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WHAT MATTERS IN ARCTIC PHYTOPLANKTON

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INTRODUCTION

There is nothing new about going into Arctic waters to look at the phytoplankton. It has been done many times before, especially by the Norwegian workers Gran (1902), Braarud (1935), Gaarder (1938) and Halldal (1953) and by British and Russian workers. From their accounts one can build up an apparently complete picture of the succession and distribution of plant life in these waters. The majority of observations has depended on samples collected by fine plankton nets, and these have been extensively supplemented by the examination of water bottle samples. The usual procedure with the latter has been to preserve the sample with neutralized formalin, to allow a portion to sediment in a counting chamber and then to count the organisms with an inverted microscope. It is not always clear from the accounts whether the samples were counted on board ship, within a few hours, or examined ashore in the laboratory.

A persual of the results shows that in most cases the organisms found had a lower size limit of about 10 µm except for colonial forms such as Phaeocystis and Dinobryon. Flagellates were represented mainly by the larger dinoflagellates, Ceratium, Peridineum, Dinophysis, and Coccolithophophorids, both of which have a relatively rigid structure. Small flagellates were usually lumped together under some collective heading like "flagellates and monads not classified". It seems possible that many of the smaller and more delicate forms just did not survive the process of preservation and so were not revealed by the examination. This possibility can only be tested by examination of live phytoplankton at sea.

METHODS

The examination of live phytoplankton at sea is not particularly new either. It was a regular feature of the June cruises of RV SIR LANCELOT in the 1950s (Wimpenny, 1952). 100 ml samples were concentrated over a membrane filter, resuspended in 1 ml and counted under bright field illumination in a

haemacytometer counting chamber. In recent years better equipment has become available for this type of work. On RV CIROLANA a Wild M11 microscope fitted with a high intensity lamp and phase contrast objectives has been used. The microscope is also equipped with a Reichert KAM.ES semi-automatic shutter for photomicrography. This coupled with Kodak High Speed Ektachrome film makes possible the taking of colour transparencies with a half-second exposure with a x20 objective or 2-second with a x40 objective. The use of a microscope at sea in calm weather does not present any serious problem, but in heavy weather it is difficult and it is essential to secure the operator so that movement relative to the microscope was reduced to a minimum. As far as counting live material is concerned the main problem is that many organisms disintegrate after quite a short time under the microscope and so the whole area of the counting chamber grid has to be covered in two to three minutes. For this reason, among others, it has not been practicable to try to identify each organism: one has to be content with an assessment of the group to which the majority belonged, and, when possible, photographs of representative samples.

Where plankton is very rich numbers of organisms can be obtained by a straight count of those encountered in 0.9 mm^3 in a haemacytometer counting chamber. Such a count depends on there being, on average, more than one organism per 0.9 mm^3 or, in round terms, more than 1×10^6 per litre. Since this is often not the case some form of concentration is essential. Ballantine (1953) and Braarud (1958) have both summarized various methods of concentration and concluded that for small and delicate forms centrifugation of living material was the most useful. In the present work the centrifuge has been placed on a gimbal table to reduce the effects of the ship's motion. Even so, there has been a very substantial loss of organism in the process; this has reduced the count to $\frac{1}{2}$ or even $\frac{1}{3}$ of what would have been expected from the results of the unconcentrated count (see below). In the absence of evidence to the contrary one must work on the basis that this loss has been spread more or less evenly through all the groups of algae present, although it is very tempting to suggest that the losses were more likely to have less among the more robust groups such as the diatoms and larger dinoflagellates than they would have been among the more delicate small flagellates.

RESULTS

Observations were made on three cruises by RV CIROLANA to the Barents Sea in 1973. During the March cruise the principal area covered was just north of Norway from about 70° to 72°N and from 20° to 35°E. Chlorophyll 'a' values, as measured by the Turner Fluorometer, were below 0.5 µg/l throughout the area

and algae were too few in number to count, even after a 10 ml sample had been spun for 15 minutes at 1,500 rpm and reduced to 0.5 ml. Some observations were made on material concentrated over a membrance filter; which, although not quantitative, provided some qualitative information. Leucocryptos marina Butcher was usually common, as were coccolithophorids (probably C. huxleyi) and small, apparently non-motile, green organisms. Diatoms were usually represented by small forms such as Nitzschia closterium, N. ninuta, Skeletonema costatum, and small species of Chaetoceros. The only dinoflagellates seen were small forms of Gymnodinium similar to arcticum or minutum.

During the May/June cruise it was found that the concentration of chlorophyll 'a' in the water had in general increased to 0.5-1 µg/l, and that in some areas there were patches several miles across with concentrations of 3-5µg/l. Some of these patches were sufficiently rich for a microscope count to be made without the necessity for concentrating the sample. One such patch, about 10-15 miles across, was found at 72°N, 24°E. Four microscope counts were made on an unconcentrated sample and gave a total of 0 diatoms, 1 dinoflagellate, 0 coccolithophorids and 64 other organisms. This latter group appeared to consist mainly of green organisms, probably motile, which were thought to belong to the Prasinophyceae, probably relatives of Heteromastix or Scourfieldia. This same sample was also spun down in the usual way and the x20 concentrate counted. Two counts were done and yielded a total of 0 diatoms, 1 dinoflagellate, 1 coccolithophorid and 218 other organisms, which again were mainly presumptive Prasinophyceae. If we convert these two sets of counts to numbers of organisms per litre we find that the unconcentrated count gave 16×10^6 per litre and the centrifuged sample only 5.5×10^6 per litre, a reduction to approximately one-third of the true value.

