A Quantitative Study of the Phytoplankton in the Bay of Fundy and the Gulf of Maine (including Observations on Hydrography, Chemistry and Turbidity)

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CONTENTS

ABSTRACT

In the gulf of Maine life conditions of the phytoplankton were found to be in agreement with those described from the coastal waters of Northern Europe. The surface layers are during

summer more or less stratified, indicating a fairly low degree of turbulence. Where the stratification is broken up, by vertical mixing, the waters are so transparent that the total effect of the turbulence on the productivity is favourable, the supply of nutrient salts resulting in an increase of the population, exceeding the loss by vertical transport.

In the bay of Fundy, on account of the exceptionally high tidal range, the turbulence of the waters is so strong throughout the year that their nitrate and phosphate content nearly always was found to be high, even at the surface. The production of phytoplankton, therefore, can hardly be limited by the lack of nutrient salts. A relatively high turbidity of the waters and much cloudy weather make the productive zone shallow. Consequently the high degree of turbulence may even diminish the productivity of the waters by carrying the diatom cells down below the illuminated zone for a greater part of their life. A pronounced phytoplankton minimum in June probably is mainly a result of this effect of turbulence.

PREFACE

During the summer of 1931 the International Passamaquoddy Fisheries Commission appointed Dr. H. H. Gran as an expert for studying the possible effect which the projected Cooper dam might have on the general productivity of the bay of Fundy, with special regard to phytoplankton production. In September 1931 a preliminary investigation was made by Dr. Gran in Passamaquoddy bay and the bay of Fundy. The same stations were worked as had been studied during the summer by Dr. Charles J. Fish with regard to the zooplankton. Chlorine determinations were made by Mr. Charles Hughes and phosphate analyses by Dr. John Morton.

Based upon the results of this preliminary survey, in collaboration with Dr. Charles J. Fish, a plan was laid for the work in 1932. Phytoplankton and zooplankton material would be collected on board the same boat, at the same stations, covering the bay of Fundy and parts of the gulf of Maine. It was found necessary to include simultaneous observations on the physical and chemical conditions affecting the growth of the phytoplankton, at all stations and depths where samples were collected for the study of the phytoplankton. At a meeting of the International Passamaquoddy Fisheries Commission in September 1931, this plan was accepted and Mr. Trygve Braarud was appointed an assistant expert for the phytoplankton investigations from March 9, 1932.

In 1932, according to the program, cruises covering the whole area of investigation were made in April, June and August, and a cruise in the bay of Fundy in September. The material obtained was supplemented by local observations at other seasons and by samples from additional stations.

The material was worked up by both authors in collaboration, partly at the Atlantic Biological Station, St. Andrews, N.B., and partly at the Woods Hole Oceanographic Institution, Woods Hole, Mass., and at the University of Oslo, Norway. The chemical analyses on nitrate, phosphate and oxygen content of the sea water, were carried out by Mr. Braarud, who also studied half the phytoplankton material, viz., that collected during March, April, May, and (in part) June and September. Dr. Gran examined the rest of the June material and that of the regular cruises in August and September. The manuscript has been prepared jointly by the two authors.

We wish to express our thanks to the International Passamaquoddy Fisheries Commission for the opportunity to carry out this very interesting investigation; to the zooplankton experts, Dr. Charles J. Fish and Dr. Martin W. Johnson; the hydrographer, Dr. E. E. Watson; the ichthyologist, Mr. Michael Graham; and the assistants, Mr. James Bates and Mr. Charles Hughes, for friendly collaboration. To Dr. A. G. Huntsman and Dr. Henry B. Bigelow we owe special thanks for the facilities given to us during the work at the Biological Station at St. Andrews and the Woods Hole Oceanographic Institution, and for their neverfailing interest in our work. We are also indebted to Dr. Viola Davidson, Mr. H. B. Hachey, Dr. John Morton and Dr. R. W. Sawyer for valuable information and discussions on special subjects of our problem.

INTRODUCTION

Program of the Investigation

How might the productivity of the bay of Fundy and the adjoining parts of the gulf of Maine be influenced, should the inlets to Passamaquoddy bay and Cobscook bay be closed by the projected dams? To give an answer to this question we regarded as the special problem to be solved by our phytoplankton investigations.

The preliminary presentation of the general problems by Dr. A. G. Huntsman (1931) and his interesting theoretical discussion were based upon the generally adopted theory of Brandt and Nathansohn, that (1) the production of phytoplankton is or can be limited by lack of nutritive substances in the illuminated surface layers, principally of phosphate and nitrogen compounds; (2) the surface layers may be depleted of phosphates and nitrogen by the metabolism of the phytoplankton and the sinking of dead and living bodies, with the effect that phosphorus and nitrogen compounds accumulate in the deeper layers and are there decomposed by bacteria, with nitrates and soluble phosphates as the final products; and (3) that vertical movements of the water must favour new growth of phytoplankton through the mixing which carries nutritive substances to the illuminated zone from deep waters.

On the other hand a series of facts observed in recent years indicates that vertical mixing, besides having a favourable effect, may have an unfavourable influence on the growth of the phytoplankton, because it prevents the living cells from accumulating in the illuminated zone where they may utilize the light for photosynthesis, and the nitrates and phosphates for growth and propagation. Particularly diatoms, which have the most rapid growth among the plankton algae and are therefore especially capable of utilizing favourable nutrient conditions, will be most liable to be carried downwards by such movements, as they have no faculty of actively moving to the zone of optimal life conditions.

This idea was first suggested by Atkins (1928) to explain the variations from one year to the other in the time for the beginning of the characteristic spring growth of diatoms in the northern European waters. Braarud and Klem (1931) also showed that this theory can explain the peculiar successive development of the spring plankton over the coastal banks off Lofoten and Möre in

Norway, described by Föyn (1929) and Gran (1929, 1930). The growth here begins near the shore and almost simultaneously at the outer edge of the banks, but it is about two weeks before the waters over the intermediate parts of the bank are populated by a rich diatom plankton. Braarud and Klem demonstrated that the waters, after the hibernal vertical circulation, are first stabilized at the coast and over the edge, while the vertical movements are still going on over the bank. As long as the vertical circulation continues and the surface waters are not stabilized, a rich diatom plankton is unable to develop, in spite of sufficient quantities of nitrates and phosphates being present at the surface. Gran (1932) described similar conditions from the Weddell sea in the Antarctic, where a rich growth of diatoms was prevented from utilizing the enormous quantities of nitrates and phosphates present, until the surface layers were stabilized about New Year's time, by the melting of the ice.

In the bay of Fundy, the preliminary investigations in September, 1931, seemed to indicate that such conditions might prevail, as the phosphate content was generally high, while the phytoplankton at several localities was extremely poor. Therefore, it was fundamental in our investigation to study and compare the positive and negative effects of the vertical mixing in these turbulent waters. For comparison the investigations were extended to the gulf of Maine, where a pronounced stratification of the waters was found by Bigelow (1927) to prevail during summer. For practical reasons only the western part of the gulf was made the object of as intensive a study as the bay of Fundy.

The following program was decided upon, for collection of material. Monthly cruises were to be made from winter to the following autumn for hydrographic observations (temperature and salinity), for some chemical studies (phosphate, nitrate and oxygen content of the sea water) and for collection of phytoplankton samples (centrifuge plankton) and of zooplankton samples (Fish and Johnson unpub). Each cruise was to include observations at the same localities (stations) in the bay of Fundy and the western part of the gulf as far south as the offing of Casco bay (see map of the Pelican stations, figure 15). Unfortunately a fire in March, 1932, at the Atlantic Biological Station, the base of the field work, destroyed the greater part of the equipment for this work. The result was that the collecting of phytoplankton material was delayed and could not start until the month of April, and the chemical work had to be left out until the May cruise. Though it was desirable to continue the investigation through part of the next year, at least, cuts in the appropriations made it necessary to discontinue the field work after the first of October 1932. These incidents, which were beyond our control, caused a considerable curtailment of our plans and made the material less complete than we had hoped for. On the other hand, through the liberal collaboration of the other investigators, we obtained valuable material from other localities than those visited on our monthly cruises.

New problems which arose during the investigation, particularly that of the influence of the light conditions, could not be followed as far as desirable because of lack of time. After all, however, the material of observations collected during the survey has given an unique opportunity to study the development of the phytoplankton through the main season of production in a very interesting area, and also its dependence on a series of physical and chemical factors.

NOMENCLATURE OF THE REGION

The following nomenclature will be used in referring to the various regions which come under consideration in reports of the International Passamaquoddy Fisheries Commission (see figures 1 and 2).

The **QUODDY REGION**, comprises the whole body of water which lies between a line drawn from West Quoddy head to the northern extremity of Grand Manan island and on to point Lepreau. Further subdivisions of the

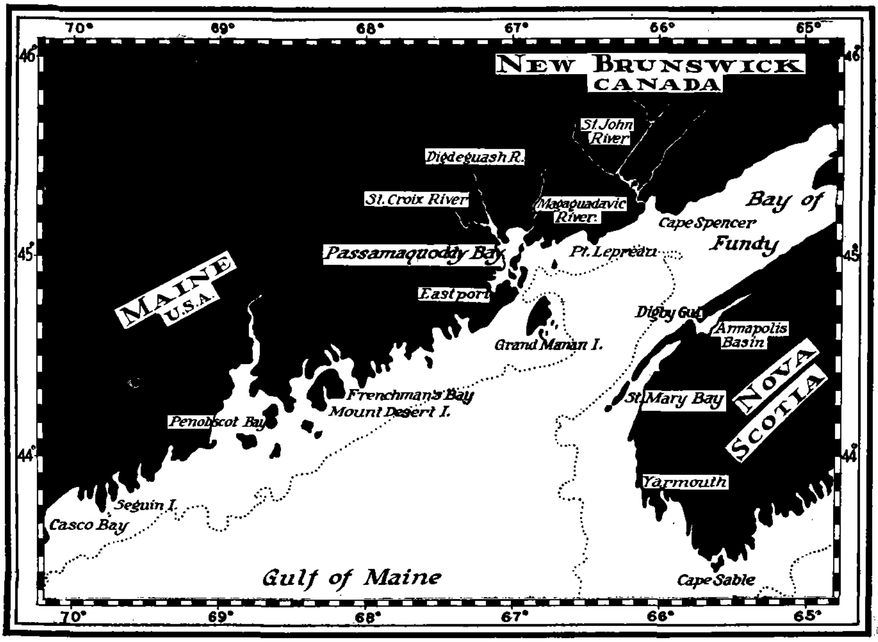


FIGURE 1. The bay of Fundy and gulf of Maine region.

Quoddy region are: **Passamaquoddy bay**, or the Inner bay, lying inside of Deer island and not including any part of the passages which connect it to the outside waters; **Cobscook bay**, lying within a line drawn from Eastport to Lubec; and the **Quoddy passages**, which include the entrance passages to those two bays with the waters among the many small islands outside Deer island as far as a line drawn from East Quoddy head (or Head harbour light) to Bliss island; and finally the **Outer Quoddy region**, which is that part of the Quoddy region lying outside of this line and within the line from West Quoddy head to Grand Manan and on to point Lepreau.

GRAND MANAN CHANNEL is the body of water between Grand Manan island and the coast of Maine extending from the Quoddy region to a line drawn from Machias bay, Maine, to Machias Seal island and up to Southwest head, Grand Manan.

The **BAY OF FUNDY** extends in a north-easterly direction from the gulf of Maine and the position of a line chosen to divide the two regions for

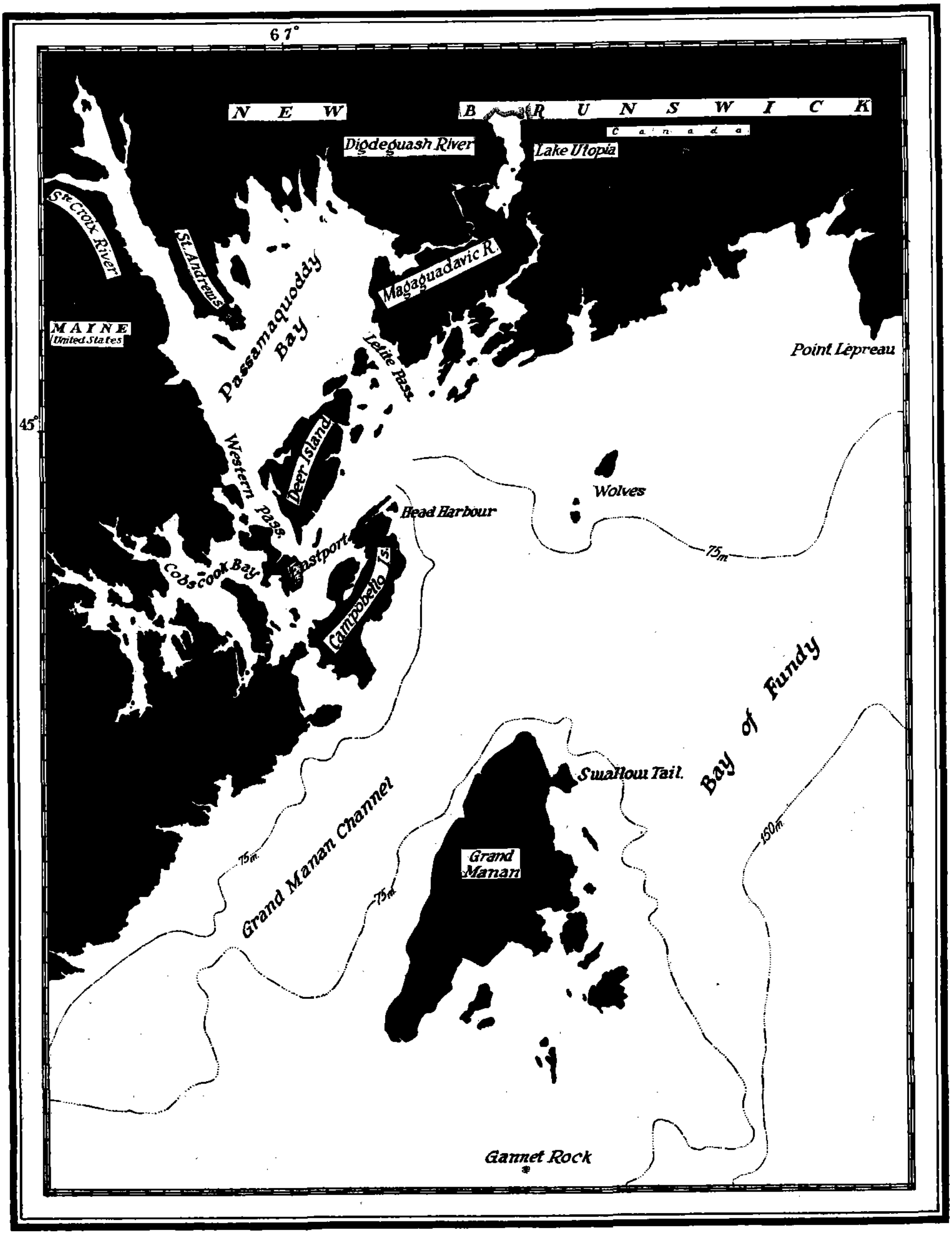


FIGURE 2. The Quoddy region.

purposes of reference must be somewhat arbitrary. We shall consider the boundary of the bay of Fundy to extend from Machias bay, Maine, to Grand Manan bank and across to Brier island, N.S. The name bay of Fundy will be used to represent the entire bay in distinction to the gulf of Maine, and also the major portion of the bay excluding the Quoddy region and Grand Manan channel in distinction to either or both of these areas.

Hydrographic Characteristics of the Region

The hydrographical part of the Commission's work was carried out by Dr. E. E. Watson and the results are to be published separately. Some hydrographical observations were also made as part of the biological survey. A few of these have been used for the hydrographical account, but most of them are chiefly of interest in connection with the plankton material and will be recorded here in the form of vertical sections.

The presentation of the phytoplankton material is to a very large extent based upon a detailed comparison of hydrographic and chemical data with the phytoplankton data. In order to give a basis for the consideration from this point of view, it is necessary to give a short account of the main hydrographic features of the bay of Fundy and the gulf of Maine. Papers by Bigelow (1927 and 1928) and Watson (unpub.) have furnished most of the material for this short review and are recommended for more detailed information on the hydrography of the region. Papers by Bigelow include a complete bibliography of the hydrographical work in these waters. For illustrating the outstanding points we are using the hydrographical sections based upon the material from the present investigation (figures 3 to 14).

The **gulf of Maine** forms an open bay, but below the 100 m. level it is land locked except for two narrow entrances, the Northern and Eastern channels on either side of Brown's bank. These topographical features and the mass of heavy slope water along the outside of the continental shelf, provide a barrier against the oceanic waters further out and are prerequisite for the anti-clockwise circulation within the gulf. The main contributions of water to the gulf are: (1) fresh water from rivers and precipitation, (2) coastal water from the bay of Fundy and at some times of the year from the banks south of Nova Scotia (the Nova Scotia current), and (3) salt slope water moving in through the deep parts of the channels. Fed from these sources and subject to heating and chilling, the different strata in various parts of the gulf retain much the same characteristics in temperature and salinity from one year to another. The salinity of the waters throughout the gulf is always found to be lower than $35^0/_{00}$ and the temperature is very seldom found to exceed the range from 0 to 20°C.

The winter cooling goes on until late February or early March and results in an almost homogeneous layer from the surface down to a depth of 100 metres. Later the vernal freshening and heating produce a warmer and lighter surface layer which is more pronounced in the central part of the gulf than close to shore where tidal currents stir the water to a greater extent. During April and May the heating continues so that in the gulf three water-layers are formed which can be recognized all through the summer: (1) a rather fresh, warm surface layer, (2) a fairly salt, cold intermediate layer and (3) the salt, medium warm bottom water. (For actual temperature and salinity figures see sections in figures 3 to 14).

The temperature of the surface layers increases through summer until

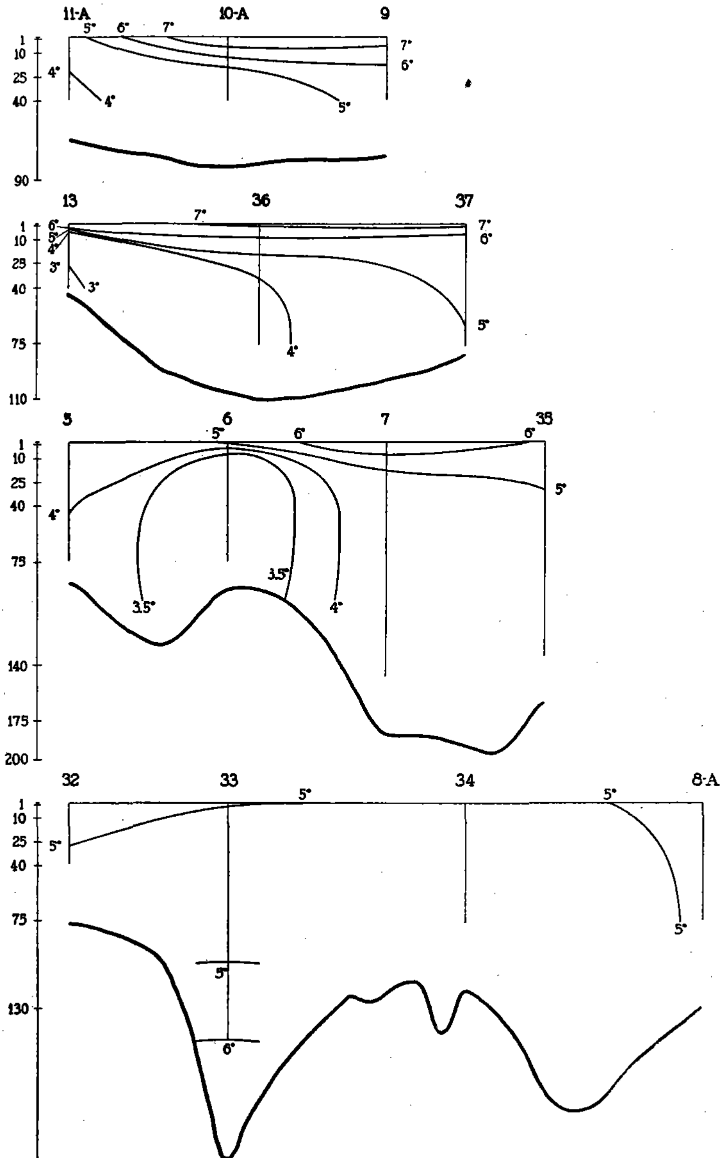


FIGURE 3. Bay of Fundy. Temperature distribution in May. Cruise 27. (For location of stations see figure 15).

late in August, reaching 18 to 20°C. in the inner part of the gulf, while the intermediate layer, insulated from direct heating by the light surface waters, is heated very slowly and as a whole is remarkably stationary. The bottom layers are supplied with water of such a uniform character and at such a rate that the salinity and the temperature there change very little throughout the year. The stratification is so marked that the surface layers in summer reach a high

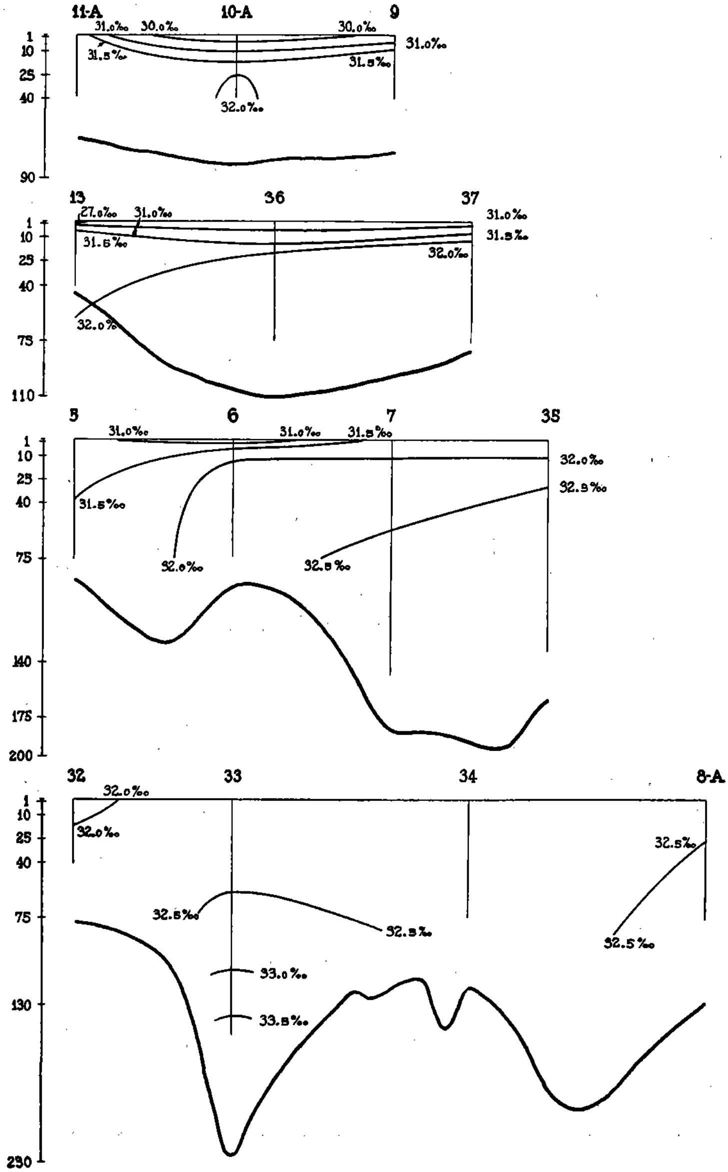


FIGURE 4. Bay of Fundy. Salinity distribution in May. Cruise 27.

degree of stability, thus forming a bulwark against atmospheric influences on the lower strata. From September through the autumn and early winter, the surface layers are cooled, and consequently the stability decreases gradually and the tides and the strong winter winds stir these water layers more and more effectively. The result is that by the end of February or the beginning of March, as previously mentioned, the upper 100 metres are practically homogeneous.

In the gulf, the mixing due to tidal currents and other water-movements is not so violent and is only noticeable in a few localities. One of these is Georges

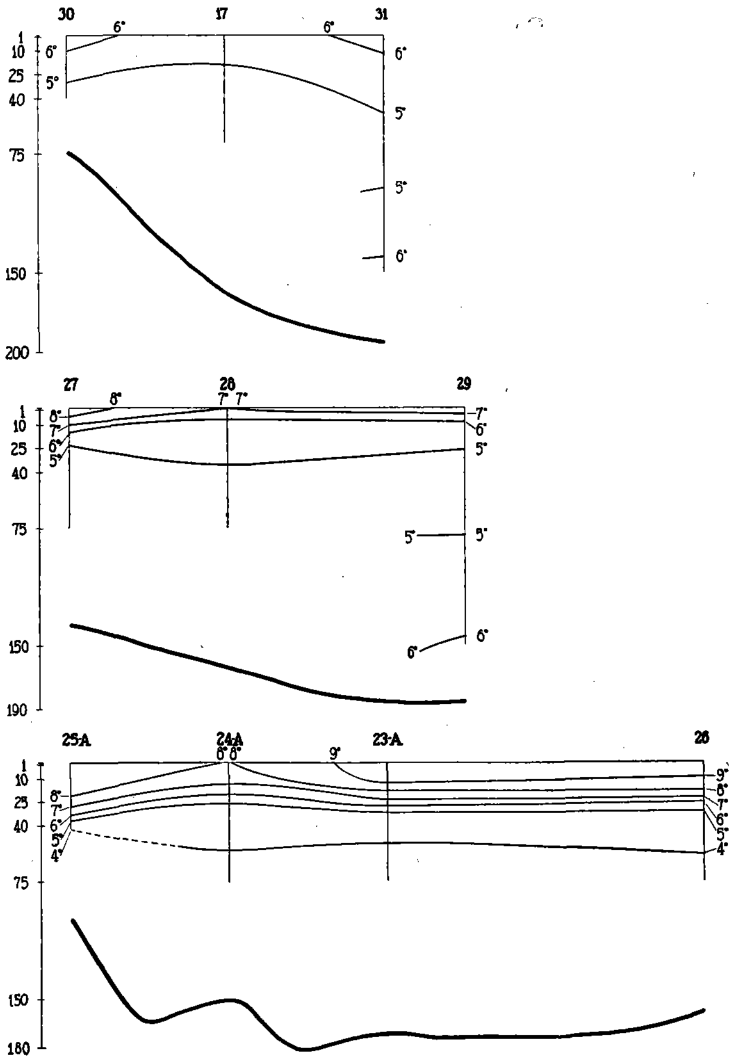


FIGURE 5. Gulf of Maine. Temperature distribution in May. Cruise 27. (See figure 15).

bank, where vertical mixing is so effective that the water, even in summer, is found to be rather homogeneous. Along the coast, the tidal currents between islands and over shoals causes turbulence, making the waters there more uniform than in the central part of the gulf. Only exceptionally does the mixing reach such an intensity that the stratification is completely destroyed. However, close to land the waters are a little less stratified than further offshore. This is illustrated in the sections by the upward trend of the isolines towards the coast (see figures 5 and 6, 9 and 10, 13 and 14).

The **bay of Fundy** is a slightly funnel-shaped side branch of the gulf of Maine. Its location and shape make the tidal currents very strong, a feature

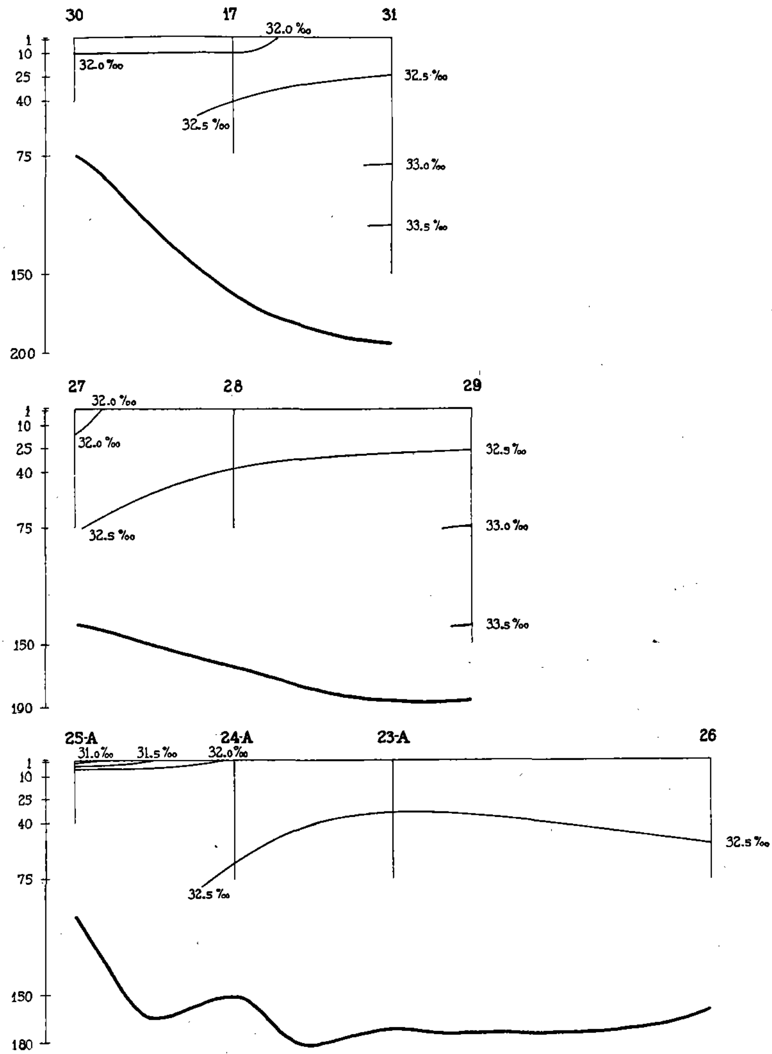


FIGURE 6. Gulf of Maine. Salinity distribution in May. Cruise 27.

which in combination with the great inflow of fresh water produces hydrographic conditions very different from those in the gulf. The mean range of the tides reaches 17 m. (51 feet) at the head of the bay, and even in Passamaquoddy bay is more than 8 m. (24 feet). The rushing tidal currents which during every tidal period transport huge water masses, necessary for such a change in water level from high to low tide, produce mixing of the upper strata. The result is that these layers as a whole are more homogeneous than in the gulf of Maine. The heat, absorbed by the surface layers during spring and summer, is thereby

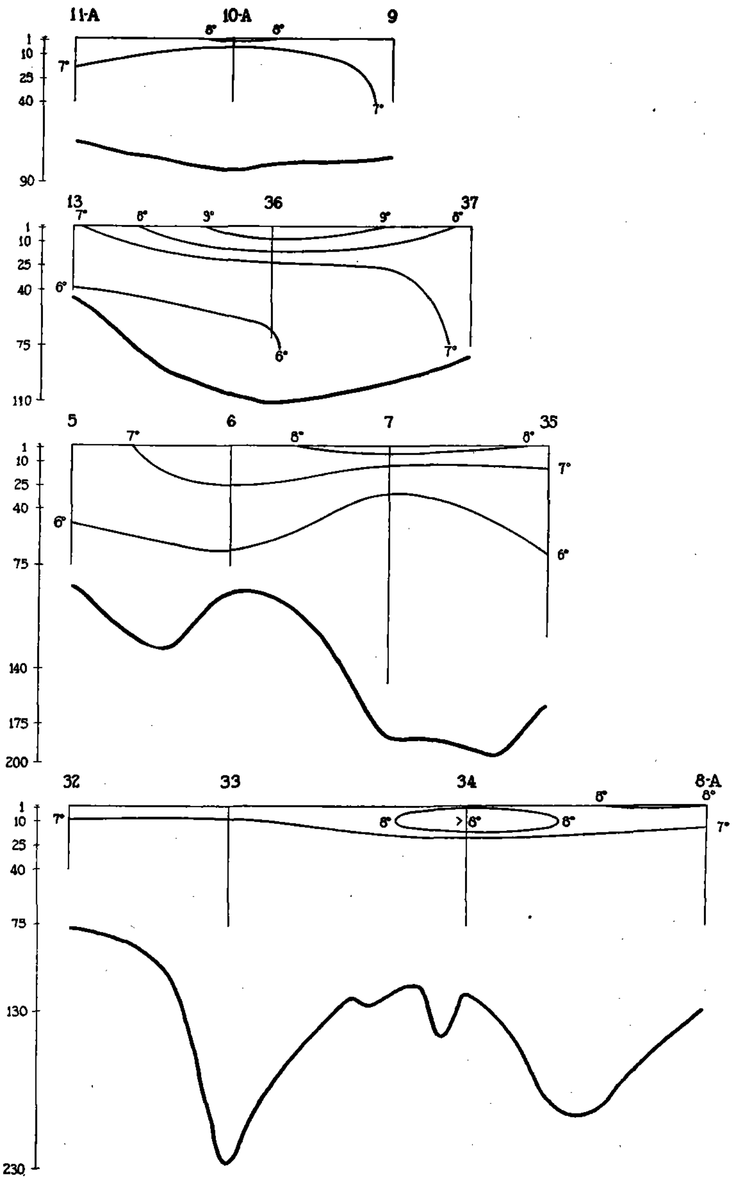


FIGURE 7. Bay of Fundy. Temperature distribution in June. Cruise 28 (See figure 15).

distributed in a thicker water layer. Consequently the surface temperatures in the bay of Fundy are, for example in April and May, found to be 6 to 8 degrees lower than in the gulf, a situation which continues throughout the summer.

