FISKERIDIREKTORATETS SKRIFTER
Serie Havundersøkelser
(Report on Norwegian Fishery and Marine Investigations)
Vol. XII. No. 11

Phytoplankton Distribution in the Norwegian Sea in June, 1954, Related to Hydrography and Compared with Primary Production Data

By

E. PAASCHE
(Institute for Marine Biology, Sect. B, University of Oslo)

1960
A.S JOHN GRIEGS BOKTRYKKERI, BERGEN

CONTENTS

I. Introduction

The present paper is based on a quantitative survey of the phytoplankton vegetation of the Norwegian Sea in June, 1954, which was undertaken with a view to supplementing and extending the present knowledge of the floristic, ecological, and bio-geographical features of the region. At the same time, observations of some morphological and taxonomic interest were made; these are being published separately (Paasche 1960 a).

From a somewhat different point of view, the working up of the material seemed to be particularly urgent, since it would afford a comparison between on one hand size and composition of the actual standing stock of phytoplankton, and on the other hand the primary production, determinations of which were made at a large number of stations at the same time as the plankton was collected (Berge 1958, and unpublished observations). The importance of such a comparison should not be under-estimated. In spite of a large number of publications on primary production having appeared since Steemann Nielsen (1952) introduced the ^{14}C method into the field of marine biology, very little, if any, detailed information has been gained as yet with respect to the producers themselves, i. e. the actual standing stock of phytoplankton, at the time and place where any measurement of primary production has been performed. There is reason to believe that the intensity of production is not solely dependent on the quantity of the standing stock of phytoplankton, since the specific composition of the latter must be of importance as well.

The results from the numerous field investigations dealing with the ecology of plankton algae, as well as experimental results obtained by various authors, indicate that the various phytoplankton species differ considerably as to the environmental conditions required for maximal photosynthetic efficiency. Since a phytoplankton community usually contains several species, it will presumably be quite able to adapt itself to changes in the environment by means of corresponding changes in its specific composition. However, it is conceivable that the productivity of a given area may actually be limited by the absence of those algal species which are best suited to the particular conditions prevailing.

The present state of knowledge does not permit a detailed, quantitative comparison between primary production values and the specific composition of the corresponding plankton communities. On the other hand, regional studies involving comparisons between production levels and phytoplankton distribution pose no great difficulties, and are likely to yield information of considerable interest. It should not be forgotten that any natural plankton community contains, in its composition, a wealth of qualitative information which is not brought out by the production measurements.

In addition to the regional studies just outlined, the material also seemed to justify an attempt to establish a quantitative relationship between standing stock of phytoplankton and its «production capacity» (Berge 1958), i. e. its ability to carry out photosynthesis under standard conditions. The whole matter relating to this aspect of the investigation will be dealt with in a separate paper (Paasche 1960 b).

The author wishes to express his sincere thanks to the various members of the Research Division of the Fisheries Directorate, Bergen, who collected the material and placed hydrographical and biological data at his disposal. Thanks are especially due to Mr. Grim Berge, who supplied data on primary production and also offered several useful suggestions, and to Prof. Trygve Braarud, who read the manuscript.

II. Earlier investigations on the phytoplankton of the Norwegian Sea

Halldal (1953) has reviewed the earlier literature dealing with the phytoplankton of the Norwegian Sea. The first quantitative investigations (Gran 1912, 1915) were preceded by studies where net haul material was used and which consequently dealt with the morphology and bio-geography of larger algal species only. The most important one of these early contributions was that of Gran (1902). More recent quantitative studies by means of the centrifuge method (Gran 1929 a; Braarud 1935) or the sedimentation method (Steemann Nielsen 1935; Braarud *et al.* 1953; Smayda 1958 a) were limited to restricted areas, mostly in the southern part of the Norwegian Sea. Halldal's investigation (1953) of the yearly phytoplankton cycle at an oceanic locality should be pointed out especially. Recently our knowledge of the phytoplankton vegetation in major parts of the region has been appreciably augmented by the extensive surveys from June 1952 and June 1953, the results of which have been published by Ramsfjell (1960).

A large number of observations on primary production, obtained by means of the ^{14}C technique, have been collected by Berge in various parts of the Norwegian Sea from 1954 onwards. The data from the survey in 1954 have been partly published (Berge 1958).

III. Material and methods

During a cruise of the research vessel «G. O. Sars» in May and June, 1954, a large phytoplankton material was collected. A great number of data on hydrography, primary production, and zooplankton, were obtained as well.

Through the courtesy of members of the Research Division of the Fisheries Directorate, Bergen, the phytoplankton material was placed at the author's disposal, and data of particular interest in connection with the present investigation were supplied. The latter are presented in charts and tables which will be discussed in later sections. It should be mentioned at this point that the production chart (Fig. 9) is not quite identical with the one published by Berge (1958), some corrections having been made according to recalculated values obtained more recently by that author.

The phytoplankton samples were usually collected at those stations and depths where production capacities were determined. The samples were stored in 100 cc glass bottles, using neutralized formalin at a concentration of 0.2 % as a preservative. Unfortunately the acidity of the water samples increased during storage, probably because the bottles which were used were of inferior quality. The observations on coccolithophorids are therefore incomplete, since coccoliths dissolve at a pH of 7.2 or lower.

In order to limit the amount of work spent in counting, usually one (0 m) or two (0 and 20 m) samples from each station were analysed. These bottles were selected in such a way as to yield a maximal amount of information on the features of horizontal and vertical phytoplankton distribution. In all, 141 samples were counted, representing 82 stations with station numbers ranging from 196 to 405. A chart showing the position of each station is presented in Fig. 1.

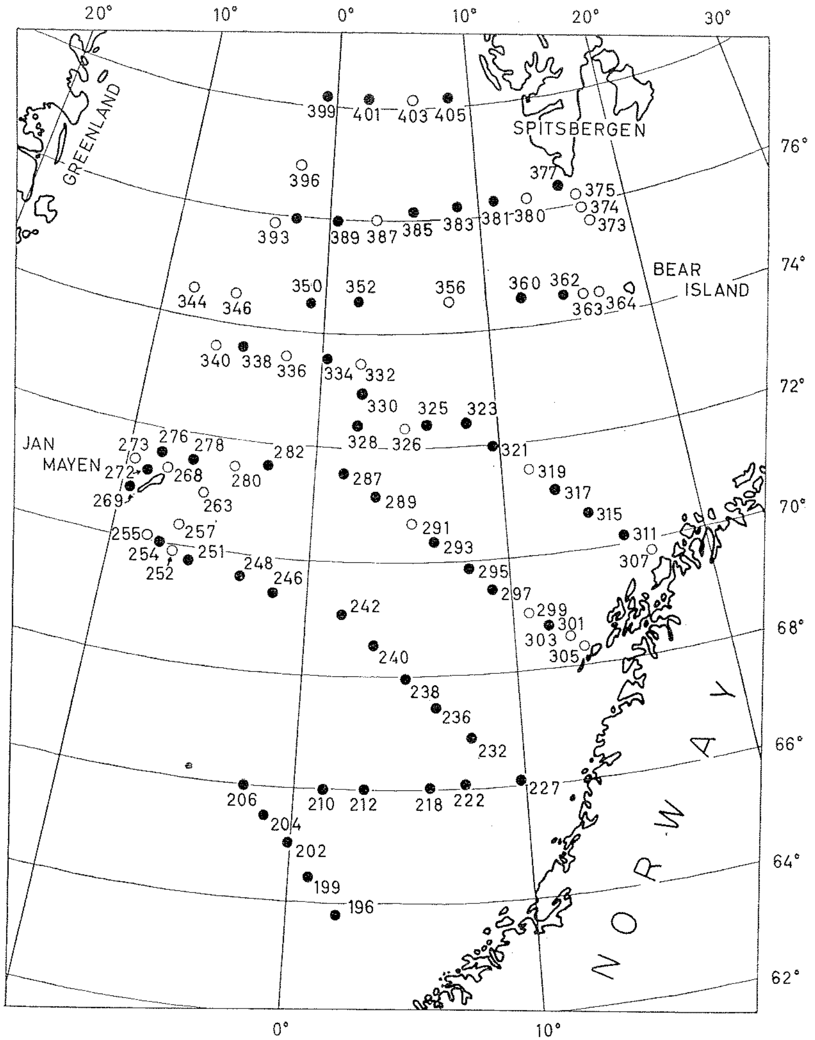

Fig. 1. Phytoplankton stations. Filled circles represent stations where production measurements were made.

The first one of these stations was occupied on May 24th, the last one on June 20th, 1954.

The quantitative analysis of the phytoplankton was carried out according to the sedimentation method (Utermöhl 1931). The larger forms were counted at 60 times and the smaller ones at 180 times magnification, after sedimentation in 50 cc and 2 cc cylinders, respectively. Very small organisms occurring in great numbers were frequently counted in a volume of only ¼ cc, the following procedure being adopted. A number of parallel counting strips, evenly distributed over the bottom of the 2 cc cylinder, were selected in such a way as to cover an area calculated to be exactly equal to $^1/_8$ of the total bottom area. The organisms in question (e.g., *Fragilariopsis nana, Nitzschia closterium, Phaeocystis pouchetii*) were counted in these strips only. This method is similar to the one suggested by Utermöhl (1958), who, however, recommends that the strips be radial instead of parallel. The organisms counted in this manner were, as a rule, sufficiently evenly distributed on the cylinder bottom to allow the employment of the procedure just described. In some cases, *Phaeocystis* formed an exception, since the colonies of this organism were not always completely broken apart in spite of the sample bottles having been vigorously shaken before the subsamples were poured into the cylinders.

The identification of very small forms frequently offered some difficulty. Naked *Chrysophyceae* are known to become disfigured to a greater or lesser extent when fixed with formalin, and in many cases they lose their flagella. While many of these small organisms may have eluded counting altogether, others may easily have been confused with single *Phaeocystis* cells. In the tables all cells of the size and approximate shape of *Phaeocystis* cells were listed under the single heading «*Phaeocystis* and Small Flagellates». There was reason to believe that, at least when large concentrations of this kind of cells were encountered, they did actually for the greater part represent *Phaeocystis*.

The results of the phytoplankton counting, expressed as number of cells per litre of sea water, were tabulated for each of the stations investigated. A complete set of tables is deposited with the Secretariate, University of Oslo. Extracts from these, summarizing the distribution of the more important species in the various sections, are presented in Tables 1—15. In addition, complete lists are given for selected stations (Tables 16—24).

It should be stressed that the numbers presented in the tables can be taken only as approximations to the true concentrations of organisms present at the localities where the samples were collected. This is due in part to the statistical uncertainties relating to the sampling procedure (see e. g., Lund *et al.* 1958), and in part to the fact that some of the larger plankton algae have been shown to be liable to incomplete sedimentation in 50 cc cylinders (Paasche 1960 b).

After the completion of the plankton countings, calculations were made of total cell volume of phytoplankton as million μ^3 per litre of sea water, at each station and depth. These calculations were based on specific cell volumes which where obtained for the various species of algae occurring in the quantitative samples. An account of the procedure employed, as well as a table of specific cell volumes (and cell surface areas) will be presented elsewhere (Paasche 1960 b).

IV. The hydrography of the Norwegian Sea

Helland-Hansen and Nansen (1909), in their monograph on the Norwegian Sea, gave a thorough presentation of the topography and hydrography of the area. The original picture as represented by these authors has been modified by more recent investigations (e. g., Alekseev and Istoshin 1956; Eggvin, unpubl.), but the monograph by Helland-Hansen and Nansen still forms an adequate background for biological surveys. Convenient summaries of their findings have been prepared by Wiborg (1955) and Ramsfjell (1960).

The essentials of the hydrography of the upper strata in the Norwegian Sea will be recapitulated here, as they form the basis for the later discussion of phytoplankton distribution.

The chart in Fig. 2 (Alekseev and Istoshin 1956) illustrates the main features of the current systems in the Norwegian Sea. The Norwegian Atlantic Current (for the sake of brevity referred to below as the «Atlantic Current»), forming a branch of the Gulf Stream System, enters the Norwegian Sea mainly through the Faroe-Shetland Channel, although considerable quantities of water may at times enter across the Faroe-Iceland Ridge also (Tait 1957). The current drifts northwards from here through the eastern part of the Norwegian Sea, where it splits up into several branches. The main branch finally sinks below colder water masses in the area west of Spitsbergen.

A considerable inflow of water also takes place through the Greenlandic Polar Current, and the Norwegian Coastal Current, and to a lesser extent through the Spitsbergen Polar Current. The Icelandic Arctic Current flows in south-easterly direction and finally sinks below the Atlantic water north of the Faroes. Through the interaction of the various currents, and partly resulting from peculiarities in the bottom configuration, eddies are formed. The most striking hydrographical features of the region are two great cyclonic eddy systems, one in the southern and the other in the northern part of the Norwegian Sea respectively. The former involves the Icelandic Arctic Current, as well as branches of the Atlantic Current which

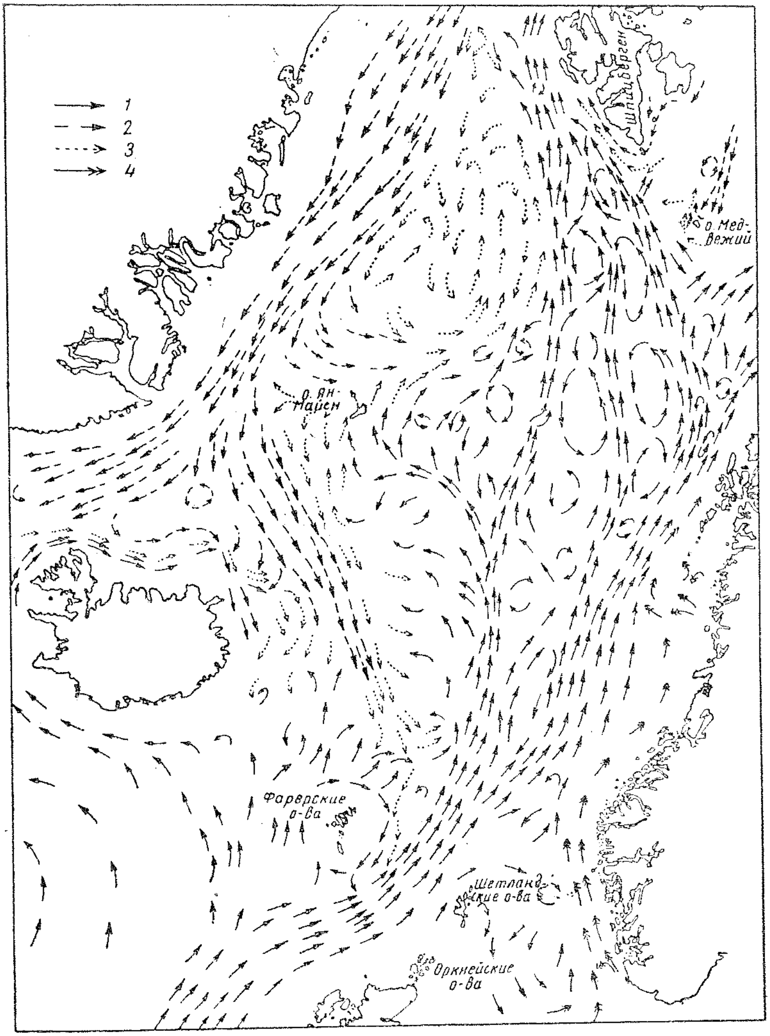

Fig. 2. Surface currents of the Norwegian Sea, according to Alekseev and Istoshin (1956). 1: warm water. 2: cold water. 3: mixed water. 4: coastal water.

spread out in fan-fashion almost as far west as Jan Mayen. The latter, northern eddy system is formed by participation of branches of the Greenlandic Polar Current and the Atlantic Current.

Resulting from variations in the strength of the various currents, as well as from changes in the climatic conditions, the detailed hydrographical picture of the upper strata is apt to change throughout the year, and also to show differences at the same season in different years. Eggvin has prepared a chart (published by Berge 1958) showing the

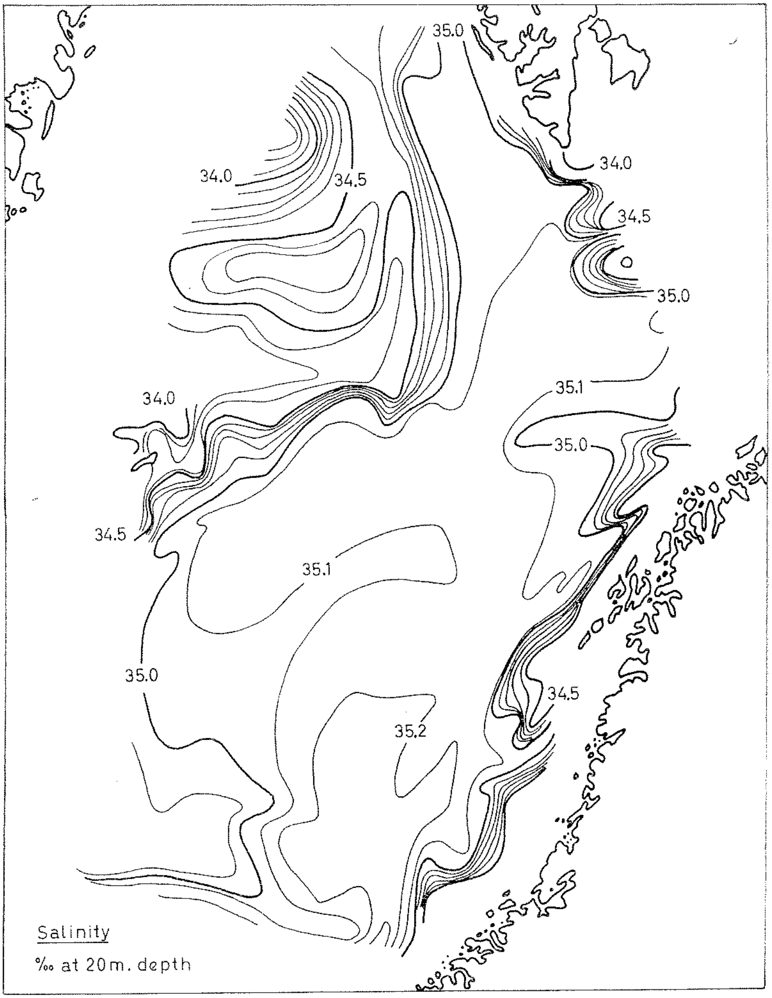

Fig. 3. Salinity at 20 metres depth in June 1954. After Eggvin (published by Berge 1958); somewhat modified.

salinity distribution at 20 m depth in May and June, 1954 (Fig. 3). It will be seen that Atlantic water, defined as possessing salinities above 35.00 ‰, occupied a major part of the Norwegian Sea at this time. Although some dilution of the Atlantic water was evident with increasing distance from the Faroe-Shetland area, the zones of transition to coastal or Polar water with salinities below 34.50 ‰ were then, in general, quite narrow.