About two weeks later, on the same cruise, the ship returned to this area. The phytoplankton was still dense enough to give useful results from counts on unconcentrated samples. Sets of five counts were done on each of two unconcentrated samples collected within about half an hour of each other, the ship was not moving much at the time. The first set gave a mean result of 12.8×10^6 organisms per litre and the second 13.8×10^6 per litre. The second sample was also concentrated by centrifugation and then counted. This gave a result of 4.42×10^6 per litre. Here again, the concentration process had reduced the number of organisms to about a third of the proper value. In the samples examined on this occasion a total of 394 organisms were seen, which included 1 dinoflagellate and no diatoms or coccolithophorids.

On the third cruise, in August/September, all the counts were done after centrifugation at 1,500 rpm for 15 minutes. At about half the stations there were substantial numbers of diatoms of the order of 0.1-0.5 x 10^6 per litre. Occasionally, at 71°24'N, 30°00'E for example, the diatoms were the most numerous group seen, but more commonly they were heavily outnumbered by the flagellates. Typical examples were at 76°20'N, 14°15'E where there were 0.5 x 10^6 diatoms and 4.14 x 10^6 flagellates/litre, and at 79°18'N, 08°35'E with 0.28 x 10^6 diatoms and 3.21 x 10^6 flagellates. The highest count of flagellates was recorded at 78°01'N, 07°24'E where there were 0.04 x 10^6 diatoms and 14.31 x 10^6 flagellates.

On the first of these three cruises (March) there was very little phytoplankton, and chlorophyll was barely measurable by the spectrophotometric method. However, although the amounts were too small for the quoting of concentrations in µg/l to be useful one can say that the three chlorophylls 'a', 'b' and 'c' were all present. As has been mentioned the flora contained both diatoms and flagellates. On the second cruise, although the concentration of chlorophyll was substantially greater, chlorophyll 'c' was not detected. This is in accord with the microscope findings that, at that time, diatoms were not important but that numbers of the Prasinophyceae were. Electron micrographs of preparations made at sea give some support to this view, although there were also a substantial proportion of organisms which appeared more likely to belong to the Haptophyceae, which one would expect to contain chlorophyll 'c'. Unfortunately these very small members of the Prasinophyceae appear to have some difficult cultural characteristics, and they have not, so far, come up in cultures prepared at sea.

DISCUSSION

At first sight the very small number of diatoms found in the present work would appear to be at variance with other people's findings. This is not really true. For an organism to be seen in 1 mm^3 of sea water it must be present to the extent of at least 1,000 per ml, or 1 x 10^6 per litre or 1 x 10^9 per m^3. In Marshall's (unpublished) account of phytoplankton investigation in these waters the highest count of diatoms he recorded was Thalassiosira gravida Cl, 162,000,000 cells per m^3: this was in May 1953 at approximately 76°N 26'E. The second highest count was Fragilaria oceanica Cl. 140,800,000 cells per m^3 at the same station. Both of these counts are well below the 10^9 needed for these to figure significantly in the counts per mm^3. Halldal (1953) in his investigations in the Norwegian Sea recorded counts of up to 8 x 10^6 Fragilaria nana

per litre in the summer of 1949. This number would be within the range of direct countability, but most of Halldal's counts at Weather Ship M, were only of the order of a few thousand. Paasche (1960) gives distribution maps for the diatoms found in the Norwegian Sea and the densest concentration shown is of the order of 100,000 per litre for Chaetoceros debilis, 500,000 per litre for Fragilariopsis nana and over 10,000,000 per litre for Phaeocystis pouchetii and "small flagellates not identified". Only the last group would be sufficiently numerous to show up in direct counts on living material. Paasche used the Utermohl method on samples preserved in neutralised formalin.

Furtner evidence on the major part played by the smaller organisms comes from measurements of chlorophyll 'a' in sea water samples before and after they have been passed through meshes of various sizes. On the cruise CIROLANA 7/71 (August-September) at 103 stations the in vivo fluorescence of samples was measured on a Turner fluorometer before and after they had been passed through a 25µm aperture nylon mesh. At 89 stations over 80% of the chlorophyll 'a' was contributed by the nanoplankton, and at 53 stations over 90%. Similarly, on the cruise CIROLANA 7/70 observations were made at 27 stations using a 10 µm pure nickel mesh. At 23 stations over 80%, and at 17 stations over 90% of the chlorophyll 'a' was contributed by the nanoplankton, including small diatoms.

The situation then is not that there is a conflict between the present findings and those of previous workers, but that the microscope examination of living material at sea has revealed the presence of a larger number of very small organisms, which are likely to be more important than had previously been appreciated.

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