At the same time the mixing accelerates the heating of the sub-superficial strata after the temperature minimum in winter (see hydrographical sections). A temporary exception to this is caused by the Saint John river outflow, which

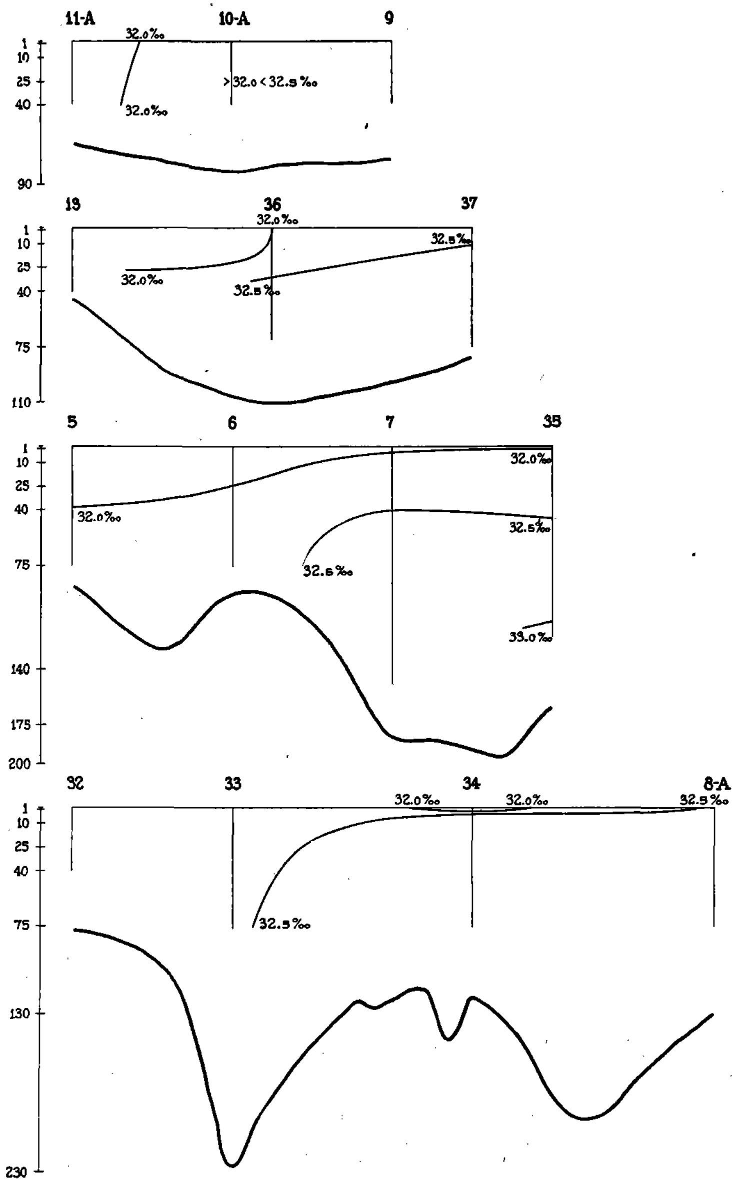


FIGURE 8. Bay of Fundy. Salinity distribution in June. Cruise 28.

has its maximum in April and May. At this time it produces a light surface layer off the New Brunswick shore, insulating the waters beneath in the same way as do the surface waters in the gulf of Maine. However, wind and tidal mixing soon embody it in the layer below, producing the characteristic low degree in stability of the surface layers.

The circulation within the bay is anti-clockwise. Surface waters from the gulf of Maine enter along the Nova Scotia side and the waters at the New

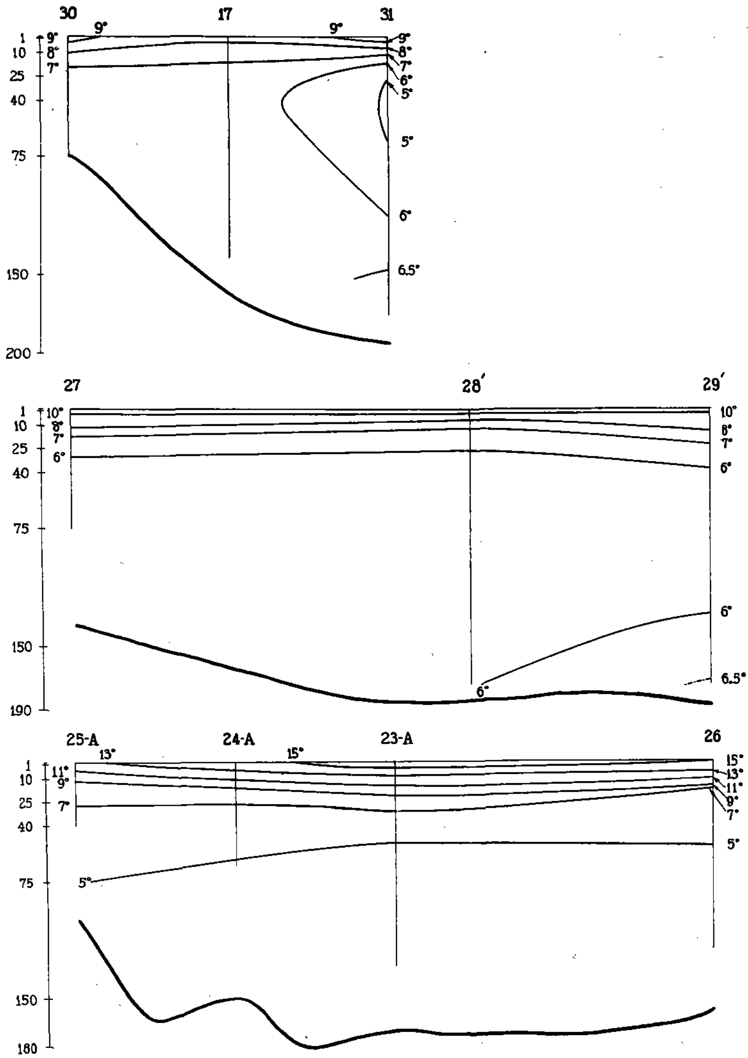


FIGURE 9. Gulf of Maine. Temperature distribution in June. Cruise 28. (See figures 15 and 38).

Brunswick shore move outwards, east of the Wolves and Grand Manan, down along the western coast of Maine into the gulf. The main part of this drift passes outside of the Quoddy region, which like the Grand Manan channel contains a water mass of rather independent character, although the outgoing waters contribute a little to the waters in these areas. The deeper strata of the bay of Fundy are fed with salt deep-water from the gulf of Maine. Some of this deep-water is continually drawn into the Quoddy region by way of the channel between Grand Manan and the Wolves and is slowly but steadily consumed by the mixing mechanism in the Quoddy passages. Water which is formed

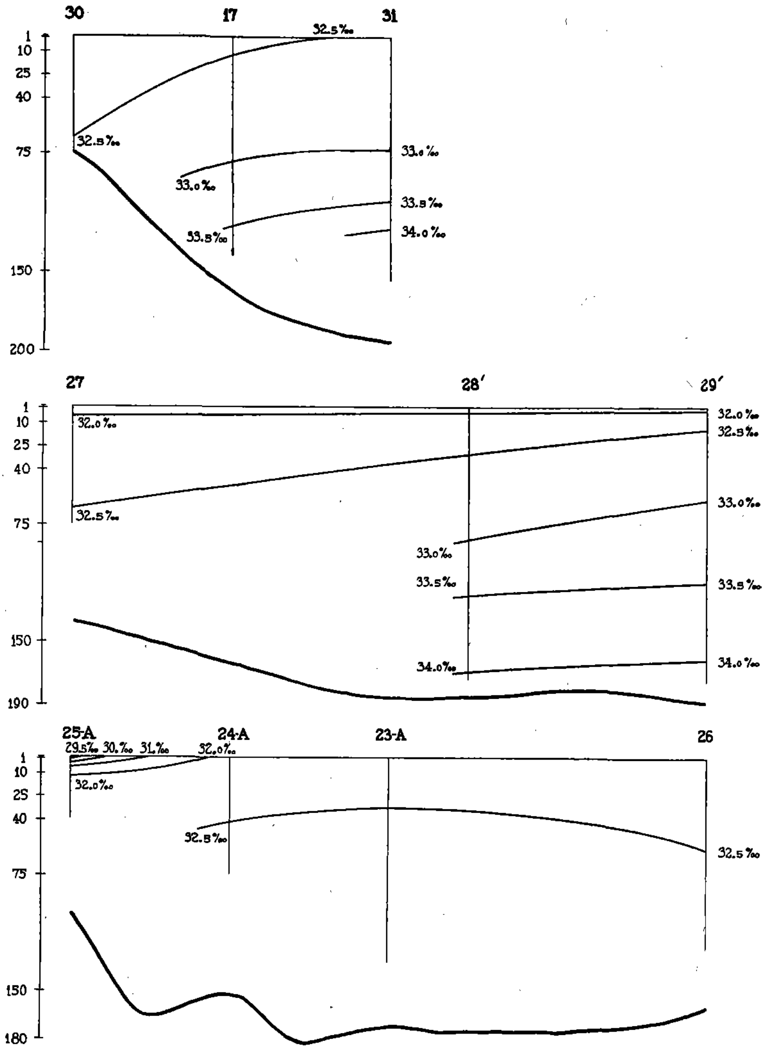


FIGURE 10. Gulf of Maine. Salinity distribution in June. Cruise 28.

by this mixing of deep water with the rather fresh water from the Passamaquoddy bay and Cobscook bay flows out at an intermediate level.

Tidal mixing, caused by turbulence of different kinds, acts with various intensity in the different parts of the bay. In general, the waters along the shores and in shallow localities are more affected than offshore waters. The most effective mixing areas are: (1) the Quoddy passages, (2) Grand Manan channel, and (3) the head of the bay of Fundy. In all these localities the water is practically thoroughly mixed from top to bottom throughout the year. The

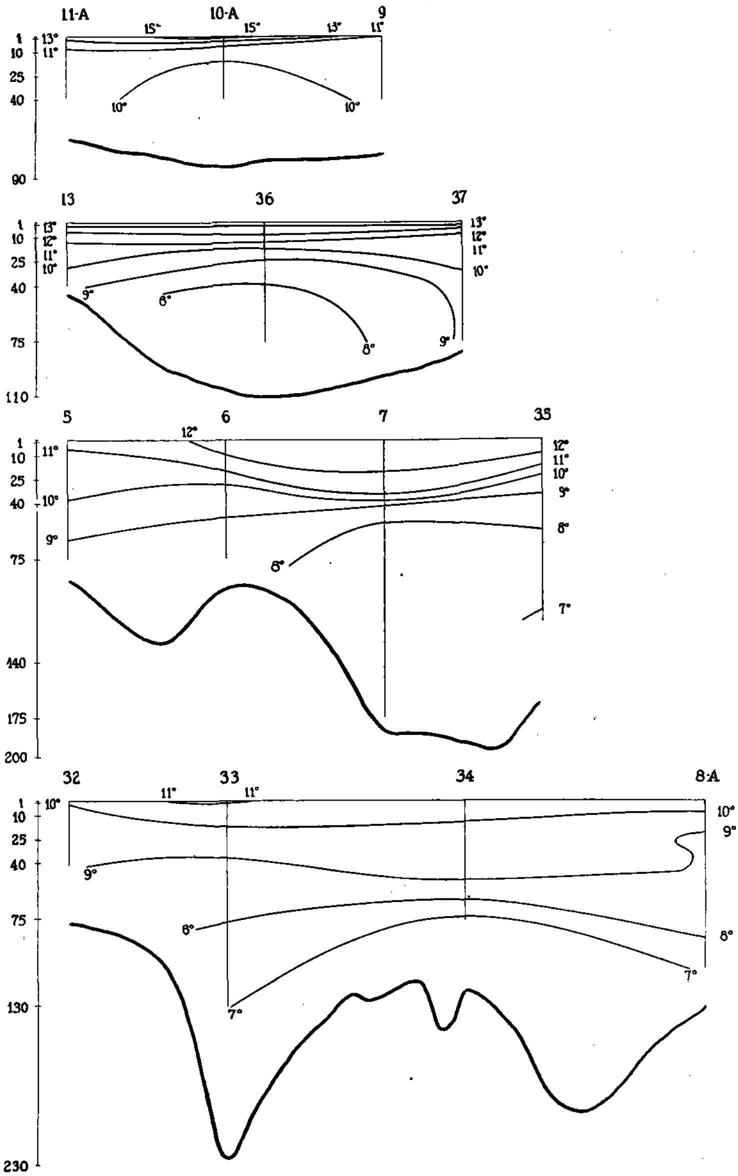


FIGURE 11. Bay of Fundy. Temperature distribution in August. Cruise 30. (See figure 15).

area where the water seems to be least affected is the central part of the bay; but even there the direct and indirect effect is considerable.

Passamaquoddy bay is separated from the rest of the bay of Fundy by a row of islands and an interchange of water can take place only through Letite passage and the Western passage (see figure 2). The freshening effect of the rivers emptying into it (St. Croix, Magaguadavic and Digdeguash rivers) is counteracted by the indraft of salt water to the deeper strata through the

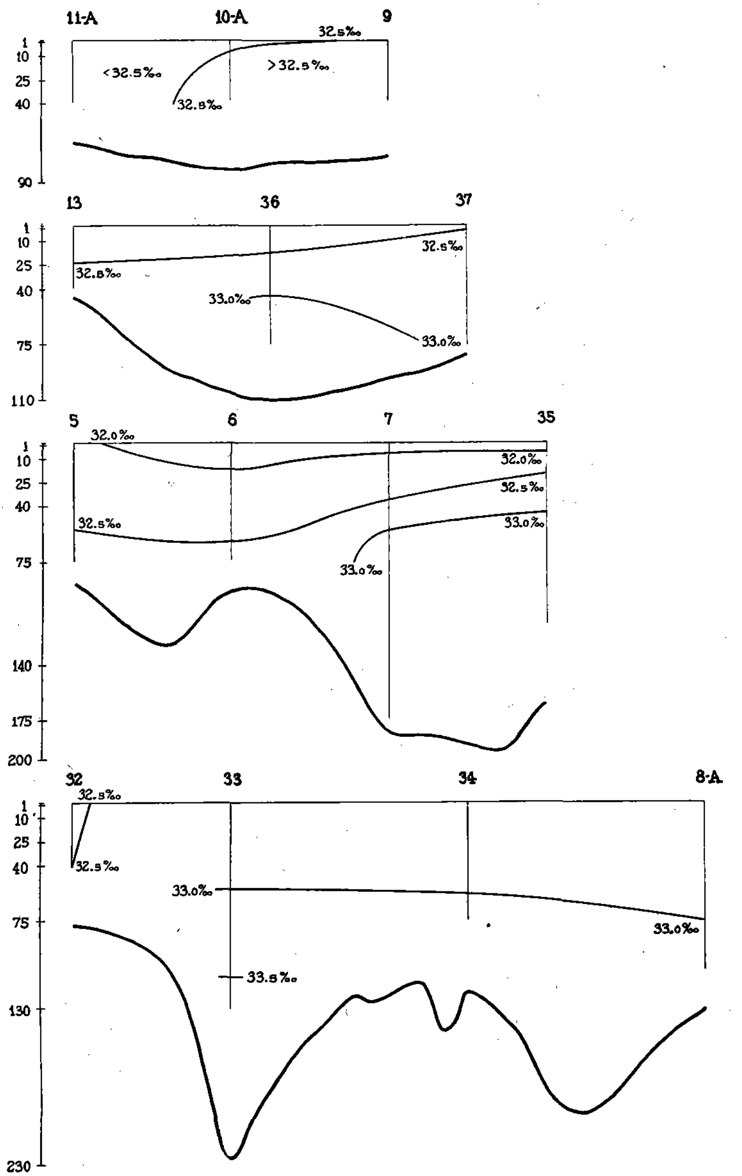


FIGURE 12. Bay of Fundy. Salinity distribution in August. Cruise 30.

passages, and the tidal mixing of this deep water with the surface layers of the bay. As a result the conditions in Passamaquoddy bay are similar to those in the rest of the bay of Fundy, although the surface layers are of a little more estuarine character, in spring and summer having a higher temperature and lower salinity, and consequently attaining a higher degree of stability, than elsewhere in the bay of Fundy. This difference is partly conditional upon the rather sheltered location of the bay in regard to wind action.

The extensive influence of the exceptional tides in the bay of Fundy also

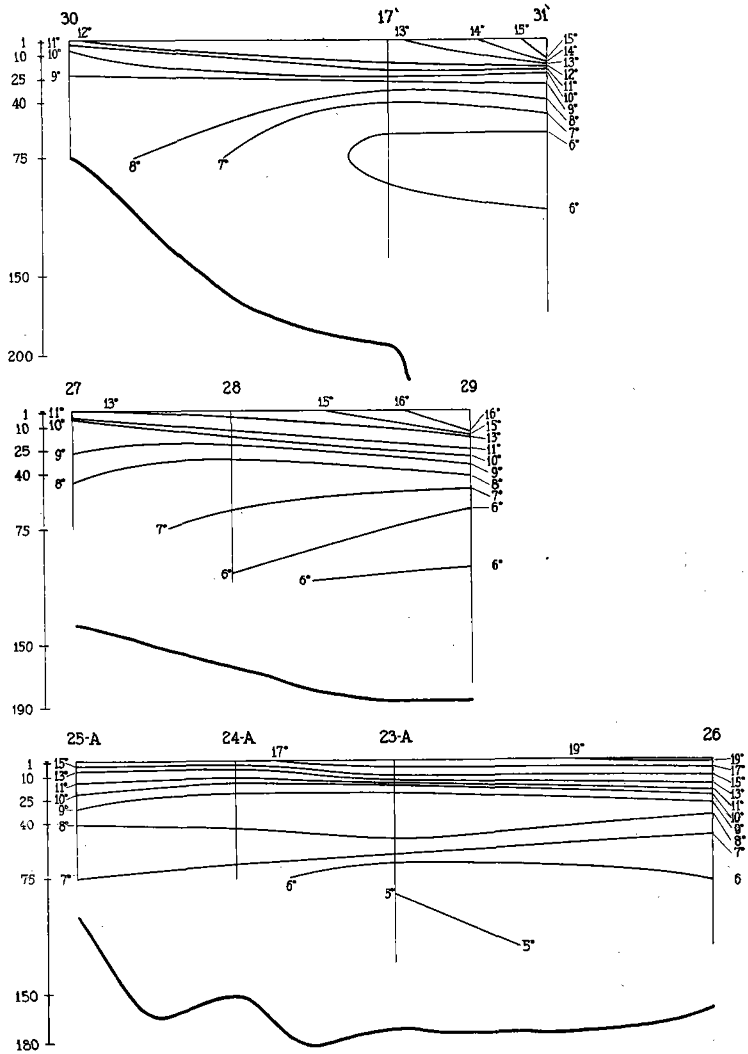


FIGURE 13. Gulf of Maine. Temperature distribution in August. Cruise 30. (See figures 15 and 39).

affects the meteorological conditions. The low temperature of the surface layers in the bay of Fundy in summer, as compared with the warmer adjacent waters, is the immediate cause of local fog formation. Within the region, fog occurs by far most frequently in the bay of Fundy or in localities where bay of Fundy water is carried into the gulf of Maine, but it is also often formed where there are for some special reason locally cold surface layers, as along the western coast of Nova Scotia. (See also page 319).

REMARKS ON THE DIFFERENT STATIONS

In the bay of Fundy the hydrographical conditions vary so much from one

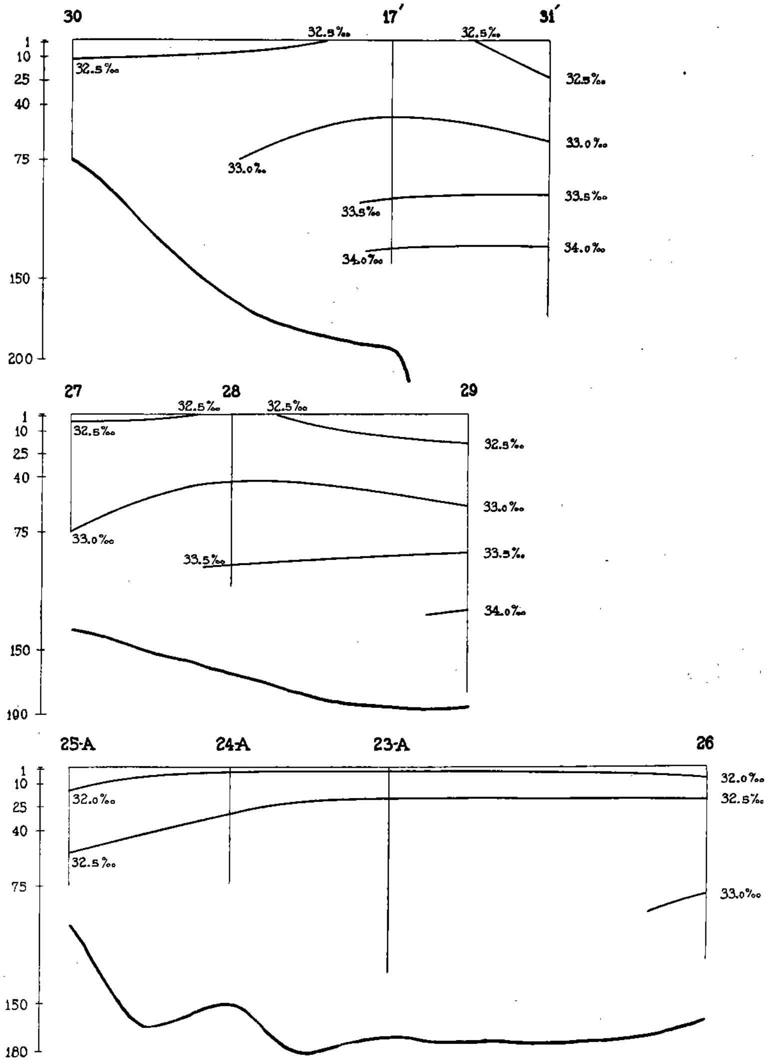


FIGURE 14. Gulf of Maine. Salinity distribution in August. Cruise 30.

locality to another that even having 14 stations within the bay proper, there are not two stations which have conditions so similar that they can be considered together. In the discussion of the plankton conditions we are, therefore, forced to treat the stations individually to a greater extent than is desirable for a clear presentation.

The principle used for the numbering of the "Pelican" stations is the following. The number for a station, for instance 30.05, indicates its location by the figure after the period (as shown in the key map, figure 15) while the figure before the period is the number of the cruise. The cruises at which phytoplankton samples were taken are: the 26th from April 15 to May 2, the 27th from May 18 to 31, the 28th from June 20 to July 1, the 29th on July 30, the 30th from August 8 to 21, the 31st from September 12 to 13 and the 32nd from September 14 to 26. Figure 15 shows the location of the stations worked at the monthly cruises and the combination of stations used for the hydrographical and chemical sections.

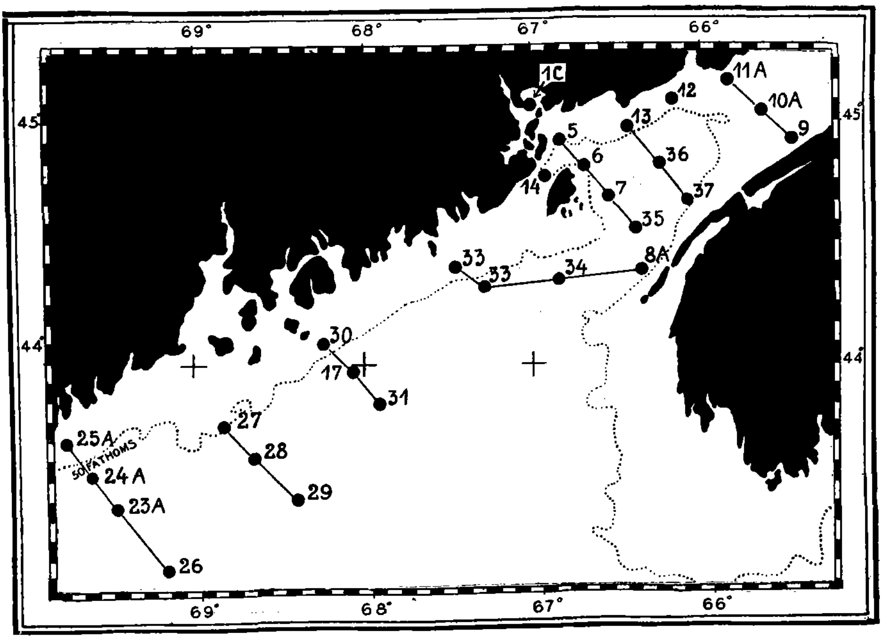


FIGURE 15. Location of stations worked during the cruises in April, May, June, August and September 1932.

We cannot undertake to give a detailed description of the hydrographic conditions at every station through the season, but we shall try to give a brief summary for each of them by referring to the map and the general remarks on the hydrography of the region found on the preceding pages.

Station 8A is the only station at the mouth of the bay of Fundy where the inflowing water mass is regularly in evidence. Station 37 lies on the border between the waters moving inwards and the more stationary layers in the central part of the bay, represented by station 36. At some phases of the tide, stations 37 and 9 are dominated by mixed water, partly originating from the Digby gut mixing mechanism. Stations 10A and 11A during the ebb show mixed water from the head of the bay, while during the flood tide they are reached by stratified water from the central part of the bay and from off Saint John. Station 12 is off the Saint John river outwash and station 13 is located further to the west in the outflowing waters along the New Brunswick shore. The only station in the outer Quoddy region is station 5, outside the passages. Station 6 is located just on the border between the Quoddy region and the New Brunswick shore waters. Its upper layers, therefore, sometimes have the characteristics of one, sometimes of the other of these regions. The two stations 7 and 35, east of Grand Manan, are often much alike, having the outward drifting water masses on the top and the deeper water moving inwards in the lower strata; but station 35 is sometimes affected by surface water from the gulf. Depending on the phase of the tide, station 14 in the Grand Manan channel either shows thoroughly mixed water (high tide) or fairly stratified water, which has moved down from the Quoddy region (Watson unpub.). Stations 32, 33 and 34, southwest of Grand Manan, all have bay of Fundy water on top and water from the gulf in the deeper strata. Stations 31 and 29 are located in the deep eastern trough of the gulf, while station 26 represents the central south-western part of the gulf. The other stations represent waters closer to shore, for example station 30 off the mouth of Frenchman's bay.

RESULTS OF THE CHEMICAL WORK

From the results obtained by recent marine investigations, it seemed necessary to combine the study of the quantitative distribution of phytoplankton with a study of the hydrography and of the supplies of nutrient salts of the waters. Previous work shows that when the phytoplankton production in northern waters is limited by deficiency in nutrient salts, this is the result of depletion of the supply in phosphates, nitrates, or both (e.g., Atkins 1928, Braarud and Klem, 1931, Brandt 1920, 1925, Cooper 1933, Gran 1930, Harvey 1928, Kreps and Verjbinskaya 1930, 1932, Schreiber 1927, and others). As only limited time could be devoted to chemical work, consideration was given as to which would be the most valuable analyses for the understanding of the productivity of the water masses. The determination of the following properties of the water was made a part of the routine work on the monthly cruises: temperature, salinity, oxygen content, phosphate and nitrate contents and the phytoplankton content. The oxygen analyses were included, partly because the oxygen content gives some basis for an estimate of the rate of photosynthesis at the time when the water sample was taken, and partly because it was hoped to be of some help for the identification of different water masses.

Following are given a description of the methods which were used and a short account of the results of the analyses. The causes of the fluctuations in the oxygen and the nutrient salt content will, however, be considered later in connection with the discussion of the conditions for the production of phytoplankton (page 394).

Phosphates

The only previous observations on the phosphate content of the bay of Fundy waters were made by Hachey and Morton (unpub.). They analysed samples from the surface and bottom layers at "Prince" stations 6 and 848 in Passamaquoddy bay and 5 and 880 just outside the Quoddy passages. The observations at these stations were made once a month from August 1929 to November 1930. For station 5 and station 3 (east of Grand Manan) they also made observations in 1931. The results of this investigation show the main features in the distribution of phosphates in the Quoddy region: the high values in the surface layers all through the year, except in the summer. However, even then there is not a general depletion. At the station east of Grand Manan (station 3), which is the only locality for which Hachey and Morton have observations outside the Quoddy region, they found high values at the surface

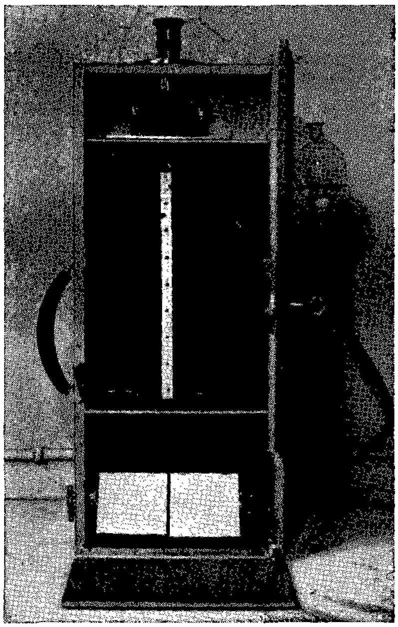


FIGURE 16. Colorimeter for the phosphate analyses, designed by A. Klem.

during the winter and decreasing values through the summer, with a minimum in the middle of August (August 17, 1931: 15 mg. P_2O_5 per cu. m.).