The hydrographical data collected during the cruise allowed a classification of the stations where plankton observations were made,

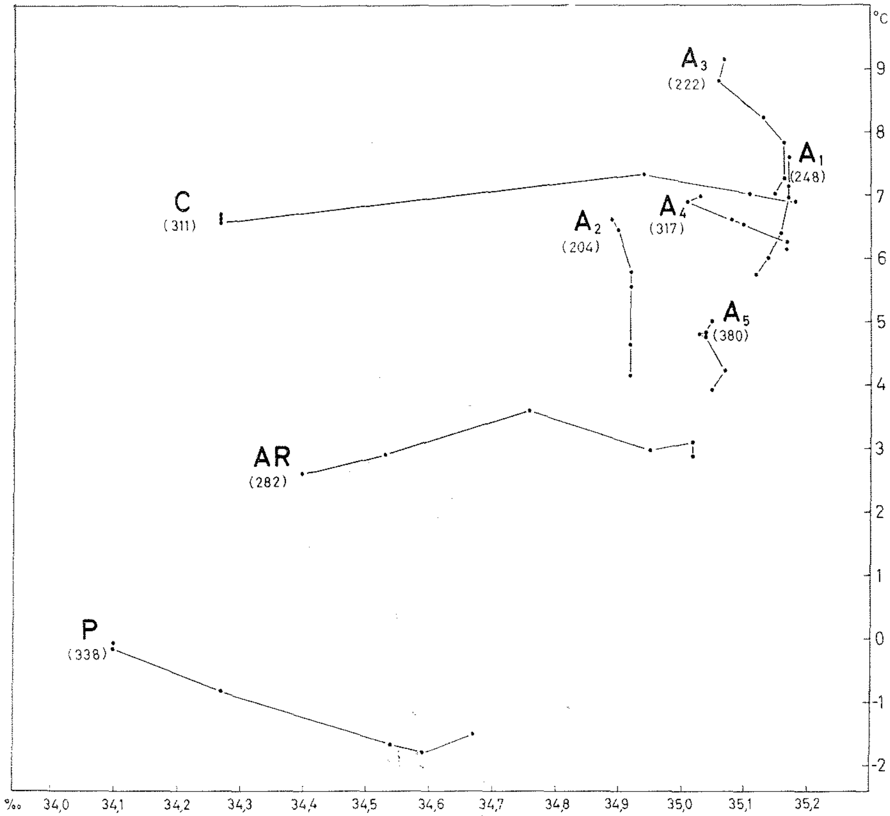

Fig. 4. t-S diagrams for the uppermost 75 metres at selected stations.
For further explanations see text, and Table I.

according to the general shape and position of their t—S diagrams. It was then possible to designate the various localities as Atlantic, Arctic, *etc.*, roughly in accordance with the definitions of the different water types of the Norwegian Sea given by Helland-Hansen and Nansen (1909). In Table I, some of the criteria used in the classification of the stations are summarized. Fig. 4 shows t—S diagrams for the uppermost 75 metres at selected stations, representing the various types of localities which could be discerned. From Fig. 5, finally, it will be seen that the grouping together of stations with similar t—S diagrams gives a picture which, although reflecting the general hydrographical situation indicated by the salinity chart (Fig. 3), does not coincide with the latter in every detail. Since the chart based on t—S diagrams takes into account temperature as well as salinity, both of which are required for an adequate characterization of water masses,

TABLE I.

Type of locality		Surface temperature (°C)	Surface salinity (‰)
A1	Atlantic	6.0—9.0	35.1—35.2
A2	Atlantic-Arctic	c. 6.0	c. 34.9
A3	Atlantic-Coastal	9.0—10.0	35.0—35.1
A4	Atlantic-Coastal	c. 7.0	c. 35.0
A5	Atlantic-Arctic	3.7—5.4	c. 35.0
AR	Arctic	1.0—3.0	34.6—34.75
P	Polar.................	below 1.0	33.7—34.8
C	Coastal	6.0—7.5	33.9—34.7

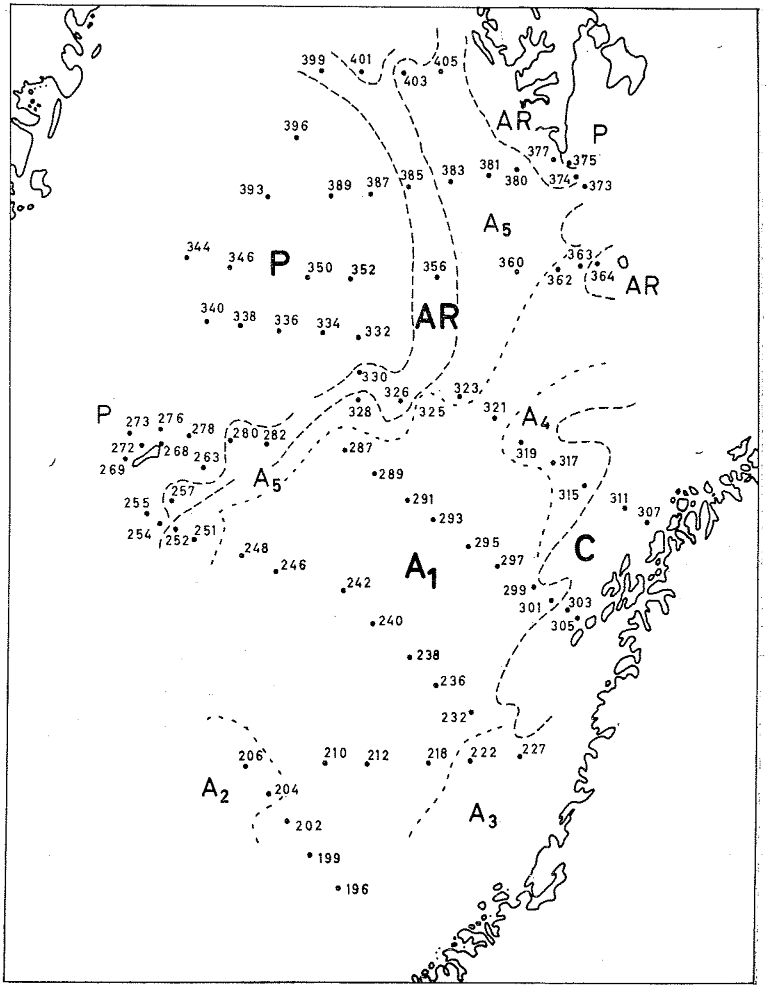

Fig. 5. Hydrographical chart based on t-S diagrams.

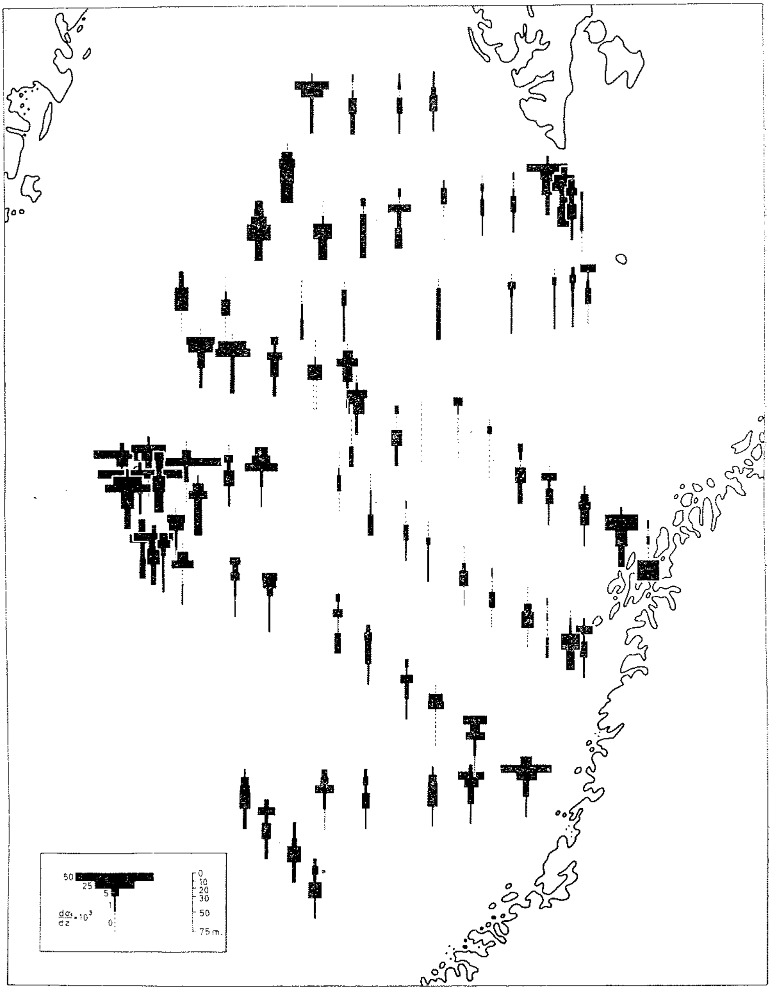

Fig. 6. Stability conditions in June 1954.

it seems to be rather well suited to the present purposes. Detailed comments on the chart have been postponed until later discussions.

References will then also be made to the stability chart presented in Fig. 6. This chart is based on values for $\frac{d\sigma_t}{dz} \times 10^3$ calculated for the uppermost 75 metres at each particular station where phytoplankton was collected.

V. The composition of the phytoplankton and the hydrographical features of the different vegetation areas

The quantitative analysis of the phytoplankton provided a basis for the division of the region investigated into *vegetation areas* in a manner analogous to that employed by Braarud *et al.* (1953) for the North Sea. Fig. 7 shows the extent of each of the eight areas which were discerned.

In the following sections, the vegetation as well as the hydrographical conditions within each area will be treated in some detail.

A. *Area I.*

The waters off northern Norway, at the time of the investigation generally possessing a very poor vegetation, were represented by six localities. Of these, the four northernmost ones were located in coastal water (hydrographical area C, Fig. 5) with low surface salinities. The high stability values recorded for these stations (Fig. 6) were due to a strong salinity gradient. – The remaining two stations, located farther south, represented Atlantic water where some admixture of coastal water was evident in the uppermost strata (hydrographical area A 3, Fig. 5). Here, stabilities were equally high, purely Atlantic water being encountered at depths of 30 or 50 metres.

The phytoplankton vegetation in this area consisted exclusively of small-celled species, most of these occurring in small concentrations only. A noteworthy exception was *Fragilariopsis nana,* a minute diatom which in this part of the Norwegian Sea attained a maximal size of only 5 μ (see Paasche 1960 a). At stations located at some distance from the coast (222, 227, 303, 311), *F. nana* was found in concentrations ranging from 100,000 to 600,000 cells per litre, while at localities in the immediate vicinity of the coast (305, 307), the stocks of this alga seemed to be much reduced (see Tables 2, 8, and 9). The dominating position of *F. nana* is evident from the complete species list for station 303 (Table 16).

Heterotrophic flagellates such as *Chilomonas marina* were fairly abundant at most stations, as were ciliates. It was noted that the occurrence of the latter in some cases seemed to bear an inverse relationship to the abundance of phytoplankton.

Station 299 in the section off Lofoten was genuinely Atlantic according to its hydrography. Nevertheless, the composition of the plankton recorded at that locality indicated a strong affinity with the vegetation of Area I, *Fragilariopsis nana* being present at a con-

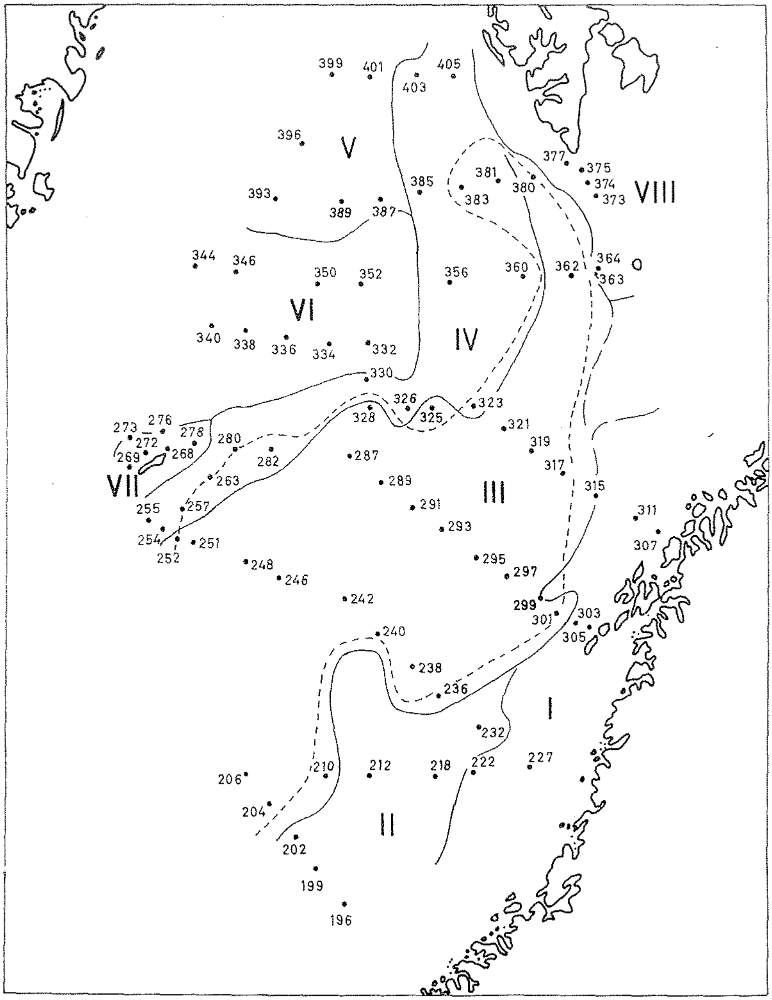

Fig. 7. Vegetation areas in the Norwegian Sea, June 1954.

centration of close on one million cells per litre. The two neighbouring stations in the section in question, both located in Atlantic water, were entirely dominated by the phytoplankton society typical of Area III (Table 8). The recorded situation suggests that eddy movements, known to be frequent off the coast of northern Norway, may be effective in carrying phytoplankton populations seawards.

B. *Area II.*

Of the considerable number of Atlantic localities surveyed (hydrographical area A 1, Fig. 5), most possessed an abundant diatom plankton composed of a number of species of large or medium cell dimensions (see Area III below). At six south-eastern stations, however, this type of vegetation was virtually absent. Instead, these stations, grouped together in Area II, were distinguished by a preponderantly small-celled plankton consisting of several diatom and coccolithophorid species.

According to the current chart (Fig. 2), the surface waters of Area II had relatively recently entered the Norwegian Sea. Salinities as well as temperatures were somewhat higher in this area than in the Atlantic waters farther north and west. From Fig. 6 it is evident that this was also true with respect to stability. Contrary to what was the case in Area I, the stratification of the uppermost layers was exclusively thermal. It may therefore be assumed that stable conditions had been created more recently here than in coastal waters.

Although reminiscent of the small-celled vegetation recorded in Area I, the phytoplankton of Area II showed a greater diversity (Tables 1, 2, and 3). Three of the stations (199, 202, 212) had a rather poor plankton where the heterotrophic *Chilomonas marina* seemed to predominate. At the remaining three stations, a fairly abundant vegetation was encountered. Table 17 shows the specific composition of the phytoplankton community at station 218. It will be seen that species such as *Fragilariopsis nana, F. atlantica, Nitzschia closterium, N. delicatissima, Thalassiosira bioculata* var. *raripora,* and *Coccolithus huxleyi,* all of which are of quite small size, were found in considerable quantities. The plankton at the more southerly station 196 was very similar, but the concentrations of some of the component species were still higher. On the other hand, at station 232, located farther north than 218 but inhabited by the same species, populations were on the whole much smaller. Judging from the current chart (Fig. 2), the close kinship of these three stations with respect to the specific composition of their phytoplankton was due to their being located along the same branch of the Atlantic current.

Of larger diatoms, only *Chaetoceros decipiens* occurred regularly in Area II, and always in small numbers.

C. *Area III.*

Huge stretches of water, occupying the central parts of the Norwegian Sea, were at the time of the investigation populated by an abundant phytoplankton, mainly consisting of various diatom species and *Phaeocystis.* It seemed justified to consider all stations having a plankton of this type as belonging to one vegetation area, in spite of the fact that there were considerable qualitative and quantitative differences between the communities observed at the various stations.

Hydrographically, most localities in Area III were Atlantic (A 1, Fig. 5), although a general decrease in surface temperatures and salinities towards north and west were observed. This phenomenon is partly explained as resulting from mixing of the surface waters with underlying water masses, which takes place to a considerable extent in the usually poorly stabilized Atlantic waters. (Helland-Hansen and Nansen 1909). Also, horizontal admixture of water originating from coastal areas or from the Icelandic Arctic current may have been of importance.

In addition to clearly Atlantic localities, Area III also included three stations in the northernmost section off Norway where a coastal influence was noticeable (A 4, Fig. 5). Furthermore, there were two localities rather strongly affected by the Icelandic Arctic Current (A 2, Fig. 5), and some stations located within the fairly narrow zone of mixed Atlantic-Arctic water (A 5, Fig. 5) at the northern and western boundaries of the Atlantic region.

According to Fig. 6, the uppermost 75 metres were in general less stratified in Area III than in any of the other areas included in the survey.

The phytoplankton table for station 248 is reproduced *in extenso* (Table 18), this locality forming an instance where the phytoplankton vegetation characteristic of the area was fully and typically developed. The most striking component of this plankton was the large diatom *Rhizosolenia styliformis.* This alga was recorded in smaller or larger quantities at every station in Area III, while only sporadically outside the area. At practically all localities referred to Area III, *Rh. styliformis* was accompanied by *Chaetoceros borealis, Ch. debilis,* and *Ch. densus,* and in most cases also by *Coscinodiscus centralis* and *Nitzschia seriata.* Since these species all had more or less the same distribution in the Atlantic part of the Norwegian Sea, there was good reason for regarding them all as representatives of a «phytoplankton society» in the sense of Gran and Braarud (1935). The «Styliformis society» seemed to be an appropriate name.

Of other species listed in Table 18, some of the more abundant ones frequently occurred together with those mentioned above. *Chaetoceros decipiens, Nitzschia delicatissima, Thalassiosira gravida,* and *Phaeocystis pouchetii* belonged to this category. However, since these species frequently were found independently and in quite large concentrations in other parts of the Norwegian Sea, they were not considered to be members of the Styliformis society.

Of smaller organisms, the dinoflagellate *Gyrodinium grenlandicum* and the craspedomonad *Monosiga marina* (including var. *minima)* were usually found in considerable quantities within the area. Coccolithophorids were, on the other hand, of little importance. *Coccolithus huxleyi,* although present at most stations, never reached very great numbers.

The above-mentioned variations between stations, with regard to their phytoplankton, are brought out in Tables 1—4, 7—10 and 12—13. (It should be pointed out that at stations belonging to Area III, the numbers listed under the heading «*Chaetoceros*» refer to those four species which were regarded as members of the Styliformis society.) It will be seen from the tables that the variations in composition were almost entirely due to fluctuations in the relative abundance of the various species, as there was a remarkable uniformity with respect to the occurrent species.

