to krill biomass. POMMERANZ (1978) gives some krill biomass values (as wet weight per m^{-2}) for the Drake Passage. Converted into mg C m^{-2} the geometrical mean of Pommeranz' data amounted to 24 mg C m^{-2} of krill biomass. The geometrical mean of the protozooplankton data reported in this study is about 63 mg C m^{-2}, that is about two and a half times as high!

The two areas and the times of investigations were not the same, though this value indicates a possible relation between the biomasses of small protozooplankton and the relatively large krill. Keeping in mind that for the protozooplankton data only samples from the euphotic zone were taken and that on some occasions below the euphotic zone an even higher protozooplankton biomass was found (reported elsewhere), the relation of protozooplankton biomass to krill biomass may be estimated somewhere between less than 1 and more than 10. Here is a wide gap in our knowledge of protozooplankton, its feeding and turnover rate, its distribution and abundancy as well as of its importance as a food source and/or food competitor for other herbivorous and omnivorous zooplankton, of which the krill is the most abundant one.

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