In the gulf of Maine, Rakestraw (1932) studied the changes in the nitrate, nitrite and phosphate content of the waters around Mount Desert island during the summers of 1929 and 1930. Besides these observations from an area close to shore, Rakestraw also has published similar data for some stations in the central and eastern part of the gulf for August 1932. We shall refer in more detail to these data after having presented our material for 1932.

The phosphate analyses were carried out according to Atkins-Denigé's method and in details the same procedure was followed as used by Braarud and Klem in the investigations at Möre in 1931 (report under preparation for the press). The colorimeter which was used was a combination of Hehner cylinders with the upper part of a Dubosque colorimeter and was designed by Mr. Alf Klem. The procedure of analysis was the following: a colour solution (from Velox Transparent Water Color Stamps) was made to match the colour in distilled water + phosphate solution (= 40 mg. P_2O_5 per cu. m.) + reagents. This colour solution was kept in the Hehner cylinder which was equipped with the glass bulb and the rubber tubing connection (see figure 16). It was calibrated by comparison with a number of samples of distilled water with added phosphate solution and reagents, corresponding to concentrations in phosphate of say: 0,10,20,30,40,.... mg. P_2O_5 per cu.m., doubling some of the samples. The curve obtained in this way for the relation between the colorimeter readings and the content of P_2O_5 is a straight line. To all samples which contained very small amounts of phosphates, there was added phosphate solution corresponding to an increase in concentration of 10 mg. P_2O_5 per cu. m. Duplicate readings as well as duplicate analyses show that the experimental error is within $\pm$ 2 mg. P_2O_5 per cu. m., in most cases better. The samples had to be stored for some days before the analyses were made. Control analyses did not show any noticeable changes in the phosphate content of the samples during the time of storage. Duplicate analyses made simultaneously in St. Andrews, N.B. and in Halifax, N.S., the latter by Dr. John Morton, who also supplied the samples, gave the following values:

Sample	St. Andrews	Halifax
a	75 mg.	72 mg.
b	32 mg.	35 mg.

The values found by this method are correct only when the distilled water which is used does not contain phosphates. In case it does, this phosphate amount must be added to the values found by the analyses of the sea water samples. For the May cruise distilled water was supplied from Saint John, N.B., as the laboratory at the Biological station in St. Andrews was not yet restored after the fire in March. This water may have contained some phosphate and the low readings for the May cruise may thus be accounted for by this fact. However, only future phosphate analyses from the region will ascertain whether an increase in phosphate content of the waters, as general as our May and June observations would indicate, actually takes place at this time of the year. According to what is known from other regions this is not likely to be the case. The figures have been entered in the tables without any corrections. In our discussion we have, however, taken into account that the values for May possibly ought to have been about 10 mg. higher than those recorded in the tables. This correction of 10 mg. is based upon a comparison between the values for the deep water samples in May and June.

The values for the phosphate content of sea water, obtained by the method of Atkins-Denigé, are generally regarded as representing the amount of phosphates available for the plankton algae. In so far as we know, the only attempt to ascertain whether this is actually the case, was made at the Oslo meeting in 1928. Three filtered water samples were then analysed both by means of the regular chemical method and by Schreiber's physiological method (Schreiber

1927), the last one giving the amount of phosphorus which can be utilized by the green flagellate *Chlamydomonas*. The results of the analyses, published by Braarud and Föyn (1931), show a very good agreement between the results obtained with the two methods. This indicates that the Atkins-Denigé method for filtered samples gives values which do not differ noticeably from the amount of available phosphorus present.

The waters of the bay of Fundy contain exceptionally large quantities of suspended particles, the amount varying with locality and time in a way yet mostly unknown (see page 322). Examinations of centrifuged water samples have given us the impression that some of these suspended particles consist of organic matter. If so, they may contain phophorus compounds, which are not immediately available for the algae growing in the same water mass. During the course of the analyses it is possible, however, that they may be liberated. The result of the analysis would then show a value somewhat higher than the actual amount of available phosphorus in the sample.

In order to check whether this had to be taken into account, by the valuation of the results as to the presence of available phosphorus, some parallel analyses of filtered and unfiltered samples were carried out. A Seitz serum filter with asbestos sheets, EK. no. 6 was used. This retains all particles down to the size of bacteria. (The asbestos sheets were washed in distilled water for a couple of weeks before they were used). Time did not allow such analyses until August and even then not for so many samples as desirable. The results of those obtained are shown in table I below.

TABLE I

Stations (see fig. 15)	Depth (m.)	Unfiltered mg./cu.m.	Filtered mg/.cu.m.	Difference U-F, mg./cu.m.	Filtered as % of unfiltered
29.05	—	33	25	8	76
29.01C	—	21	18	3	86
30. Fr. bay	1	16	12	4	75
— " —	10	36	37	− 1	100
30.14	40	37	25	12	68
30.23A	40	47	37	10	79
30.23A	75	48	39	9	81
30.25A	1	12	4	8	33
30.26	1	7	0	7	—
30.26	75	54	44	10	80
30.31	25	22	18	4	82
30.31	10	12	6	6	50
30.35	75	43	30	13	61

In one instance the filtered sample shows a higher value than the unfiltered one, but the difference is only 1 mg. In all the other cases the filtered sample is found to have the lower value and in most cases the difference between the values for filtered and unfiltered samples is so large that it is obvious that the particles held back by the filter contain a considerable part of the phosphate content recorded by the analysis of the unfiltered sample. This part differs from sample to sample. The number of these analyses is too small to give any positive information in regard to the variation of particle phosphate content with depth or from station to station. These results indicate that one would get a truer picture of the distribution of immediately available phosphorus in the upper water layers if filtered or centrifuged samples were analysed. For the deeper layers the question may not be so important as it is probable that then the "potential" phosphorus content, present in particles, may be transformed into available form before reaching the surface layers where it becomes subject to utilization. For a closer study of the phosphate regeneration, the comparison of the phosphate content of filtered (or centrifuged) and unfiltered samples ought to be useful, for surface as well as for deep water samples.

As to the values in our tables, it may thus be concluded that the values recorded sometimes may show a little higher phosphate content than the amount of available phosphate actually present. For the higher values the differences are not directly of interest in regard to the conditions for growth of phytoplankton.

The results of the phosphate analyses are presented graphically in figures 17 to 20 and are also found in the plankton tables. The absolute values agree well with those recorded by Rakestraw (1932), but are as a whole lower than those found by Hachey and Morton (unpublished) for the Quoddy region and those published by Rakestraw (1933) for the gulf of Maine.

For the purpose of comparison we have figured the means of the phosphate values for waters within certain salinity limits, omitting the values for the 1, 10 and 25 m. levels and for lower depths in cases where supersaturation in oxygen indicates mixing with surface water. (The May values are not included at all, see page 301).

Salinity	31 to $32^0/_{00}$	32 to $33^0/_{00}$	33 to $34^0/_{00}$	34 to $35^0/_{00}$	$35^0/_{00}$ –
Mg P_2O_5 cu.m.	28	39	49	62	

Corresponding values recorded from the Norwegian coast for 1930 (Braarud and Klem 1931):

Mg P_2O_5 cu.m.			19	48	55

Moberg found for water below a depth of 50 m. at the coast of southern California (salinity: 33.5 to $33.9^0/_{00}$), phosphate values of 100 to 150 mg. P_2O_5 cu.m. For Puget sound, Thompson and Johnson (1930) record the following mean values for the year 1928-29:

Depth 12.8 m.: phosphate content 141 mg. P_2O_5 cu.m., salinity $30.93^0/_{00}$
" 0 m.: " 139 " " , " $30.81^0/_{00}$

Ruud (1930) found in the Antarctic (latitude 55 to 65°S.) 150 mg. P_2O_5 per cu.m. at a salinity of between 33 and $34^0/_{00}$.

As will be seen from these scattered examples, there is no general relationship between salinity and phosphate content of the sea water. The phosphate content in water of a certain salinity varies from one region to another according to the "life history" of the water. The low oxygen content of the waters brought

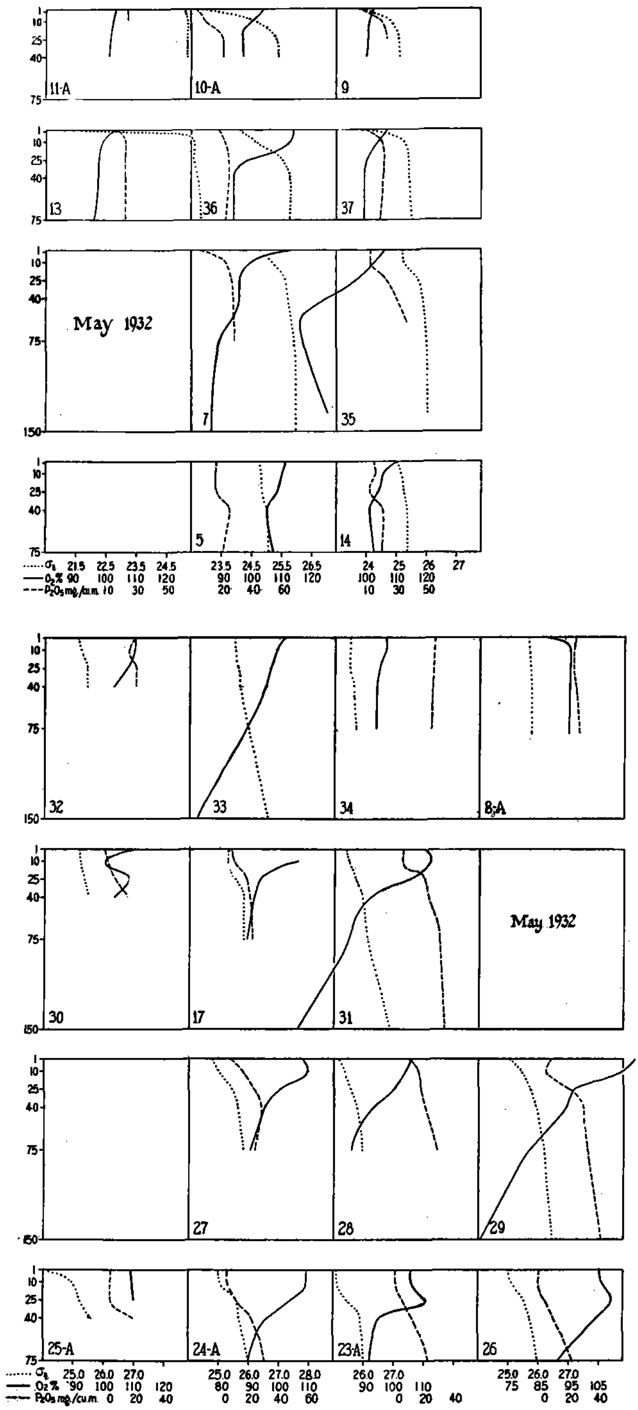


FIGURE 17. Vertical distribution of σt, oxygen percentage and phosphate in May. Cruise 27. (See figure 15).

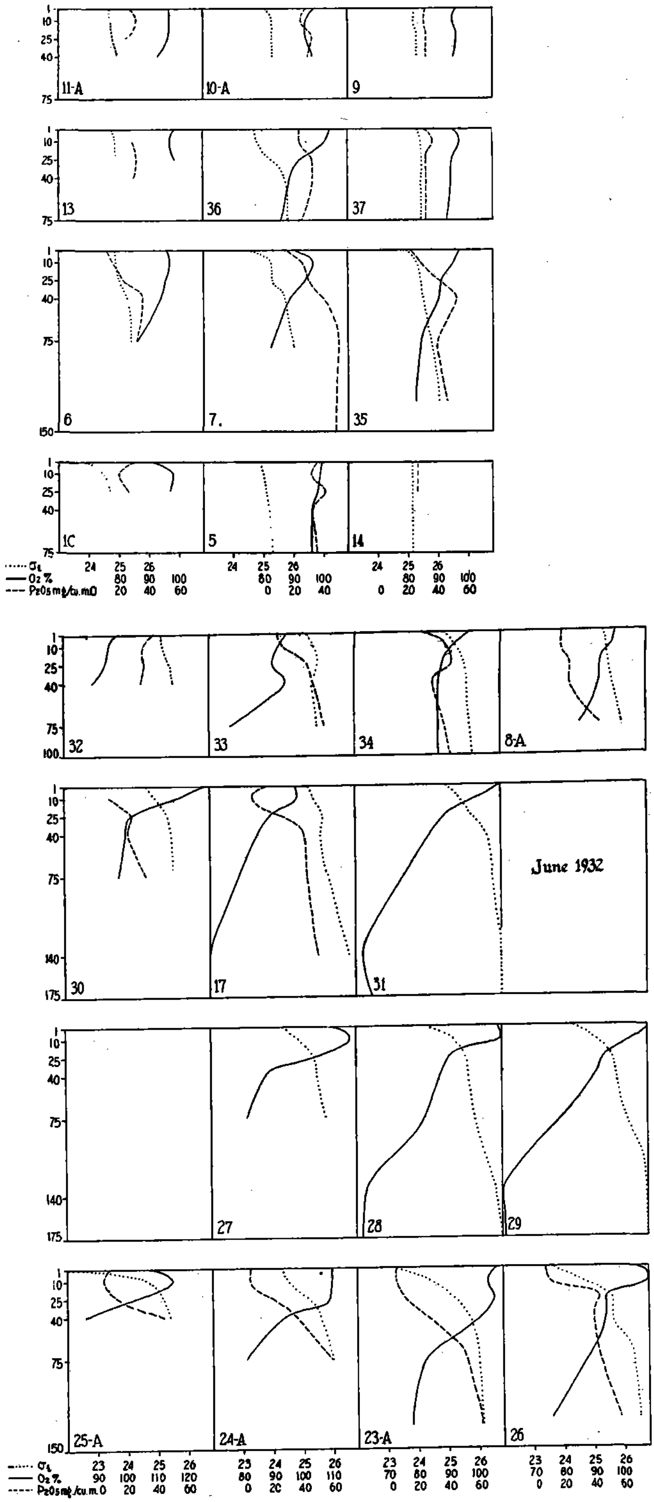


FIGURE 18. Vertical distribution of σt, oxygen percentage and phosphate in June. Cruise 28. (See figure 15).

to the surface in the Antarctic (Ruud 1930) and at the west coast of North America (Johnson and Thompson 1929, Thompson and Johnson 1930) indicates that these waters have been brought up from depths where photosynthesis and consequently consumption by phytoplankton have not taken place and where therefore sinking of dead organisms from above has resulted in a steady increase in phosphorus compounds. Even where the oxygen content does not give such clear evidence, waters of the same salinity may in different regions have a different phosphate cycle on account of specific hydrographic and biological conditions.

Within a restricted area differences in salinity usually characterize the distinguishable water masses and in such cases a comparison between the phosphate content and the salinity of the waters may reveal interesting features in the hydrobiological conditions (e.g.: influence from melting ice (Ruud 1930), dilution with fresh water (Thompson and Johnson 1930), difference between "Atlantic water" and coastal water (Sund 1929, Braarud and Klem 1931)).

In the gulf of Maine the highest phosphate values are to be found in the deep layers, which according to Bigelow (1927) are formed by slope water entering the gulf as a bottom drift. This is the main source of water with high salinity and the rest of the water masses in the gulf may be considered as being formed by dilution of this water with fresh water. (In the spring the Nova Scotia current contributes a large quantity of water of low salinity to the surface layers of the gulf. This is, however, of similar character to the water already present, viz. a mixture of slope water with fresh water). River water contains, according to the obtainable analyses, only small quantities of phosphates (see compilation of data by Braarud and Klem 1931). As a result of the gradual dilution of deep water with fresh water, the phosphate concentration therefore decreases with decreasing salinity, notwithstanding decrease caused by consumption in the surface layers. In agreement herewith, we find in the gulf and the bay of Fundy a close relationship between the vertical distribution of temperature and salinity and the vertical distribution of phosphates. This fact is illustrated in figures 17 to 20 by the similar form of the curves for σ_t and P_2O_5. The consumption of phosphate in the surface layers makes the P_2O_5 curves for the stratified stations still more pronounced than if the dilution alone had affected the phosphate distribution.

As to the horizontal distribution of phosphates the most striking feature is the relatively high values for the surface layers in the bay of Fundy as compared with the gulf of Maine in summer. As this is caused mostly by special biological conditions, we shall postpone the discussion of this phenomenon (see page 421). For the same reason it is also natural to treat the phosphate cycle in the two areas in connection with the discussion of the fluctuations in the phytoplankton.

The minimum values for phosphate in the bay of Fundy are high compared with those of the gulf of Maine and the coastal waters of northern Europe, but low as compared with coastal waters off western America and Antarctic waters (Moberg 1928, Johnson and Thompson 1929, Ruud 1930).

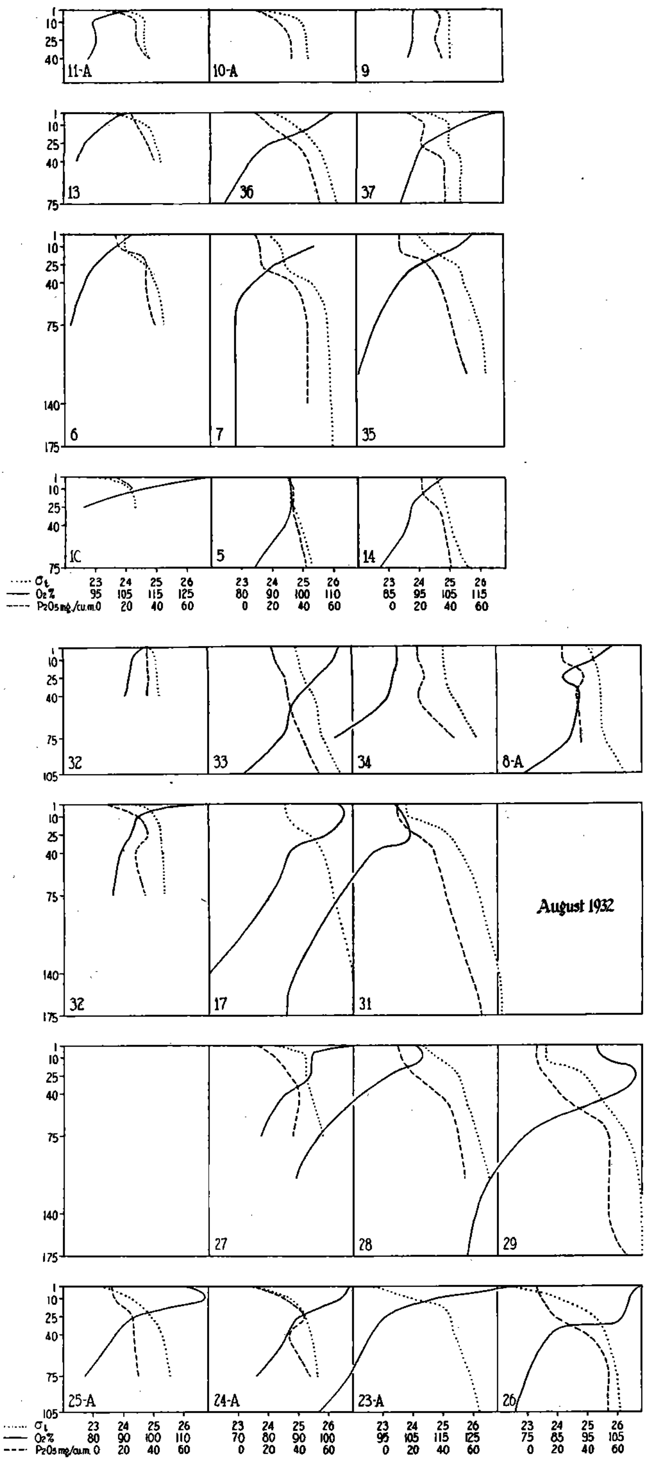


FIGURE 19. Vertical distribution of σt, oxygen percentage and phosphate in August. Cruise 30. (See figure 15).

NITRATES

The strychnine method was used for determination of nitrates (Harvey 1926). The reagent was stored for three months before use and was practically colourless. At sea the samples were collected and stored in the same bottles which were used for analyses and three drops of a saturated sublimate solution were added immediately after the filling from the water bottle. After the reagent had been added, the samples were stored for 24 hours and then compared with a standard series of colour solution. This comparison was always carried out with artificial light. The standard series was calibrated by comparison with a series of bottles with nitrate-free sea water, to which had been added nitrate solution in different quantities. These samples were kept under the

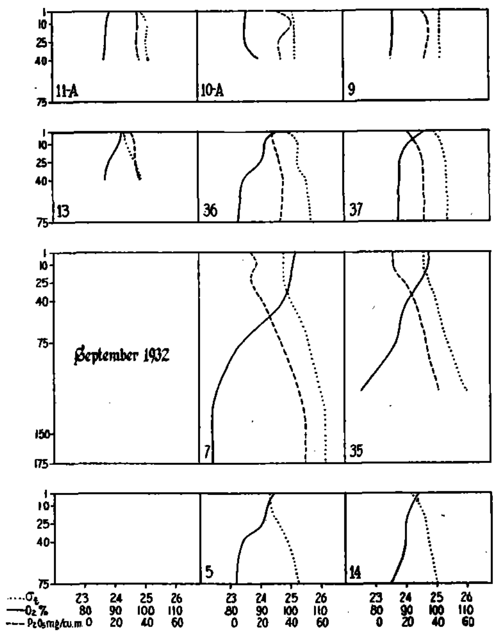


FIGURE 20. Vertical distribution of σt, oxygen percentage and phosphate in September. Cruise 32. (See figure 15).

same conditions as the samples which were to be analysed. The nitrate-free sea water was obtained by storage of a sea water sample. When nitrate reduction had gone to a point where the sample did not give any colour with the reagent, sublimate solution was added (see Braarud and Klem 1931). Various experiments which it seemed desirable to have made in order to ascertain the accuracy of the analyses, could not be carried out on account of lack of time between the cruises. The results ought, therefore, to be regarded as less accurate than would have been the case provided more time had been available for this work. The values above 200 mg./cu.m. are not reliable and we have therefore only included them in the tables to show the increase towards the bottom. The values obtained seem to agree well with those found by Rakestraw (1932) for the Mount Desert region, but seem to be a little lower than those Rakestraw has published for the stations in the gulf from August 1932 (Rakestraw 1933). The general distribution of the nitrates is so similar to that found for the phosphates that it appears unnecessary to describe it in detail.

The values found for the gulf of Maine and the bay of Fundy area (see plankton tables) are higher than those found in coastal waters off northern Europe (Harvey 1926, Braarud and Klem 1931, Kreps and Verjbinskaya 1930, 1932), but smaller than those found by Moberg (1928) on the coast of California and by Ruud (1930) in the Antarctic. The proportion NO_3-N/P_2O_5, viz. between 2 and 3, is similar to that found in Norwegian coastal waters.

Oxygen

The amount of dissolved oxygen was determined according to Winkler's method. Calibrated bottles of 150 to 200 cc. capacity, with faultless fitting ground glass stoppers, were used. The bottles filled with sea water and added reagents were kept in covered cylinders with water and stored in darkness. In calculating the oxygen volumes, no corrections were made for the reagents introduced. The results are given in the tables as cc. oxygen per litre and as "percentage of saturation", viz. the percentage which the observed volume is of the volume dissolved in sea water (of the same temperature and salinity as the sample at 760 mm. pressure shaken with air). The saturation volumina were taken from Fox's tables (Fox 1907). (The terms "supersaturation, saturation and subsaturation of oxygen" have been used in the discussion, meaning oxygen percentages of > 100, 100, < 100, as conventionally used in phytoplankton literature.) In figures 17 to 20 is shown the vertical distribution of the oxygen percentage in the gulf of Maine and the bay of Fundy during May, June, August and September.

Previous to the year 1932 no data had been obtained on the oxygen content of the waters of the gulf of Maine. Besides our records from the western part of the gulf during the period May to August 1932, Rakestraw (1933) made some observations during August, 1932, in the central and eastern part of the gulf. The available data are thus confined to the months May to August, and the picture we can give of the aeration of the various water layers therefore will have to be incomplete. This is especially regrettable as the hydrographic conditions of the gulf are favourable for the study of the oxygen cycle of the waters.

The oxygen dissolved in sea water is supplied from two sources, from the atmosphere by absorption at the surface, and from plants splitting carbonic acid and giving off oxygen by the biochemical process of photosynthesis. The photosynthetical process is restricted to a rather thin surface layer (0 to 25 or 40 m. in this region). The aeration of the waters below this stratum must therefore take place either by raising the water mass to the surface layer or by mixing with the upper layers (or those which recently have been surface layers). When considering the gulf of Maine, we shall treat separately the three main layers found there during the time for which we have observations, i.e., the surface layer (0 to 25 m.), the intermediate layer (25 to 75 m.) and the bottom layer (below 75 m.). (The limitation of the layers is to some extent determined by the depths at which our observations were taken, viz. at 1, 10, 25, 40, 75, 140 or 150 and 175 metres).

The chilling during the winter reduces the differences in density of the water layers so much that wind and tide by their mixing effect make the upper 100 m. layer practically homogeneous (Bigelow 1927). This probably results

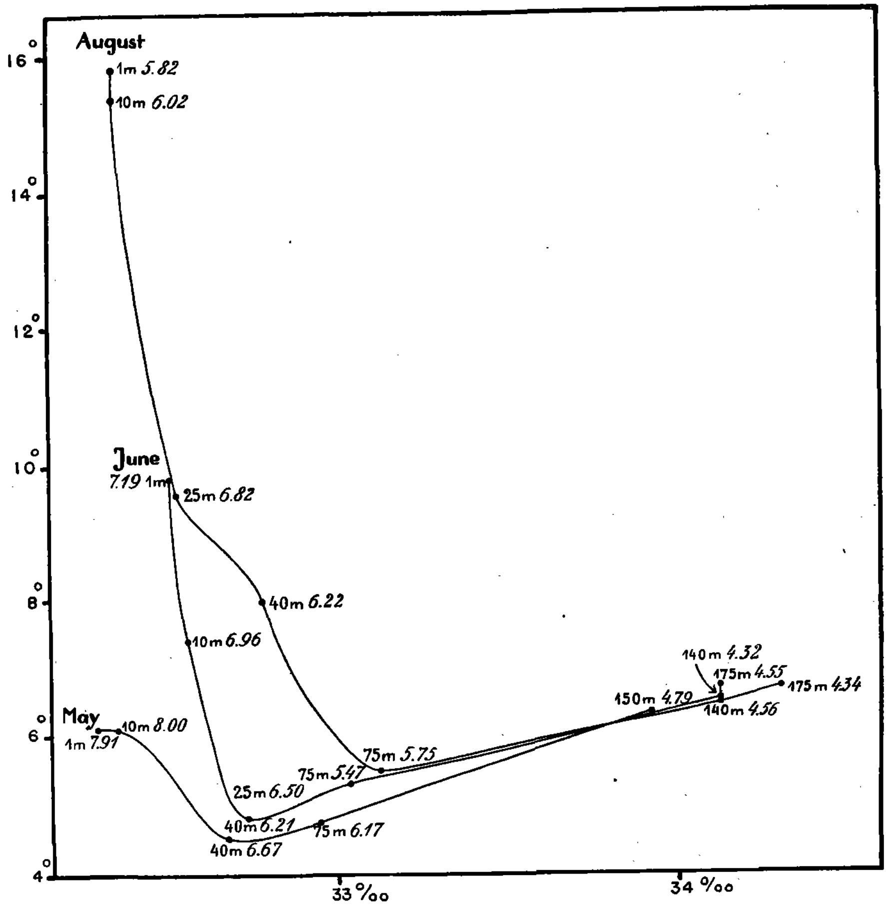


FIGURE 21. TS-diagram for station 31 in May, June and August. Depth in metres and oxygen volumes in cc. per litre.

in aeration of this water mass to such an extent that the oxygen content approaches the saturation point (95 to 100%).

When stratification is established by freshening and heating during March, the **surface layer** is the only part of the water column which partly has contact with the air. During March the oxygen content in this layer probably decreases, with the result that the percentage of saturation falls below 100%, but in April the oxygen production by plankton algae soon results in supersaturation. In May supersaturation was found at 1 m. at all stations in the gulf of Maine proper, varying from slight supersaturation up to 117%. The limit between supersaturated and subsaturated water varied from station to station, but was found mostly around a depth of 25 m. At station 34, there was still subsaturated water at the surface. Our observations from June 1 show a very similar situation, all stations in the three southern sections being supersaturated, except station 17, with 98.4% at 1 m. Stations 32, 33, and 34, southwest of Grand Manan, had subsaturated surface layers, showing, as we shall see, similar conditions to those found at that time in the bay of Fundy proper. In August the surface layers were still rich in oxygen, the maximum at some stations being found at the 10 or 25 m. level. At station 23A the percentage of saturation was at 1 m., 132%. As the conditions in the surface layer mainly depend on the plankton production, we shall later make a comparison between the phytoplankton distribution and the oxygen conditions at the different stations (see page 394).

While the surface layer undergoes a great change both in temperature and salinity during spring and summer, the water masses found below it are less subject to such changes. A comparison between the TS-diagrams for station 31 in May, June and August (figure 21) illustrates the changes which took place between May and June. The curves for May and June indicate the three different water masses: surface layer, intermediate layer and bottom layer, with different mixing products between them (Jacobsen 1930, Defant and Wüst 1930).

The **intermediate** layer is represented by the 40 m. sample. Judging from the small change from May to June it must be rather stagnant at this time of the year. In August the intermediate layer cannot be identified, the TS-curve then having a more curved form than in the previous months, which according to Defant (1930) should be expected if the mixture with the two adjacent waters had been going on for some time. The origin of this intermediate layer would probably be water of salinity about 32.40‰ and temperature between 1 and 2°C., such as according to Bigelow (1927) in the spring of 1920, in this part of the gulf was found as a rather homogeneous layer from the surface to the 40 m. level.