A comparison between the complete phytoplankton tables for the two stations 248 (Table 18) and 362 (Table 19) may serve to illustrate the extent of the fluctuations mentioned. Calculations showed that the standing stocks at these two localities, when expressed in terms of cell volume (biomass), were of about the same size. Allowing for the large specific differences in cell volume, the plankton at 248 appeared to form a community where several species were of about equal importance. In contrast, the population at 362 was entirely dominated by *Chaetoceros debilis,* at the expense of the other members of the community.

It is noteworthy that there was a very close agreement between the western boundary of Area III and the border of the Atlantic water masses (cp. Fig. 5 and Fig. 7). This was especially the case in the area due east of Jan Mayen. Of the stations in one section crossing that area, 325 and 328 were both Atlantic and had a plankton where the Styliformis society was well represented. At the Arctic station 326 the vegetation was very different, none of the members of the mentioned society being present.

D. *Area IV.*

The two large diatoms *Thalassiothrix longissima* and *Rhizosolenia hebetata* f. *semispina* were occasionally recorded in Area III, especially at localities modified by an admixture of Arctic water (e. g., station 206). On the whole, however, these two species were confined to the narrow zone of mixed or Arctic water which separated the Atlantic waters from the Polar water masses occupying the north-western part of the Norwegian Sea. Closely associated with the species mentioned were two small *Coscinodiscus* species, *C. excentricus* and *C. kützingii.* In view of the very similar distribution of these four plankton algae, there seemed to be good reason for considering them to be members of a «Semispina society».

Area IV (Fig. 7) was defined as including localities where the Semispina society formed a characteristic or even predominant component of the vegetation, with the exception of some such localities in the immediate vicinity of Jan Mayen (see Area VII below).

Stations in the southern part of Area IV mostly represented the Arctic type (AR, Fig. 5), while several of the more northern localities were Atlantic, although showing a marked Arctic influence (A 5, Fig. 5). Stability values in the uppermost 75 metres were higher than in Area III (Fig. 6).

At the Arctic station 356 (Table 20), the Semispina society was notably well developed. It will be seen from the table that members of the Atlantic Styliformis society, although present, were of minor importance. At other localities, such as the Arctic 326 and the Atlantic-Arctic 383, where the Semispina society formed a characteristic component of the vegetation, plankton of the Styliformis type was practically absent. In the southern part of the area, however, there were also instances (280, 282) where the Semispina society played a more subordinate role. These stations, although located in Arctic water, supported a plankton where *Rhizosolenia styliformis* and its associated species were conspicuous, which indicated that an admixture of Atlantic water had taken place (Table 6).

The situation recorded at station 254 south-east of Jan Mayen demonstrates strikingly the extent to which stratification in the euphotic layer may affect the vertical distribution of plankton (Table 21). At this station, Arctic water with a temperature of about 1.4°C was present as a thin layer on top of Polar water of about -1°C, the latter water type being encountered at a depth of 20 metres. Berge (personal communication) found that the production capacities of the plankton in 0 and 10 metres depht were about 1×10^{-7} mg C per litre and lux-hour, while the production capacity recorded at 20 metres was about forty times higher. The peculiar vertical distribution of plankton indicated by these observations is fully brought out by Table 21. It vill be seen that a number of species which were poorly represented or totally absent in the uppermost, Arctic layer, were abundant in the Polar water immediately below. High concentrations of ciliates in the upper strata indicate that production in the latter had ceased some time prior to the sampling date, probably primarily as a result of nutrient exhaustion.

Obviously, in a case like this, «formula» methods similar to those employed by Steemann Nielsen and Aabye Jensen (1957) or Ryther and Yentsch (1957) would have been quite inadequate for determining total production in the euphotic layer.

E. *Areas V and VI.*

The large water masses of Polar nature occupying the western and central parts of the eddy system between Spitsbergen and Jan Mayen were, in June 1954, poor in phytoplankton. This was especially true of those stations in the southern part of this region which were included in Area VI (Fig. 7). Here, an almost complete absence of vegetation formed a remarkable contrast with the abundance of plankton recorded in nearby Atlantic waters. At northern localities, however, conditions seemed to be somewhat more favourable for phytoplankton growth. These localities were treated separately as Area V.

The hydrography of this north-western, Polar part of the Norwegian Sea seems to be highly variable from one year to another (see Ramsfjell 1960 for a further discussion). According to Eggvin (quoted by Ramsfjell loc. cit.) bottom water is formed in this region in some years, but not in others. Also, depending on meteorological factors, ice conditions vary greatly, which in turn affects the hydrography. In early spring 1954, according to Thomsen and Lorck (1957), the ice cover extended abnormally far east, occupying the major part of Areas V and VI. In May 1954, the mean air temperature in the north-western part of the Norwegian Sea was 2—3°C above the normal, and the wind was blowing mainly from north-east (according to data which were kindly supplied by the Meteorological Institute, Oslo). An abnormally rapid disappearence of the ice which was observed to take place during May over wide areas (Thomsen and Lorck loc. cit.) was probably caused partly by the ice being displaced westwards, and partly by a high melting rate. The latter assumption fits in well with the fact that in June, salinities in the uppermost strata were quite low, while they increased rapidly with depth, as demonstrated by the shape of the t—S diagrams for Polar localities (P, Fig. 4). Accordingly, stability values recorded in the uppermost 75 metres in Areas V and VI were generally quite high (Fig. 6).

The phytoplankton in Areas V and VI was remarkable in so far as none of the species occurring were of the «Arctic-neritic» type which commonly form the most characteristic component of the vegetation in Polar waters during and immediately after the disappearence of the ice (Braarud 1935; Ramsfjell 1960).

The Polar waters of Area V were found to support a small-celled plankton curiously reminiscent of the phytoplankton encountered in the approximately 10°C warmer water masses occupying the south-eastern part of the Norwegian Sea (Areas I and II). The most important difference was the absence of coccolithophorids in Area V, while other small algae, such as *Fragilariopsis nana, Nitzschia closterium, N. delicatissima, Thalassiosira bioculata* var. *raripora* and *Exuviaella baltica,* were present at most localities, although generally in small or moderate concentrations only (Tables 14 and 15). A complete phytoplankton table is presented for station 399 (Table 22). This station, located close to the ice edge, was on the whole the richest locality in the area. It will be seen that of larger diatoms only *Thalassiosira gravida* was represented. This alga also formed an important part of the vegetation at 396 farther south, but was otherwise not recorded.

In Area VI, apart from unidentified naked flagellates, the only phytoplankton species of significance was *Fragilariopsis nana,* moderate amounts of which were observed at south-eastern localities (332, 334, 338). The major part of the area seemed to be practically devoid of any kind of phytoplankton growth (Tables 10—12).

Ciliates were occasionally present in abundance in Areas V and VI, especially at localities where the phytoplankton standing stocks were relatively well developed.

F. *Area VII.*

Six stations in Polar water in the immediate vicinity of Jan Mayen, though quite similar in their hydrography, showed some variability with respect to their phytoplankton. On the whole, however, the plankton in this area was clearly different from the small-celled type of vegetation which was predominant in Areas V and VI, larger diatom species forming an important part of the plankton communities.

Stabilities in the uppermost strata were higher in Area VII than anywhere else in the Norwegian Sea (Fig. 6). The t—S diagrams indicated that the stratification was due to ice melting.

The composition of the communities at some localities (269, 276) indicated a clear relationship with the vegetation of Area IV, members of the Semispina society being present in fair concentrations. At others (268, 272), some of the *Chaetoceros* species considered as members of the Atlantic Styliformis society were represented in small numbers. The most important fraction of the plankton, quantitatively, included species which were rather widely distributed in the Norwegian Sea at the time of the investigation, such as *Chaetoceros decipiens, Nitzschia delicatissima, Phaeocystis pouchetii,* and *Thalassiosira gravida.* In addition, however, the plankton at every station also contained several diatoms which were rarely found outside Area

VII. Species belonging to this category were *Chaetoceros convolutus*, *Ch. borealis* f. *concavicornis*, *Thalassiosira hyalina*, *Th. nordenskiöldii*, and *Rhizosolenia alata*. Smaller diatoms such as *Thalassiosira bioculata* var. *raripora* and *Fragilariopsis nana* were generally of little importance.

Table 23 gives the detailed composition of the community at station 278. This locality was one of the richest in the area. Nevertheless, as shown by the table, the populations of the various species were not very large.

G. *Area VIII.*

Some stations in the coastal waters off Bear Island and Spitsbergen, representing various water types, were somewhat artificially referred to this area.

In the Arctic waters around Bear Island, represented by station 364, stratification in the uppermost layers was considerably more pronounced than in adjacent Atlantic water masses (Fig. 6). The phytoplankton encountered here was extremely poor. The neighbouring station 363, although Atlantic with respect to its hydrography, showed a similar poverty, but the presence of *Chaetoceros debilis* at this locality indicated that it represented a transition to the extremely densely populated waters at station 362 in Area III.

In the section southwards from Spitsbergen, station 375 near the coast was located in water of extreme Polar type, having temperatures below —1.6°C and obviously originating from the Polar current running in a southerly direction along the eastern coast of Spitsbergen. A branch of the Atlantic current which, according to the current chart (Fig. 2) is present further off the coast and has an opposite direction, was represented by station 373. The Arctic water type at station 374 probably resulted from lateral mixing between these two currents.

The hydrographical conditions in this section were closely reflected by the vegetation at the three stations mentioned (Table 13). At the Atlantic 373, a rather poor plankton was observed, the only noteworthy species being *Nitzschia delicatissima* and *Phaeocystis pouchetii*. At 374, *Thalassiosira gravida* was the predominant plankton alga. The presence of the cold-water species *Chaetoceros furcellatus* clearly demonstrated the admixture of Polar water at this station.

The complete table is given for station 375 (Table 24), this being the only one of the 82 stations included in the survey where a characteristic cold-water («Arctic») phytoplankton community was recorded. *Chaetoceros furcellatus*, clearly predominant here, and *Fragilaria oceanica* were both regarded by Gran (1902) as belonging to the

«Arctic-neritic plankton element». Two of the other species of some importance at this locality, *Thalassiosira nordenskiöldii* and *Peridinium conicoides,* are likewise typically found only at low temperatures.

At station 377, located in Arctic, strongly stratified coastal water at South Cape, *Phaeocystis pouchetii* was present in considerable quantities (Table 13). One remarkable feature of the plankton at this station was the presence of a fairly abundant population of *Rhizosolenia setigera* (see Paasche 1960 a).

VI. Size of total standing stocks in different areas compared with the production measurements

The size of the standing stocks of phytoplankton was tentatively calculated in two different ways, viz. as cell surface area, and cell volume, respectively. It has been shown elsewhere (Paasche 1960 b) that it was not possible, with the present material, to decide statistically which of these methods was most suitable for the purpose of comparing standing stock size with data on primary production. In practice, however, it proved to be of little consequence whether one or the other method of calculation was used when constructing a chart illustrating regional variations in the size of standing stock. Cell volume (biomass) was chosen as the unit because of its possible usefulness in connection with recalculations using existing conversion factors.

The chart shown in Fig. 8 is based on values for the maximum cell volume per litre of sea water at each station. On comparing this chart with the vegetation chart (Fig. 7) it will be seen that the occurrence of large biomasses (above 0.5 mm^3) was restricted to Vegetation Area III, while at the majority of localities within the remaining parts of the Norwegian Sea, the standing stocks of phytoplankton were quite small (below 0.1 mm^3).

When comparing the biomass chart with Berge's production chart (Fig. 9), it should be borne in mind that the calculation of total cell volumes, as well as the determination of primary production, especially where production capacities are small, involve considerable sources of error. Furthermore, a strict proportionality between production intensity and total cell volume of a plankton population is not to be expected theoretically (see Paasche 1960 b). For these reasons, a detailed comparison between the two charts should not be attempted. It seems fully justified however, to conclude that there was a very

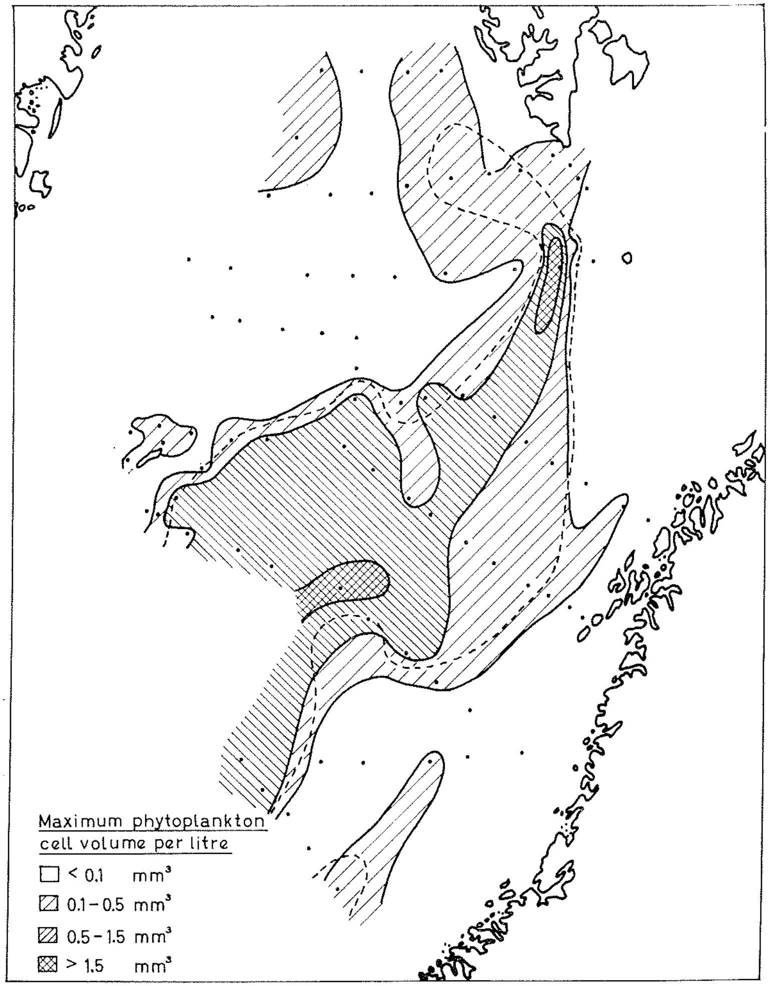

Fig. 8. Biomass distribution in June 1954, based on maximum values of mm³ algal cell volume per litre of sea water.

good general agreement between the regional distribution of biomass and that of production intensity. By arbitrarily choosing the iso-line of 0.8 g C/m²/day as a limit of the area of high production (dashed line in Figs. 7 and 8), the latter can be made to coincide rather closely with the area of large biomasses (Vegetation Area III).

At times the thought has been advanced that very small naked flagellates (μ-flagellates) play an important part in the primary production in the sea (e. g., Atkins 1945). It has been mentioned in earlier sections that organisms of this category may have been present in the living populations in larger numbers than those which were

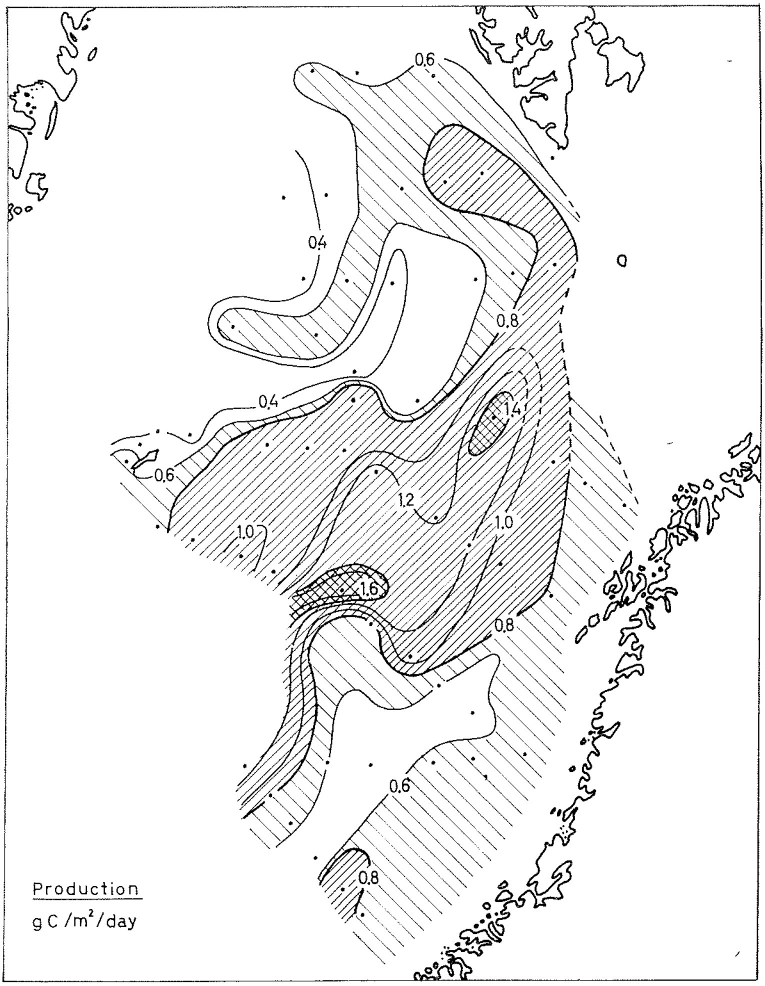

Fig. 9. Primary production in June 1954, expressed as daily gross production in g C below 1 m² of sea surface. After Berge (1958), slightly modified on the basis of recalculated values (Berge, unpublished).

recorded during the counting. It is therefore quite likely that some of the production observed in areas where, according to the tables, very little plankton was present, might be attributed to μ-flagellates. This would agree with observations made by Grøntved (1958) in Danish fjords in the summer. In the highly productive Atlantic waters on the other hand, according to calculations of the degree of utilization of incident radiation energy (see Paasche 1960 b), the production rates could be largely or entirely accounted for without there being any need for assuming that other primary producers had been active in addition to those which were recovered in the sedimentation samples.

Accordingly, it would seem that the results obtained in the present investigation offer the biological explanation of the fact, noted by Berge (1958), that there was a marked correlation between the regional variations in production intensity and the hydrographical features of the Norwegian Sea in June, 1954. The main conclusion of the findings may be stated as follows: the high production rates observed in the central, western and northern parts of the Atlantic region were caused by an abundant vegetation composed of several diatom species, many of which were restricted to these water masses, and of *Phaeocystis pouchetii*. In the remaining parts of the Norwegian Sea, other types of vegetation prevailed, but their quantitative development was generally much inferior; accordingly, production rates were lower.