From May 27 to June 28 the oxygen content at 40 m. (station 31) was reduced from 6.67 cc. to 6.21 cc., that is by 0.46 cc. per litre. If this is taken as an average for the consumption at this temperature and the general assumption is made that the respiration is twice as intensive at 10°C. as at 0°, the following calculation of the original oxygen content of the water may be made:

Content on May 27	6.67 cc/l	
Consumption in May	.43 cc/l	(at 4°C.)
Consumption in April	.38 cc/l	(at 3°C.)
Consumption in March	.34 cc/l	(at 2°C.)
Content on March 1	7.82 cc/l	

The saturation volume for water of the above mentioned character (salinity

$32.40^0/_{00}$, temperature 2°C.) is 7.81 cc/l. The agreement between this and the value found by calculation should indicate that, provided the layer had been saturated with oxygen in the beginning of March, the consumption had not been

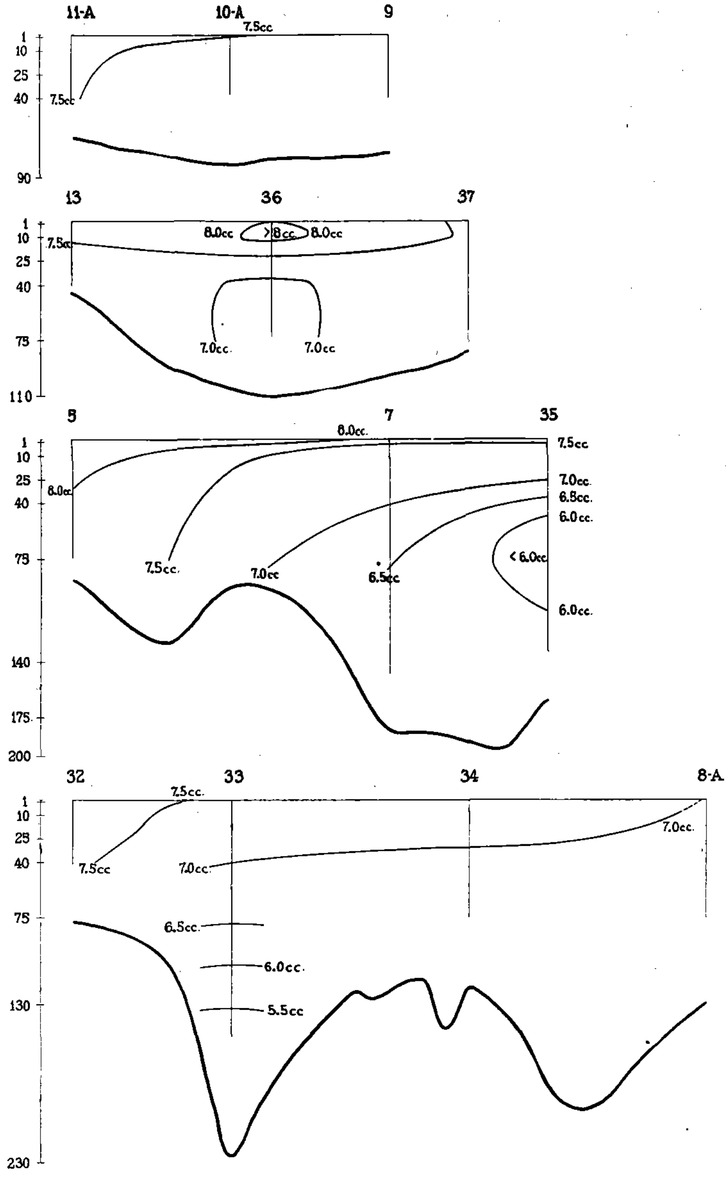


FIGURE 22. Bay of Fundy. Oxygen (cc./l.) distribution in May. Cruise 27 (See figure 15)

very different from what has been assumed according to the consumption between the May and the June cruise.

In August the admixture of surface water, shown by the TS-diagram, had resulted in an increase in the oxygen content for 75 m., and at 40 m. the same value was found as for the previous month.

The intermediate layer is not so well defined at the other stations as at

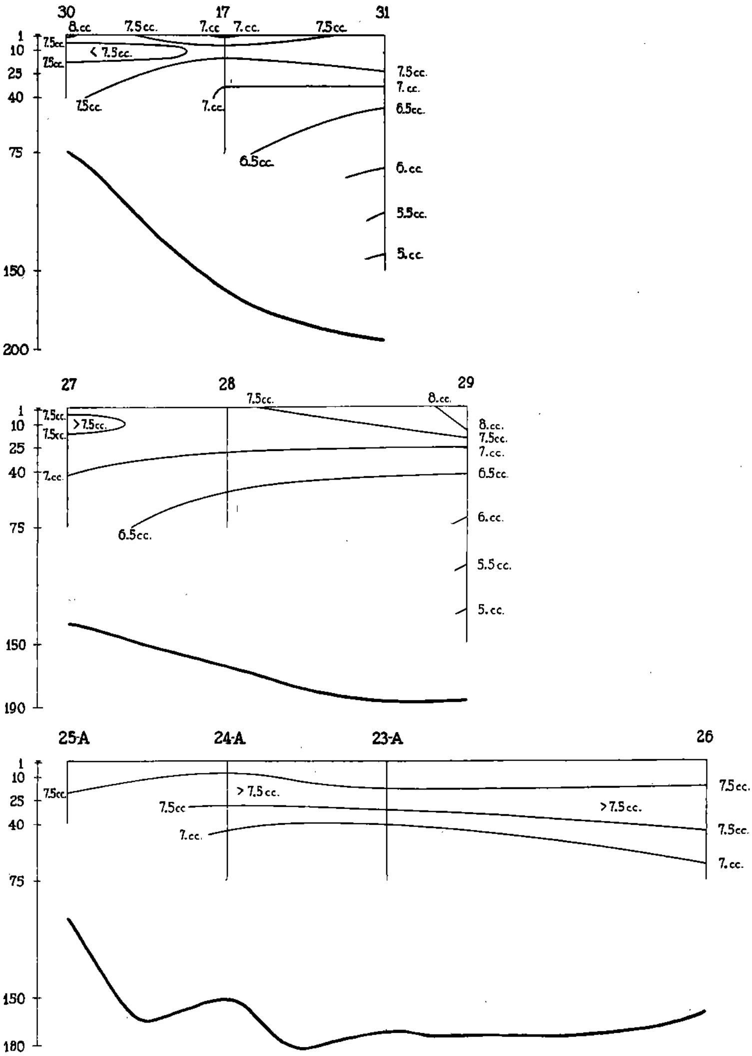


FIGURE 23. Gulf of Maine. Oxygen (cc./l.) distribution in May. Cruise 27.

station 31. It consists of mixing products between the intermediate layer from the central part of the gulf (similar to the one found at station 31) and the surface layers. (See sections in figures 3 to 14).

The **bottom water** found in the eastern trough, where we have observations, is, according to Bigelow (1927), slope water formed by the mixing of warm ocean water with Arctic coastal water. Its actual origin is little known and as to its oxygen content, nothing has as yet been published. Observations are, however, being made by the Woods Hole Oceanographic Institution, where a study of this water type is planned. Judging from the hydrographical data this water layer does not receive any considerable amounts of oxygen from the

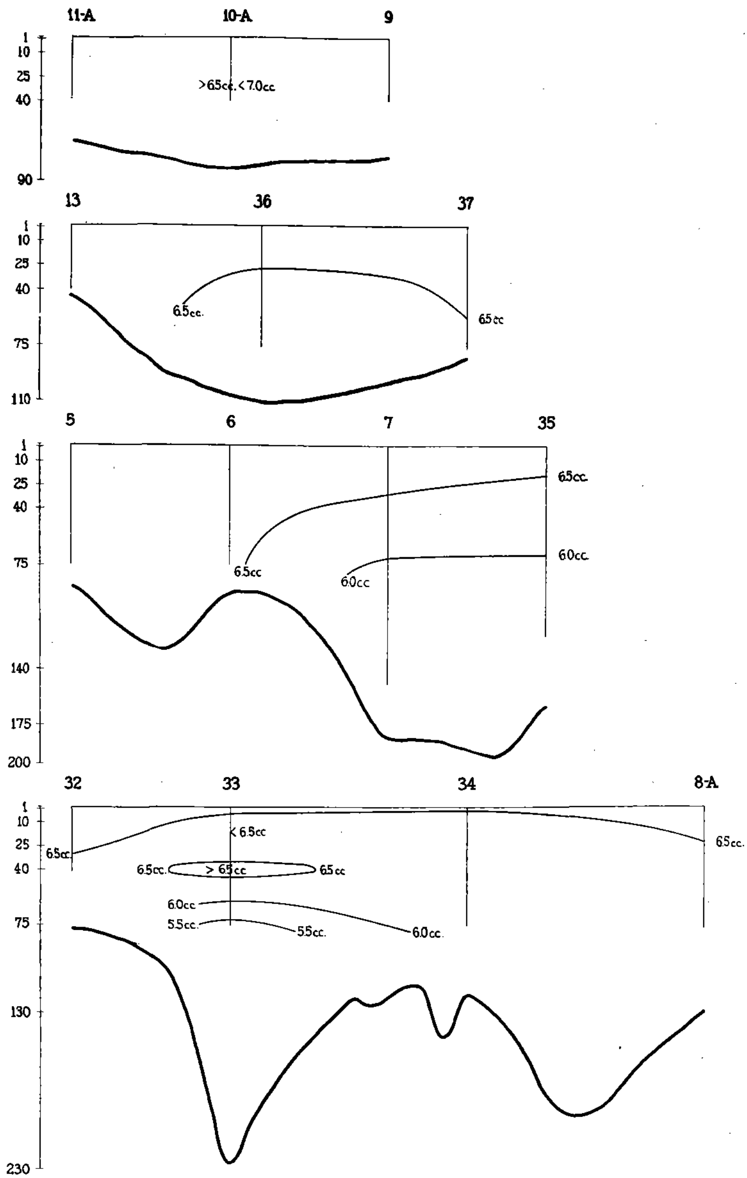


FIGURE 24. Bay of Fundy. Oxygen (cc./l.) distribution in June. Cruise 28. (See figure 15).

above lying waters. In May and June the oxygen volumes of the bottom water were always lower than in the intermediate layer. The bottom water must therefore either originally have had a lower oxygen content or the consumption must have been greater, or perhaps both these factors are responsible for the low values found.

The increase in salinity of the bottom water in the eastern trough (station

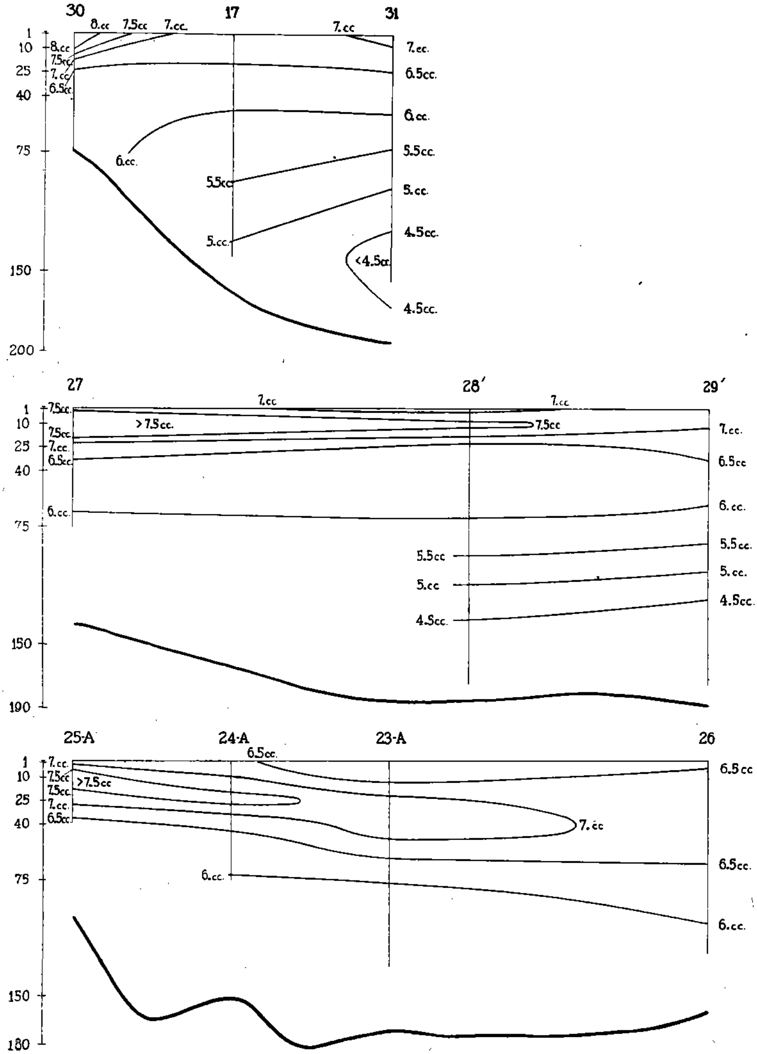


FIGURE 25. Gulf of Maine. Oxygen (cc./l.) distribution in June. Cruise 28. (See figures 15 and 38).

31) from May to August, indicates an inflow in the bottom layers in agreement with what previously has been found (Bigelow 1927). The steady decrease in oxygen which takes place during the same period, shows that the inflowing water is at least as poor in oxygen as the water which it replaces. This feature is characteristic for the gulf of Maine and is in striking contrast to such conditions as, for instance, are to be observed on the Norwegian coast. There heavy water

from the coastal bank at some times of the year is able to pass the shallow barrier in the channels and replace the bottom layers of the deep fjord basin inside.

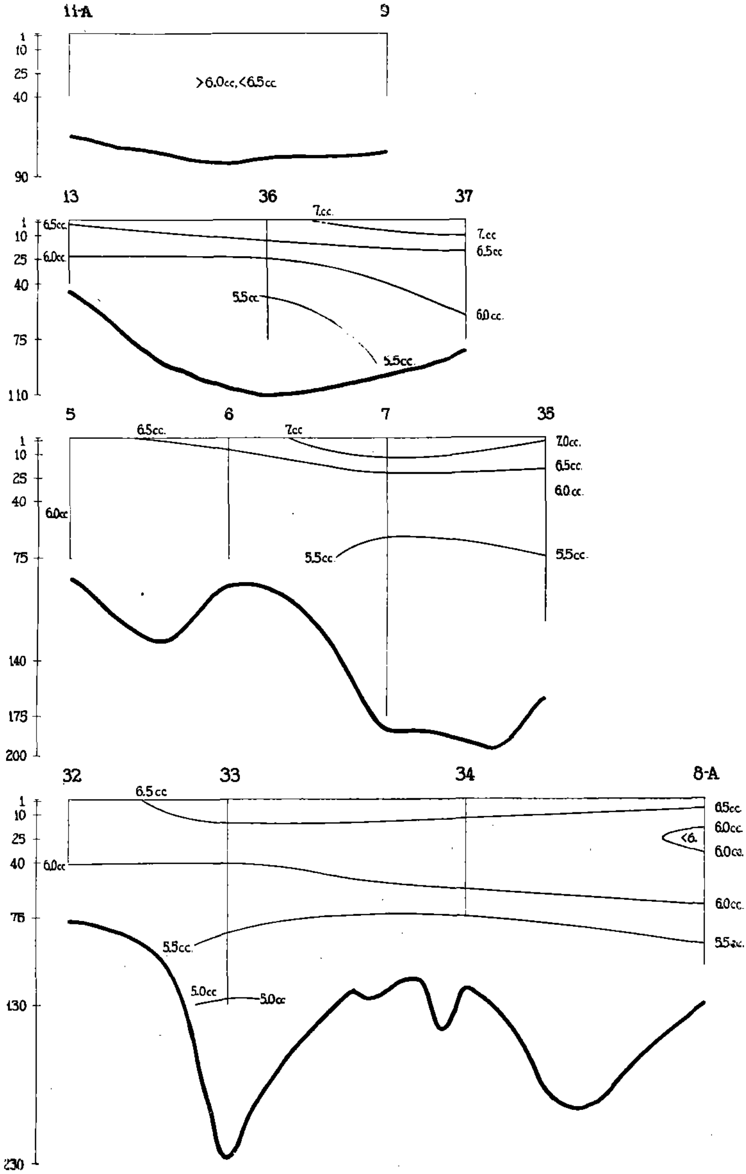


FIGURE 26. Bay of Fundy. Oxygen (cc./l.) distribution in August. Cruise 30. (See figures 15 and 39).

The inflowing water is there always richer in oxygen than the stagnant deep water in the fjord and is thus easily identified. (Gaarder 1915, Braarud and Klem 1931).

In regard to the consumption in the bottom layers our material is too scanty to give any reliable quantitative information. The slow decrease in

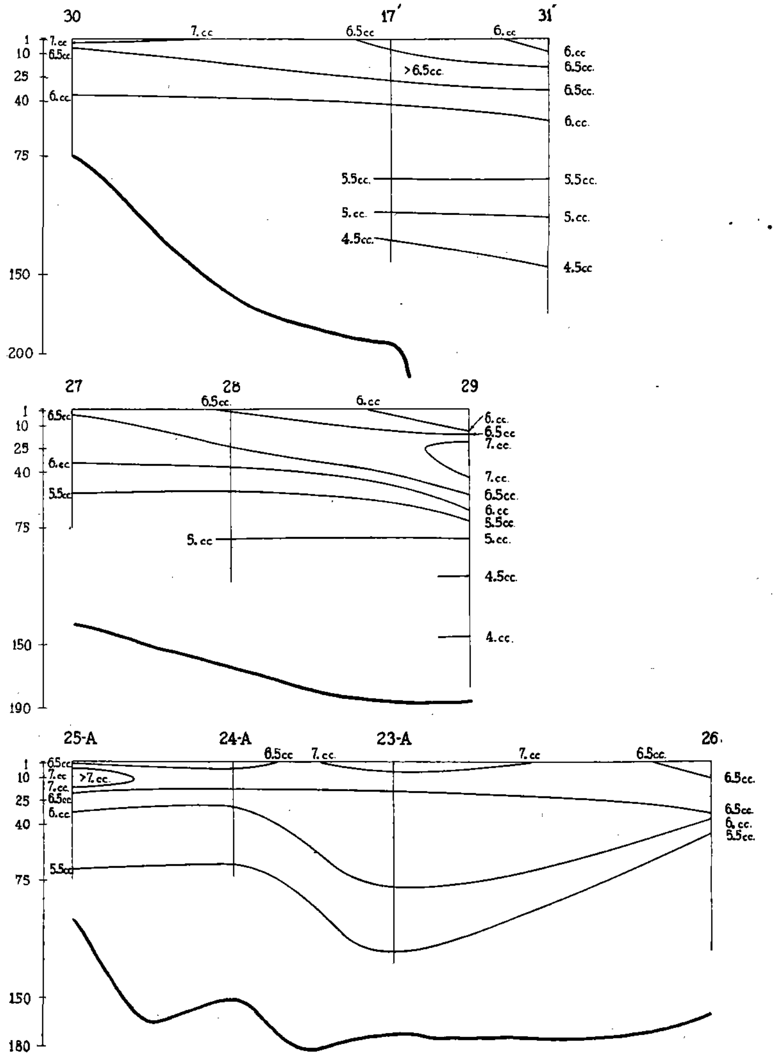


FIGURE 27. Gulf of Maine. Oxygen (cc./l.) distribution in August. Cruise **30.**

oxygen during the summer in the layers which seem to be most undiluted slope water, indicates that the consumption is smaller in this layer than in the intermediate layer.

The distribution of oxygen in the western part of the gulf of Maine is illustrated by the sections in figures 22 to 27.

In the **bay of Fundy** the surface layers were rich in oxygen in May, but the content dropped conspicuously during June. In August the surface layers had again gained in oxygen content and we found at most of the stations volumes exceeding the value of saturation. In the middle of September all over the bay the oxygen content had fallen considerably below that of saturation. In Passamaquoddy bay the supersaturation in August reached 136%, but in September the percentage was only 92. Here at 25 m. the percentage of saturation stayed below 100 throughout the summer, decreasing gradually from 97.5 to 87.4% during the period from June to September. In the deeper parts of the bay of Fundy, the percentage of saturation decreased from May to September, at which time it was found to be between 70 and 80. The increase

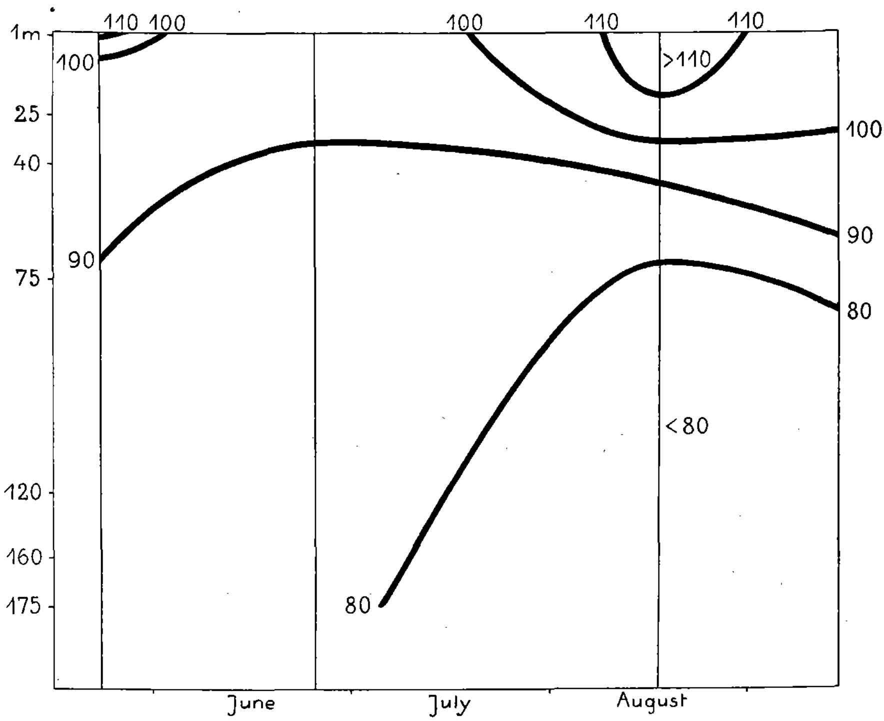


FIGURE 28. Changes in oxygen percentage from May 22 to September at station 7.

in salinity indicates admixture of a larger amount of deep water from the gulf of Maine than earlier in the summer. The inflowing water, which was poor in oxygen, may partly account for the decrease recorded at this time. In figure 28 the changes in the percentage of saturation for station 7 are illustrated. It gives at the same time a picture of the changes in the surface layers as well as in the deep layers, this station being the deepest one in the bay of Fundy. Figure 28 shows the June minimum in the surface layers and the decreasing oxygen content of the deeper layers during the summer. On account of the small differences in oxygen content, this property of the water is not of any great value as an indicator of the different water masses within the bay of Fundy.

LIGHT CONDITIONS

The striking differences in the hydrography of the two areas, which have been briefly mentioned above, are accompanied by considerable differences in the meteorological conditions. Since the light supply, in so far as the radiation at the sea surface is concerned, is affected by the amounts of clouds, fog and humidity in the atmosphere, the meteorological conditions have to be taken

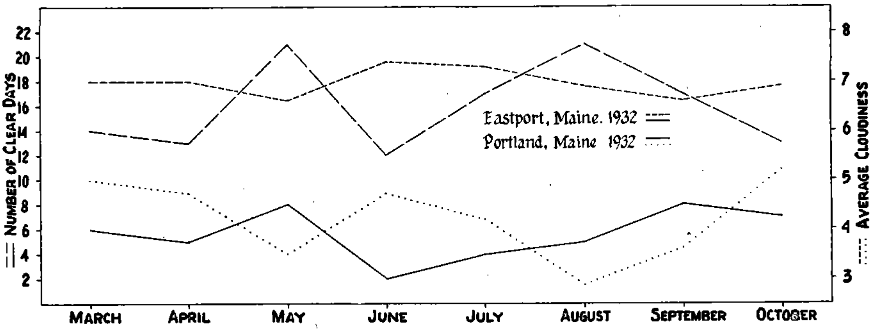


FIGURE 29. Number of clear days and average cloudiness per month at Eastport and Portland, Maine.

into account in a consideration of the life conditions of the phytoplankton. We shall in the following present the data which we have been able to obtain on the intensity of solar radiation in the two areas. Thereafter the turbidity conditions will also be considered, because they determine the fraction of the radiation at the surface which reaches sub-surface localities.

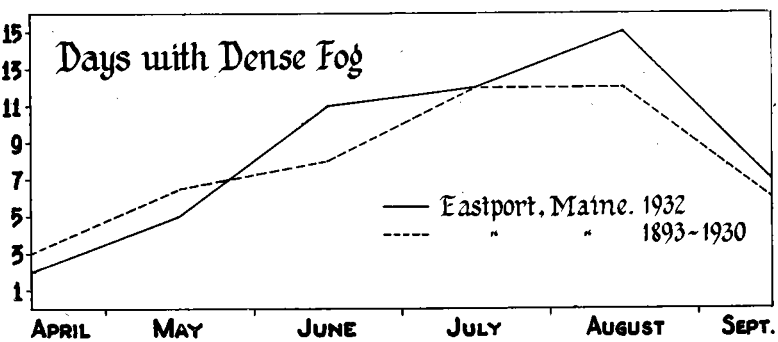


FIGURE 30. Days with dense fog at Eastport, Maine, 1893-1930 and 1932.

THE SOLAR RADIATION

For a comparison of the conditions in the two areas we are using meteorological observations from two stations, viz., Eastport, Me. and Portland, Me. (near Casco bay, see figure 1). The former represents the bay of Fundy, the latter the south-western part of the gulf. Meteorological observations for the Fundy region are also available from the Canadian station at Saint John, but we have chosen to use the data from Eastport in order that we may compare observations from two stations within the United States, assuming that they then are more comparable. Eastport appears to be a good representative for the bay of Fundy region, judging from our experiences gained on the cruises during the summer of 1932 and from the fog data for Head harbour light-house, compared with data for the other light-houses in the bay.

In figure 29 are given curves showing the numbers of clear days per month in 1932 for the two stations and for the average cloudiness per month in tenths. At Eastport, Me., the number of clear days varies from a minimum of 2 in June to a maximum of 8 in May and September. For Portland, Me., the range is from 12 days in June to 21 in May and September. Such great differences in the number of clear days per month indicate very different weather conditions in the bay of Fundy and the Gulf of Maine.

The variations from month to month at the two localities go parallel in spring and early summer and in this manner: May is a clear month in both

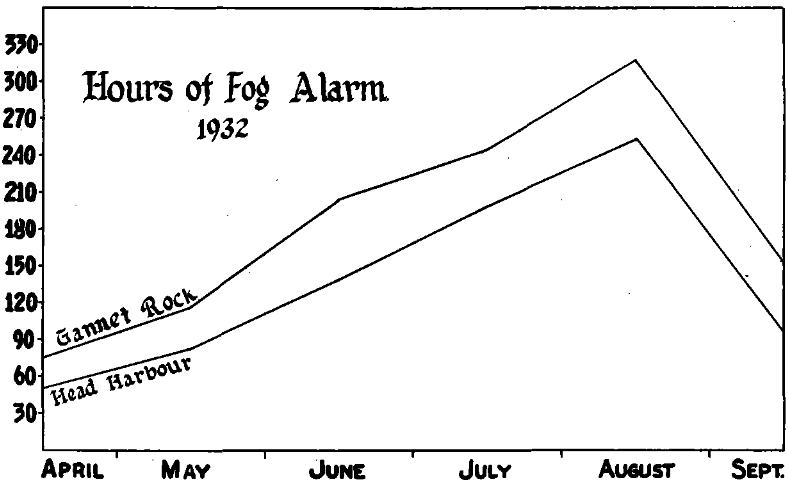


FIGURE 31. Hours of fog alarm per month at two lighthouses in the bay of Fundy.

places and is followed by a very cloudy June, showing the lowest figure for the whole year. Later in the summer the agreement is not so good. This is probably due to the large amount of fog in the Fundy region at this time of the year. The records for fog, giving the number of hours of fog alarm at different light-houses in the Fundy region, show an abundance of fog during the months of June, July and August. In 1932 the maximum amount of fog occurred in August, but there were also considerable amounts both in June and July (see figure 30). The form of the curve for hours of fog alarm is very much the same for the different light-houses. As examples are shown the curves for Gannet Rock and Head Harbour light-houses (figure 31). The actual number of hours varies a little, however, from one place to another.

While the meteorological observations give a good expression of the main differences in the light conditions in the two areas, they do not furnish any direct information on the quantitative side of the problem. However, we are fortunately able to publish the results of a calculation of the total solar radiation per month during 1932 for both localities (table II). These calculations were made by Dr. W. Reginald Sawyer and a full account of the calculations is to be found in his paper (Sawyer unpub.). The material for these calculations consists partly of Dr. Klugh's and Dr. Sawyer's light measurements at St. Andrews, N.B. during the last and previous summers, and partly of results of the investigations by Dr. H. Kimball, of the U. S. Weather Bureau. In addition to these observations on the light intensity, data from the meteorological station at Eastport, Me., and Portland, Me., giving the number of hours of sunshine per month during 1932, have been used. In table II is given "the total solar radiation received per cm^2/month on a *horizontal* surface from the sun and sky" according to Sawyer (unpub.). The unit is g.cal./month.

TABLE II. Total solar radiation received g. cal per cm^2/month (Sawyer unpub.) on a horizontal surface from sun and sky.

1932	EASTPORT	PORTLAND
January	2189	2817
February	3951	4933
March	5818	7888
April	7219	9484
May	10335	13107
June	9452	12862
July	9290	13087
August	8854	12373
September	6476	8996
October	3784	5248
November	2211	3703
December	1781	3206
	71360	97704

From U. S. Weather Bureau data and measurements taken at St. Andrews, N.B.

These figures reveal two important features in the light conditions, viz. (1) the seasonal changes at both localities, and (2) the regional differences between the two areas.

(1). In January and December the total radiation both at Eastport and Portland is only between one fourth and one fifth of the radiation in the months of May, June, and July at the same localities. It increases gradually during spring, and in May, in both localities, it reaches its maximum, with an amount twice as high as in March. June, July and August also have high values, but from September they decline quickly.

(2). The total radiation for the whole year of 1932 is for Eastport 27% lower than at Portland, and a similar difference is found for every month. The amount for Portland in April is thus as large as that for Eastport in June or July. The differences which thus exist in the light conditions in the two areas are mainly due to atmospheric conditions, as the difference in latitude is too small to account for a great part of the differences recorded (Sawyer unpub.). The abundance of fog in the bay of Fundy reduces the radiation in June, July and August to such an extent that there is an even decline in the monthly radiation from the maximum in May. At Portland the maximum is also to be found in May and is followed by a lower radiation in June. July, however, has almost as high a value as June and the decline in August is rather small.

The Turbidity

The microscopical examination of the centrifuged phytoplankton samples revealed that a great number of the samples from the bay of Fundy contained unusually high amounts of detritus. The amount was so considerable that it seemed obvious that the detritus essentially must lower the light supply of subsurface localities. On the basis of the examination of the quantitative phytoplankton samples it was not possible to get more than a rough estimate of the relative detritus distribution. As, however, no samples had been collected for the study of this problem, we had only what was left of the phytoplankton samples as material when we made an attempt to gain a little further information on the turbidity question. These samples had been collected in thoroughly cleaned bottles, and 5 cc. of a filtered 10% neutralized formaldehyde solution had been added to a 200 cc. sample. It may therefore be assumed that no great changes had taken place in the particle content of the samples.

The method which was chosen to obtain an illustration of the content of detritus in a sample, was as follows: 50 cc. of the thoroughly shaken sample was centrifuged in the same way as were the samples for the quantitative phytoplankton study. The sediment was transferred by means of a pipette to a cylindrical cell on a slide, covered with a cover glass and photographed. The same amount of water was transferred each time in order to make the photographs comparable. As it was impossible to get the particles evenly distributed in the cell the whole sediment sample had to be photographed in order to obtain representative pictures. This necessitated the use of such a low magnification that the diatoms and other phytoplankton organisms are invisible in the prints. For a comparison of the detritus and the phytoplankton contents of the samples, we shall, therefore, refer to the plankton tables. Only a limited number of photomicrographs could be taken, and the number of samples among which these could be selected was also restricted because in a great many cases the volume of water which remained after the phytoplankton examination was smaller than 50 cc. The material which we have for an estimate of the amount of detritus in the different waters and at different times is therefore not very satisfactory. It confirms, however, in every respect the impression which the examination of the phytoplankton samples had given.