VII. The distribution of the various species and their relative importance in production

Distribution charts for the more important species are shown in Figs. 10—28. In order to facilitate a comparison with the production chart, the limit of the high production area, defined as in the previous section, has been drawn on each chart. On the basis of the distribution charts, species with similar patterns of distribution could be grouped together as follows:

1. Species entirely, or almost entirely, restricted to the area of high production (Vegetation Area III):

Rhizosolenia styliformis (Fig. 10).
Coscinodiscus centralis (Fig. 11).
Chaetoceros borealis (Fig. 12).
Chaetoceros debilis (Fig. 13).
Chaetoceros densus (Fig. 14).
Nitzschia seriata (Fig. 15).

2. Species having their centre of distribution and attaining their largest concentrations in the high production area (Area III), but frequently occurring in less productive areas also:

Chaetoceros decipiens (Fig. 16).
Thalassiosira gravida (Fig. 17).
Phaeocystis pouchetii (Fig. 18).
Nitzschia delicatissima (Fig. 19).
Gyrodinium grenlandicum (Fig. 20).

3. Species attaining large concentrations at south-eastern Atlantic localities (Vegetation Area II) while being much less important in the area of high production (Area III) in spite of their occurring at most localities:

Coccolithus huxleyi (Fig. 21).

Thalassiosira bioculata var. *raripora* (Fig. 22).

4. Species having two centres of distribution, one in the south-eastern, Atlantic or coastal waters (Areas I and II), the other one in north-western, cold water masses (Areas IV and V), while more or less completely missing in the high production area:

Fragilariopsis nana (Fig. 23).

Nitzschia closterium (Fig. 24).

Exuviaella baltica (Fig. 25).

5. Species mainly restricted to a narrow zone of Arctic water at the north-western boundary of the area of high production (Vegetation Area IV):

Rhizosolenia hebetata f. *semispina* (Fig. 26).

Thalassiothrix longissima (Fig. 27).

Coscinodiscus excentricus and

Coscinodiscus kützingii (Fig. 28).

Obviously, only those species which formed a significant component of the plankton in Area III, i. e. species belonging to groups 1 and 2, could be held responsible for the high production rates observed in this area. The distribution charts themselves do not offer any definite clue as to which of these algae were, generally speaking, the most important producers. The striking similarity between the distribution of members of group 1 (the Styliformis society) and the extent of the area of high production might perhaps be taken to indicate that this category of species, taken as a group, were of prime importance. On the other hand, assuming that the cell surface area of plankton algae serves as a reasonably close estimate of their ability to carry out photosynthesis (Paasche 1960 b), it would seem that *Phaeocystis pouchetii* was, on the whole, the most active individual producer. In 52 surface samples from the high production area, an average of 41.6 % of the total cell surface area of the populations was due to *Phaeocystis,* the remaining 58.4 % mainly representing the various diatoms of the first and second group. In reality, the relative shares in production of the different algae probably varied greatly from one locality to another, as indicated by the following example. Stations 242 and 321 were, according to the production chart (Fig. 9), those two localities where the highest production rates were observed. At station 242, which possessed a plankton of average

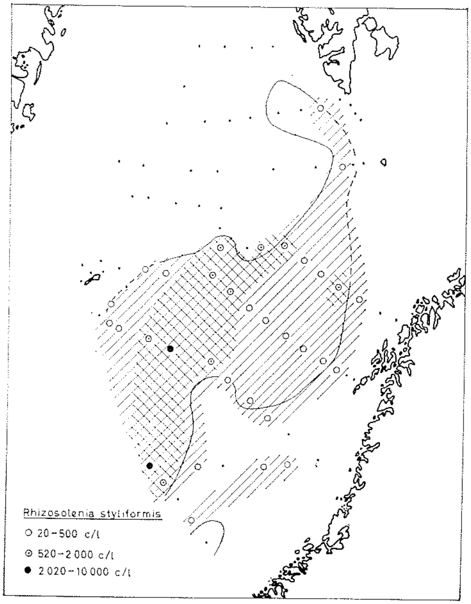

Fig. 10. Distribution of *Rhizosolenia styliformis*.

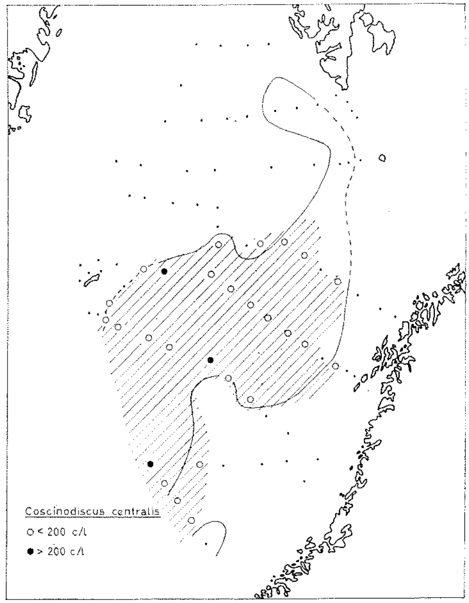

Fig. 11. Distribution of *Coscinodiscus centralis*.

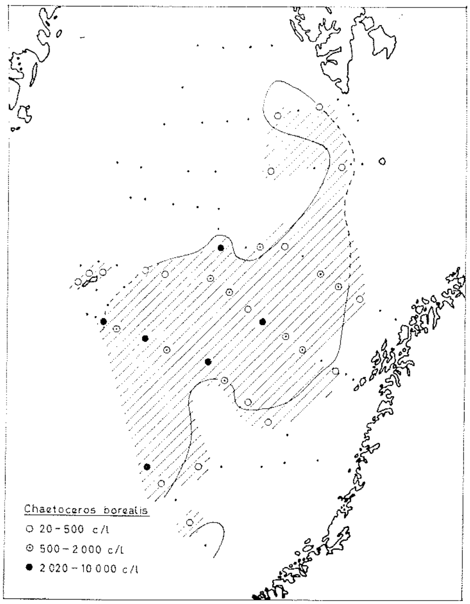

Fig. 12. Distribution of *Chaetoceros borealis*.

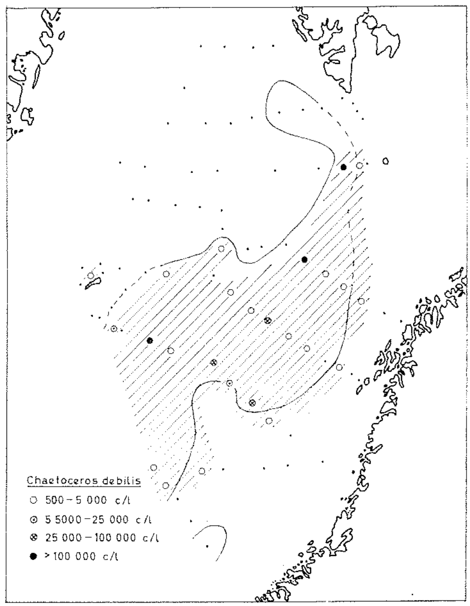

Fig. 13. Distribution of *Chaetoceros debilis*.

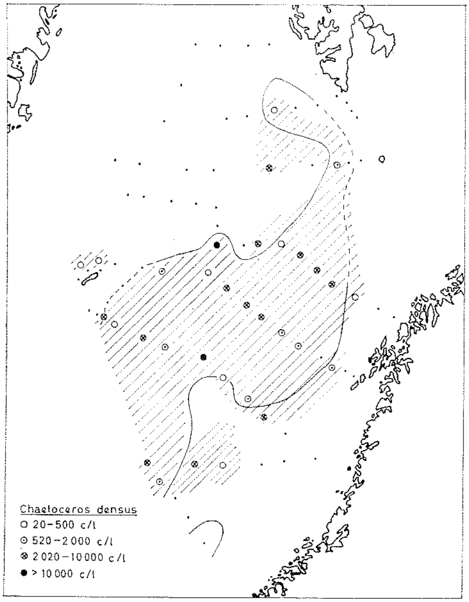

Fig. 14. Distribution of *Chaetoceros densus.*

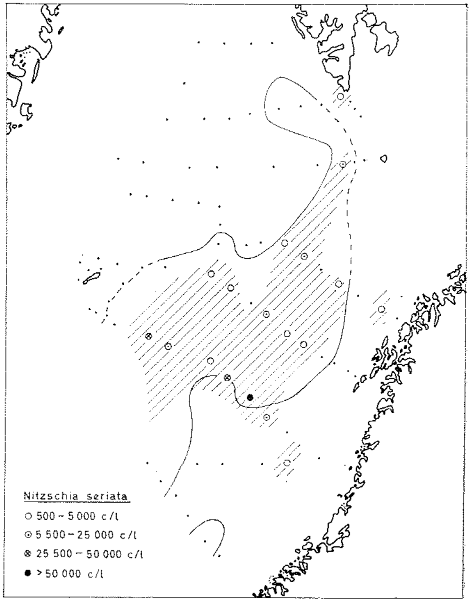

Fig. 15. Distribution of *Nitzschia seriata.*

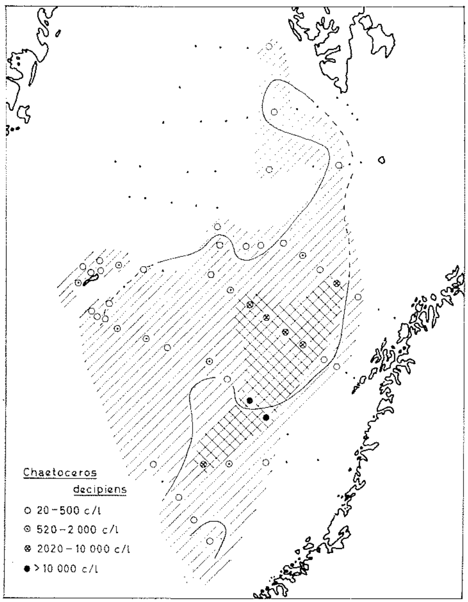

Fig. 16. Distribution of *Chaetoceros decipiens.*

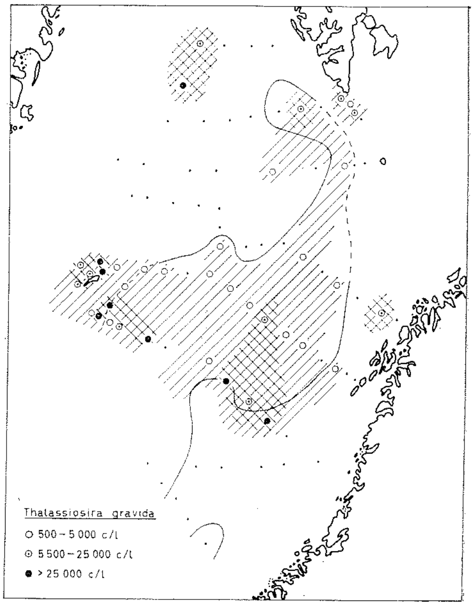

Fig. 17. Distribution of *Thalassiosira gravida.*

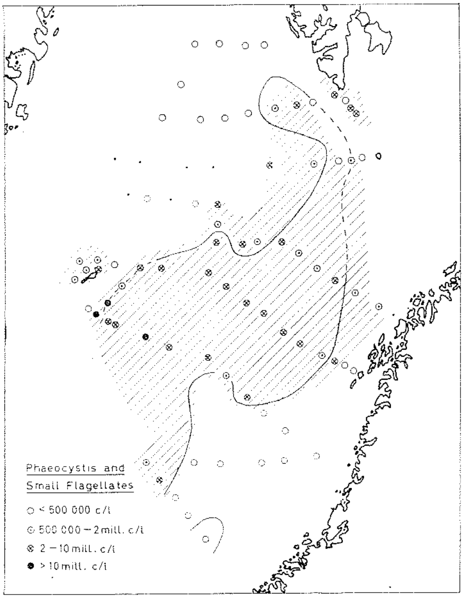

Fig. 18. Distribution of *Phaeocystis pouchetii*, including small flagellates not identified.

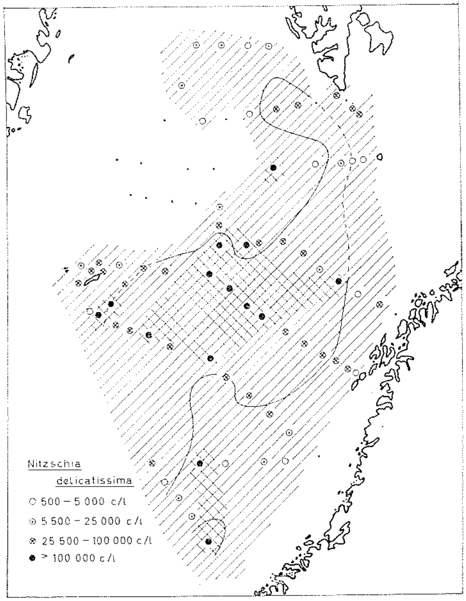

Fig. 19. Distribution of *Nitzschia delicatissima*.

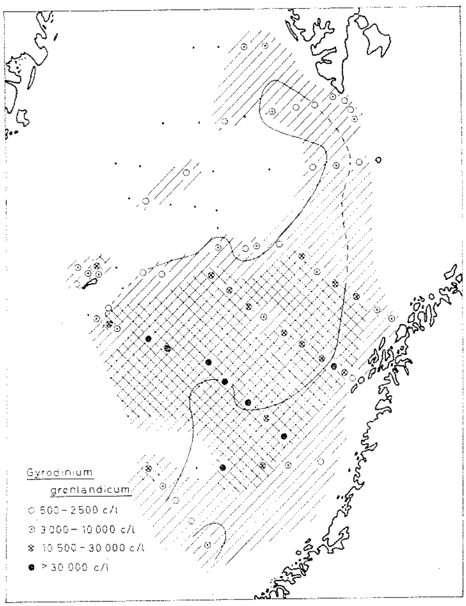

Fig. 20. Distribution of *Gyrodinium grenlandicum*.

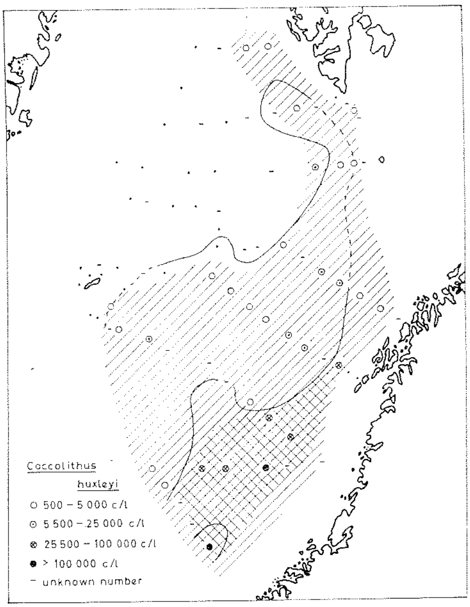

Fig. 21. Distribution of *Coccolithus huxleyi*.

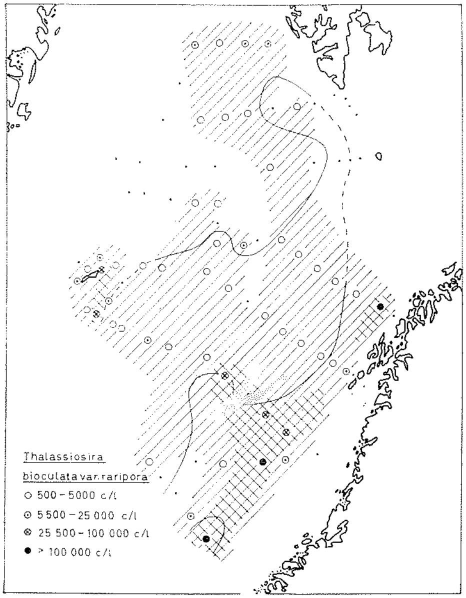

Fig. 22. Distribution of *Thalassiosira bioculata* var. *raripora*.

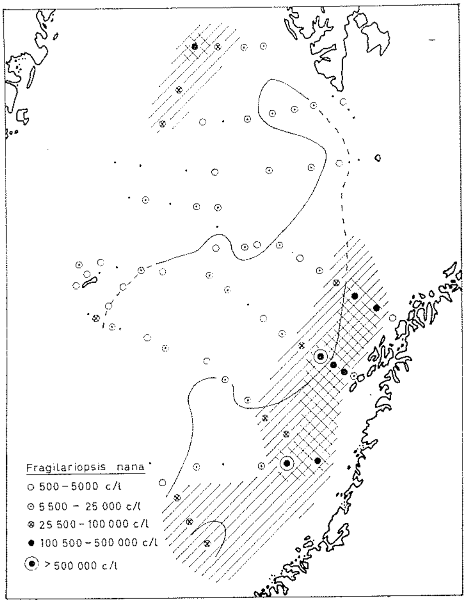

Fig. 23. Distribution of *Fragilariopsis nana*.

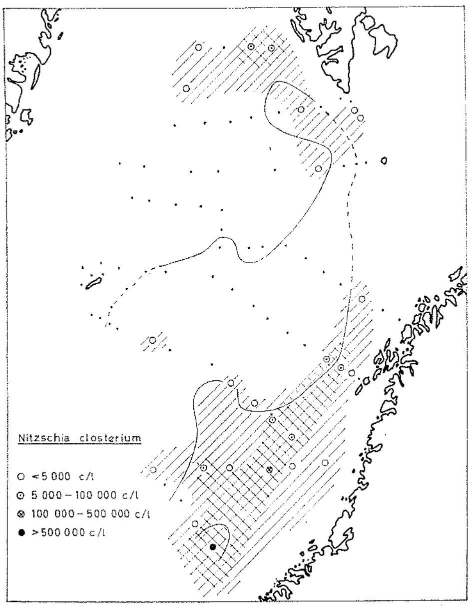

Fig. 24. Distribution of *Nitzschia closterium*.

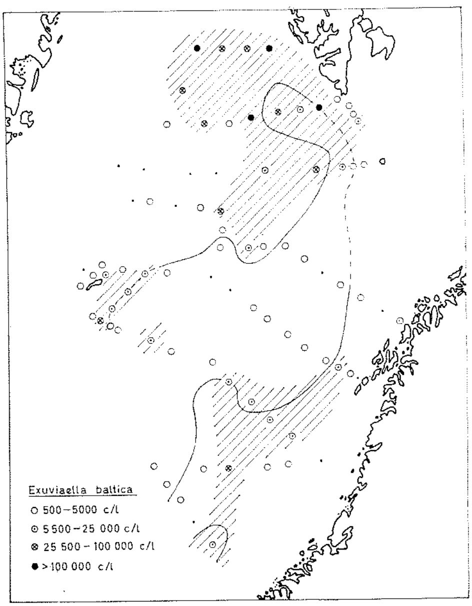

Fig. 25. Distribution of *Exuviaella baltica*.