In figure 32 are found reproductions of some of the photomicrographs which were taken. (The microphotographs were made by Mr. M. Schneckenburger, Buffalo Museum of Science). The prints were made a little darker than ordinarily used, in order that as many as possible of the small particles should show up. The samples are all from a depth of 1 m. (except those of the S-series, which are from 10 m.), for the 1 m. sample would seem to be more representative of the upper water layer than the 10 m. sample, when turbidity and light conditions are in question.

Station 12, located outside the Saint John river outflow, and 1C in Passamaquoddy bay, into which the St. Croix river, the Magaguadavic and the Digdeguash rivers empty, show the highest detritus content recorded, giving evidence of the well known fact that rivers carry large amounts of silt which is slowly deposited after the admixture of fresh water to the sea water. The first sample from station 12 was taken on April 19 when the spring freshets were at their maximum. (The monthly discharge of the Saint John river in 1932 reached its maximum in April, and the daily discharge on April 14). This sample shows most detritus of all examined, while the May and June samples from the same station had a little less. The sample from Passamaquoddy bay (1C) on April 25 had a medium turbidity, while the June and September samples were very turbid. Stations 11A and 13 also show many particles, being influenced by the Saint John river outflow. Similarily the samples from station 5 outside the Quoddy passages, which receives water from Passamaquoddy bay, had a very high detritus content in April and considerable amounts during the summer.

From the Swallow Tail section on April 25 (stations S_1,S_2,S_3,S_4, see figure 35) we have samples from the 10 m. level. There is a clear distinction between the S_4-sample which was poor in particles and the other three which were rich. This is closely in agreement with the hydrographic data and the phytoplankton records for the same samples, as these also show that the S_4-sample differs from the samples at the other three stations. S_1,S_2,S_3 have surface layers (0 to 10 m.) which show admixture of much fresh water (according to Watson, unpub., in this case mainly Saint John water), while the surface layer at S_4 has a smaller range in salinity. Since the Saint John water according to what we have seen carried a large amount of detritus, the relative detritus content of the four samples is thus easily explained by the salinity distribution at these stations. The samples from this section show that the detritus which is brought out with the Saint John river water in spring is very noticeable at the 10 m. level so far out in the bay of Fundy as off Grand Manan.

The material from the rest of the bay of Fundy and the gulf of Maine is rather scanty. It shows, however, that even the clearest samples from the central and outer parts of the bay of Fundy (station 36) contained at least as much detritus as the samples from station 30, the station in the gulf which is located closest to shore. They all contained more than the sample from station 26 in the central area of the south-western part of the gulf, taken in May at a time when the waters there ought to have more particles in suspension than at any other time during the spring and summer season.

The rather few microphotographs which we were able to obtain thus seem to show the following features in the occurrence of detritus within the region: (a) very high amounts were found at the mouths of rivers or in water originating from such localities; (b) the detritus content was high in the surface waters of the bay of Fundy as compared with those of the gulf of Maine; (c) within the bay of Fundy the central part seemed to have least detritus.

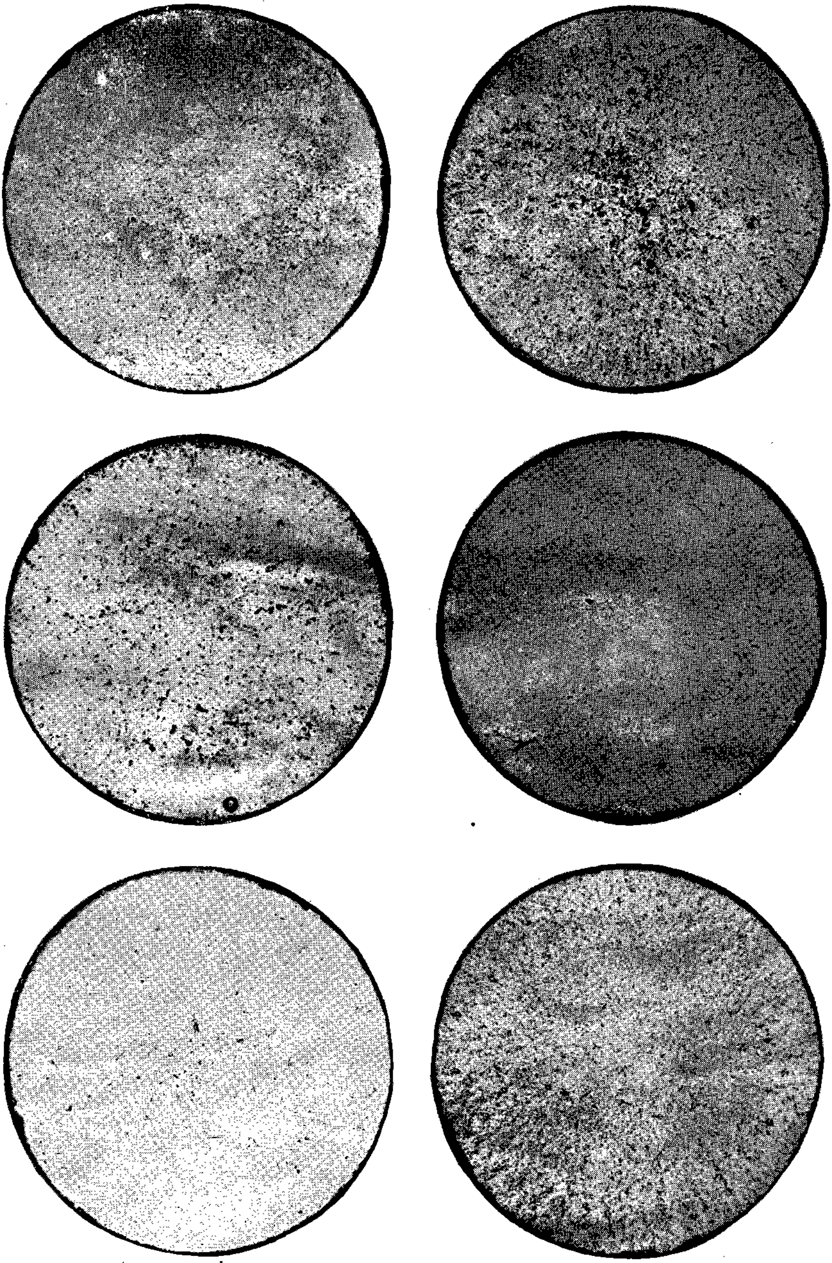


FIGURE 32A. Photomicrographs of centrifuged water samples. a,—S_1, 10 m.; b—S_2, 10 m.; c—S_4, 10 m.; d—26.12, 1 m.; e—26.05, 1 m.; f,—28.01C, 1 m.

g j

h k

i l

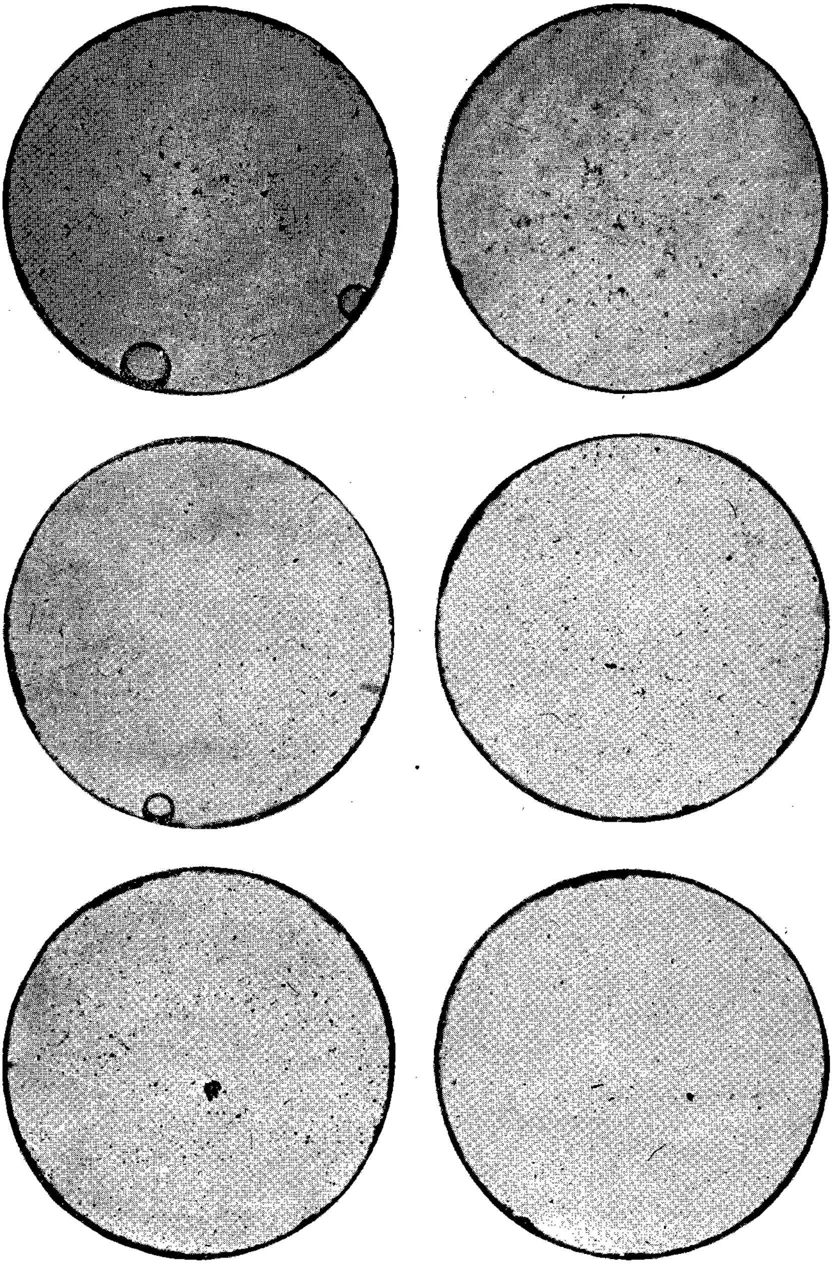


FIGURE 32B. Centrifuged water samples. g—27.08A, 1 m.; h—27.07, 1 m.; i—27.36, 1 m; j—27.30, 1 m.; k—26.30, 1 m.; l—27.26, 1 m.

The main cause for the difference in this regard between the two areas is without doubt the relatively high fresh water discharge into the bay of Fundy. However, the extensive mixing of the surface waters in the Fundy region may also sometimes be the direct cause of high turbidity. The samples from station 27.08A (see figure 32) and N 182, from an area where according to the hydrographic data there is violent mixing, show a rather high detritus content. In this locality there is little fresh water discharge and the high turbidity of these samples should thus indicate that the mixing brings particles up from the bottom. The sample from 27.11A which represents thoroughly mixed water from the inner part of the Bay, is also rather rich in detritus. Bigelow (1927) mentions that surface waters at Georges bank sometimes contain large quantities of sand in suspension, another evidence in the same direction. However, we have not sufficient material for a detailed discussion of the relation between turbidity and hydrographic conditions, a problem which ought to be attacked by a combined study of hydrography, turbidity and light conditions by means of actual light measurements.

Mr. Graham, in connection with his herring investigations, made some observations on the turbidity in these waters by means of Secchi disc readings (Graham unpub.). He found that

"in July the most turbid water (between Portland, Me. and Liverpool, N.S.) was in Passamaquoddy bay and off the Saint John river. The central part of the bay of Fundy, the mouth of St. Mary's bay and the water near cape Sable was relatively clear. The whole coastal water between cape Spencer and Seguin, which is approximately the sardine area, was more turbid than anywhere else except the inner part of St. Mary's bay and the Annapolis basin, where sardines are also taken."

Similarily, the results of some Secchi disc readings carried out in the gulf of Maine during the summer of 1912 (Bigelow 1927, p. 822) support the conclusions which we have drawn from our data on the detritus content.

According to what had been considered on the previous pages, the differences which exist in the solar radiation and in turbidity affect the light conditions in the same way: They both tend to make the light conditions of subsurface localities in the bay of Fundy poorer than in the gulf of Maine. The difference cannot be accurately estimated on the basis of the observations which are at hand. The lower amount of total radiation in the bay of Fundy will have a different effect upon the thickness of the productive layer according to the transmission coefficient, and as long as we do not know more on this point, we are not able to tell how much thinner the productive layer may be in the Fundy region as compared with the gulf. The difference certainly is considerable.

Assimilation Experiment

In order to determine the point of compensation between the assimilation and the respiration of the phytoplankton algae, we had planned to carry out assimilation experiments with persistent cultures of plankton algae. Such cultures were started, but the work could not for various reasons (mainly the lack of time) be carried to an end. We only succeeded in getting one observation on the depth at which the compensation point was to be found in Passamaquoddy bay in summer. This was carried out with raw plankton and thus only gives the compensation point for the whole population in the culture bottles for a certain interval of time.

The experiment was carried out in the following way. A large bottle was filled with surface water to which was added a part of a no. 20 net haul, just made in the same locality, in order to enrich the population. To prevent heating by the air, the bottle was kept in a large bucket of water, which was changed, and it was kept in the shadow, to prevent heating by the sunshine. The contents of the bottle were stirred thoroughly by means of a glass rod which was moved in the completely filled bottle. The water was then siphoned into the oxygen bottles, which were filled and closed by faultless-fitting ground glass stoppers, and these bottles were also kept in cool water before they all were lowered to the various depths.

TABLE III. August 2, 1932. Passamaquoddy bay (off Davidsons head, Deer island). Clear sky during most of the time, only for a little while overcast. The air a little hazy. Time of exposure: 10.45 to 16.45.

Depth (metres)	Oxygen content	Mean oxygen content	Change in oxygen content
Original sample	6.17	6.17	—
1	8.02		
1	8.13	8.08	+1.91
5	6.85		
5	6.92	6.89	+0.72
10	6.57		
10	6.52	6.55	+0.38
15	6.26		
15	6.28	6.27	+0.10
20	6.06		
20	6.03	6.05	−0.12
30	5.96		
30	5.96	5.96	−0.21

According to this experiment, there was a gain in oxygen above a depth of about 17 m. and a loss below this depth. Provided that the animals were evenly distributed (and the good agreement between the pair of bottles at the same depths indicates that they were), the results show that photosynthesis had taken place down to a depth of 20 m. at least, since the consumption at 30 m. was higher than at 20 m.

THE PHYTOPLANKTON

Previous Investigations

THE FUNDY REGION

Bailey (1912 and 1915) and Bailey and Mackay (1921) have contributed to the knowledge of the diatom vegetation of the eastern part of Canada, including the coast of the bay of Fundy. These observations are floristic and since they are based mainly upon collections in the littoral region, they tell little about the seasonal variations in the constitution of the phytoplankton.

McMurrich (1917), in his paper on the winter plankton in the neighbourhood of St. Andrews, N.B., 1914-15, gives some data on the phytoplankton at this time of the year. Fritz, however, made the first detailed study of the phytoplankton in this region, of its dominant species and quantity throughout the year (Fritz 1921). This study was based upon countings from net hauls at the surface and at a depth of 5 m., and also to a smaller extent upon hauls made at various other depths. The observations were from 7 stations in Passamaquoddy bay and as far out in the bay of Fundy as off Swallow Tail lighthouse at Grand Manan island. She found a great similarity in the flora of these localities, only the vegetation of the exposed waters of the bay of Fundy was poorer as to the number of species as well as to the number of individuals. She observed a prevalence of free living, compact diatoms in winter, of *Biddulphia* and *Thalassiosira* in spring and of *Chaetoceros* (principally *Ch. debilis*) in summer. As to the bathymetric range, she found for the Fundy station that the most favourable level seemed to be from 10 to 20 metres, and that below that depth a rapid decrease might be expected. One form, *Melosira sulcata* was on one occasion found to be greatly increased at lower depths.

For seven and one-half consecutive years Davidson (1934) continued these studies. She found that dinoflagellates never were important contributors to phytoplankton abundance in net hauls made in the Quoddy region. Every year diatoms began to increase quickly in numbers as soon as the snow melted and the salinity of the surface layers began to decrease. Augmentation was rapid during the spring, reached its maximum in June at the station in the outer Quoddy region and in late June or early July in Passamaquoddy bay. The plants seemed to be fairly uniformly distributed throughout the water mass. In spring the plankton community was an arctic-neritic one in the whole Quoddy region, while in June and July a mixture of arctic and boreal species was found. In late summer and autumn temperate and oceanic species usually prevailed. At all seasons, more especially in the winter, bottom or littoral species were present in the plankton.

Bigelow in his extensive study of the plankton of the gulf of Maine, also included the available observations from the Fundy region, but he did not himself have many observations from this area. However, with his knowledge of the conditions in the gulf as a background, he gives an excellent compilation and interpretation of the available data. (Bigelow 1926.)

THE GULF OF MAINE

For the gulf proper, Bigelow's paper (1926) is the main source of information. He had at his disposal records from a very large number of net hauls from most parts of the offshore waters in the gulf, taken at various times of the year. Within the limitations of the net method (the loss of the nannoplankton and the difficulty in getting comparative quantitative data), his study gives a thorough picture of the main features of the phytoplankton distribution, qualitatively and to some extent also quantitatively. The seasonal variation of the phytoplankton of the various localities were clearly pointed out, and also the characteristic differences in the plankton conditions of the various parts of the gulf. Since chemical data were mostly lacking, Bigelow was not able in detail to trace the causes of these differences.

Bigelow's paper was mostly concerned with the offshore waters. Burkholder (1933), however, studied the phytoplankton of the inshore localities, Frenchmans bay and Penobscot bay, in the western part of the gulf. The method which was used for this investigation was filtering a large quantity of water through a no. 20 silk net. The material was collected during July and August 1930. Interesting is Burkholder's study of the changes in the plankton conditions at a locality according to the phase of the tide.

Although chemical and hydrographical studies were carried out parallel to the phytoplankton studies by Burkholder, the conditions in the tideswept waters of the two bays were so complicated that he was not able to detect definite connections between the hydrographic and chemical factors and the phytoplankton production.

Gran (1933) has given an account of the distribution of phytoplankton in the gulf in August 1932, and Braarud (1934) has published phytoplankton observations for July 1933 from a couple of localities in the gulf. Both papers are based upon material collected for the Woods Hole Oceanographic Institution, on board its vessel "Atlantis".

Method and Terminology

For the study of the phytoplankton the centrifuge method was generally used (Gran 1932). Water samples for centrifuging were collected from the water bottles which supplied the samples for the chemical analyses. At each station samples were taken from the following standard depths: 1, 10, 25, 40 and 75 m., occasionally also samples from greater depths. The water samples of 150 to 200 cc. were preserved by adding 5 cc. of a neutralized, carefully filtered 10% formalin solution. Of each sample 50 cc. were centrifuged, or smaller quantities (25 or 10 cc.) when the plankton was very rich.

The main advantage of the centrifuge method is that it gives a representative determination of the quantitative occurrence of the dominant species at a distinct depth, where the physical and chemical life conditions may be exactly determined. It is thus possible to study the influence of the various life conditions on the phytoplankton production *in situ*, and also to study how the phytoplankton may have been removed from the levels of good life conditions, either by sinking or by the turbulence of the water.

On the other hand, the method cannot give an accurate determination of the quantitative occurrence of all species present, or the total sum of organisms living in a volume of water. The larger species may escape observation or be too scarce to give the basis for a calculation of their frequency, as the volume of the centrifuged water sample must necessarily be limited; and the smallest species, particularly the naked cells, may be insufficiently preserved or discolored by preservation, making the classification too difficult. By centrifuging the material while the organisms are alive, this difficulty may partly be overcome, as Hentschel has successfully proved on the "Meteor" expedition. But when it is necessary for the solution of a problem to collect comparable samples from a number of stations during the shortest possible time, as was the case in our investigation, the preservation of the samples becomes necessary.

Recently Steeman Nielsen (1933) has shown that the sedimentation method of Utermoehl (1931) gives a more accurate determination of the total plankton content of a water sample than the centrifuge method, and that the latter may give only 10% of the total number of such minute forms as *Pontosphaera Huxleyi* or *Nitzschia delicatissima* (see also Allen 1919, and Gran 1932). At the meeting of the International Council in Copenhagen in 1934, Steeman Nielsen (Nielsen and von Brand 1934) reported that he had succeeded in improving the centrifuge method to give the same accuracy as the sedimentation method by producing in the centrifuged water samples colloidal precipitates keeping the sedimented cells at the bottom of the centrifuge tubes and preventing them from being lost by the pouring off of the water above the sediment. (The precipitate may be dissolved before examination of the samples).

Unfortunately it was impossible for us to revise our material according to these improvements. Therefore, in judging our results we have had to take into account the possible errors, which from E. J. Allen's observations (1919) were of course also known to us beforehand. Fortunately, for all the dominant species, and particularly for those of the coastal waters, the errors will be far below the maximal ones, found by Steeman Nielsen, as also has been shown by the same author. In waters rich in colloidal detritus, as in the bay of Fundy, the detritus will also make the sediments in the tubes more coherent and thus diminish the loss. For the offshore waters of the gulf of Maine the error may be considerable for such species as *Pontosphaera Huxleyi*. Fortunately, the local and seasonal variations are so large that even wide limits of error in the quantitative determinations may be ignored.

The exceptional tides change the hydrographic conditions at a station within a short period of time, but this is not very serious for our study of the phytoplankton, as it is here based on a comparison between the plankton data and the physico-chemical data for the same water sample. In order to illustrate what changes may take place between one phase of the tide and another, we shall give the results of observations from station 5 at low and high water one day and high water the next day (table IV). Unfortunately samples from 1 m. were not taken. If the most important species, *Thalassiosira Nordenskiöldi*, is considered, at 10 m. it was at low water found to the number of 113,900 cells per litre, the following high water 157,500 and at high water the following day only 35,000 cells per litre. There is thus a great difference between the numbers found at the two high waters. By comparison of the hydrographic data, it is easy to find the explanation of the change. They show that the surface water which was rich in plankton, at the two first observations was found at the 10 m. level (salinity less than $31^0/_{00}$), and on the next day was thinner so that at 10 m. there was water of the same character as was the previous day found at 25 m. and below. Accordingly the 10 m. sample at high water on the last day had a plankton content which was about the same as that which on the first day was found at the lower levels.

TABLE IV. Station 5.

Depth (m.)	Low Water April 19, 1934			High Water April 19, 1934			High Water April 20, 1934		
	T.	S.	Thal. Nord. (cells/l.)	T.	S.	Thal. Nord. (cells/l.)	T.	S.	Thal. Nord. (cells/l.)
10	2.59	30.72	113,900	2.71	30.72	157,500	2.76	31.13	35,000
25	2.36	31.20	49,500	2.69	31.08	59,700	2.59	31.22	45,700
40	2.38	30.55	37,600	2.57	31.24	70,600	2.58	31.27	57,600
75	2.36	30.97	61,700	2.54	31.91	32,600	2.51	31.85	20,300

Such changes in the vertical distribution of the different water layers do not seriously affect the interpretation of the material collected at different phases of the tide. For determination of the horizontal distribution, it would have been desirable to have had observations taken at the same phase of the tide, but this was impossible on account of the large area which had to be covered and the many different observations which had to be made on board the same boat. The distribution charts must therefore be regarded with the reservation necessitated by possible tide influence.

In drawing our conclusions we have tried to be cautious, and we have the conviction that the variations described give on the whole an approximate picture of the natural conditions, and this is corroborated by the good agreement between the observations on the phytoplankton and the variations in the oxygen, phosphate and nitrate content of the waters.

For the description of terrestrial vegetation a very complete terminology has been worked out by the students of plant sociology. In the recent plant sociological works, many terms which have had an extensive use in their conventional meaning have been reserved for special use, but still there exists no uniformity in the definitions of these words by the various authors (Braun-Blanquet 1928, DuRietz 1932, Nordhagen 1927-28, Tansley and Chipp 1926). Partly for this reason, but mainly on account of special features in the structure and biology of the planktonic vegetation, we have not found it advisable to adopt for the description of phytoplankton vegetations the methods and terminology which are now commonly used for terrestrial vegetation.

In oceanic waters the habitat and its vegetation are mostly so stable that even fairly few samples may give material for the description of characteristic communities (Hentschel 1934). In waters close to the continents, as those dealt with here, the changes are, however, rapid both in the properties of the habitat and in their vegetation. A description of the various plant communities corresponding to the associations of the terrestrial vegetation (in the sense of

DuRietz and Nordhagen), would therefore be unattainable with the amount of material which is usually obtainable.

At present it seems most rational in each case to use the method which appears to suit best the treatment of the phytoplankton material at hand. This the more, since the work on planktonic plant life, which has recently been carried out, is too varied as to scope, methods and area of investigation for any strict standardization of phytoplankton work to seem practicable or even possible at the moment. As examples of the variety in the methods which on the basis of quantitative data have been used for the description of phytoplankton vegetations, we may mention the investigations by Gran (1915 to 1933), Lohmann (1912, 1920) and Hentschel (1930 and 1934).

In the presentation of our material we have found it convenient to use some terms which are enumerated below. We have avoided the use of the word "association", since it is so compromised in the special terrestrial plant sociology and by Hentschel (1934) has been given a special definition for planktonic vegetation, which cannot be applied to our material.

The words **phytoplankton population, community** and **vegetation** have here been used in the conventional meaning of a small or large, homogeneous or heterogeneous group of phytoplankton organisms.

A group of species which have a similar distribution within the area of investigation, and which have their maxima in the same water mass, we have called a **phytoplankton society.** (The term society has been used by Tansley and Chipp, 1926, for terrestrial vegetation, and then with a specially defined meaning).

For a general description of the seasonal changes in the vegetation of the area of investigation, we shall distinguish between a few **types of phytoplankton vegetation.** To each of these we assign those phytoplankton populations which have their main occurrence (quantitatively) during the same season and whose dominant species all belong to the same one of the groups,—diatoms, dinoflagellates, coccolithophorides . . ., (e.g., spring diatom vegetation, summer dinoflagellate vegetation . . .).

In considering the changes which take place in the population of a certain, fairly well defined, water mass, we have used the term **succession** of populations (communities or vegetations). Circulation of the water masses involves that, at a locality, a series of samples taken during a certain period of time usually will not give direct information on successions. When we discuss such changes in the phytoplankton population of a locality, defined by its geographical position, we shall use the term **sequence** of populations. In stagnant waters the successions and the sequences will be identical, otherwise the difference between them may be small or large, according to the rate of circulation and of the changes which take place in the various waters which are involved.

For an ecological characterization of the species we use the classification into various **plankton elements,** according to the binary system of Gran (1902). A further discussion of the various elements is given later, on page 351.

Distribution of Phytoplankton

The area of investigation comprises waters which are very heterogeneous as to their phytoplankton as well as to their physico-chemical character. The hydrographic and chemical data have been treated separately in previous chapters and we have found it necessary also to give a separate description of the phytoplankton distribution before we enter the discussion of the relationship between the biological and the physico-chemical data, which follows later on (page 394).

A descriptive part in which the phytoplankton vegetation in each month from March to September has been treated separately is followed by a few biogeographical remarks on the phytoplankton of the region.

March 1932. Table XXV

In March the waters of the bay of Fundy had a very scanty phytoplankton population. The character of the phytoplankton at the four stations was much the same: neritic forms, such as *Chaetoceros debilis* and *compressus*, *Ditylum Brightwelli*, *Sceletonema costatum* and *Thalassiosira decipiens*, *Asterionella japonica*, were found together with oceanic forms like *Corethron hystrix* and

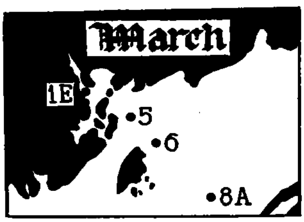


Figure 33. Phytoplankton stations in March 1932.

Rhizosolenia hebetata semispina, and also tychopelagic genera, such as *Cocconeis* and *Pleurosigma* were represented. The bulk of the phytoplankton was made up of diatoms, but also the silicoflagellate *Distephanus speculum* and a number of dinoflagellates were observed.

The maximum number of diatoms (all) was 8860/l. At station 25.05 *Sceletonema costatum* was a little more abundant at 10 m. than at the lower levels, but in general there was no greater population at 10 m. than at the lower depths. (Unfortunately the samples from 1 m. were lost in a fire at the Atlantic Biological station.)

April 1932. Tables XXVI to XXXIII

The Nova and Pelican observations (*tables XXVI to XXXII*). The investigations of Bigelow (1926) and Davidson (1934) show that in March and April an immense increase in the numbers of phytoplankton takes place all over the gulf and in the Quoddy region, caused by a flowering of diatoms similar to what is known from most northern waters. It occurs at somewhat different times and proceeds at various rates of speed in the offshore and inshore waters. Our observations from the latter part of April 1932 give an illustration of how different the phytoplankton conditions for this reason may be in the various localities.

In three parts of the region: the south-western coastal area off Penobscot and Casco bay, in Passamaquoddy bay and the waters over the coastal shelf south of Nova Scotia, the spring diatom vegetation was found to be very abundant. In the central part of the gulf, the spring diatom maximum had passed and was succeeded by a sparse dinoflagellate vegetation in the upper levels, while remainders of the diatom vegetation were still to be observed in the deeper layers.

In the inner part of the bay of Fundy, winter conditions yet prevailed, while in the outer parts a fairly numerous vegetation of diatoms was observed. A restricted area in the central part of the bay seems to have had a rich diatom

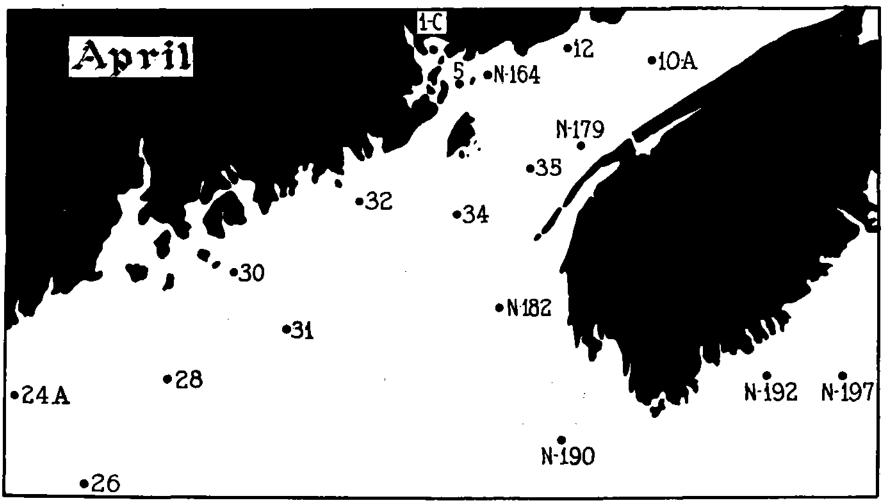


FIGURE 34. Phytoplankton stations in April 1932. Nova and Pelican observations.

vegetation at this time, but our observations are too few to give any idea of the extent of the rich area (see below).