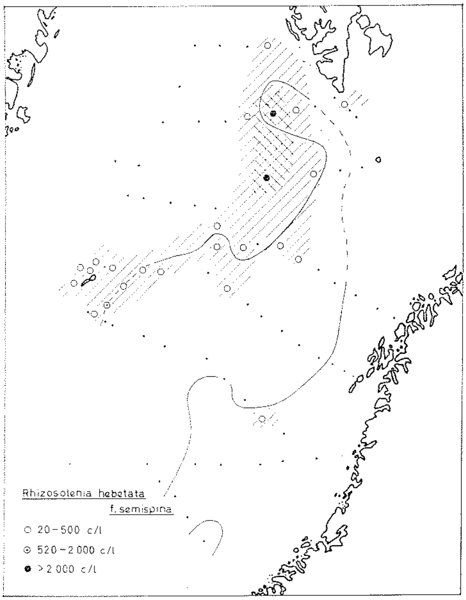

Fig. 26. Distribution of *Rhizosolenia hebetata* f. *semispina*.

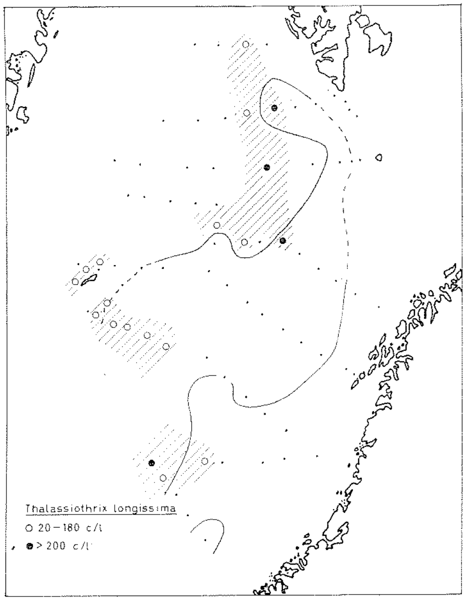

Fig. 27. Distribution of *Thalassiothrix longissima*.

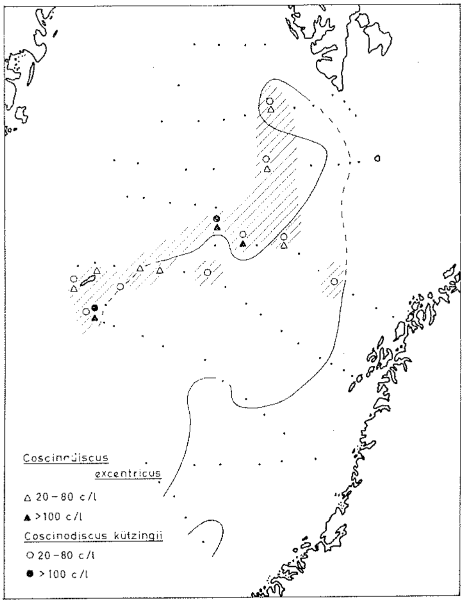

Fig. 28. Distribution of *Coscinodiscus excentricus* (triangles) and *Coscinodiscus kützingii* (circles).

composition, *Phaeocystis* represented about 40 % of the total cell surface at both sampling depths. At 321, on the other hand, *Chaetoceros debilis* was, even numerically, the most important species, and its share in the total cell surface was about 70 % at both depths, that of *Phaeocystis* being only 1—2 %.

VIII. The vegetation in June 1954 in relation to the seasonal development of the phytoplankton in the different water masses

The principles governing the quantitative development of phytoplankton populations are known (see Braarud 1935, and Harvey 1950, for summaries). However, as has been pointed out by Braarud *et al.* (1953), a full application of this general knowledge to surveys of the present kind is practically impossible, partly because of the complexity of the environmental factors involved, and a corresponding incompleteness or even absence of observations on such factors, and partly because exact knowledge of the response of the various plankton algae to a given set of environmental circumstances is, at best, only fragmentary.

When discussing the results from the present investigation, it is desirable that the time factor be considered as well. This leads to further complications, since it requires that the phenomenon of succession (Gran and Braarud 1935), at present not very well understood, be taken into account.

In the following discussion, where the different water masses or vegetation areas will be treated separately, use will be made of hydrographical and biological data obtained during the cruise in 1954, as well as of additional information available in literature. However, before entering upon the discussion, it seems appropriate to mention a circumstance of some general interest.

In the well-known paper by Sverdrup (1953), a formula is derived for the estimation of the critical depth, i. e. the depth that may not be exceeded by the thickness of the mixed layer if multiplication of the plankton algae is to result in an increase in population size. Predictions of the time of onset of the vernal blooming, made according to Sverdrup's method, have been verified in practice for Atlantic waters at Weather Ship M by Sverdrup himself (loc. cit.), using data obtained by Halldal, and for Atlantic and Arctic waters at

Bear Island by Marshall (1958). Hence it would seem that Sverdrup's theory on the whole is valid for the Norwegian Sea.

According to some tables published by Smayda (1959), the average daily total influx of radiation energy in June is probably not much smaller in the northern than in the southern part of the Norwegian Sea. If an extrapolation is made from Sverdrup's figure (loc. cit., Fig. 2) illustrating temporal variations in the position of the critical depth at Weather Ship M (which is located relatively far south in the Norwegian Sea), it would appear that in June, even on cloudy days, the critical depth is always greater than 150 metres. This means that in waters where no marked stability was recorded in the uppermost 75 metres (see Fig. 6), conditions for phytoplankton growth in June might very well have been excellent, even if, or maybe particularly if, turbulence was constantly carrying parts of the plankton populations down to greater depths.

On the other hand, in water where stratification of the uppermost layers was considerable and had already remained so for an appreciable period of time prior to the investigation, there would be some likelihood of growth conditions being less favourable. The presumably quite early blooming in such waters would soon have caused an exhaustion of the relatively small reserves of nutrients present in the thin mixed layer.

A. *The Norwegian coastal waters (Vegetation Area I).*

Off southern Norway, the vernal blooming of phytoplankton usually commences in late March (Gran 1927, 1929 b; Braarud *et al.* 1958), while it is usually about three weeks later in coastal waters at Lofoten in northern Norway (Føyn 1929; Braarud *et al.* 1958).

The observations from the coastal waters in June 1954 indicate that a transition to a pronounced summer situation had taken place some time earlier, when nutrient deficiency in conjunction with a marked stratification had become seriously limiting to production. One remarkable feature was that relatively uniform conditions seemed to prevail over wide areas. This is not always the case at the time of spring maximum, when the coastal current usually carries with it a series of rather distinct plankton communities (Braarud *et al.* 1958). Surprisingly, dinoflagellates were hardly observed at all in 1954, although they may, in other years, form an important component of the coastal summer plankton (Braarud *et al.* loc. cit.).

B. *Atlantic waters (Vegetation Areas II and III).*

In Atlantic water, the spring increase starts considerably later than in the Norwegian coastal waters (Gran 1927), but may, in the southern part of the Norwegian Sea, be well on its way at the end of April (Halldal 1953). In the northern part a further delay occurs: in Atlantic water off Bear Island, Marshall (1958) did not observe an increase in production until May.

Since investigations carried out in years earlier than 1954 included neither production measurements nor determinations of biomass, very little quantitative information is available on the development of Atlantic phytoplankton communities subsequent to the onset of vernal blooming. Judging from the data from Weather Ship M (Halldal 1953), the standing stocks seemed to remain at a fairly low level throughout the summer of 1948, possibly because of high grazing rates. The data obtained by Ramsfjell (1960) for Atlantic localities in June 1952 and June 1953 seem to indicate that in 1953, the biomasses present were on the whole larger than in 1952. In June 1954, the quantities of plankton recorded in major parts of the Atlantic region appeared to be greater than in any of the years previously investigated.

Each year the specific composition of the plankton observed in Atlantic water in June was, generally speaking, different. It is conceivable that the specific nature of the initial stocks originally present at the onset of blooming, or introduced later, may have had some influence on the quantitative aspects of phytoplankton development and production. On the whole, however, it must be assumed that the time of maximum plankton development, as well as the size and the productivity of the standing stocks then present in Atlantic waters, was largely dependent on environmental factors.

A comparison between the hydrographical data from the month of June in 1952, 1953, and 1954 respectively, revealed some differences in temperature and stability, but it seems doubtful whether they might *per se* have been of very great ecological importance. Meteorological data (kindly supplied by the Meteorological Institute, Oslo) demonstrate that the climatic conditions in May and June were quite different each year. Unfortunately, the data at hand are not sufficiently comprehensive to permit a detailed analysis.

Halldal's study (1953) indicated the importance of grazing in regulating the quantitative development of Atlantic phytoplankton. It is suggestive that, according to Wiborg (1955), the zooplankton volumes recorded at Weather Ship M in April, May and June, 1954, were much smaller than during the same months in any of the previous years.

Although it is evident that the yearly development of the vegetation in Atlantic waters by no means follows a uniform pattern, the available information seems to indicate that certain features are common to at least some years.

It appears that sooner or later a transition may occur, leading from a spring plankton, characterized by diatoms of medium or large size, to a summer plankton consisting of *Fragilariopsis nana* and other small diatoms, as well as coccolithophorids. Halldal (1953) noted such a change at Weather Ship M during July and August in 1948. According to observations by Ramsfjell (1960), a corresponding change must have taken place much earlier in 1952, since a characteristic summer vegetation was then found to prevail everywhere in Atlantic waters in June.

If a similar interpretation is applied to the situation recorded in June 1954, it appears that spring conditions still prevailed in the highly productive, central, northern and western Atlantic water masses (Area III), while a typical summer vegetation had gained the upper hand in the south-eastern part of the Atlantic region (Area II). To a certain extent this situation probably reflected the general displacement towards north and west of the Atlantic surface waters which continually takes place in the Norwegian Sea. According to the current velocities reported by Helland-Hansen and Nansen (1909), the rapid-flowing waters in Area II might have entered the Norwegian Sea as late as the beginning of May.

Although the transition to summer conditions in Area II was thus to some extent promoted by sequence phenomena, it probably first and foremost indicated a true succession. Ramsfjell (1960) concluded, on the basis of his observations from 1952, that a succession of this type had taken place that year, and ascribed it to a supposed lowering of the concentrations of nutrient salts in the euphotic zone in the course of the vernal blooming. The assumption that a similar process had actually occurred in the south-eastern Atlantic waters in the spring of 1954, gains some support from the fact that stratification of the uppermost layers was slightly more pronounced in Area II than elsewhere in the Atlantic region. In Area III, as was pointed out in an earlier section, vertical as well as horizontal admixture of non-Atlantic water was probably taking place to a considerable extent. Here turbulence may have kept nutrient salt concentrations on fairly high levels for quite a long period of time: even at those stations within Area III which were worked in the latter half of June, there was no indication that the Styliformis society or its accompanying species were about to yield to the small-celled plankton of Area II.

Since the onset of the spring increase was probably soon followed by maximal production rates, while the transition to a small-celled summer plankton again led to lower production, the conclusion may be arrived at that in 1954, high production in Atlantic waters probably first appeared in the south-eastern part of the Norwegian Sea, whence it spread in a wave-like motion towards north and west. The period of high production may have been of shorter duration in south-eastern than in north-western water masses.

It was mentioned that the quantitative development of the Atlantic phytoplankton seems to be closely connected with changes taking place in its specific composition as a result of succession and sequence phenomena. It seems desirable, at this point, to discuss in some detail the composition of the vegetation especially in the highly productive waters in Area III.

The observations made by Halldal (1953) in 1948 indicate that the vegetational changes taking place in Atlantic waters subsequent to the onset of blooming, bear little resemblance to the ordinary *Thalassiosira—Chaetoceros* succession which is a well-known feature of coastal waters during spring. The material from 1954 does not contain any information suggesting that a succession, involving the various species recorded in Area III, was taking place during the period of high production. The variations which were observed between stations in this area with respect to the relative concentrations of the different algal species, showed no clear correlation with either the sampling dates, the geographical position or the hydrography of the localities in question. Rather than reflecting stages of a general succession pattern, these variations were due to minor local differences in hydrogaphy or in the supply of initial stock.

On reviewing the distribution charts, it becomes evident that sequence was of just as little importance in determining the specific composition of the phytoplankton in Area III, since species forming an important component of the community at any one locality were present at all or nearly all other localities in the area as well.

The great uniformity of the plankton throughout Area III with respect to its qualitative composition may seem rather surprising, considering that the Atlantic surface waters probably require a couple of months to cross the Norwegian Sea (according to the surface current velocities reported by Helland-Hansen and Nansen 1909), and on their way mix to a considerable extent with other water masses present in the region. However, the striking similarity which was noted between the distribution patterns of several algae, particularly the members of the Styliformis society, lends some support to the idea that at least this group of species had a common centre of distribution. According to Gran (1902), the occurrence of *Rhizosolenia styliformis* during the winter is restricted to the southernmost part of the Norwegian Sea, where the stock of this alga is presumably frequently renewed by the introduction of populations with the Atlantic water entering in the Faroe-Shetland region. Accordingly, *Rh. styliformis* probably owed its wide distribution in June 1954 to a quite recent admixture of Atlantic water throughout Area III. *Chaetoceros densus, Ch. borealis, Coscinodiscus centralis* and *Nitzschia seriata* might then be assumed to have been of southern origin as well. It may be noted that several of these species were recorded by Corlett (1953) in Atlantic water south of the Faroe-Shetland area. The remaining member of the Styliformis society, *Chaetoceros debilis,* differs from the others in being mero-planktonic. This alga seems to form an important component of the spring plankton in the coastal waters around the Faroes (Gran 1915; Braarud *et al.* 1953). It is thus rendered likely that Atlantic waters passing the Faroe-Shetland Channel early in 1954 were seeded with cells or resting spores of *Ch. debilis* in sufficient numbers to produce the large populations encountered in Area III in June.

Turning to the remaining species prominent in Area III, two of these, viz. *Thalassiosira gravida* and *Phaeocystis pouchetii* are known to be able to survive during the winter at the coasts or in the ice everywhere in the Norwegian Sea (Gran 1902). However, both of these species, as well as *Nitzschia delicatissima,* occur in the spring in the coastal waters at the Faroes or in the mixing area between Atlantic and Arctic water immediately north of these (Gran 1915; Steemann Nielsen 1943; Braarud *et al.* 1953). Thus it seems likely that the populations of these species might originally, at least in part, have been introduced into Atlantic water in this region.

If the above interpretation is correct, it would seem that the biological and hydrographical conditions in the southernmost part of the Norwegian Sea during the early seasons of the year, as well as the velocities, directions and transport rates of the Atlantic surface currents, are of vital importance for the composition of the phytoplankton during the period of high production in Atlantic waters everywhere in the region. The circumstance that in 1953, the Atlantic plankton, although containing several of the species recorded in 1954, differed in some important respects, may be viewed against this background. It suffices to mention that, according to the observations by

Ramsfjell (1960), *Rhizosolenia styliformis* was virtually absent in the former year, while on the other hand, *Chaetoceros atlanticus* was abundant. It would seem that in 1953, local influences made themselves felt more strongly, since the specific composition of the plankton was not then uniform over wide areas in the same way as in 1954.

C. *The mixing zone between Atlantic and Polar waters (Vegetation Area IV).*

The hydrographical data, when considered *per se*, do not explain why the narrow, mostly Arctic zone of mixing, which in June 1954 separated the Atlantic from the Polar water, was at that time inhabited by a distinct plankton society. Consequently, the discussion will be focused on what is known of the bio-geography of the two principal members of that society, *Rhizosolenia hebetata* f. *semispina* and *Thalassiothrix longissima.*

According to Smayda (1958 b), both of these species are cosmopolitan, but observations by Gran (1902) indicate that in the Norwegian Sea, they never reach high concentrations, except in Arctic or Polar waters in the summer months. Gran (loc. cit.) and Ostenfeld (1913) found that *Rhizosolenia hebetata* f. *semispina* and *Thalassiothrix longissima* occur regularly throughout the Atlantic part of the region during the winter. Observations by the former author (Gran loc. cit.), and in the case of *Th. longissima,* by Halldal (1953), indicate that the two algae in question do not participate even in the early stages of the vernal blooming in these waters. On the contrary, they seem to decline in numbers as the year advances.

Ramsfjell (1960) observed fairly high concentrations of *Rh. hebetata* f. *semispina* at most localities in the Polar waters north-east of Jan Mayen (corresponding to our Areas V and VI) in June, 1952. In the same month in 1954, conditions in that part of the Norwegian Sea were such that growth of large diatoms was no longer possible (see below). The Arctic waters in Area IV were less stabilized, and probably more turbulent, than the Polar water masses in Areas V and VI. Apparently, by supplying relatively high nutrient salt concentrations, as well as sufficiently low temperatures, they served as a refuge for species which at some earlier time of the year may have had a much wider distribution.

D. *Polar waters between Jan Mayen and Spitsbergen (Vegetation Areas V and VI).*

The paucity of the vegetation in the north-western, Polar part of the Norwegian Sea in June 1954 is well in agreement with the assumption that, at this time of the year, a persistent stratification of the uppermost layers was strongly inhibiting to a continued phytoplankton growth.

Braarud (1935) has demonstrated that the spring outburst in Polar water follows immediately upon the establishment of ice-free conditions. In the Polar water masses between Jan Mayen and Spitsbergen, the onset of phytoplankton development and the duration of the period of blooming are probably subject to great variations from one year the next, depending on meteorological and hydrographical conditions (see Ramsfjell 1960). In June 1952, and particularly in June 1953, Ramsfjell recorded a very abundant vegetation in this region. The stability values calculated for the waters in question in the latter year (Ramsfjell loc. cit.) were extremely low. There is, then, convincing evidence that the period of high production in 1954 started relatively early, and possibly that it was of quite short duration only.

Wiborg (1955) has shown that in the summer months, the Polar water masses in the north-western part of the Norwegian Sea generally support great concentrations of zooplankton, indicating that the amounts of organic matter produced here during the period of high production are of considerable magnitude. In June 1954, the zooplankton volumes recorded in Areas V and VI were several times larger than those observed in other parts of the Norwegian Sea. High grazing rates may be assumed to have contributed towards the rapid reduction of the phytoplankton standing stocks in the uppermost strata after the peak of production had been reached.

Ramsfjell (1960) found that the phytoplankton recorded in 1953 consisted to a great extent of mero-planktonic coldwater diatom species, which presumably were of local origin. The vegetation observed in 1952 was regarded as representing a somewhat later stage in the spring succession, comprising, among other algae, species such as *Chaetoceros atlanticus, Ch. borealis,* and *Ch. decipiens,* which might well have been introduced with the admixture of Atlantic water known to take place in this area. It is possible that an Atlantic influence made itself felt in 1954 also. This would then explain why the small-celled algal species forming the bulk of the vegetation in Areas V and VI, were, on the whole, the same ones that were encountered in Atlantic water wherever summer conditions were prevailing.

The populations of *Thalassiosira gravida* recorded at two northern localities in Area V probably represented a remnant of the earlier, autochtonous vegetation which was predominant during the period of high production.

E. *Polar waters around Jan Mayen (Vegetation Area VII).*

In spite of the very marked stratification of the waters in the immediate vicinity of Jan Mayen, the vegetation mostly consisted of diatoms of fair cell dimensions, and the biomasses were slightly larger than elsewhere in Polar waters. It appears from the current chart (Fig. 2) that the hydrographical situation is rather complicated in this area, and this may account for the fact that the conditions obtaining here were different from those recorded in Areas V and VI.