This spring diatom vegetation consisted of much the same species, but varied a little in its composition. The dominant species was *Thalassiosira Nordenskiöldi*, with *Porosira glacialis* as a regular companion. At the stations off Nova Scotia (N190, N192 and N197) there were some highly arctic forms mixed in, viz., *Achnanthes taeniata*, *Fragilaria oceanica*, *Navicula Vanhöffeni* and *Thalassiosira hyalina*. Otherwise the most obvious differences in the qualitative composition of this diatom vegetation were caused by variations in the relative amount of *Chaetoceros*. The most numerous *Chaetoceros* species were *Ch. compressus*, *debilis* and *diadema*. In some localities they only formed a subordinate part of the total population, while at others they were numerous. Thus at station 31, 46,000 cells per litre were recorded of *Ch. compressus* and at station 26, 26,800 of *Ch. debilis*.

In general the distribution of *Chaetoceros* in proportion to *Thalassiosira*

Nordenskiöldi gives the impression that they occur together, but that *Thalassiosira* is able to grow better than *Chaetoceros* in spring at the prevailing low temperatures (1 to 5° C.).

The highest figure for *Thalassiosira Nordenskiöldi*, 760,600 per litre, was recorded at station 24A. The other two stations in the western part of the gulf, at a similar distance from land, both show figures for this species which are higher than 500,000. At station 26, which is the most offshore station in the gulf taken at this time of the year, the numbers of diatoms were much smaller than at the stations closer to shore in the same area, and the diatom population was here mainly found in the 75 m. samples, where *Thalassiosira Nordenskiöldi* occurred with 110,500 and *Chaetoceros debilis* with 16,400; in both cases more than 10% were resting spores.

At station N197 also the diatom maximum seemed to have passed, since the maxima of the most important species were to be found at 25 and 40 m. The sinking of the diatom vegetation was not by far so advanced here as at station 26 in the gulf.

In the inner part of the bay of Fundy (stations 10A and 12) there was a community like that which had been observed in the outer part of the bay in early March. The most characteristic species were *Melosira sulcata* and *Thalassiosira decipiens*, but neither of them occurred in any great quantities, viz., less than 4,000 per litre.

The Prince observations (*table XXXIII*). During a cruise which had been planned for hydrographic purposes, phytoplankton samples were collected for general information on the spring conditions in the bay of Fundy. At these stations only 10 m. samples were collected for the phytoplankton study, except at one station in each of the Lepreau and the Swallow Tail sections. Besides these, one station in Passamaquoddy bay and one in the outer Quoddy region were also worked. All observations were taken at or close to ebb tide. From station 5 we have an observation taken on April 19, a week before the others were taken. (For the location of the stations see figure 35.)

The vegetation which was recorded for all the localities, where the population was large, had *Thalassiosira Nordenskiöldi* as the dominant species. At the stations with a small population, *Melosira sulcata* and *Thalassiosira decipiens* were the most important species, the vegetation here being of the same type as in early March was to be found in the outer part of the bay of Fundy.

The distribution of *Thalassiosira Nordenskiöldi*, as shown in figure 35, illustrates the distribution of these two types of vegetation and thus also shows the limits of the waters which were rich and poor in phytoplankton. In figure 35 the observations from the Tiner section have not been entered. All the stations in this section located further to the east along the New Brunswick shore had a very poor phytoplankton population of the same type as that of the inshore stations in the Lepreau section.

Water with a similar poor phytoplankton population as that of the New Brunswick coastal waters was to be observed at the two innermost stations in the Swallow Tail section, while at the stations on both sides (station SW_2

and the two outer stations) the phytoplankton was very abundant with *Thalassiosira Nordenskiöldi* as the dominant species. In the Swallow Tail section as well as in the Lepreau section the two outermost stations show an increase in the *Thalassiosira Nordenskiöldi* figures outwards (see figure 35). It seems clearly to be shown by these observations that the poor New Brunswick water protruded towards the eastern coast of Grand Manan island, thus separating two areas which were rich in phytoplankton, viz., (1) an area in the central part of the bay of Fundy, and (2) the Quoddy area, comprising the inner and the outer Quoddy regions.

Such immense differences in the phytoplankton content of waters within a fairly small region must be the result of some remarkable difference in the properties of these various water types.

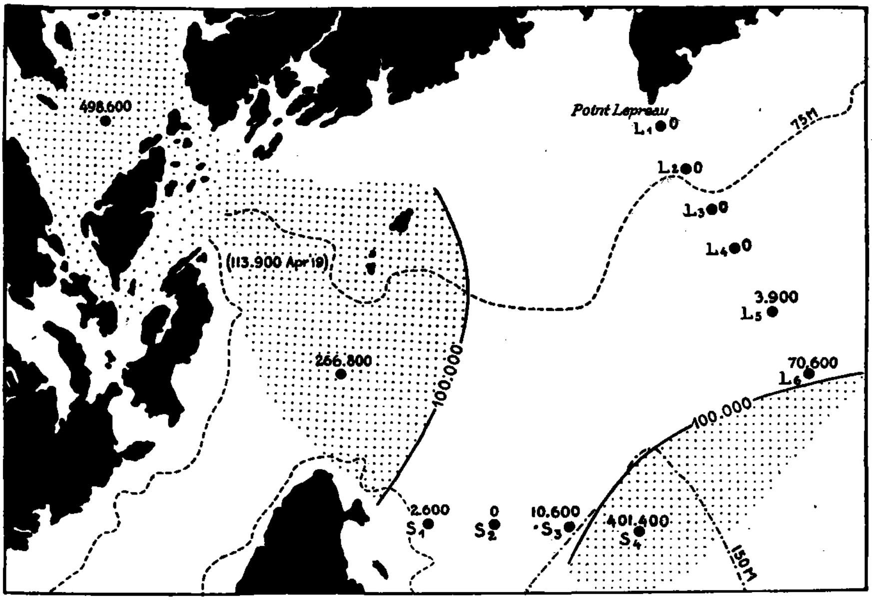


FIGURE 35. The distribution of *Thalassiosira Nordenskiöldi* at the 10 m. level in the S-section (the four lower stations), the Lepreau section, and at three stations in the Quoddy region.

TS-diagrams for the stations in the S- and L-sections, reveal that the outermost station in the S-section had in the upper layers water which was of a different character from the waters of the other stations in this section (Watson unpub.), while the inner stations had TS-curves which are closely related to those of the stations in the L-section. A similar difference is shown in the photographs illustrating the turbidity conditions at the 10 m. level at the various stations in the S-section. The outermost station seems less turbid than the other ones, which are much alike and have a high degree of turbidity (see figure 32). The waters of the Quoddy region seem (at this time of the year) to be less influenced by the coastal waters moving along the New Brunswick coast than the waters outside the line between point Lepreau and Grand Manan.

The *Thalassiosira Nordenskiöldi* figures show a gradual decrease at the outermost stations shorewards. This is probably the result of the mixing which the violent tidal currents produce between the poor and the rich water masses. The clear distinction between the three water masses in this area, is, however, an interesting evidence of how the identity of water masses may be preserved for a long period of time in spite of violent tidal action. The great differences in the phytoplankton content can not have been produced unless the prehistory of the waters had been different for a fairly long time.

Chemical data, other than for the salinity, are not available from this cruise and we are, therefore, only able to suggest the possible explanation of the great differences in the phytoplankton content of these three water bodies.

During the microscopical examination of the centrifuge samples from these stations, it was noticed that the samples which were poor in phytoplankton were

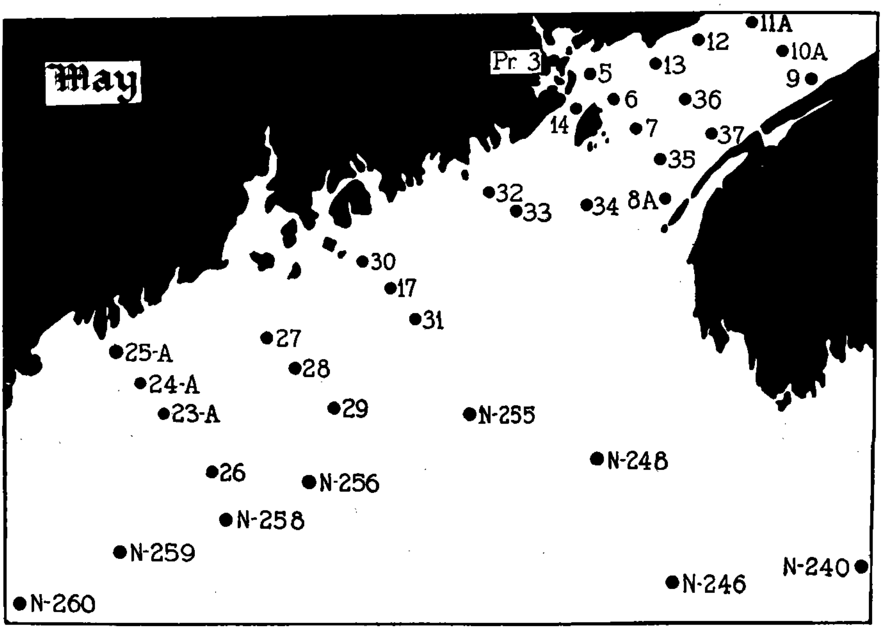


FIGURE 36. Phytoplankton stations in May.

very rich in detritus, much more so than those rich in phytoplankton. For the S-section we have photographs which give an illustration of this fact (figure 32). In our opinion the high turbidity of the coastal waters along the New Brunswick coast is the main cause of the paucity of these waters in phytoplankton. High turbidity reduces the thickness of the productive layer, and then also other factors than the light reduction may have a greater checking effect upon the plant production than otherwise would have been the case. For a further discussion of this question see page 421.

MAY 1932. TABLES XXXIV TO XXXIX

In May the *Thalassiosira Nordenskiöldi*-vegetation in its full development was only found in the Quoddy region, at stations 3, 5, 6 and 14. Here the temperature ranged from 3 to a little above 5°C. At the other stations in the outer part of the bay of Fundy (7, 35, 36, 37, 32, 33, 34) and the adjoining area of the gulf along the coast of Maine (30, 17, 31), there was also a *Thalassiosira Nordenskiöldi*-vegetation, but here a much larger *Chaetoceros* population was mixed in with it. The figures for *Thalassiosira Nordenskiöldi* (see figure 37) were here small as compared with those found in the Quoddy region and in the previous months further south in the gulf.

In the inner part of the bay of Fundy (9, 10A, 11A, 12, 13) a *Chaetoceros* vegetation with *Ch. compressus*, *debilis* and *diadema* as the most important species was predominant. The population at these stations was, however, small. At stations 36 and 37 the spring diatoms with *Thalassiosira Nordenskiöldi* still formed an important component of the population. Small brown dinoflagellates (*Exuviaella baltica* and *Peridinium triquetrum*) were fairly abundant at these central and eastern stations in the bay.

South of Mount Desert island, at the stations which were located fairly close to the shore (27, 25A, 24A) the population consisted mainly of dinoflagellates with a few *Chaetoceros*. At the offshore stations (23A, 26, 28, N255, N256, N258, N259, N260) *Ceratia* dominated the phytoplankton, which practically was without any other diatoms than a few remainders of the sinking spring diatom vegetation to be found in the deeper layers. The offshore station 29, however, had a diatom population like that of the stations in the section further north and closer to the shore (30, 17, 31). This would indicate that the waters of the coast of Maine north of Mount Desert at this time of the year protruded tongue-like as far out into the gulf as to station 29.

The distribution of the various phytoplankton populations in May gives a good illustration of the very different rate of change at the various localities. While in the Quoddy region the spring diatom population was still abundant, the central part of the gulf had only a few diatoms at the lower levels as reminiscences of the spring vegetation. In the upper levels a *Ceratium* population of a quite different character was now prevalent. In the bay of Fundy (outside the Quoddy region) and the coastal part of the gulf, various transitional states between the vegetation dominated by *Thalassiosira Nordenskiöldi*, via the *Chaetoceros compressus* and *debilis* stage with an introduction of an *Exuviaella-Peridinium triquetrum* population to a *Ceratium* vegetation were observed.

At the stations south of Nova Scotia, a *Chaetoceros compressus* population with a fairly abundant company of heterotrophic peridineans and members of the ciliate genus *Laboea* had succeeded the *Thalassiosira Nordenskiöldi* vegetation. The lack of observations from these waters prevented us from keeping track of the further changes, which might have been of interest, since the conditions so far in many ways seem related to those described from northern European waters.

In this month, as in April, the most striking feature in the quantitative distribution is the poverty of the inner part of the bay of Fundy. The Nova Scotia side was a little richer than was the New Brunswick side. The richest area in diatoms in May was the Quoddy region, where up to 464,000 cells per litre of *Thalassiosira Nordenskiöldi* were observed. The other stations in the outer part of the bay of Fundy were moderately rich, while station 8A was very poor.

The dominant *Chaetoceros* and dinoflagellate population of the coastal waters of the gulf was not very abundant, and the *Ceratium* population of the central part of the gulf was also scanty, except at station N259, where the distribution of "all *Ceratia*" was as follows: 1 m., 2,620; 10 m., 3,240; 25 m., 1,820; 40 m., 1,840; and 75 m., none observed in the centrifuge samples.

The coastal waters of Nova Scotia were poor in phytoplankton.

JUNE 1932. TABLES XL TO XLVI

The changes which took place in the phytoplankton conditions between

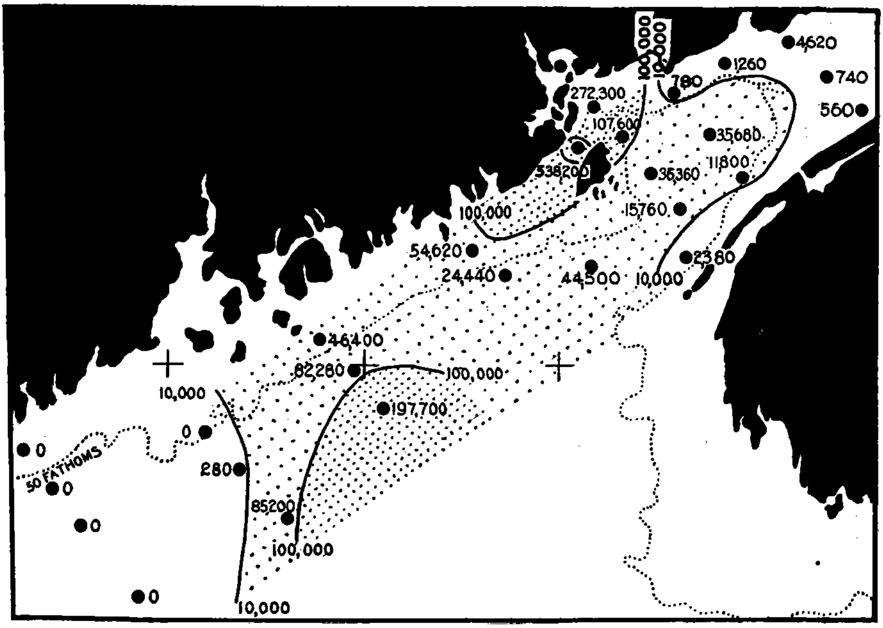


FIGURE 37. *Thalassiosira Nordenskiöldi.* Maximum numbers at the stations in May.

the May and the June observations were in the Fundy region very radical. The most obvious feature was the extreme decline in phytoplankton of the greater part of the region, but the changes which had taken place in the composition of the phytoplankton were also remarkable.

In Passamaquoddy bay, *Thalassiosira Nordenskiöldi* had been replaced by *Chaetoceros debilis* as the dominant diatom (more than 150,000 per litre). In the outer part of the Quoddy region and the rest of the bay of Fundy inside of Grand Manan, with the exception of the waters represented by stations 36 and 37, the very poor phytoplankton consisted of diatoms like *Actinoptychus undulatus*, *Melosira sulcata*, *Thalassiosira decipiens*, a few *Chaetoceros*, and at some stations *Leptocylindrus danicus* and *Sceletonema costatum.* The total number of organisms at these poor stations only amounted to a few thousands or less per litre at the richest level.

At the central station in the bay of Fundy, no. 36, the population was composed of *Detonula confervacea*, *Eucampia recta*, *Sceletonema costatum*, *Eutreptia Lanowi*, *Exuviaella baltica* and *Peridinium triquetrum*, with some other forms mixed in. This was the richest station in the bay of Fundy outside the Quoddy region, with about 13,000 *Detonula*, 3,000 *Sceletonema* and 20,000 *Eutreptia* as the maximum numbers at the station. The neighbouring station on the Nova Scotia side (37) had much the same species and in addition *Leptocylindrus* and *Rhizosolenia fragilissima*, which seem to have been carried in with the water from the gulf, since they were predominant forms at station 8A, where inflowing water enters the bay. The same forms were also found at the neighbouring station, 35.

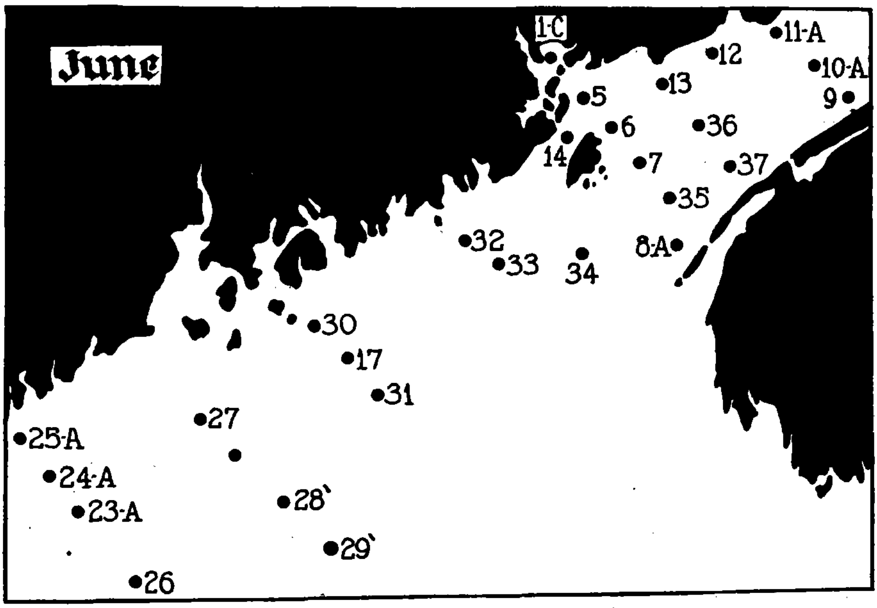


FIGURE 38. Phytoplankton stations in June.

The outer part of the Fundy region, south of Grand Manan (32, 33, 34) had a population with *Detonula confervacea*, *Rhizosolenia fragilissima*, *Thalassiosira decipiens* and *Eutreptia Lanowi* as the main species. Close to shore (32) a *Chaetoceros debilis* population was found to be mixed in and at the outer station (34) *Pontosphaera Huxleyi* was observed, but in rather small numbers only. At neither of them were *Ceratia* numerous.

In the gulf *Chaetoceros debilis* was predominant at the shore stations off Mount Desert island and Penobscot bay (30, 27), while further west, off Casco bay, *Sceletonema costatum* was predominant.

The offshore stations off Mount Desert island had a scanty population of *Rhizosolenia fragilissima* with some *Ceratia* and *Pontosphaera Huxleyi*, while in the next section westward, all the stations had a vegetation with *Chaetoceros* dominant, similar to that which has been described from the stations close to shore (27). The salinity distribution shows that the less saline coastal waters off Penobscot bay reached out beyond our outermost station. This gives an explanation of the difference in the phytoplankton conditions at the same distance from land in the Mount Desert and the Penobscot sections.

The offshore stations in the westernmost section, had a *Ceratium* population with some remnants of the sinking *Chaetoceros* population of the previous months and some *Pontosphaera Huxleyi* at the outermost station. The *Ceratia* had their greatest abundance at station 24A, where they, as at most of the stations, were found in greatest numbers at the intermediate depths (25 and 40 m.). At station 26, however, they were as numerous at 1 m. as at the other depths.

Quantitatively the most remarkable features in the phytoplankton distribu-

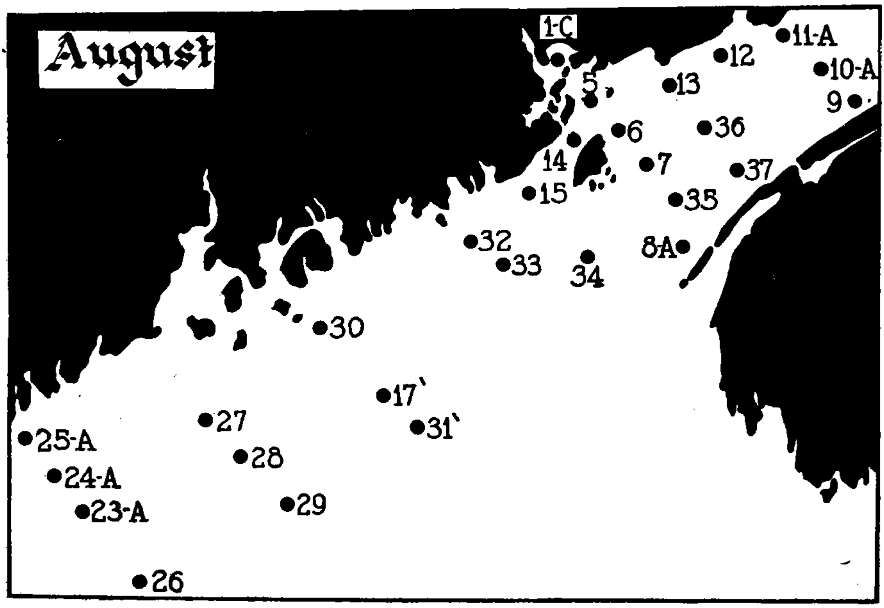


FIGURE 39. Phytoplankton stations in August.

tion in June were: (1) the poor vegetation in the greater part of the Fundy region; (2) the fairly rich diatom vegetation along the coast of Maine and in Passamaquoddy bay; and (3) the moderately rich *Ceratium* vegetation of the offshore waters in the gulf.

AUGUST AND JULY 1932. TABLES XLVII TO LV

The phytoplankton conditions in the gulf of Maine were in the middle of August not very different from those observed at the end of June. The oceanic stations (26, 28, 29 and 31) showed an oceanic plankton consisting of *Ceratia*, *Rhizosolenia alata* (and less abundantly *R. imbricata* var. *Shrubsolei*) and *Pontosphaera Huxleyi*, similar to the plankton described by Gran (1933) from the cruise of the "Atlantis" at the same season. *Ceratium longipes*, which dominated in June, was now replaced by *C. fusus* and *C. tripos*, but still considerable numbers both of *C. longipes* and of *C. bucephalum* were found in the cold waters at a depth of 75 m.

In the shallower waters near the coast, at stations 27 and 30, the same mixed vegetation of neritic diatoms as observed in June was still growing (see figure 40). The relative abundance of the species had changed a little. *Chaetoceros debilis*, which dominated and had its maximum in June (255,000 cells per litre at station 27, and 707,000 at station 30), had decreased to 13,000 and 8,000 cells per litre. *Ch. compressus* had decreased less and was now dominant together with *Ch. cinctus*. At both stations the plankton was rich in species, among which *Ch. constrictus* and *Rh. fragilissima* may be named. At these localities, near Mount Desert island and Penobscot bay, a rich vegetation of plankton diatoms was also observed by Bigelow in the years 1912 to 1915. (Bigelow 1926).

At the intermediate stations of all sections the phytoplankton showed transitions between the oceanic and coastal conditions. In all sections it was characteristic that the abundance in phytoplankton and the existence of a surplus in oxygen and a low content of phosphates were limited to a shallow surface layer of 10 m. or less at the coastal stations, while at the offshore stations a vivid production was going on as far down as to the 25 m. or at station 29 even to the 40 m. level. Here the water was supersaturated with oxygen at 40 m., the *Ceratia* (*C. fusus* and *tripos*) were abundant at the same depth, even if their maxima were found higher up, and *Rhizosolenia alata* had its maximum at 40 m.

At station 30, the deeper layers, below the zone of photosynthesis and propagation, contained at the depth of 25 to 40 m., diatoms which otherwise were characteristic of the bay of Fundy, viz., *Sceletonema costatum*, *Asterionella japonica* and as minor components, *Ditylum Brightwelli* and *Coscinodiscus excentricus*. This population may probably have drifted out with currents from the bay of Fundy.

In the bay of Fundy the situation showed remarkable changes since June. The waters were no longer so barren, but contained at various localities a fairly rich vegetation of phytoplankton. The inflowing waters along the Nova Scotian coast and the outflowing waters along the New Brunswick coast each had their characteristic phytoplankton, while the more stable waters in the centre seemed to be influenced from both sides.

The inflowing waters were characterized by a society of neritic diatoms with *Chaetoceros constrictus* as the leading species (see remarks on the terminology, page 332). It had a maximum of 74,000 cells per litre at station 8A and 75,000 at station 37. It was found in abundance also at stations 35 (24,000) and 34 (29,000), in smaller numbers at the stations 33 (11,000), 7 (8,000) and 6 (3,000), but quite scarce farther in and on the New Brunswick side (see figure 69). It had already formed many resting spores and was evidently sinking, as its maximum was often found to be at 25 to 40 m. Of subordinate components of this society may be mentioned *Cerataulina Bergoni*, which had a maximum of 3,500 at station 8A and 2,700 at station 37.

Another society of diatoms, more abundant on the western side of the bay, was represented by *Sceletonema costatum* and, as minor components, by

Asterionella japonica, Ditylum Brightwelli and *Coscinodiscus excentricus*. *Sceletonema* was found over the whole bay, but with a pronounced maximum at stations 7 (527,000 per litre), 6 (491,000) and 35 (517,000). At these localities it was concentrated in the surface layer (the 1 m. and 10 m. levels). It was abundant also in Grand Manan channel (station 14) and here more or less evenly distributed through the whole water column, down to 75 m. or more, with a frequency of 113,000 to 369,000 cells per litre. Along the New Brunswick coast (stations 11A, 12, 13 and 5) it occurred regularly at all depths, but in small numbers, up to 8,000 per litre.

Asterionella japonica was neither observed in the inflowing waters (stations 8 and 37), nor outside the bay of Fundy, except in the deeper layers at station 30,

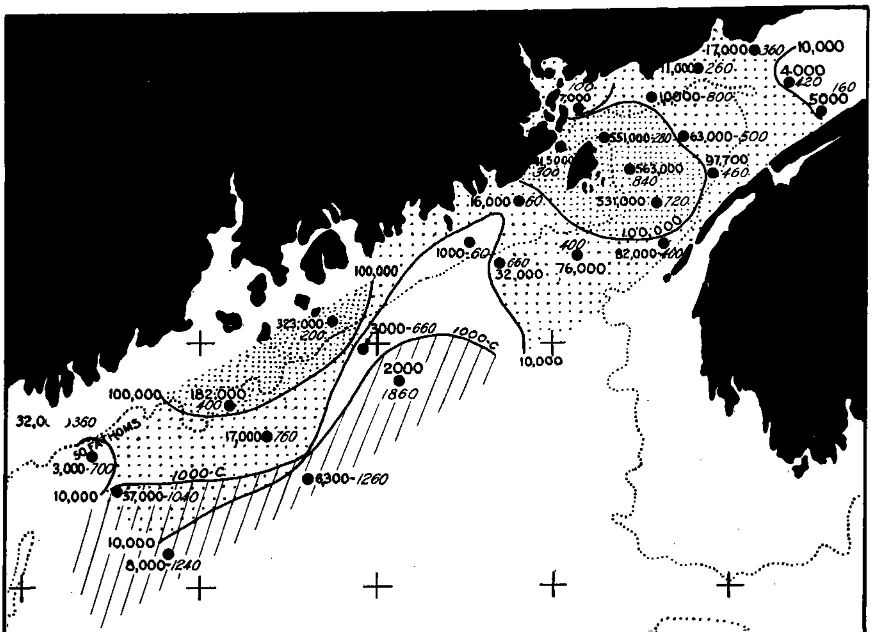


FIGURE 40. Maximum figures for "all diatoms" and "all *Ceratia*" at the stations in August.

as mentioned above, but regularly at stations 11A, 12 and 13 along the New Brunswick coast. A rich vegetation of this species was found only at the same stations where *Sceletonema* had its mass occurrence, viz., station 6 (45,000), 7 (18,000), 35 (4,800) and 14 (11,000). The same distribution characterized *Ditylum Brightwelli*, which is a slower growing species and at its maximum, at station 6, only reached a frequency of 1,000 per litre. Numbers of above 100 per litre were found only at stations 6, 7, 11A, 12, 13, 14, 5 and 35. *Coscinodiscus excentricus* also had a similar distribution, but was still scarcer. With these four species a number of other diatoms were observed. At stations 6, 7 and 35 as many as 32 to 33 species of diatoms were observed in the centrifuged samples.

It may be said with certainty that the above named four species had a centre of distribution in the bay of Fundy in summer. They seemed to have been drifting, without rapid propagation, along the New Brunswick coast, but their maxima were always found around Grand Manan.

Another important society is represented by some species of brown peridineans, too small to be caught regularly in the nets and therefore insufficiently known with regard to their distribution and biology. The species occurring regularly in our area are *Peridinium faeroense*, *P. triquetrum* and *trochoideum* and the somewhat larger species *Gonyaulax tamarensis*. During their propagation they regularly form naked zoospores. These as well as the normal cell with cell walls and the cysts, have a dense plasma and are certainly most important as food for the zooplankton, when they occur in great numbers as in the bay of Fundy in summer time.

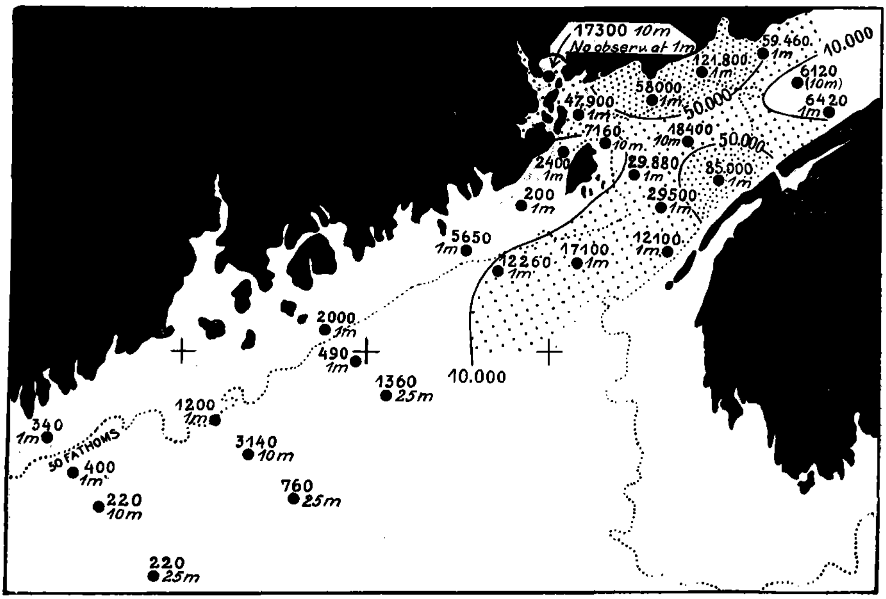


FIGURE 41. *Peridinium triquetrum.* Maximum numbers at the stations in August and the depths at which they occurred.

The species mentioned above have all nearly the same distribution in our area. As a representative we choose *Peridinium triquetrum,* the most characteristic and commonest species, and propose to name the society the *Triquetrum*-society. The distribution of *P. triquetrum* in August is shown in figure 41.

The species was observed over the whole area, but most abundantly in the bay of Fundy, where it had two centres of distribution with a frequency of above 50,000 cells per litre, one at station 37 near the outlet from Digby gut, another at station 12, outside the Saint John river, with a maximum of nearly 122,000 per litre. The maximum at each station was always found in the surface layer, most often at the very surface. Its occurrence in the gulf of Maine seems to indicate that it had a tendency to accumulate at the depth corresponding to the optimal combination of sufficient light and nutrition. At the outermost stations

(26, 29 and 31) the highest number was found at a depth of 25 m., at the intermediate stations (23A and 28) at 10 m., and at the inner stations (24 A, 25A, 27 and 30) at 1 m. as at most of the stations of the bay of Fundy.

The *Triquetrum*-society consists of undoubtedly neritic species, probably originating each year from shallow waters, where the cysts may be hibernating, and spreading rapidly along the surface over wide areas during the summer. Nothing can be said as yet about the factors favouring a rapid propagation and the formation of dense populations of these species within limited areas. Special studies on these questions would certainly give valuable results.

Besides these neritic societies, we found in August a number of oceanic species occurring regularly and in relative abundance. The most important ones of these were *Pontosphaera Huxleyi* and *Ceratia*, particularly *Ceratium fusus* and *tripos*, and the diatom *Rhizosolenia alata*. All of them were characteristic inhabitants of the open waters in the gulf of Maine, where they had their maxima at the outermost stations (26, 23A, 28, 29, 17 and 31), but all of them were also abundant in the outer and central parts of the bay of Fundy.

Pontosphaera Huxleyi was even more abundant at some stations in the bay of Fundy than in the gulf of Maine (see figure 42). At station 37, 65,000 cells per litre were found at the surface; at station 7, 51,000 at 25 m.; at station 36, 26,000; station 35, 22,000; while the maximum in the gulf of Maine was about 15,000. Considerable numbers, 13,000 to 14,000 per litre, were also observed at the inner stations along the New Brunswick coast (10A and 12). Around Grand Manan this species was very scarce. Also the new species, *Pontosphaera Bigelowi*, which was much rarer, had a similar distribution. Its maximal frequency, 600 per litre or more, was found at the outer stations in the gulf, but it was also observed in numbers of 200 to 300 at stations 36 and 37 in the bay of Fundy, and in smaller numbers at station 7 and further in (stations 10A, 11A and 12).

Ceratium fusus, which at the outer stations in the gulf (26 and 29) had its maximum of 600 to 7,000 per litre at a depth of 25 m., was also found in numbers of 500 or more at the surface at stations 7, 35, and 13, and in numbers up to 200 at stations 33, 36, 37, 8A, 10A, 11A, and 12. This species was also very rare around Grand Manan. *C. tripos* had a similar distribution, but occurred less abundantly.

Rhizosolenia alata, which along the Norwegian coast used to accompany the "*Tripos*-plankton" of Cleve (the *Tripos*-society), is also a characteristic member of the *Ceratium*-summer-plankton of the gulf of Maine and the bay of Fundy. Maxima of 5,000 per litre or more occurred at 25 to 40 m. in the gulf of Maine, but numbers of 2,000 to 4,000 were also found at a depth of 1 to 10 m. at the following stations in the bay of Fundy: 33, 34, 35, 36, 7, 10A, 11A, 12 and 13. Around Grand Manan this species, like the other members of this society, was very scarce (stations 5, 14, 15 and 32). *R. alata* was often, but not always, accompanied by its larger relative, *R. imbricata* var. *Shrubsolei*, in numbers up to 1,000 per litre.

Thus, the phytoplankton of the bay of Fundy in August was characterized by the following societies: (1) the *Sceletonema*-society of neritic diatoms of local origin, with a maximum development around Grand Manan; (2) the *Constrictus*-society of neritic diatoms, introduced with currents along the coast of Nova Scotia; (3) the *Triquetrum*-society of neritic, autotrophic peridineans of uncertain origin, widely spread along the surface, with a minimum around Grand Manan; (4) the *Tripos-fusus*-society of oceanic *Ceratia*, coccolithophorides (*Pontosphaera*) and diatoms (*Rhizosolenia*), connected with a similar society dominant in the offshore waters of the gulf of Maine, and propagating with about the same intensity in the central parts of the bay of Fundy (but here nearer to the shore than in the gulf), and having a minimum of frequency around Grand Manan.

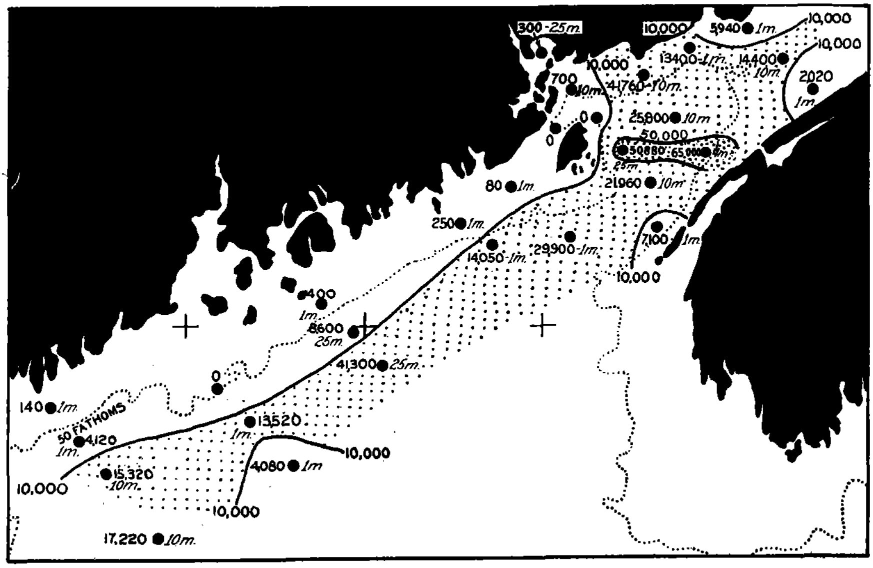


FIGURE 42. Maximum numbers of coccolithophorides at the stations in August, and the depths at which they occurred.

SEPTEMBER 1931 AND 1932

Observations of the general survey (Tables XX to XXIV and LVIII to LX). For the month of September we have observations in the bay of Fundy during two successive years, viz., 1931 and 1932. From August to September 1932, the phytoplankton had decreased strongly over the whole bay. At most of the stations the oxygen tension was below saturation even at the surface, and the phosphate content was high. Station 7 was one of the few stations where an effective production was still going on. Most of the species (and societies) from August were still present, but in much smaller quantities.

The *Sceletonema*-society was still represented by the same species as before. *Sceletonema costatum* was found at most of the stations with a maximum of only 8,600 at station 7. *Asterionella japonica* had the same distribution with 2,300 per litre at station 7 and 3,600 at station 13. The more slowly growing species had decreased less. *Ditylum Brightwelli* was still represented by 260 per litre at station 5 and 200 at station 12, *Coscinodiscus excentricus* by 80 cells per litre at the two stations 12 and 14.

The *Constrictus*-society had almost disappeared, as might be expected from the numerous resting spores observed in August. *Chaetoceros constrictus* was observed at a few stations in quite small numbers.

The *Triquetrum*-society was strongly reduced, and its distribution limited to some stations near the mouth of the bay (7, 35, 36, and 37). At station 7 still 3,620 cells per litre were found of *Peridinium triquetrum* at 1 to 10 m., and at station 37, 4,920 per litre at the surface.

The oceanic species, the *Tripos-fusus*-society, had also decreased in frequency. At station 7, *Ceratium tripos* and *C. fusus* were still represented by 160 per litre each, and 80 per litre at station 35; elsewhere only single specimens were observed. *Pontosphaera Huxleyi* had maxima of about 800 per litre at station 7 and 37; 500 at station 8A; 320 at station 36 and 120 at station 35 and quite a few at station 10A. At the other stations it was not observed at all. *Rhizosolenia alata* had disappeared nearly completely; its highest frequency was 80 per litre at station 7.

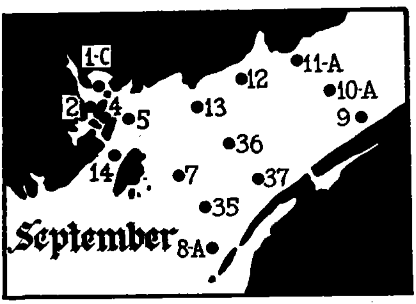


FIGURE 43. Phytoplankton stations in September 1932.

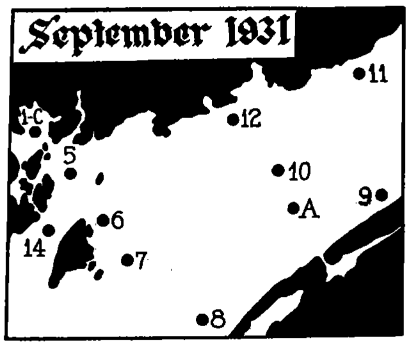


FIGURE 44. Phytoplankton stations in September 1931.

It may be mentioned that single specimens of oceanic species were observed, certainly introduced from the gulf of Maine, such as *Rhabdosphaera stylifera* (station 36), *Acanthoica acanthifera* (stations 36 and 37), *Lohmannosphaera subclausa* (stations 7 and 36) and *Pontosphaera Bigelowi* (station 10A).

Single specimens were also observed of two species of diatoms, which according to Davidson (1934) are characteristic inhabitants of the shallow waters at the head of the bay, viz., *Biddulphia regia* (station 5, 12, 13 and 14) and *Streptotheca thamesis* (station 13). Only in September these species occurred abundantly enough to be observed in the centrifuge samples.

The observations from 1931 show how the character of the phytoplankton may vary from one year to another. In 1931, the *Sceletonema*-society was much more abundantly represented in September than was the case in 1932, and its occurrence reminded one more of the situation in August 1932. *Scele-*

tonema costatum had at station 6 a maximum of 145,000 per litre on the 11th of September, and 161,000 on the 22nd of September. At the stations along the New Brunswick coast (11, 12 and 5) it was found through the whole water column, in numbers from 4,000 to 8,000 cells per litre. *Asterionella japonica* had a maximum of nearly 15,000 per litre at station 6, but was rare elsewhere. *Ditylum Brightwelli* also had its maximum (1,420 per litre) at station 6, likewise *Coscinodiscus excentricus* (160 per litre), but this species was also well represented at stations 5, 11 and 12, and in Passamaquoddy bay.

The *Triquetrum*-society was abundant in the inflowing waters on the Nova Scotian side (8A, 10A and 7) with a marked maximum at station 7.

The *Tripos-fusus*-society was very poorly represented in September 1931. *Pontosphaera Huxleyi* was quite scarce, as well as *Ceratium tripos* and *fusus*. Each of these had a maximum of only 80 per litre at station A in the centre of the bay. *Ceratium longipes* and particularly *C. bucephalum* were more numerous in 1931 than in 1932, and dominated the more thermophile species *C. tripos* and *fusus*. All of the species had their maxima at the same station, viz., station A, *C. longipes* with 100, and *bucephalum* with 200 cells per litre. *Rhizosolenia alata* was not observed at all in 1931. It was replaced by *R. imbricata* var. *Shrubsolei*, which had a maximum of 1,560 per litre at station 10.

The most remarkable feature was in September 1931 the relative abundance of oceanic species, indicating clearly a strong inflow of Atlantic water. The most characteristic one of them was *Rhabdosphaera stylifera* which was observed at all stations on the Nova Scotian side (8A, 10 and A), in numbers of 1,000 per litre and more, in the surface waters (1 and 10 m.). Many of the cells were empty, and the species evidently did not propagate in the bay; so its abundant occurrence was the more astonishing. It was observed in smaller numbers also at station 7, and a single specimen at station 6. *Coccolithus pelagicus* occurred regularly at the same stations in numbers up to 320 per litre (station 10), *Acanthoica acanthifera* with a maximum of 280 per litre at station 8A, and single specimens at stations A and 10. *Syracosphaera pulchra* was observed as single specimens in the samples from stations 8A and 10, and *Calyptrosphaera oblonga* at station A.

As visitors from the head of the bay, were observed *Biddulphia regia* at stations 7, 11 and 12, most regularly at station 11, and *Streptotheca thamesis* at stations 11 and 12.

Passamaquoddy bay had on the 12th of September, 1931, a characteristic phytoplankton. It was not rich, the total number of diatoms being 2,560 cells per litre at a depth of 1 m. and 4,040 at 40 m. At this depth it consisted mostly of sinking cells of tychopelagic species, such as *Melosira sulcata*. The surface water contained an extraordinary number (16,260 per litre) of *Distephanus speculum*, which elsewhere was mostly observed only as single specimens in the samples. *Guinardia flaccida* had also a characteristic local occurrence, 460 per litre at the surface, of relatively small specimens. *Chaetoceros simplex*, which in other areas has been observed as a characteristic inhabitant of more or less closed basins, had a local maximum of 740 per litre at the surface. On the 21st of September all these species had decreased to less than half the number, while

Thalassionema nitzschioides, which in 1932 was very abundant in the bay at this time of the year (see below), had increased from 220 to 1,100 cells per litre.

As results of these observations in September, it may be summarily stated that the phytoplankton of the bay of Fundy was decreasing in number and that visitors from outside were found more abundantly at this season than during the rest of the year.

Special observations on the phytoplankton of Passamaquoddy bay, the Western Quoddy passage and the outer Quoddy region in September 1932. The violent currents which pass through the entrances to Passamaquoddy bay at every rising tide transport about 700,000,000 cu. feet (19,822,000 cu. m.) of water from the outer Quoddy region to the inner, and in the reverse direction at falling tide. The churning in the channels obviously mixes the waters which pass through, but the effect of this mixing on the waters inside and outside is less easily perceptible. Since this question of the interchange of water through the passages was of special interest in this investigation, a combined hydrographical and planktological study of the problem was made in the middle of September 1932.

Observations were made at high and low tide. Since we had only two boats at our disposal, the observations could not be made simultaneously, but they were carried out in such a way that at flood the inner stations were worked last and at ebb the outer stations last, so that presumably the maximal effect of the tidal transport should be obtained. At low water one station was worked in the inner part of Passamaquoddy bay and one in the outer Quoddy region, both in the regular localities for the monthly observations. In the passages three stations were worked during flood and two during ebb. The locations of the stations are shown in figure 43.

In September there was a remarkable difference between the plant communty within the bay and that outside. In the upper water layers in the bay, where the "inside or bay community" was purest, the dominant species was *Thalassionema nitzschioides*, which with its 100,600 cells per litre at 1 m., here numerically represented 94.9% of the total diatom population recorded (see tables LVI and LVII). At 7 m. it was relatively a little less abundant, with 85%, and at 20 m it only formed 61% of all diatoms. At station 5, in the outer Quoddy region, *Thalassionema nitzschioides* formed less than 5% at any of the depths at which we have observations. In this "outside community" *Asterionella japonica* and *Sceletonema costatum* were the dominant species, constituting more than 85% of all diatoms at every level.

In figure 45 the relative percentages which *Thalassionema* forms of the sum of the three species *Asterionella japonica*, *Sceletonema costatum* and *Thalassionema* have been used to show the distribution of the two communities.

At ebb tide the stations in the passages contain water which in its phytoplankton content is much influenced by the bay. The isoline for 50% *Thalassionema* is found at a lower depth at station 2 than in Passamaquoddy bay proper, which is shallower (1C), and even at station 4, in the outer part of the passage, the relative percentages of *Thalassionema* are at all depths above 25%.

At station 5 there is a pure "outside community" with a relative *Thalassionema* percentage of less than 5 (see figure 45).

At flood tide we have no observations for the innermost and the outermost stations, since it was considered to be highly probable that these stations would have the same characteristics at flood as at ebb tide. At station 4, in the outer passage, the outside community was at this phase of the tide to be found practically unchanged, while at 2A in the inner part, almost within the bay, the community was a mixture of the two, with a *Thalassionema*-percentage of between 18.2 and 27.4%.

The fact that the water of the bay and that of the outside region have such different communities as here recorded, shows that the interchange in the productive layers between the inner and the outer Quoddy region is not very intensive. The waters in the passages at ebb tide seem to consist of a

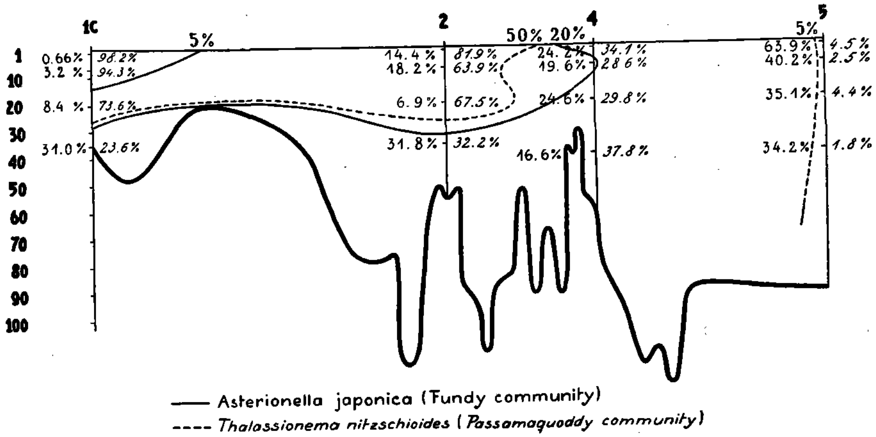


FIGURE 45. The relative distribution of *Asterionella* and *Thalassionema* in the Quoddy region in September 1932.

mixture of outside water and bay water. At high tide a great part of this water mass is forced into the bay, where it sinks down under the bay water proper, while outside water fills the outer part of the passage. On the border between the bay water and this inflowing water mixing takes place. The fact that the 35 m. sample at station 1C at ebb contained a far greater percentage of the outside forms than of the inside ones, is an indication that the population here has been brought in recently, because it seems improbable that the community should have propagated much in this locality, where light, according to the other phytoplankton observations and the oxygen observations, is hardly sufficient to maintain any considerable photosynthesis.

The observations at ebb, which show that the waters at station 5 contained very little of the inside community, viz., less than 5% of *Thalassionema*, indicate that the passage water only slowly influences the waters of the outer Quoddy region. Therefore, according to the phytoplankton observations it seems reasonable to consider the waters as if there were three different water masses. The **bay water,** to be found in the upper layers of Passamaquoddy bay; the **out-**

side water to be found in the outer Quoddy region; and as a third the **passage water,** which at low tide is to be found in the deeper layers of the bay and the inner part of the passages and in the whole outer part of the passages, while at flood tide it is to be found in the inner part of the passages and in the bottom layers of the bay. This distinction is in agreement with the hydrographical observations for this time of the year, and according to observations for June, the hydrographical situation is at that time much the same in regard to the interchange of the outside and inside waters of the Quoddy region (Watson unpub.).

The observations at station 2 for flood tide have not been taken into account, since the samples by mistake were not preserved. They were counted and although the results are not quite comparable with the others, there is one striking feature which is so pronounced that we shall mention it. The 1 m. sample at station 2 had 65.7% *Thalassionema*, so the waters were here decidedly of bay character, very much more so than at the station 2A inside (see figure 45). This observation is corroborated by the oxygen data.

The records of the percentages of oxygen saturation from these localities show such small differences that this property of the water cannot be generally used for tracing the various water masses in detail. There is, however, one striking feature, viz., that the water in the bay has a little higher oxygen percentage, above 90%, in the upper levels (1 and 7 m.) than elsewhere. In the lower levels and in the passages the percentages were about 87 to 90. The surface water at station 2 at flood tide has an oxygen percentage of 91.4%, which is in agreement with the planktological characteristic of this water as bay water. The hydrographical observations also support this identification (Watson unpub.). It therefore seems as if some tongue of bay water must have remained in the adjoining cove and drifted out or in some other way have been kept aside from the churning currents in the passage.

These few observations from the Quoddy region in September seem to indicate that the bay water is influenced by the mixing chiefly in the deep layers. The waters of the outer Quoddy region seem to be only little influenced by the water from the productive layer in the bay.

Biogeographical Remarks on the Phytoplankton

The picture which in the foregoing pages we have endeavoured to give of the shifting populations of phytoplankton in the waters of the bay of Fundy and the gulf of Maine, gives examples of the multitude of vegetations which are to be found wherever in temperate waters the phytoplankton is studied. For a comparison of the various vegetations it has proved useful to classify the species occurring in the plankton in biogeographical groups according to their general distribution. As principles for such a division into **plankton elements** (Gran 1902) may be used primarily (1) the relation of the species to the bottom, and, for subdivision, (2) their temperature requirements.

A. The **oceanic** species (Haeckel 1890) may survive for an unlimited number of generations in the open ocean, where the biological conditions are uniform. They are **holoplanktonic** (Haeckel) and have no dependence on the bottom in any stage of their life. In the coastal waters where the life conditions are variable, they may survive in smaller numbers also during winter, often representing the greater part of the scanty winter plankton.

B. The **neritic** species (Haeckel) occur in coastal waters, periodically, many of them as a very dense population of short duration. Most of them are **meroplanktonic** (Haeckel), surviving during unfavourable seasons as **resting spores** attached to algae or other substrata in the littoral zone. They may be drifting with currents far out in the open sea where their occurrence indicates an admixture of waters of coastal origin.

C. The **tychopelagic** species belong to the littoral zone, where they move along the bottom in shallow waters or grow attached to algae, hydroids and similar objects; but they may be washed out from the shores, often in considerable numbers, particularly in turbulent waters. Of the numerous littoral species only a few occur so regularly in the plankton that they are observed in the centrifuged water samples. Some of the littoral diatoms, as some of the *Licmophora* species, may grow attached to pelagic animals, particularly on the abdomen of copepods, such as *Centropages*.

A subdivision of these groups has been made according to the temperature requirements of the species. Gran (1902) distinguished in the North Atlantic **arctic, boreal** and **temperate-atlantic** species. The distinction must be more or less arbitrary, because many of the species are eurythermic, and because at each locality the temperature changes with the season, favouring the growth of arctic or northern species in early spring, while in August and September the conditions are more favourable for species which have their main distribution farther south. Nevertheless, a distinction of plankton elements on these principles has been possible. In the following we have tried to arrange the species of phytoplankton of our area in such biogeographical elements, omitting until more observations are available, such species as are observed in so small numbers that their biological relations are doubtful.

A. OCEANIC SPECIES

A1. The arctic oceanic plankton element.

Ceratium arcticum
Dinophysis arctica

A2. The boreal oceanic plankton element.

Chaetoceros atlanticus
" *borealis*
" *convolutus*
" *decipiens*
Coscinodiscus centralis
" *curvatulus*
" *radiatus*
Nitzschia delicatissima
" *seriata*
Rhizosolenia hebetata-semispina
Thalassiothrix longissima
Ceratium longipes
Peridinium depressum
" *ovatum*
" *pallidum*

A3. The temperate oceanic plankton element.

Chaetoceros densus	*Ceratium bucephalum*
Corethron hystrix	" *fusus*
Rhizosolenia alata	" *tripos*
" *imbricata v. Shrubsolei*	*Dinophysis acuta*
" *styliformis*	*Peridinium crassipes*
	Coccolithus pelagicus
	Pontosphaera Huxleyi

It may be added that members of a subtropic oceanic plankton element may occur occasionally as visitors, particularly in September, as for instance, *Rhabdosphaera stylifera.*

B. NERITIC SPECIES.

B1. The arctic neritic plankton element.

To this group Gran (1902) referred only the purely arctic species, while those which occur in boreal waters are included in the next group.

Achnanthes taeniata	*Fragilaria oceanica*
Asterionella kariana	*Navicula Vanhöffeni*
Bacteriosira fragilis	*Thalassiosira hyalina*
Chaetoceros furcellatus	

B2. The boreal neritic plankton element.

Biddulphia aurita	*Coscinosira polychorda*
Chaetoceros compressus	" *Östrupi*
" *debilis*	*Detonula confervacea*
" *diadema*	*Leptocylindrus danicus*
" *laciniosus*	" *minimus*
" *pseudocrinitus*	*Porosira glacialis*
" *radicans*	*Rhizosolenia fragilissima*
" *similis*	*Rhizosolenia setigera*
" *simplex*	*Sceletonema costatum*
" *socialis*	*Thalassionema nitzschioides*
" *teres*	*Thalassiosira bioculata*
Exuviaella baltica	" *decipiens*
Dinophysis acuminata	" *gravida*
" *norvegica*	" *Nordenskioeldi*

B3. The temperate neritic plankton element.

Actinocyclus Ehrenbergi	*Dactyliosolen mediterraneus*
Asterionella japonica	*Ditylum Brightwelli*
Biddulphia regia	*Eucampia recta*
Cerataulina Bergoni	" *zoodiacus*
Chaetoceros affinis (incl. *v. Willei*)	*Guinardia flaccida*
" *brevis*	*Lauderia borealis*
" *cinctus*	*Streptotheca thamesis*
" *constrictus*	*Gonyaulax tamarensis*

Chaetoceros danicus	*Peridinium faeröense*
" *didymus*	" *triquetrum*
Coscinodiscus excentricus	" *trochoideum*

C. TYCHOPELAGIC SPECIES.

All the littoral species observed in our plankton samples are most naturally referred to the boreal group.

C2. The boreal tychopelagic plankton element.

Actinoptychus undulatus
Biddulphia alternans
Melosira sulcata
Navicula distans
Nitzschia closterium
Pleurosigma Normani

Although our area of investigation is located between latitudes 41° and 43° N., the phytoplankton is of much the same character as that of the northern European waters, located 20° or more further to the north. The great majority of species are common to both sides of the Atlantic. Only one neritic diatom, *Coscinosira Oestrupi*, is characteristic of the American side, and those parts of the open Atlantic influenced from American waters. On the other hand, two species are very common and often abundant on the European side, but not at all observed in our material from the bay of Fundy and the gulf of Maine, viz., the temperate neritic diatom *Chaetoceros curvisetus* and the temperate oceanic dinoflagellate, *Ceratium furca.*

The species which are the most important ones in the production in our area belong to the boreal and temperate plankton elements. In spring the boreal neritic element dominates the rich production, not only in the bay of Fundy and along the coast of the gulf of Maine, but also in the offshore waters of the gulf. In summer the temperate species take the lead, oceanic species in the offshore parts of the gulf, and neritic species along the coasts and in the whole bay of Fundy.

The whole productive season is shorter in the bay of Fundy than in northern European waters. The rich diatom population of spring may in Skagerack, about 59° N., have its beginning in the first part of February, while the same society of species in the bay of Fundy is to be found beginning the latter half of March. In the bay of Fundy the phytoplankton was already decreasing in September, while in Skagerack a rich plankton of diatoms or dinoflagellates may be found even in November. The seasonal periodicity of the individual species also shows some differences. *Chaetoceros constrictus*, for instance, on the coast of southern Norway has a regular maximum in April, while in the northern part of the gulf of Maine and in the bay of Fundy it does not occur in abundance until August. *Sceletonema costatum*, one of the dominant neritic diatoms of the bay of Fundy, here a distinct summer species, very scarcely or not at all represented in the spring plankton, is along the Norwegian coast and also in Scotland (loch Striven, Marshall and Orr 1927) one of the very first species which occurs in abundance in early spring. On the European coasts it may also occasionally form a dense local population at other seasons, thus appearing as a distinctly eurythermic species.

The phytoplankton populations of the various waters in the region do not change or succeed each other in the same way. The sequence of vegetations from season to season differs considerably according to locality and it might have been an interesting problem to follow these changes in detail and trace the connections with the factors of the habitat. Our material is, however, too scanty to allow any such study, so we shall confine ourselves to a broad summary of the main types of populations, which were observed in our material. We shall then distinguish between six main types of phytoplankton vegetations, in the sense defined above (see page 332).

1. A **winter vegetation**, composed of members of five plankton elements, viz., boreal tychopelagic, boreal neritic and oceanic, temperate neritic and oceanic forms. The number of species is fairly large while the quantities of each species, as well as of the total population, are small.

2. A **spring diatom vegetation** of boreal neritic species. This type of vegetation is quantitatively perhaps the most important one, since it is represented by the enormous populations which in late March and April are to be found in the greater part of the area. The composition varies somewhat according to the locality and the season, but the following species always form important parts of it: *Thalassiosira Nordenskioeldi*, *Porosira glacialis*, *Chaetoceros debilis*, *compressus* and *diadema*. The accompanying dinoflagellates are numerically of subordinate importance.

3. A **summer diatom vegetation**, with boreal and temperate neritic species as the most prominant ones. The occurrence of this type of vegetation may be somewhat more local than that of the previous ones. In some localities, however, it is very abundant and doubtless of great importance for the productivity of the waters. The most important members are: *Asterionella japonica*, *Chaetoceros constrictus* and *Sceletonema costatum*.

4. A **summer dinoflagellate vegetation** of temperate neritic and boreal and temperate oceanic species. In summer (the actual time varies considerably from one locality to another) the diatom vegetations are succeeded by a vegetation which is dominated by flagellates. In the offshore waters this vegetation is made up of oceanic species, mostly temperate ones, but also boreal ones (*Ceratium longipes*), while in inshore waters the most important members of the vegetation are of temperate character (*Gonyaulax tamarensis*, *Peridinium faeroense*, *triquetrum* and *trochoideum*).

5. A **coccolithophoride vegetation** with *Pontosphaera Huxleyi* as the main component.

The composition of these different vegetations is conditional upon so many factors, of which the greater number indirectly are dependent upon the hydrographical conditions, that it has to be subject to great changes from place to place and from one year to another. It would be impossible to draw up a scheme for the sequence of vegetations for any locality in the area which would be valid for every year. When we consider the conditions in the year 1932, we have to be aware that another year the discordance with this sequence may be considerable. From the gulf of Maine and the coast of northern Europe, we have striking examples of changes in the seasonal sequences. The sudden appearance of a numerous *Asterionella japonica* population in the offshore waters of the gulf of Maine in 1912 (Bigelow 1926) and along the coast of Norway in 1927 (Gran 1929), radically changed the composition of the vegetation which usually occurs in these waters at this time of the year. Similar changes, although on a much smaller scale, seem to be regularly occurring in inshore waters and are also sometimes noticeable far out from the shore (Gran 1930).

In the bay of Fundy the sequence of plankton vegetations in 1932 may be roughly summarized in the following way. A scanty winter vegetation (type 1) was followed by a spring diatom vegetation (type 2) which reached a great abundance at very different times in the various localities of the bay. It started in the sheltered bay of Passamaquoddy and the Quoddy region (with a simultaneous flowering in a restricted area of the very central part of the bay), while in the inner part of the bay the winter plankton prevailed until late in spring. After a period of great poverty in phytoplankton at midsummer (June-July), during which a scanty mixed diatom-dinoflagellate-*Eutreptia*-population reached some abundance in a few localities only, a summer diatom vegetation (type 3) and in some places a summer dinoflagellate vegetation (type 4) of neritic character was predominant all over the Fundy region. The composition of the diatom vegetation was rather uniform in the bay of Fundy proper, while in Passamaquoddy bay a local vegetation with other dominant species was found.