Smayda (1958 a) studied the phytoplankton around Jan Mayen in April, 1955. The specific composition of the plankton was then quite different from that observed in the present survey. The variations between the different stations in 1954 with respect to their phytoplankton, and especially the fact that members of the Atlantic Styliformis society occurred at some localities, indicate that the vegetation in the area was subject to changes under the influence of the various currents. It is, therefore, difficult to evaluate how well the present results fit in with those obtained by Smayda.

F. *Coastal waters at Bear Island and Spitsbergen (Vegetation Area VIII).*

Due to the quite strong stratification in the cold surface waters at Bear Island, the spring phytoplankton development here starts as early as April (Marshall 1958). In June 1954, the period of blooming in these waters was over, judging from the very poor plankton then present.

The material from the coastal waters at Spitsbergen is too scanty to allow any detailed comparison with the observations made in that area in 1952 and 1953 (Ramsfjell 1960). However, the situation in the water masses off the western coast in the region of South Cape in 1954 must have been very different from the one obtaining in 1953. The hydrographical data from station 377 show that the temperature near the surface was about 3°C higher than was the case at the identical locality one year earlier. Accordingly, the plankton at 377 contained none of the typical cold water algae which were abundant at the same position in June 1953. Clearly, the yearly development of the phytoplankton in this area must be greatly dependent on hydrographical conditions.

IX. Summary

1. Quantitative phytoplankton samples, collected during a cruise in the Norwegian Sea in June, 1954, by the research vessel «G. O. Sars», were worked up by means of the sedimentation method. Data on hydrography, primary production, and zooplankton, were supplied by the Research Division of the Fisheries Directorate, Bergen. The survey included stations in Coastal, Atlantic, Arctic, and Polar water.

2. On the basis of the analyses of the phytoplankton communities, eight vegetation areas were recognized. It was demonstrated that the extent of each vegetation area largely depended on hydrographical features.

3. In Norwegian coastal waters, as well as in Atlantic water in the south-eastern part of the Norwegian Sea, the vegetation was relatively poor, and consisted of small-celled diatoms and coccolithophorids. In the central and north-western parts of the Atlantic region an abundant plankton was present, consisting of *Rhizosolenia styliformis* and several other diatom species of large or medium cell dimensions, as well as of *Phaeocystis pouchetii.* A narrow zone of mostly Arctic water at the border of the Atlantic water masses supported a vegetation where the presence of *Rhizosolenia hebetata* f. *semispina* and associated species was a characteristic feature. In Polar waters in the north-western part of the Norwegian Sea, the plankton was, in general, very sparse, and was composed mostly of small-celled algae.

4. The size of standing stocks of phytoplankton was expressed as total cell volume (biomass) per litre of sea water. A comparison was undertaken between available data on hydrography, phytoplankton distribution, biomass and primary production.

5. The occurrence of large biomasses was restricted to the central and north-western Atlantic waters. Production in these waters was markedly higher than elsewhere in the Norwegian Sea (Berge 1958). There was evidence that production here was largely or entirely due to those algae which had been recognized in the preserved plankton samples. The relative shares of the various algae in the total production probably varied greatly between localities, but there was some reason to believe that *Phaeocystis pouchetii* was, on the whole, the most important producer.

6. Using data obtained in the course of the investigation, as well as additional information available in literature, the development of the vegetation in the different parts of the Norwegian Sea during the spring of 1954, was discussed.

7. The spring increase probably started earlier in Coastal, Arctic, and Polar waters, where stability in the uppermost strata was achieved early in 1954, than in Atlantic water where a discontinuity layer, if present, was then located at greater depths.

8. In June 1954, the period of high production had been brought to an end in Coastal, Arctic, and Polar waters, possibly because of nutrient exhaustion in the upper strata. The same was true of south-eastern Atlantic water masses, where some degree of stability was likewise apparent. In the central and north-western Atlantic waters, however, a general absence of stratification, in conjunction with favourable light conditions and possibly a moderate degree of turbulent activity, accounted for the fact that the plankton here was apparently still at the stage of spring maximum.

9. The possible origin of the initial stocks of the various species was discussed. There was evidence that many of the species constituting the vegetation in the area of large biomasses and high production, had been introduced into Atlantic water in the southern-most part of the Norwegian Sea early in 1954. The importance of the surface currents in distributing initial stocks was stressed.

10. The investigation amply confirmed the earlier idea (Ramsfjell 1960) that the quantitative as well as the qualitative aspects of the spring development of the phytoplankton in the Norwegian Sea are subject to great variations from one year to another.

X. References.

ALEKSEEV, A. P., & B. V. ISTOSHIN 1956: An outline of the permanent currents in the Norwegian and Greenland Seas. (In Russian). — Trudy PINRO 9: 62—68.

ATKINS, W. R. G. 1945: Autotrophic flagellates as the major constituent of the oceanic phyto-plankton. — Nature 156: 446—447.

BERGE, G. 1958: The primary production in the Norwegian Sea in June 1954, measured by an adapted 14C technique. — Rapp. Cons. Explor. Mer 144:85—91.

BRAARUD, T. 1935: The "Øst" Expedition to the Denmark Strait 1929. II. The phytoplankton and its conditions of growth. — Norske VidenskAkad. Hvalråd. Skr. 10:1—173.

BRAARUD, T., K. RINGDAL GAARDER & J. GRØNTVED 1953: The phytoplankton of the North Sea and adjacent waters in May 1948. — Rapp. Cons. Explor. Mer 133:1—89.

BRAARUD, T., K. RINGDAL GAARDER & O. NORDLI 1958: Seasonal changes in the phytoplankton at various points off the Norwegian West coast. — Rep. Norweg. Fish. Invest. 12(3):1—77.

CORLETT, J. 1953: Net phytoplankton at ocean weather stations "I" and "J". — J. Cons. int. Explor. Mer, 19(1):178—190.

FØYN, B. RUUD 1929: Investigation of the phytoplankton at Lofoten March—April, 1922—1927. — Skr. norske VidenskAkad. I. Mat.-Nat. Kl. 1928, 10:1—71.

GRAN, H. H. 1902: Das Plankton des Norwegischen Nordmeeres von biologischen und hydrografischen Gesichtspunkten behandelt. — Rep. Norweg. Fish Invest. 2(5): 1—223.

— 1912: Preservation of samples and quantitative determination of the plankton. — Publ. Circ. Cons. Explor. Mer 62:1—15.

— 1915: The plankton production of the North European waters in the spring of 1912. — Bull. plankt., Copenh. 1912.

— 1927: The production of plankton in the coastal waters off Bergen March—April 1922. — Rep. Norweg. Fish. Invest. 3(8):1—74.

— 1929a: Quantitative plankton investigations carried out during the expedition with the "Michael Sars", July—Sept. 1924. — Rapp. Cons. Explor. Mer 56(5):1—50.

— 1929b: Investigation of the production of plankton outside the Romsdalsfjord 1926—27. — Ibid. 56(6): 1—112.

GRAN, H. H., & T. BRAARUD 1935: A quantitative study of the phytoplankton in the Bay of Fundy and the Gulf of Maine (including observations on hydrography, chemistry and turbidity). — J. biol. Bd. Can. 1(5):279—467.

GRØNTVED, J. 1958: Planktological contributions III. Investigations on the phytoplankton and the primary production in an oyster culture in the Limfjord. — Medd. Komm. Havundersøg. Kbh. N.S. 2(17):1—18.

HALLDAL, P. 1953: Phytoplankton investigations from weather ship M in the Norwegian Sea, 1948—49. (Including observations during the "Armauer Hansen" cruise, July 1949.) — Norske VidenskAkad. Hvalråd. Skr. 38:1—91.

HARVEY, H. W. 1950: On the production of living matter in the sea off Plymouth. — J. Mar. biol. Ass. U.K. 29(1):97—137.

HELLAND-HANSEN, B., & F. NANSEN 1909: The Norwegian Sea. Its physical oceanography based upon the Norwegian researches 1900—1904. — Rep. Norweg. Fish. Invest. 2(2):1—390.

LUND, J. W. G., C. KIPLING & E. D. LE CREN 1958: The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. — Hydrobiologia 11(2):143—170.

MARSHALL, P. T. 1958: Primary production in the Arctic. — J. Cons. int. Explor. Mer 23(1):173—177.

OSTENFELD, C. H. 1913: On the distribution of Bacillariales (Diatoms) in the plankton of the North European waters according to the international sea investigations, with special relation to the hydrographical conditions. — Bull. Crois. pér. Explor. Mer, Résumé Planktonique, 3:403—508.

PAASCHE, E. 1960a: Notes on phytoplankton from the Norwegian Sea. — Botanica Marina 2. (In press).

— 1960b: On the relationship between primary production and standing stock of phytoplankton — J. Cons. int. Explor. Mer 26(1). (In press).

RAMSFJELL, E. 1960: Phytoplankton distribution in the Norwegian Sea in June 1952 and 1953. — Rep. Norweg. Fish. Invest. (In press).

RYTHER, J. H., & C. S. YENTSCH 1957: The estimation of phytoplankton production in the ocean from chlorophyll and light data. — Limn. Oceanogr. 2(3):281—286.

SMAYDA, T. J. 1958a: Phytoplankton studies around Jan Mayen Island March—April, 1955. — Nytt Mag. Bot. 6:75—96.

— 1958b: Biogeographical studies of marine phytoplankton. — Oikos 9(2):158—191.

— 1959: The seasonal incoming radiation in Norwegian and Arctic waters and indirect methods of measurement. — J. Cons. int. Explor. Mer 24(2): 215—220.

STEEMANN NIELSEN, E. 1935: The production of phytoplankton at the Faroe Isles, Iceland, East Greenland and in the waters around. — Medd. Komm. Havundersøg. Kbh. S.: Plankton. 3(1):1—93.

— 1943: Über das Frühlingsplankton bei Island und den Faröer-Inseln. — Ibid. 3(6):1—14.

— 1952: The use of radio-active carbon (C^{14}) for measuring organic production in the sea. — J. Cons. int. Explor. Mer 18(2):117—140.

STEEMANN NIELSEN, E., & E. AABYE JENSEN 1957: Primary oceanic production. The autotrophic production of organic matter in the oceans. — Galathea Rep. (Sci. Res. Dan. Deep Sea Exped. 1950—52.) 1:49—136.

SVERDRUP, H. U. 1953: On conditions for the vernal blooming of phytoplankton. — J. Cons. int. Explor. Mer 18(3):287—295.

TAIT, J. B. 1957: Hydrography of the Faroe-Shetland Channel 1927—1952. — Scot. Home Dep., Mar. Res. 2:1—309.

THOMSEN, H. & M. V. L. LORCK 1957: The state of the ice in the Arctic seas 1954. — Naut.-met. Aarb., Kbh. 1954.

UTERMÖHL, H. 1931: Neue Wege in der quantitativen Erfassung des Planktons. (Mit besonderer Berücksichtigung des Ultraplanktons.) — Verh. int. Ver. Limnol. 5:567—596.

— 1958: Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. — Mitt. int. Ver. Limnol. 9:1—39.

WIBORG, K. F. 1955: Zooplankton in relation to hydrography in the Norwegian Sea. — Rep. Norweg. Fish. Invest. 11(4):3—66.

XI. List of species.

Diatoms:

Asteromphalus robustus Castracane
Biddulphia aurita (Lyngbye) Brébisson & Godey
Chaetoceros atlanticus Cleve
— *borealis* Bailey
— — f. *concavicornis* (Mangin) Braarud
— *cinctus* Gran
— *convolutus* Castracane
— *debilis* Cleve
— *decipiens* Cleve
— *densus* Cleve
— *furcellatus* Bailey
— *septentrionalis* Østrup
— *simplex* var. *calcitrans* Paulsen
— *teres* Cleve
Corethron hystrix Cleve
Coscinodiscus centralis Ehrenberg
— *concinnus* W. Smith
— *curvatulus* Grunow
— *excentricus* Ehrenberg
— *kützingii* A. Schmidt
— *lineatus* Ehrenberg
— *oculus-iridis* Ehrenberg
— *radiatus* Ehrenberg
Coscinosira polychorda Gran
— *poroseriata* Ramsfjell
Eucampia zoodiacus Ehrenberg
Fragilaria oceanica Cleve
Fragilariopsis atlantica Paasche
— *nana* (Steemann Nielsen) Paasche
Nitzschia closterium W. Smith
— *delicatissima* Cleve
— *seriata* Cleve
Rhizosolenia alata Brightwell
— *fragilissima* Bergon
— *hebetata* f. *hiemalis* Gran
— — f. *semispina* (Hensen) Gran
— *setigera* Brightwell
— *styliformis* Brightwell
Thalassionema nitzschioides Grunow
Thalassiosira bioculata (Grunow) Ostenfeld
— — var. *raripora* Gaarder
— *decipiens* (Grunow) Jørgensen
— *gravida* Cleve
— *hyalina* (Grunow) Gran
— *nordenskiöldii* Cleve
Thalassiothrix longissima Cleve & Grunow

Dinoflagellates:

Ceratium arcticum (Ehrenberg) Cleve
— *bucephalum* (Cleve) Cleve
— *fusus* (Ehrenberg) Dujardin
— *horridum* Gran
— *longipes* (Bailey) Gran
Cladopyxis claytonii Holmes
Dinophysis acuta Ehrenberg
— *borealis* Paulsen
— *islandica* Paulsen
— *lachmannii* Paulsen
Exuviaella apora Schiller
— *baltica* Lohmann
Glenodinium lenticula f. *minor* (Paulsen) Pavillard
Goniaulax parva Ramsfjell
— *spinifera* (Claparède & Lachmann) Diesing
Gymnodinium lohmannii Paulsen
Gyrodinium grenlandicum Braarud
Oxytoxum nanum Halldal
Peridinium breve Paulsen
— *brevipes* Paulsen
— *conicoides* Paulsen
— *curvipes* Ostenfeld
— *depressum* Bailey
— *globulus* Stein
— — var. *ovatum* (Pouchet) Schiller
— — var. *quarnerense* Br. Schröder
— *granii* Ostenfeld
— *grenlandicum* Woloszynska
— *islandicum* Paulsen

Peridinium minusculum Pavillard
— *pallidum* Ostenfeld
— *pellucidum* (Bergh) Schütt
— *pentagonum* Gran
— *pyriforme* Paulsen
— *subinerme* Paulsen
Phalacroma rotundatum (Claparède & Lachmann) Kofoid & Michener
— *ruudii* Braarud
Pronoctiluca pelagica Fabre-Domerque

Coccolithophorids:

Acanthoica quattrospina Lohmann
Anthosphaera robusta (Lohmann) Kamptner
Calciopappus caudatus Gaarder & Ramsfjell
Coccolithus huxleyi (Lohmann) Kamptner
— *pelagicus* (Wallich) Schiller
Crystallolithus hyalinus Gaarder & Markali
Ophiaster hydroideus (Lohmann) Gran
Pontosphaera cf. *pietschmannii* Kamptner
Syracosphaera cf. *tuberculata* Kamptner

Other flagellates, etc.:

Carteria sp.
Chilomonas marina (Braarud) Halldal
Distephanus speculum (Ehrenberg) Haeckel
— — var. *octonarius* (Ehrenberg) Jørgensen
— — var. *septenarius* (Ehrenberg) Jørgensen
Halosphaera viridis Schmitz
Monosiga marina Grøntved
— — var. *minima* Paasche
Phaeocystis pouchetii (Hariot) Lagerheim
Pterosperma sp.
Sphaeropsis sp.

Ciliates:

Acanthostomella sp.
Coxliella sp.
Didinium parvulum Gaarder
Laboea conica Lohmann
— cf. *crassula* Leegaard
— cf. *emergens* Leegaard
— *strobila* Lohmann
Parafavella sp.
Ptychocylis sp.
Salpingella sp.
Tintinnus sp.
Woodania conicoides Leegaaard

The following of the above-mentioned species and varieties have been described by the present author (Paasche 1960a).
Fragilariopsis atlantica
Fragilariopsis nana (Syn.: *Fragilaria nana* Steemann Nielsen)
Monosiga marina var. *minima*

XII. Tables.

Where nothing else is indicated, the populations are recorded as number of cells per litre.

. . indicates that the species in question was not observed ar that depth.

The absence of observations on coccolithophorids is indicated by a question mark.

Table 1.

Vegetation Area Stations Date		II 196 24/5	II 199 24/5	II 202 24/5	III 204 24/5	III 206 25/5
	Depth					
Temperature, °C	0		8.70	8.60	6.58	6.51
	20		8.36	8.38	5.77	6.44
	50		6.70	6.38	4.64	4.37
Salinity, $^0/_{00}$	0		35.23	35.20	34.89	34.92
	20		35.23	35.22	34.92	34.99
	50		35.17	35.12	34.92	34.92
Production, g C/m²/day		0.83	0.55	0.61	0.77	1.31
Chaetoceros	0	..	20	20	1 080	14 060
	20	120	180	..		3 120
Coscinodiscus centralis	0	..	..	20	20	240
	20	..	..	..		160
Fragilariopsis nana	0	25 500	33 000	16 000	1 000	..
	20	60 500	37 500	36 500		..
Nitzschia closterium	0	285 000	500	..	..	..
	20	550 000	..	..		1 000
N. delicatissima	0	68 000	7 000	5 500	1 000	10 500
	20	64 500	500	6 500		17 500
Rhizosolenia styliformis	0	..	..	..	900	3 040
	20	..	20	..		1 420
Thalassiosira bioculata var. *raripora*	0	500 000	8 500	..	..	..
	20	238 000	3 000	..		..
Thalassiothrix longissima	0	..	..	..	..	240
	20	..	..	..		20
Coccolithus huxleyi	0	48 500	?	?	500	3 000
	20	173 000	?	?		..
Chilomonas marina	0	27 500	29 000	18 500	10 500	13 000
	20	69 000	75 500	92 500		14 500
Phaeocystis and Small Flagellates[1]	0	119	12	24	45	1 087
	20	74	35	56		1 008
Ciliates	0	1 280	40	..	14 480	1 140
	20	280	40	20		2 420

[1] Number of cells per cc.

Table 2.

Vegetation Area		III	II	II	I	I
Stations		210	212	218	222	227
Date		25/5	25/5	26/5	26/5	26/5
	Depth					
Temperature, °C	0	8.81	8.68	9.00	9.15	10.20
	20	8.42	8.14	8.64	8.22	7.95
	50	7.35	7.55	7.60	7.26	7.01
Salinity, $^0/_{00}$	0	35.20	35.24	35.20	35.07	35.00
	20	35.23	35.21	35.20	35.13	35.03
	50	35.23	35.24	35.23	35.17	35.10
Production, g C/m²/day		0.60	0.55	0.65	0.63	0.63
Chaetoceros	0	1 540	100	20	..	..
	20	8 480	80	..	..	..
Coscinodiscus centralis	0	20	..	..	..	..
	20	..	..	..	..	..
Fragilariopsis nana	0	..	..	13 000	596 000	101 000
	20	10 500	..	23 000	30 500	58 000
Nitzschia closterium	0	..	500	71 000	2 500	1 000
	20	6 000	..	71 000	..	500
N. delicatissima	0	90 500	500	14 000	14 000	..
	20	151 500	..	15 500	15 500	..
Rhizosolenia styliformis	0	20	..	..	80	..
	20	..	..	30	..	..
Thalassiosira bioculata var. *raripora*	0	..	3 500	200 000	5 500	..
	20	..	2 000	187 000	6 000	..
Thalassiothrix longissima	0	20	..	..	..	..
	20	..	..	..	..	..
Coccolithus huxleyi	0	?	?	?	?	?
	20	30 000	?	118 000	?	?
Chilomonas marina	0	37 500	46 000	91 000	171 000	73 000
	20	41 500	17 500	77 000	60 000	16 500
Phaeocystis and Small Flagellates[1]	0	53	180	172	583	103
	20	43	122	116	48	16
Ciliates	0	..	1 380	4 080	13 180	..
	20	160	600	10 020	1 160	500

[1] Number of cells per cc.

Table 3.

Vegetation Area / Stations / Date		II 232 27/5	III 236 27/5	III 238 27/5	III 240 28/5	III 242 28/5
	Depth					
Temperature, °C	0	9.80	8.70	8.30	8.21	7.00
	20	8.43	7.95	8.06	7.79	6.68
	50	7.53	7.48	7.22	6.95	6.34
Salinity, $^0/_{00}$	0	35.21	35.22	35.20	35.20	35.11
	20	35.19	35.20	35.19	35.19	35.10
	50	35.22	35e23	35.19	35.19	35.11
Production, g C/m²/day		0.45	0.60	1.05	0.70	1.67
Chaetoceros	0	..	13 840	108 300	6 860	82 400
	20	..	60	22 800	2 780	27 580
Coscinodiscus centralis	0	..	..	40	20	320
	20	..	..	20	20	140
Fragilariopsis nana	0	20 500	3 500	5 000	9 500	..
	20	47 000	32 000	13 500	18 000	2 000
Nitzschia closterium	0	21 000	8 000	1 500	3 500	..
	20	17 000	9 000	4 500	3 500	2 000
N. delicatissima	0	..	40 000	52 000	45 500	105 000
	20	13 500	77 500	27 500	26 000	105 000
N. seriata	0	..	23 000	76 500	49 500	20 000
	20	..	1 000	19 500	18 000	3 000
Rhizosolenia styliformis	0	..	240	60	200	1 580
	20	..	..	20	20	1 420
Thalassiosira bioculata var. *raripora*	0	17 500	25 000	54 500	81 000	2 000
	20	28 000	44 000	23 000	52 000	1 000
Th. gravida	0	..	29 500	17 000	45 000	2 500
	20	..	2 500	6 000	15 500	3 500
Coccolithus huxleyi	0	47 500	46 000	1 500	?	?
	20	?	80 500	?	?	?
Chilomonas marina	0	60 500	16 000	5 500	5 000	11 500
	20	12 500	2 000	22 500	1 000	7 000
Phaeocystis and Small Flagellates[1]	0	280	68	464	434	8 744
	20	66	83	2 688	768	4 092
Ciliates	0	3 440	7 560	4 660	13 260	5 760
	20	620	1 980	4 400	2 300	1 660

[1] Number of cells per cc.

Table 4.

Vegetation Area Stations Date	Depth	III 246 28/5	III 248 29/5	III 251 29/5	III 252 29/5	IV 254 29/5	IV 255 29/5
Temperature, °C	0	7.64	7.63	5.16	5.29	1.40	1.22
	20	6.29	6.91	4.57	4.35	−1.11	0.05
	50	5.48	6.01	2.90	3.77	0.22	−1.44
Salinity, ‰	0	35.17	35.17	35.03	35.05	34.20	34.25
	20	35.13	35.17	35.03	35.08	34.40	34.26
	50	35.13	35.14	35.03	35.07	34.70	34.48
Production, g C/m²/day		0.93	1.04	0.86		0.61	
Chaetoceros	0	1 540	105 480	480	20 960	500	60
	20	2 660	52 580			380	
Coscinodiscus centralis	0	100	120	100	100	..	..
	20	100	60			..	
C. excentricus and *C. kützingii*	0	..	..	..	..	..	20
	20	..	..			880	
Fragilariopsis nana	0	20 000	..	..	16 500	..	..
	20	7 500	3 000			26 500	
Nitzschia delicatissima	0	36 000	149 000	88 000	50 000	16 000	13 000
	20	71 500	64 000			381 000	
N. seriata	0	11 500	16 500	..	..	..	..
	20	1 000	16 000			..	
Rhizosolenia hebetata f. *semispina*	0	..	..	..	..	240	..
	20	..	..			60	
Rh. styliformis	0	1 100	500	480	340	..	..
	20	2 120	600			..	
Thalassiosira bioculata var. *raripora*	0	1 000	10 000	1 000	1 500	..	3 000
	20	500	16 000			40 500	
Th. gravida	0	..	740	3 000	3 500	3 500	5 000
	20	..	25 500			34 000	
Thalassiothrix longissima	0	..	..	20	40	..	..
	20	20	20			120	
Exuviaella baltica	0	500	17 000	1 000	4 500	..	500
	20	..	..			59 000	
Phaeocystis and Small Flagellates[1]	0	3 260	8 548	7 144	2 380	243	220
	20	1 492	6 188			11 204	
Ciliates	0	720	4 060	4 720	16 060	25 760	3 800
	20	3 570	40			4 180	

[1] Number of cells per cc.

Table 5.

Vegetation Area Stations Date		IV 257 29/5	IV 263 30/5	VII 268 30/5	VII 269 31/5	VII 272 1/6
	Depth					
Temperature, °C	0	3.02	0.63	−0.20	0.23	−0.40
	20	2.32	1.03	−0.87	0.20	−0.47
	50	1.85	−1.81	−1.38	−0.41	−1.71
Salinity, ‰	0	34.72	34.25	34.22	33.91	33.98
	20	34.79	34.39	34.32	34.15	33.91
	50	34.92	34.57	34.55	34.66	34.60
Production, g C/m²/day					0.74	0.51
Chaetoceros	0	420	480	460	2 260	2 440
	20					40
Nitzschia delicatissima	0	380 000	38 000	98 000	71 000	25 500
	20					10 000
Rhizosolenia hebetata f. *semispina*	0	670	60	20	180	20
	20					..
Thalassiosira bioculata var. *raripora*	0	14 500	3 500	27 000	6 000	1 500
	20					3 000
Th. gravida	0	52 500	2 500	70 000	12 000	18 000
	20					4 000
Th. nordenskiöldii	0	..	..	460	..	60
	20					..
Thalassiothrix longissima	0	80	..	..	20	20
	20					..
Exuviaella baltica	0	9 000	11 000	7 000	2 000	1 000
	20					..
Monosiga	0	33 000	177 000	77 500	20 500	123 000
	20					35 000
Phaeocystis and Small Flagellates[1]	0	16 700	872	5 360	1 864	1 576
	20					768
Ciliates	0	1 680	4 700	6 800	1 400	2 720
	20					

[1] Number of cells per cc.

Table 6.

Vegetation Area		VII	VII	VII	IV	IV
Stations		273	276	278	280	282
Date		1/6	1/6	1/6	2/6	2/6
	Depth					
Temperature, °C	0	−0.50	0.02	0.40	1.92	2.60
	20	−1.09	−0.97	−0.94	3.40	2.97
	50	−1.78	−1.80	−1.75	−0.75	2.87
Salinity, ‰	0	34.06	34.16	33.96	34.57	34.40
	20	34.57	34.36	33.95	34.82	34.76
	50	34.60	34.62	34.53	34.65	35.02
Production, g C/m^2/day			0.39	0.22		0.89
Chaetoceros	0	2 700	240	900	440	
	20					180
Coscinodiscus centralis	0	..	..	..	80	
	20					60
C. excentricus and *C. kützingii*	0	..	..	..	60	
	20					80
Nitzschia delicatissima	0	23 500	36 500	13 000	81 000	
	20					14 000
Rhizosolenia hebetata f. *semispina*	0	..	340	80	20	
	20					20
Rh. styliformis	0	..	..	..	180	
	20					20
Thalassiosira gravida	0	8 000	30 000	4 500	4 000	
	20					4 500
Th. nordenskiöldii	0	120	..	760	..	
	20					..
Exuviaella baltica	0	3 000	2 000	500	17 500	
	20					3 500
Monosiga	0	109 000	317 000	186 000	3 500	
	20					500
Phaeocystis and Small Flagellates[1]	0	941	1 852	380	2 752	
	20					1 844
Ciliates	0	4 620	4 500	3 640	3 980	
	20					120

[1] Number of cells per cc.

Table 7.

Vegetation Area		III	III	III	III	III
Stations		287	289	291	293	295
Date		2/6	2–3/6	3/6	3/6	3/6
	Depth					
Temperature, °C	0	5.98	6.31	6.95	6.82	7.40
	20	5.92	6.30	6.79	6.70	7.30
	50	5.41	6.08	6.08	5.82	6.46
Salinity, $^0/_{00}$	0	35.14	35.13	35.16	35.12	35.14
	20	35.12	35.12	35.14	35.10	35.13
	50	35.13	35.13	35.14	35.13	35.16
Production, g C/m²/day		0.99	1.22		1.13	1.20
Chaetoceros	0	640	6 200	13 080	85 780	10 420
	20	840	2 980		75 580	4 960
Coscinodiscus centralis	0	140	80	20	80	..
	20	..	160		120	20
Nitzschia delicatissima	0	150 000	155 000	130 000	164 000	90 000
	20	170 000	97 000		150 000	51 000
N. seriata	0	3 000	2 500	..	9 000	1 500
	20	800	2 500		12 000	640
Rhizosolenia styliformis	0	380	1 060	480	360	260
	20	880	1 340		200	40
Thalassiosira gravida	0	..	1 500	2 500	3 500	3 000
	20	1 000	1 500		3 500	2 500
Coccolithus huxleyi	0	..	500	500	500	11 500
	20	?	..		?	23 500
Monosiga	0	1 000	34 500	1 256 000	254 000	742 000
	20	2 000	42 000		173 000	620 000
Phaeocystis and Small Flagellates[1]	0	2 932	8 364	6 880	7 484	6 200
	20	2 792	7 946		7 688	5 700
Ciliates	0	4 960	2 100	2 260	1 880	720
	20	1 820	1 100		1 520	1 180

[1] Number of cells per cc.

Table 8.

Vegetation Area		III	I—III	III	I	I
Stations		297	299	301	303	305
Date		3/6	4/6	4/6	4/6	4/6
	Depth					
Temperature, °C	0	7.45	7.90	7.68	7.63	6.80
	20	7.37	7.48	7.54	7.55	6.57
	50	6.88	6.95	7.49	6.17	6.27
Salinity, $^0/_{00}$	0	35.15	35.10	35.14	34.66	34.01
	20	35.15	35.10	35.14	34.64	34.13
	50	35.17	35.18	35.13	34.72	34.22
Production, g C/m²/day		0.87		0.78		
Chaetoceros	0	7 080	40	920	..	..
	20	9 140		460		
Coscinodiscus centralis	0	40	..	20	..	..
	20	60		20		
Fragilariopsis nana	0	20 500	892 000	51 000	275 000	6 000
	20	27 000		76 000		
Nitzschia delicatissima	0	82 000	31 000	57 000	37 000	3 500
	20	70 000		47 000		
Rhizosolenia styliformis	0	..	80	180	..	..
	20	140		100		
Coccolithus huxleyi	0	12 500	?	66 000	..	..
	20	17 000		32 000		
Chilomonas marina	0	16 000	174 000	92 000	180 000	41 000
	20	17 000		91 000		
Monosiga	0	648 000	196 000	730 000	86 000	11 500
	20	537 000		812 000		
Phaeocystis and Small Flagellates[1]	0	3 980	1 936	3 528	212	541
	20	3 844		6 316		
Ciliates	0	4 200	5 320	1 860	17 700	32 100
	20	460		200		

[1] Number of cells per cc.

Table 9.

Vegetation Area		I	I	I–III	III	III	III
Stations		307	311	315	317	319[2]	321
Date		8/6	8/6	8/6	9/6	9/6	9/6
	Depth						
Temperature, °C	0	6.29	6.70	7.50	6.98	6.82	6.26
	20	6.13		7.09	6.60	6.54	5.99
	50	6.54	7.01	6.39	6.27	6.23	5.92
Salinity, ‰	0	33.91	34.27	35.02	35.03	35.00	35.16
	20	33.90	34.27	35.02	35.08	35.00	35.17
	50	33.92	35.11	35.15	35.17	35.14	35.15
Production, g C/m²/day			0.76	0.62	0.85		1.42
Chaetoceros	0	..	..	20		6 420	540 440
	20			340	8 860		
Coscinodiscus centralis	0	..	..	..		..	20
	20			..	..		
Fragilariopsis nana	0	2 000	383 000	105 000		10 000	2 000
	20			173 000	25 500		
Nitzschia delicatissima	0	..	45 000	4 000		15 000	39 000
	20			4 500	64 000		
N. seriata	0	..	1 000	..		..	14 500
	20			..	1 500		
Rhizosolenia hebetata f. *semispina*	0	..	..	..		..	460
	20			..	..		
Rh. styliformis	0	..	..	..		300	460
	20			200	80		
Thalassiosira bioculata var. *raripora*	0	..	115 000	..		2 500	500
	20			1 500	1 500		
Chilomonas marina	0	20 500	94 000	82 000		28 000	4 000
	20			143 000	10 000		
Monosiga	0	6 500	24 500	32 000		18 000	24 500
	20			20 500	66 500		
Phaeocystis and Small Flagellates[1]	0	1 300	952	1 804		1 620	544
	20			1 900	5 772		
Ciliates	0	27 400	20 700	420		8 700	9 800
	20			160	240		

[1] Number of cells per cc.
[2] The figures in this column represent 10 m depth.

Table 10.

Vegetation Area		IV	III	IV	III	IV	VI
Stations		323	325	326	328	330	332
Date		9/6	9/6	10/6	10/6	10/6	11/6
	Depth						
Temperature, °C	0	4.96	5.52	2.60	4.57	1.56	0.24
	20	4.59	5.45	2.33	4.52	1.22	−0.17
	50	4.58	5.42	2.39	4.46	0.28	−1.59
Salinity, ‰	0	35.08	35.17	34.69	35.09	34.40	34.31
	20	35.11	35.17	34.69	35.08	34.39	34.37
	50	35.11	35.17	34.87	35.08	34.72	34.63
Production, g C/m²/day		0.96	0.52		0.90	0.33	
Chaetoceros	0	520	3 340	20	19 760	..	..
	20	540	5 060			40	
Coscinodiscus centralis	0	..	80	..	80	..	..
	20	..	..			..	
C. excentricus and *C. kützingii*	0	20	..	240	..	140	..
	20	140	..			340	
Fragilariopsis nana	0	5 000	2 000	7 780	4 500	..	26 000
	20	7 500	500			80	
Nitzschia delicatissima	0	19 000	33 000	161 000	340 000	29 000	9 000
	20	26 000	35 000			69 000	
Rhizosolenia hebetata f. *semispina*	0	40	..	340	80	120	..
	20	40	..			180	
Rh. styliformis	0	220	1 560	..	680	..	..
	20	360	440			..	
Thalassiothrix longissima	0	200	..	60	..	60	..
	20	120	..			60	
Exuviaella baltica	0	500	1 000	9 000	1 000	1 000	46 000
	20	2 000	1 000			5 000	
Chilomonas marina	0	3 500	4 000	3 500	1 500	500	28 000
	20	2 500	2 500			500	
Monosiga	0	18 000	50 000	2 500	68 000	..	7 000
	20	14 500	56 500			500	
Phaeocystis and Small Flagellates[1]	0	4 008	492	7 620	6 248	648	4 544
	20	3 540	536			876	
Ciliates	0	240	540	1 320	1 600	2 720	14 240
	20	720	1 640			2 280	

[1] Number of cells per cc.

Table 11.

Vegetation Area...		VI	VI	VI	VI	VI	VI	VI
Stations		334	336	338	340	344	346	350
Date.............		11/6	11/6	11/6	12/6	12/6	12/6	13/6
	Depth							
Temperature, °C .	0	−0.14	0.31	−0.08	0.15	−0.10	−0.18	−0.36
	20	−0.21	−0.16	−0.84	−0.61	−0.30	−0.22	−0.46
	50	−1.63	−1.02	−1.79	−1.68	−1.32	−1.47	−0.65
Salinity, $^0/_{00}$	0	34.45	34.38	34.10	34.29	34.47	34.72	34.77
	20	34.46	34.44	34.27	34.47	34.52	34.72	34.76
	50	34.63	34.65	34.59	34.75	34.79	34.78	34.77
Production, g C/m^2/ /day		0.65		0.64				
Fragilariopsis nana..	0	11 500	..	5 500	..	..	..	..
	20	12 500		3 000				
Monosiga	0	3 500	..	500	..	..	..	..
	20	500		..				
Phaeocystis and Small Flagellates[1]	0	172	36	164	60	160	18	265
	20	187		366				
Ciliates	0	8 160	..	1 260	160	700	600	40
	20	60		100				

[1] Number of cells per cc.

Table 12.

Vegetation Area		VI	IV	IV	III	VIII	VIII
Stations		352	356	360	362	363	364
Date		13/6	14/6	14/6	15/6	15/6	15/6
	Depth						
Temperature, °C	0	0.10	3.06	5.18	6.23	5.88	2.38
	20	−0.50	2.85	4.79	5.95	5.47	1.81
	50	−0.98	2.80	4.56	5.67	4.78	2.06
Salinity, ‰	0	34.74	34.76	35.10	35.13	35.11	34.67
	20	34.74	34.76	35.11	35.12	35.12	34.64
	50	34.77	34.80	35.11	35.14	35.10	34.77
Production, g C/m²/day		0.67		0.69	0.89		
Chaetoceros	0		5 500	..	1 456 240	4 500	..
	20	..			785 000		
Eucampia zoodiacus	0		..	..	14 500	500	..
	20	..			8 000		
Fragilariopsis nana	0		17 000	11 500	1 000	11 500	..
	20	3 000			2 000		
Nitzschia delicatissima	0		165 000	500	11 500	500	2 500
	20	..			6 500		
N. seriata	0		..	..	8 500	..	...
	20	..			2 500		
Rhizosolenia hebetata f. *semispina*	0		7 500	..	..	..	..
	20	..			..		
Thalassiothrix longissima	0		260	..	..	..	..
	20	..			..		
Exuviaella baltica	0		19 000	55 000	8 000	3 000	500
	20	..			1 000		
Coccolithus huxleyi	0		..	7 000	500	3 000	?
	20	..			3 500		
Monosiga	0		1 000	8 500	24 000	9 500	1 000
	20	..			5 500		
Phaeocystis and Small Flagellates[1]	0		4 148	700	2 920	700	+
	20	70			+		
Ciliates	0		14 460	5 840	1 300	360	4 400
	20	220			1 120		

[1] Number of cells per cc.

Table 13.

Vegetation Area		VIII	VIII	VIII	VIII	III
Stations		373	374	375	377	380
Date		16/6	16/6	16/6	16/6	17/6
	Depth					
Temperature, °C	0	4.35	3.10	−1.65	1.90	5.00
	20	3.97	3.18	−1.73	2.17	4.81
	50	4.11	3.05	−1.60	1.64	4.22
Salinity, ‰	0	35.01	34.64	33.65	34.34	35.05
	20	35.00	34.79	33.82	34.64	35.03
	50	35.07	34.96	34.16	34.81	35.07
Production, g C/m²/day					0.54	
Chaetoceros furcellatus	0	..	11 500	341 000	..	..
	20				1 000	
Fragilariopsis nana	0	..	..	1 000	..	18 000
	20				..	
Nitzschia delicatissima	0	28 000	43 000	..	12 000	..
	20				34 000	
Rhizosolenia setigera	0	..	..	..	600	..
	20				..	
Rh. styliformis	0	..	..	..	..	180
	20				..	
Thalassiosira gravida	0	..	17 000	220	8 000	..
	20				2 000	
Th. nordenskiöldii	0	..	..	5 400	500	..
	20				..	
Exuviaella baltica	0	7 500	2 500	500	1 000	153 000
	20				2 000	
Monosiga	0	43 000	21 000	1 000	12 000	9 500
	20				115 000	
Phaeocystis and Small Flagellates[1]	0	4 076	3 612	386	7 164	605
	20				4 144	
Ciliates	0	100	7 640	18 520	2 240	10 640
	20				3 800	

[1] Number of cells per cc.

Table 14.

Vegetation Area		IV	IV	IV	V	V	V
Stations		381	383	385	387	389	393
Date		17/6	17/6	17/6	18/6	18/6	18/6
	Depth						
Temperature, °C	0	5.00	4.20	1.60	0.40	0.68	−2.28
	20	4.82	4.04	1.45	0.15	0.48	−0.60
	50	4.77	3.82	1.42	−0.98	−0.89	−0.35
Salinity, ‰	0	35.04	34.99	34.48	34.55	34.44	34.07
	20	35.02	35.03	34.50	34.57	34.43	34.18
	50	35.06	35.05	34.74	34.61	34.64	34.29
Production, g C/m²/day		0.96	0.84	0.62		0.50	
Fragilariopsis nana	0	12 500	9 500	9 500	..	3 500	35 000
	20			4 000		1 500	
Nitzschia delicatissima	0	44 000	47 500	2 000	..	1 000	..
	20			500		2 000	
Rhizosolenia hebetata f. *semispina*	0	..	3 800	..	..	..	..
	20			20		..	
Thalassiosira gravida	0	6 000	..	..	..	..	..
	20			..		..	
Thalassiothrix longissima	0	..	260	20	..	..	..
	20			..		..	
Exuviaella baltica	0	14 000	55 000	11 500	2 500	30 000	500
	20			111 000		22 000	
Monosiga	0	167 000	3 500	1 000	42 500	3 500	4 500
	20			500		11 500	
Phaeocystis and Small Flagellates	0	2 424	1 380	235	320	102	220
	20			302		107	
Ciliates	0	3 480	5 560	16 160	2 900	12 000	3 720
	20			12 500		11 840	

[1] Number of cells per cc.

Table 15.

Vegetation Area		V	V	V	IV	IV
Stations		396	399	401	403	405
Date		19/6	19/6	19/6	20/6	20/6
	Depth					
Temperature, °C	0	−0.45	0.49	0.99	3.70	4.38
	20	−1.45	1.30	0.81	3.45	4.19
	50	−1.61	2.05	0.42	2.88	3.11
Salinity, $^0/_{00}$	0	33.61	34.25	34.59	34.99	34.99
	20	33.66	34.37	34.59	34.99	34.99
	50	34.00	34.86	34.70	35.02	35.00
Production, g C/m²/day			0.68	0.41		0.64
Fragilariopsis nana	0	82 000	104 000	60 000	13 500	9 000
	20		16 500	57 000		
Nitzschia closterium	0	500	500	..	6 000	9 500
	20		500	..		
N. delicatissima	0	24 500	15 500	7 000	5 000	8 000
	20		4 000	11 000		
Thalassiosira bioculata var. *raripora*	0	..	7 500	2 500	6 000	2 000
	20		9 500	1 500		
Th. gravida	0	53 000	8 000	..	..	..
	20		2 000	..		
Exuviaella baltica	0	71 000	132 000	27 000	99 000	319 000
	20		110 000	25 000		
Monosiga	0	46 000	11 000	9 000	9 500	50 000
	20		11 500	9 500		
Phaeocystis and Small Flagellates[1]	0	1 048	1 112	1 372	1 232	2 676
	20		880	1 280		
Ciliates	0	6 040	7 600	4 540	14 400	2 220
	20		3 000	13 620		

[1] Number of cells per cc.

Table 16.

Station 303. June 4, 1954.

Depth in metres	0
Diatoms:	
Fragilariopsis atlantica	500
— *nana*	275 000
Nitzschia closterium	1 000
— *delicatissima*	37 000
Thalassiosira bioculata var. *raripora*	500
Dinoflagellates:	
Ceratium bucephalum	20
Exuviaella baltica	500
Gymnodiniaceae	500
Gyrodinium grenlandicum	20 000
Dinoflagellates not classified	9 500
Other Flagellates, etc.:	
Chilomonas marina	180 000
Monosiga marina	56 000
— — var. *minima*	30 000
Flagellates not classified	212 000
Ciliates:	
Acanthostomella sp.	180
Laboea conica	20
Lohmanniella oviformis	11 500
Woodania conicoides	6 000

Table 17.

Station 218. May 26, 1954.

Depth in metres	0	10	20
Diatoms:			
Chaetoceros decipiens	20	..	..
— sp.	2 000	500	..
Corethron hystrix	..	20	..
Fragilariopsis atlantica	13 000	18 500	23 000
— *nana*	32 000	31 500	41 000
Nitzschia closterium	71 000	110 000	71 000
— *delicatissima*	14 000	23 000	15 500
Rhizosolenia styliformis	..	..	30
Thalassiosira bioculata var. *raripora*	200 000	260 000	187 000
— sp.	2 000	..	1 500
Diatoms not classified	3 000	..	6 500
Dinoflagellates:			
Exuviaella baltica	13 500	13 000	16 500
Gymnodiniaceae	10 500	5 500	16 500
Gyrodinium grenlandicum	4 000	7 000	10 000
Peridinium minusculum	4 000	1 000	4 500
Dinoflagellates not classified	3 000	9 500	6 500
Coccolithophorids:			
Anthosphaera robusta	?	?	6 500
Calciopappus caudatus	?	?	15 000
Coccolithus huxleyi	?	?	118 000
— *pelagicus*	?	?	1 500
Crystallolithus hyalinus	?	?	6 000
Pontosphaera pietschmannii	?	?	1 000
Coccolithophorids not classified	?	?	1 000
Other Flagellates, etc.:			
Chilomonas marina	91 000	100 000	77 000
Distephanus speculum	..	..	2 500
Monosiga marina	9 500	12 000	17 000
— — var. *minima*	2 000	2 000	1 000
Flagellates not classified	172 000	203 000	116 000
Ciliates:			
Acanthostomella sp.	1 880	2 760	2 240
Didinium parvulum	2 000	20	6 500

Table 18.

Station 248. May 29, 1954.

Depth in metres	0	10	20
Diatoms:			
Chaetoceros atlanticus	160	..	100
— *borealis*	2 140	1 340	1 340
— *debilis*	98 000	109 000	49 000
— *decipiens*	820	160	480
— *densus*	4 360	1 760	1 660
— *teres*, resting spores	1 500	60	460
Corethron hystrix	..	..	40
Coscinodiscus centralis	120	160	60
Fragilariopsis nana	..	..	3 000
Nitzschia closterium?	20	..	1 000
— *delicatissima*	149 000	139 000	64 000
— *seriata*	16 500	28 000	16 000
Rhizosolenia alata	..	..	40
— *styliformis*	500	700	600
Thalassiosira bioculata	20	..	40
— — var. *raripora*	10 000	14 500	16 000
— *gravida*	740	14 500	25 000
Thalassiothrix longissima	..	..	20
Diatoms not classified	1 000	2 000	2 000
Dinoflagellates:			
Ceratium arcticum	..	..	20
— *fusus*	20	..	..
Exuviaella apora	..	40	40
— *baltica*	17 000	10 500	..
Goniaulax sp.	20	..	..
Gymnodinium lohmannii	600	60	40
Gymnodiniaceae	520	220	20
Gyrodinium grenlandicum	8 500	46 500	3 500
Peridinium brevipes	20	..	..
— *depressum*	60	40	..
— *minusculum*	500	..	..
Dinoflagellates not classified	2 000	1 000	..
Coccolithophorids:			
Anthosphaera robusta	..	?	500
Coccolithus huxleyi	9 500	?	5 500
— *pelagicus*	1 500	?	120

Table 18 (continued).

Depth in metres	0	10	30
Other Flagellates, etc.:			
Chilomonas marina	4 500	10 000	9 000
Monosiga marina	18 000	21 000	3 000
— — var. *minima*	6 000	8 000	1 000
Phaeocystis and Small Flagellates	8548 000	15048 000	6188 000
Ciliates:			
Acanthostomella sp.	80	..	20
Laboea conica	2 400	40	..
— *emergens*	..	..	20
— *strobila*	20	..	..
Lohmanniella oviformis	1 000	500	..
Woodania conicoides	500	..	..
Ciliates not classified	60	..	..

Table 19.

Station 362. June 15, 1954.

Depth in metres	0	20
Diatoms:		
Chaetoceros borealis	260	..
— *debilis*	1 455 000	785 000
— *decipiens*	320	..
— *densus*	720	..
Corethron hystrix	20	..
Eucampia zoodiacus	14 500	8 000
Fragilariopsis nana	1 000	2 000
Nitzschia delicatissima	11 500	6 500
— *seriata*	8 600	2 500
Rhizosolenia alata	..	20
— *styliformis*	360	80
Thalassionema nitzschioides	1 500	..
Thalassiosira gravida	20	500
Diatoms not classified	20	..
Dinoflagellates:		
Dinophysis islandica f. *obtusa*	20	..
Exuviaella baltica	8 000	1 000
Glenodinium (?) sp.	500	..
Gymnodinium lohmannii	180	1 500
Gymnodiniaceae	2 500	500
Gyrodinium grenlandicum	6 500	1 500
Peridinium minusculum	500	..
— *pyriforme*	20	..
Dinoflagellates not classified	500	500
Coccolithophorids:		
Calciopappus caudatus	..	1 500
Coccolithus huxleyi	500	3 500
Other Flagellates, etc.:		
Chilomonas marina	1 500	1 500
Monosiga marina	18 000	5 000
— — var. *minima*	6 000	500
Phaeocystis and Small Flagellates	292 000	+
Ciliates:		
Acanthostomella sp.	20	20
Didinium parvulum	..	1 000
Laboea conica	1 080	40
Lohmanniella oviformis	20	..
Parafavella sp.	40	20
Ptychocylis sp.	20	40
Woodania conicoides	120	..

Table 20.

Station 356. June 14, 1954.

Depth in metres	0
Diatoms:	
Asteromphalus robustus	200
Chaetoceros atlanticus	20
— *borealis*	460
— *decipiens*	40
— *densus*	5 000
Coscinodiscus excentricus	80
— *kützingii*	60
— sp.	20
Coscinosira poroseriata	360
Fragilariopsis atlantica	1 200
— *nana*	17 000
Nitzschia delicatissima	165 000
Rhizosolenia hebetata f. *hiemalis*	20
— — f. *semispina*	7 500
Thalassiosira bioculata var. *raripora*	2 500
— *gravida*	500
Thalassiothrix longissima	260
Diatoms not classified	40
Dinoflagellates:	
Dinophysis borealis	140
Exuviaella baltica	19 000
Glenodinium (?) sp	2 500
Gymnodinium lohmannii	60
Peridinium brevipes	40
— *globulus var. ovatum*	40
— *pellucidum*	20
— *subinerme*	60
Pronoctiluca pelagica, cysts	40
Dinoflagellates not classified	500

Dept in metres	0
Coccolithophorids:	?
Other Flagellates, etc.:	
Chilomonas marina	500
Distephanus speculum	20
Monosiga marina	1 000
Phaeocystis and Small Flagellates	4 148 000
Ciliates:	
Acanthostomella sp.	300
Laboea conica	9 000
— *strobila*	60
Lohmanniella oviformis	2 000
Ptychocylis sp.	20
Tintinnus sp.	20
Woodania conicoides	3 000
Ciliates not classified	60

Table 21.

Station 254. May 29, 1954.

Depth in metres	0	10	20
Diatoms:			
Chaetoceros atlanticus	80	..	240
— *borealis*	40	20	..
— *convolutus*	160	..	..
— *decipiens*	380	..	120
Coscinodiscus curvatulus	20	..	..
— *excentricus*	..	..	660
— *kützingii*	..	..	220
— *lineatus*	..	..	20
Coscinosira poroseriata	..	..	380
Eucampia zoodiacus	..	..	500
Fragilariopsis atlantica	80	80	2 380
— *nana*	..	..	26 500
Nitzschia delicatissima	16 000	3 000	381 000
Rhizosolenia alata	160	..	20
— *fragilissima*	20	..	40
— *hebetata* f. *semispina*	240	..	60
Thalassionema nitzschioides	..	1 000	..
Thalassiosira bioculata	..	..	20
— — var. *raripora*	..	550	40 500
— *gravida*	3 500	4 000	34 000
— — resting spores	..	..	420
— *hyalina*	..	..	20
— *nordenskiöldii*	..	..	360
Thalassiothrix longissima	..	..	120
Diatoms not classified	20	..	380
Dinoflagellates:			
Dinophysis borealis	..	..	380
— *islandica*	..	..	20
Exuviaella baltica	..	..	59 000
Goniaulax parva	..	..	1 000
Gymnodinium lohmannii	20	240	120
Gymnodiniaceae	2 000	..	20
Gyrodinium grenlandicum	..	..	6 500
Peridinium brevipes	..	..	20
— *depressum*	..	..	20
— *globulus* var. *ovatum*	..	..	20
— — — *quarnerense*	20	..	40
— *minusculum*	500	1 500	500
— *pellucidum*	20	..	160
Phalacroma rotundatum	..	..	20
— *ruudii*	..	40	140
Dinoflagellates not classified	3 500	2 000	500

Table 21 (continued).

Dept in metres	0	10	20
Coccolithophorids:			
Coccolithus pelagicus	..	?	1 500
Other Flagellates, etc.:			
Chilomonas marina	1 000	1 000	500
Distephanus speculum	..	..	100
— — var. *octonarius*	..	..	20
— — — *septenarius*	500	..	20
Monosiga marina	3 500	4 500	1 500
— — var. *minima*	11 500	1 500	9 500
Phaeocystis and Small Flagellates	243 500	226 500	11 204 000
Ciliates:			
Acanthostomella sp.	200	440	1 940
Coxliella sp.	20	..	..
Laboea conica	19 000	11 000	..
— *crassula*	..	..	20
— *strobila*	..	..	60
Lohmanniella oviformis	3 000	500	2 000
Parafavella sp.	40	..	20
Ptychocylis sp.	..	..	120
Tintinnus sp.	..	..	20
Woodania conicoides	3 000	500	..
Ciliates not classified	500	20	..

Table 22.

Station 399. June 19, 1954.

Depth in metres	0	20
Diatoms:		
Eucampia zoodiacus	500	..
Fragilariopsis atlantica	3 500	2 000
— *nana*	104 000	16 500
Nitzschia closterium	500	500
— *delicatissima*	15 500	4 000
Thalassiosira bioculata var. *raripora*	7 500	9 500
— *gravida*	8 000	2 000
Diatoms not classified	..	1 000
Dinoflagellates:		
Cladopyxis claytonii	..	500
Exuviaella baltica	132 000	110 000
Glenodinium (?) sp.	500	3 000
Gymnodinium lohmannii	..	500
Peridinium minusculum	3 000	2 500
Other Flagellates, etc.:		
Carteria sp.	500	..
Chilomonas marina	4 500	3 500
Monosiga marina	8 500	6 500
— — var. *minima*	5 500	5 000
Flagellates not classified	1 112 000	880 000
Ciliates:		
Acanthostomella sp.	320	..
Laboea conica	280	..
Lohmanniella oviformis	4 500	2 500
Salpingella sp.	..	500
Woodania conicoides	2 500	..

Table 23.
Station 278. June 1, 1954.

Depth in metres	10
Diatoms:	
Chaetoceros convolutus	140
— *decipiens*	760
— cf. *furcellatus*	500
Eucampia zoodiacus	1 000
Fragilariopsis atlantica	500
Nitzschia delicatissima	13 000
Rhizosolenia alata	240
Thalassiosira bioculata var. *raripora*	500
— *gravida*	4 500
— — resting spores	40
— *hyalina*	200
— *nordenskiöldii*	760
Diatoms not classified	500
Dinoflagellates:	
Dinophysis borealis	20
Exuviaella baltica	500
Gymnodinium lohmannii	700
Peridinium curvipes	140
— *minusculum*	500
— *pallidum*	40
— *pellucidum*	20
— sp.	20
Phalacroma ruudii	20
Dinoflagellates not classified	1 000
Other Flagellates, etc.:	
Monosiga marina	63 000
— — var. *minima*	123 000
Phaeocystis and Small Flagellates	380 000
Cilates:	
Acanthostomella sp.	120
Laboea conica	40
— *strobila*	100
Lohmanniella oviformis	3 000
Woodania conicoides	240
Ciliates not classified	40

Table 24.
Station 375. June 16, 1954.

Depth in metres	0
Diatoms:	
Chaetoceros furcellatus	341 000
— *septentrionalis?*	500
Fragilaria oceanica	4 240
— — , resting spores	600
Fragilariopsis nana	1 000
Nitzschia closterium?	500
Rhizosolenia hebetata f. *semispina*	20
Thalassiosira gravida	220
— *nordenskiöldii*	5 400
Diatoms not classified	4 500
Dinoflagellates:	
Exuviaella baltica	500
Glenodinium (*?*) sp.	1 000
Glenodinium sp.	500
Gymnodinium lohmannii	2 500
Gyrodinium grenlandicum	2 000
Peridinium brevipes	160
— *conicoides*	260
— *islandicum*	60
— *minusculum*	500
— *pellucidum*	260
— *subinerme*	120
Dinoflagellates not classified	40
Coccolithophorids:	?
Other Flagellates, etc.:	
Carteria sp.	500
Monosiga marina	1 000
Flagellates not classified	386 000
Ciliates:	
Laboea conica	80
Lohmanniella oviformis	18 000
Woodania conicoides	40
Ciliates not classified	400