In the gulf of Maine the sequence proceeded differently. A similar winter plankton (1) probably was vegetating through the first part of the winter, but as early as in March, the spring diatom vegetation (2) must have been in full development in the offshore waters and parts of the inshore region, where it became numerous mostly a little later. This immense flowering of diatoms was followed by a summer dinoflagellate vegetation in the offshore waters (type 4), while in the bays and inshore parts of the gulf, a diatom vegetation (3) was abundant till late in summer. The diatom vegetation in summer, may, according to Bigelow (1926), occur rather far out in the gulf, but its occurrence seems to be capricious. The dinoflagellate vegetation was found all through the summer, only in some localities replaced by a scanty coccolithophoride vegetation (5) with *Pontosphaera Huxleyi* predominant. This last type of vegetation was not very numerous in either of the summers of 1932 and 1933 (Gran 1933, Braarud 1934) and was mostly restricted to the warmest water layers. According to the observations from the gulf in the said two summers, there seem to exist considerable variations in the abundance of these two summer vegetation types.

The seasonal changes in the phytoplankton population which have been described from the gulf resemble remarkably those which have been observed in northern European waters (Gran 1929, 1930; Ostenfeld 1913). The causes of these changes shall be discussed in the following chapter, in which the conditions of phytoplankton productivity are treated.

The circulation of the water masses in the bay of Fundy and the gulf of Maine makes it difficult to trace the **successions** of phytoplankton populations within restricted water masses. Only in such localities as Passamaquoddy bay or in the central part of the gulf, one might be able to study the successions in detail, if one had more complete material than the present. Davidson's (1934) observations for the Quoddy region throughout the year for seven and one half consecutive years, gave as a result that the following species there are regularly found to succeed each other as dominants in the net haul catches: *Biddulphia aurita*, *Thalassiosira Nordenskiöldi*, *Chaetoceros debilis* and other species of this genus, but there seem to be considerable differences in the details of the successions for the various years. Our few observations for the Quoddy region are in accordance with Davidson's results.

REMARKS ON THE SPECIES

List of New Species and Forms

Diatoms

For this group we have followed the nomenclature and classification of Hustedt (1930). Only in a couple of cases changes have been introduced and in each case we have stated our reasons for doing so.

Amphiprora alata Kützing

A littoral species, recorded from station 11A, September 1931.

Achnanthes taeniata Grunow

This species was only observed at the station south of Nova Scotia (N190 and N197) April 20 to 23, in numbers up to 800 chains per litre. It is a neritic species, growing abundantly only in icy waters, as on the coasts of the Arctic ocean and—in early spring—in the Baltic.

Actinocyclus Ehrenbergi Ralfs

Scarce and scattered over the whole area, observed from June to September in numbers up to 40 per litre.

Actinoptychus undulatus (Bailey) Ralfs

Observed from April to September, more often in the bay of Fundy than in the gulf of Maine, always scarce, in numbers up to 60 per litre. At station 190 south of Nova Scotia, April 20, 1932, it was found in a frequency of 200 to 500 per litre. It is a tychopelagic species with a wide distribution, occurring in the plankton mostly in turbulent waters.

Asterionella gracillima Hassall

This species, common in fresh water plankton, was found at the surface at two stations, 12 and 13, outside the Saint John river in May 1932.

Asterionella japonica Cleve

In August, this species had a distinct yearly maximum; it was observed in decreasing numbers during September, was scarce in March, April and May, and not recorded at all in June. It was more abundant in the bay of Fundy than in the gulf of Maine, with its centre of distribution around Grand Manan. The highest frequency observed was 45,000 cells per litre at station 6, August 18, 1932. At this station also in September 1931 it had its maximum, viz., 14,000 cells per litre. In the gulf of Maine it was more common along the coast than in the open gulf.

Bigelow reports this species to have been quite predominant in August 1912, from Grand Manan channel across the mouth of Penobscot bay (Bigelow 1914, p. 133; 1926, p. 431). In 1932 it was always subordinate to other species, particularly to *Sceletonema costatum*, which had its maxima at the same stations as *Asterionella*. In European waters it has its centre of distribution in the English channel and the southern North Sea, with a maximum in April. In 1927 it was found in enormous numbers as far north as the Romsdal coast, Norway (Gran 1929), where it in April replaced the rich population of *Sceletonema costatum*, which had been regularly observed in other years.

Asterionella kariana Grunow

Some few chains of this arctic-neritic species were found from April to September in the bay of Fundy, particularly along the New Brunswick coast and at station N190, south of Nova Scotia (in April). Its maximum of frequency was 500 cells per litre at station 11A, May 19, 1932, and in the Grand Manan channel, station 14, September 1932.

Bacteriosira fragilis Gran

Like the previous one, this is also an arctic species which was observed in April, viz., at two stations south of Nova Scotia, N192 and N194, in numbers of 2,400 cells per litre, and in Passamaquoddy bay in a number of 4,000 per litre.

Biddulphia alternans (Bailey) VanHeurck

At a couple of stations in the bay of Fundy in September 1931 (6 and 11A), this littoral species was observed in the plankton.

Biddulphia aurita (Lyngbye) Brebisson et Godey

This is a widely distributed littoral species which usually has a short period of growth as a neritic diatom in spring. It was found in the bay of Fundy as well as along the coast of Maine, but most abundantly (up to 6,000 cells per litre) at station N190 south of Nova Scotia. Scattered individuals were observed also at other seasons.

Biddulphia regia (Schulze) Ostenfeld

This species, specifically different from *B. mobiliensis*, with which it has been confounded, was observed in small numbers, up to 80 per litre, in September 1931 and 1932, in the bay of Fundy and Grand Manan channel. Davidson (1934) has found it to be rather abundant in the shallow inner part of the bay. From this locality it is also reported by Bailey (1915), as *B. mobiliensis*, to be locally abundant in August (Bigelow 1926, p. 433).

In Europe it is relatively abundant in the shallow waters of the English channel and the southern part of the North sea.

Cerataulina Bergoni H. Peragallo

From May to September, this neritic species is distributed over the whole area, but is always scarce. In Passamaquoddy bay it had a maximum of 16,000 cells per litre (July 30, 1932), but elsewhere its frequency did not exceed 5,000 per litre (station 34, August 1932).

Chaetoceros affinis Lauder, incl. var. *Willei* (Gran) Hustedt

This neritic species was found from May to September in the gulf of Maine as well as in the bay of Fundy, but as a rule scarce only, rarely in numbers above 1,000 cells per litre. A maximum was found in June at stations 27 and 28, with 16,000 per litre at station 28. In May the highest figure (1,100) was recorded at station 30. In September 1931, it had a slight maximum in the bay at station 6, with nearly 1,000 cells per litre.

On the coasts of northern Europe, *Ch. affinis* is most common in late summer and autumn; it seems to be favoured by relatively high temperatures.

Chaetoceros atlanticus Cleve

This oceanic species is rather rare in the area. The maximum of frequency observed was 100 cells per litre.

Chaetoceros borealis Bailey, (including *Ch. concavicornis* Mangin)

This is an oceanic species with a pronounced northern distribution. *F. typica*, (Braarud 1935), was observed in a number of 1,000 per litre at station 28, in August, but otherwise mostly in numbers of 100 per litre or less. *F. concavicornis*, (Braarud 1935), was found to be widely spread, particularly in April and May, but always scarce, mostly in numbers up to 1,000 per litre.

Chaetoceros brevis Schuett

Observed only on three occasions. At station 30, 300 cells per litre were recorded in August.

Chaetoceros ceratosporus Ostenfeld

A specimen without resting spores was classified as belonging to this species. It was observed at station 32 in May.

Chaetoceros cinctus Gran

In August this species was very abundant at two stations near the coast of Maine, stations 30 and 27. Elsewhere it was rare.

Chaetoceros compressus Lauder

This species has a very wide distribution and is one of the commonest *Chaetoceros* species in our area. In April it was rather abundant in the arctic diatom plankton south of Nova Scotia (stations N192 and N197) with up to 60,000 cells per litre, and fairly common but not abundant at most stations in the gulf of Maine (maximum 46,000 at station 31), more scarce in the bay of Fundy. In May it was observed at nearly all stations in the gulf of Maine, with maxima at the stations 29 and 31 (up to 36,000 per litre), and in the south-eastern part of the bay of Fundy (stations 7, 36 and 37). In June it had formed a new maximum at the coastal stations of the gulf of Maine (30, 27 and 28). At station 30 it reached a frequency of 214,000 cells per litre. Elsewhere, it was rare and observed mostly as resting spores in the deeper layers. In August it was still concentrated along the coast of Maine (stations 25A, 27 and 30) with a maximum of 60,000 per litre at station 27, but scattered and rare at the other stations, where small numbers of resting spores were found (see figure 69). In September it was rare in the bay of Fundy, both in 1931 and in 1932. In Passamaquoddy bay it is never abundant, according to Davidson's observations (Davidson 1934). We found at the end of July, 2,000 per litre at a depth of 40 m., probably introduced from the outer Quoddy region.

It is remarkable that *Ch. compressus* was found to be abundant in the cold water south of Nova Scotia in April, while on the other hand, it had its maximum along the coasts of the gulf of Maine in the warmest season. In north European waters, its main growth usually takes place after the spring growth of the cold water species (*Thalassiosira* and *Ch. debilis*) has declined.

Chaetoceros concavicornis Mangin, see *Ch. borealis f concavicornis*

Chaetoceros constrictus Gran

It is remarkable that this species, which in northern European waters occurs most abundantly in April and May, in our area has its annual maximum in the warmest season, in August. It seems to have its centre of distribution along the coast of the gulf of Maine (stations 27, 30, 32, 33 and 34) and in the waters flowing into the bay of Fundy along the Nova Scotian coast (stations 8A and 37). At the two last named stations it reached a maximum of about 75,000 cells per litre. In the gulf of Maine (stations 27 and 30) it had already begun to grow in June, with 3,000 to 5,000 cells per litre. It was rather rare in the bay of Fundy in September, and had then (1931) a maximum of 2,000 per litre at station 6, north-east of Grand Manan, the only station where a rich diatom growth was still going on.

Chaetoceros convolutus Castracane

This species was found to be widely distributed over the area, particularly in April and May, but always in small numbers, usually less than 1,000 cells per litre. A maximum of 10,000 per litre was found at station 24A, April 1932.

Chaetoceros danicus Cleve

On two occasions this species was observed in the bay of Fundy, viz., at station 37 in August 1932, and at station 6 in September 1931. It is usually found in water of low salinity.

Chaetoceros debilis Cleve

This is the commonest of the neritic *Chaetoceros* species. On the northern European coast it is an important member of the diatom populations propagating just after the temperature minimum of early spring (March-April) and may be quite dominant, when the temperature is about 5 to 6°. Where it is lower, as in Skagerack, *Thalassiosira Nordenskioeldi* usually is the dominant species.

In our area *Ch. debilis* is in April and May subordinate to *Thalassiosira*, but where the diatom growth continues till June, as along the coast of Maine and in Passamaquoddy bay, *Ch. debilis* dominates the diatom vegetation after the decline of *Thalassiosira* (Davidson 1934).

In April 1932, the maximum of *Ch. debilis* was at station 24A, at the south-western corner of our area, with 75,000 cells per litre, while its maximum had already passed at the outermost station (26), where remains of its vegetation were found in deep water, with nearly 15,000 per litre at a depth of 75 m.

In May it had nearly disappeared from the south-western part of the gulf of Maine (stations 23A to 26), and the maximal frequency was found farther in, with 65,000 per litre at station 29 and 80,000 at station 31. In the bay of Fundy, the highest figures were 23,000 at station 7 and 27,000 at station 36.

In June it had increased strongly along the coast of Maine, at our stations 24A (where it was sinking and forming resting spores), 27, 28, (resting spores) and 30. At this last station it reached its highest number, 708,000 cells per litre. Also in Passamaquoddy bay it was the dominant species with more than 150,000 cells per litre. At all other stations *Ch. debilis* was in June rather scarce.

In August it had greatly decreased, even at the coastal stations, where a rich diatom plankton still prevailed. At station 23A only 10,000 per litre were found, at station 27, 12,000, and at station 30, 8,000. In September 1931 and 1932 *Ch. debilis* was rare everywhere in the bay of Fundy.

Chaetoceros decipiens Cleve

Of the oceanic *Chaetoceros* species this is by far the commonest one over the whole area and at all seasons, but its frequency is rarely above 1,000 per litre. The highest figure recorded was 3,600 at station 30, August 1932.

Chaetoceros densus Cleve

This oceanic species was scarce, but was observed in small numbers up to 700 per litre at some stations in August, quite rarely at other seasons.

Chaetoceros diadema (Ehrenberg) Gran. Syn. *Ch. subsecundus* (Grunow) Hustedt.

The name *Syndendrium diadema* Ehrenberg was based upon the resting spores, the stage in its development first known, just as *Dicladia mitra* Ehr. and *Chaetoceros didymus* Ehr. We find no reason to replace these names by newer ones.

This neritic species, common also in the Arctic, had its maxima in April and May. In April it was more abundant in the gulf of Maine than in the bay of Fundy, with a maximum of 40,000 cells per litre at station 31. In May it was observed at nearly all stations in numbers up to 10,000 per litre, rather more abundantly in the bay of Fundy than in the gulf of Maine. In June it was more scarce, but with a local maximum of 16,000 per litre at station 30, and in August-September its numbers were decreasing.

Chaetoceros didymus (Ehrenberg) Cleve

On the coasts of northern Europe this neritic species has its maxima at relatively high temperatures in late summer and autumn. In this area it was observed as single chains distributed over the whole area in April, May, August and September. It is remarkable that its highest frequency, 2,000 to 4,000 per litre, was found in April at two stations south of Nova Scotia, N192 and N197, where it lived in cold waters together with *Thalassiosira* and such arctic species as *Fragilaria oceanica* and *Achnanthes taeniata.*

Chaetoceros furcellatus Bailey

This is an arctic-neritic species, easily recognized by its resting spores. In the vegetative state it may have been overlooked. It was common in April and particularly in May, but scarce in June, and then mostly as single pairs of resting spores. The highest frequency observed was 70,000 per litre in Passamaquoddy bay in the last days of April.

Chaetoceros laciniosus Schuett

At all seasons this species is common over the whole area, but never abundant. It was more common from April to June than in August and September and had maxima of frequency in the inner part of the gulf of Maine, in April and May at station 31 (14,000 and 5,000 per litre), and in June at station 30 (13,000 per litre), where at the same time *Ch. cinctus* and *compressus* were abundant.

Chaetoceros pseudocrinitus Ostenfeld

Observed only once, at station 24A in June.

Chaetoceros radicans Schuett. (syn. *Ch. scolopendra* Cleve)

This was scarce in April, rather common in May with a maximum of 10,000 per litre at station 31, scarcer in June, but with a maximum of 15,000 at station 30. In August it was on the whole very scarce, but at one station (14) in the Grand Manan channel, 9,000 per litre were recorded. It was rare in the bay of Fundy in September.

Chaetoceros similis Cleve

This is a widely distributed neritic species, which never has been found to be abundant. In our area it was observed only once, viz., at station 30 in June.

Chaetoceros simplex Ostenfeld (figure 46).

This little species is as a rule an inhabitant of shallow, more or less closed bays, often with brackish water. It had a distinct maximum of up to 800 cells per litre in Passamaquoddy bay, from July to September. At other localities it was observed as single specimens from June to September.

Chaetoceros socialis Lauder

This is a neritic species with a very wide distribution, occurring abundantly on the coasts of northern Europe in early spring. In our area it was observed on only a few occasions in the bay of Fundy in April and May. At station N197, south of Nova Scotia, it was rather abundant at the end of April, at a depth of 40 m. Miss Davidson has observed it in Passamaquoddy bay (Davidson 1934).

Chaetoceros subtilis Cleve

Observed only once, at station 5 in the bay of Fundy, September 1931.

Chaetoceros teres Cleve

The highest number recorded was 900 cells per litre, in Passamaquoddy bay in June, 1932. It was observed rarely in June and August.

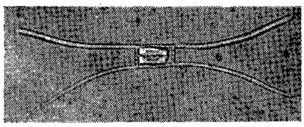


FIGURE 46. *Chaetoceros simplex.*

Corethron hystrix Hensen

This is an oceanic species with a wide distribution in northern waters. It has never been observed as dominating the phytoplankton, as the much larger, closely related species, *C. Valdiviae*, does in the Antarctic. In our material *C. hystrix* occurred rather regularly in August. It was commonest in the gulf of Maine, with a maximum of 300 cells per litre at station 27, and also rather common in those parts of the bay of Fundy which were influenced by the gulf (station 8A). In September it had decreased in number. It was observed also from April to June, but more scattered. At station 31 in the gulf of Maine fair numbers (100 to 200 per litre) were observed both in April and in June.

Coscinodiscus excentricus Ehrenberg

This was the only representative of its genus regularly observed in the centrifuge samples. It was commoner in August-September than earlier in the season and had a distinct maximum in the bay of Fundy, particularly around Grand Manan, in the Quoddy area and along the coast of New Brunswick. Its maximum of frequency, 160 cells per litre, was observed at station 6, September 1931. It seems to have a distribution similar to *Ditylum Brightwelli* and is certainly a neritic species.

The larger species *C. centralis* Ehrenberg, *C. concinnus* W. Smith and *C. radiatus* Ehrenberg were only occasionally observed in the centrifuge samples, one or two specimens in 50 cc. *C. curvatulus* Grunow was observed rather regularly in May, commoner in the deeper layers than at the surface, in numbers up to 100 per litre (station 34, 40 m.). At the other seasons it was rare. *C. stellaris* Roper was observed once, and *C. cinctus* Kuetzing three or four times.

Coscinosira Oestrupi Ostenfeld

This was observed over the whole area at all seasons, from April to September, most abundantly in April (maximum 18,000 per litre at station 31) and May (maximum 3,400 at station 5). It was scarce in June, but occurred again regularly in August, in numbers up to 700 per litre at some offshore stations in the gulf of Maine (17, 23A).

Coscinosira polychorda Gran

This occurred at all seasons, mostly in numbers from 200 to 600 per litre, most regularly in August. At station 23A, as many as 19,000 per litre were recorded on the 11th of August, at a depth of 40 m., and 10,000 at station 28, on April 30. On the coasts of northern Europe, it usually has its maximum in winter, like *Thalassiosira decipiens*.

Dactyliosolen mediterraneus Peragallo

This was observed once, at station 28, in August. It was, as usual, infected with the flagellate *Solenicola setigera*.

Detonula confervacea Cleve

This was observed only in June, but was then rather common at some stations in the central and outer parts of the bay of Fundy, with a maximum of 12,960 cells per litre at station 36.

Ditylum Brightwelli (West) Grunow

This had its maximum in August-September, but was also observed in March and April. It was most abundant around Grand Manan and along the New Brunswick coast. At station 6 it had a maximum of 1,420 per litre in September 1931 and 1,000 in August 1932. The specimens were all relatively small.

Endictya oceanica Ehrenberg

Single specimens were observed from April to June.

Eucampia recta n. sp.

Cells single or in chains of 2 to 4 cells, straight, thin-walled, with few (4 to 6) chromatophores. Processes thin and straight, nearly cylindrical. Diameter of the cell (apical axis) 12-23 μ, length (including the processes) 42-64 μ.

This little species, of which we had rather little material, is distinguished from the slender specimens of *E. zoodiacus* (f. *atlantica*) by the straight cells and the slender and long processes. It was observed only in June, with a maximum in the central and outer parts of the bay of Fundy (2,720 per litre).

Eucampia zoodiacus Ehrenberg

This neritic species was observed from April to June and rarely in August (station 33). It was never abundant; in May it occurred more regularly on the coast of the gulf of Maine than elsewhere, with a maximum of 2,000 cells per litre at station 29.

Fragilaria oceanica Cleve

This arctic-neritic species was observed only in April, rare at all localities except south of Nova Scotia, where it had a maximum of 97,000 cells per litre at a depth of 40 m.

Guinardia flaccida Peragallo

This large and beautiful diatom occurred only sparsely in our samples, from June to September. In September 1931, it had a distinct maximum in Passamaquoddy bay, with 460 cells per litre.

Leptocylindrus danicus Cleve

This is a neritic species which on northern European coasts may be very abundant and even dominant in May and June. In our area it occurred from May to September, but was never abundant. The highest figures recorded were 3,000 cells per litre at station 30 in June, and 5,000 in Passamaquoddy bay in July.

Leptocylindrus minimus Gran

This is a very small species with about the same distribution as the preceding one. Its maximum of frequency along the coast of Maine was found to be in June (8,000 per litre at station 30), and in Passamaquoddy bay in July.

Melosira sulcata (Ehrenberg) Kuetzing

This is a tychopelagic species, probably not propagating in the plankton. Nevertheless it was found in the centrifuged samples at nearly every station at all seasons, more regularly in the bay of Fundy than in the gulf of Maine, and commoner in April and May than in the warmer season, in numbers up to 3,000 to 4,000 cells per litre.

Navicula distans W. Smith

This is a littoral species with thick cell walls, occurring regularly in the plankton samples over the whole area at all seasons in the same way as *Melosira sulcata*, but less abundantly, with 100 cells per litre as its maximum. It was commoner in the bay of Fundy than in the gulf of Maine.

Navicula Vanhöffeni Gran

This is an arctic-neritic species. It was observed only in April at station N197, south of Nova Scotia.

Nitzschia closterium W. Smith

This is a littoral species with a wide distribution, regularly found moving in the mucilaginous walls of the littoral algae. It also occurs regularly in the plankton and was recorded at nearly every station, and through the whole year, always quite scarce. In most cases only up to 100 cells per litre were found, at some stations in the bay of Fundy 300 to 400, and on one occasion, in Passamaquoddy bay, July 27, about 2,000 per litre.

Nitzschia delicatissima Cleve

This widely distributed species may perhaps be regarded as oceanic, although it is also often abundant in inshore waters. In our samples it occurred rather regularly from March to September, but was as a rule scarce. The highest figures recorded were in the bay of Fundy in September 1931, at station 6, where it reached a frequency of nearly 10,000 cells per litre. Another maximum of about 4,500 per litre, was found in Grand Manan channel in August 1932.

Nitzschia seriata Cleve

This occurs under the same conditions as *N. delicatissima*, often in its company. In our area it was found regularly from March to September, on the whole commoner than *N. delicatissima*, in numbers up to 8,000 cells per litre, and with a maximal frequency in the inner parts of the gulf of Maine.

Pleurosigma sp.

Single cells of *Pleurosigma*, in most cases *P. Normani* Ralfs, were found at all seasons in numbers up to 100 per litre. All species of this genus are littoral, but occur under the same conditions as *Navicula distans*, as tychopelagic members of the plankton, in turbulent waters, mostly near to the coast.

Porosira glacialis (Grunow) Joergensen

This is an arctic-neritic species, occurring in the *Nordenskioeldi*-plankton in early spring. Its maxima were found in April in the inner part of the gulf of Maine. At station 28 it reached a frequency of 29,000 cells per litre, and at the stations 30 and 31, 18,000 and 15,000 per litre. It was less common in the bay of Fundy and had decreased in number in May. In June and August it was quite rare.

Rhizosolenia alata Brightwell

This oceanic species occurred from April to June and was quite scarce, in numbers up to 100 per litre. In August it was common in the gulf of Maine, except at the stations near the coast, with a maximum of 5,000 to 6,000 per litre at stations 26, 28 and 29. About the same numbers were found in the central and inner parts of the bay of Fundy. In September it was rare in 1932 and not observed in 1931.

Rhizosolenia fragilissima Bergon

This is a neritic species observed from April to September over the whole area, mostly in small numbers, up to 1,000 per litre, but with a distinct maximum in June, particularly at the coastal stations in the gulf of Maine (27 and 30), and in the outer part of the bay of Fundy (stations 33, 34 and 8A). Here numbers from 5,000 to 8,000 were recorded.

Rhizosolenia hebetata Bailey, f. *semispina* (Hensen) Gran

This species was found regularly from April to June, but was never abundant. Its maximum of frequency was 300 per litre (station 31 in April). In August and September it was quite scarce. In the tables it has been referred to as *R. semispina.*

Rhizosolenia setigera Brightwell

This occurred from April to September over the whole area, but was always scarce, 100 cells per litre or less.

Rhizosolenia imbricata Brightwell, var. *Shrubsolei* (Cleve) Schroeder

This oceanic species was found in August and September, over the whole area, in numbers up to 1,500 per litre.

Rhizosolenia styliformis Brightwell

Of this large oceanic species, only single specimens were observed in the centrifuge samples, from March to August.

Sceletonema costatum (Greville) Cleve

This is a boreal-neritic species, which on the European coasts may occur abundantly at all seasons, but most regularly in early spring, and then often as the dominant species. In our area it has distinctly its maxima in the warmest season. It was observed in small numbers, up to 3,000 per litre, in the bay of Fundy during April and May, and south of Nova Scotia 20,000 cells per litre were found at station N197, on April 23. In June it was still scarce, but with a local maximum at the surface at station 25A, close to the coast of Maine. It was very abundant, with up to 780,000 cells per litre in Passamaquoddy bay in July. In August it occurred over the whole bay of Fundy with a distinct maximum in the outer part (stations 6, 7, 14 and 35) in numbers up to 500,000 cells per litre. In the gulf of Maine its mass occurrence was limited to the coastal stations (27 and 30) with maxima of 15,000 to 20,000 cells per litre. In September it had on the whole decreased in numbers, only at station 6, inside Grand Manan, still about 150,000 per litre were found.

Streptotheca thamesis Shrubsole

This species is a characteristic inhabitant of the shallow waters of the English channel. In our material it was only observed on three occasions in the inner part of the bay of Fundy in September (stations 11A, 12 and 13) and once on the coast of Maine in June.

Thalassiosira bioculata (Grunow) Ostenfeld

This was observed at many stations in March, April and May, but it was always scarce, with numbers less than 400 per litre. It was quite rare in June and not observed later in the season.

Thalassiosira decipiens (Grunow) Joergensen

Although this species never occurred in great numbers, it was by far the commonest of all the diatoms in the area, observed at all seasons (March to September) and nearly at every station. It had its maxima in April (12,000 cells per litre at station 31, and 9,000 at station 34). In May it was more frequent at some stations in the bay of Fundy (3,000 to 4,000 per litre at stations 11A, 12, 13 and 14) than in the gulf of Maine. In June its numbers had decreased slightly, but at the end of July it was relatively abundant (8,000 per litre) in Passamaquoddy bay. In August it had a local maximum of 14,000 per litre at station 23A in the gulf of Maine, but elsewhere it was rather scarce. Only at station 6 up to 2,600 per litre were found. In September the situation was about the same with a slight maximum of 4,000 at station 6, northeast of Grand Manan.

In European waters *Th. decipiens* has a similar distribution; it is very common, but never abundant. It usually is relatively prominent in the plankton in winter and probably has a slow rate of propagation and relatively low light requirements.

Thalassiosira gravida Cleve

This is rather common, but abundant only in April, particularly in the gulf of Maine, with maxima up to 100,000 cells per litre at stations 28 and 31. It was rather abundant also south of Nova Scotia with a maximum of 51,000 per litre at station N197. Resting spores were observed, but not in any great numbers.

Thalassiosira hyalina (Grunow) Gran

This distinctly arctic species was found abundantly only south of Nova Scotia in April, with a maximum of 55,000 cells per litre at station N197. In the gulf of Maine and the bay of Fundy, it was observed only in April, and was then rather scarce, in numbers up to 3,400 cells per litre at station 34.

Thalassiosira Nordenskioeldi Cleve

This species was dominating the diatom plankton in April and May over the whole area except along the New Brunswick coast in the bay of Fundy. In April its highest numbers (700,000 per litre and more) were recorded near the coasts of the gulf of Maine (stations 24A and 30) and in Passamaquoddy bay up to 500,000 per litre were observed at the end of the month. In May the numbers had decreased in the gulf of Maine, although it was still the dominant species. It had on the other hand increased in the outer part of the bay of Fundy, with maxima of 200,000 to 400,000 per litre in Grand Manan channel and outside Passamaquoddy bay (station 5). It was the dominant species also in the waters south of Nova Scotia in April with a maximum of 180,000 per litre at station N197. Resting spores were found in great numbers both in April and in May. In June the species was scarce; at station 30, where a rich *Chaetoceros*-plankton was growing, *Th. Nordenskioeldi* occurred still in numbers up to 7,000 per litre.

Thalassiosira sp.

In August and September small specimens of *Thalassiosira*-cells with quite thin cell walls were observed at the stations in the bay of Fundy, where a rich *Sceletonema*-plankton was growing. Because of the thin cell walls, the specimens were difficult to classify; some of them were certainly small specimens of *Th. Nordenskioeldi.*

Thalassionema nitzschioides Grunow

This species was distributed over the whole area from April to September, but was never abundant except in Passamaquoddy bay in September of 1932, where it occurred with a frequency of 100,000 per litre at the surface. In September of 1931, its maximum at the same station was just above 1,000 per litre. At most other stations less than 100 per litre were found.

Thalassiothrix longissima Cleve and Grunow

This large oceanic species was observed as scarce in April, May and August in the gulf of Maine and at station 8A in the waters flowing into the bay of Fundy.

DINOFLAGELLATES

The literature on dinoflagellates from the eastern coast of North America is confined to a few papers. Calkins (1902) observed members of this group in the waters off the Massachusetts coast and Wright (1907) has records of representatives for the commonest genera from the waters off the east coast of Nova Scotia. Gran (1919) in his quantitative study of the phytoplankton of the gulf of St. Lawrence, included the most frequent dinoflagellates. Later Martin (1929 *a* and *b*) has given records for the species occurring in marine and brackish waters off New Jersey, including some new species.

The knowledge of the dinoflagellates of these waters is, however, still more fragmentary than is the case for the European side of the north Atlantic. On account of the nature of the present work, the study of the dinoflagellates had to be carried out as a sideline as a means of completing the picture of the phytoplankton distribution. Only a few of the species, however, played any important role in the production and were subjected to special study. Those which occurred so frequently that they were found in the centrifuge samples were classified and notes on their size and forms were made during the whole work. Larger forms which occurred less frequently and were found only in the net hauls, were not recorded so regularly, because the net haul samples have not been carefully examined for dinoflagellates. *Gymnodinia* may also to some extent have been overlooked, as many of them are not recognizable in preserved samples as were these.

Amphidinium sp.

Only recorded once at station 27.09,10 m.

CERATIUM Schrank.

The members of this genus formed an important part of the phytoplankton through the greater part of the year (see page 355). According to their relative importance, they may be arranged in the following order: *longipes, fusus, bucephalum* and *tripos, arcticum* and *lineatum.* Besides these species, Bigelow has recorded *macroceros* as an occasional invader from the Gulf Stream area outside the gulf of Maine (Bigelow 1926).

For the gulf of Maine, Bigelow (l. c.) has given a detailed account of the occurrence of the various *Ceratium* species, based upon net haul material from the entire gulf, collected in various years. He found that the *Ceratium* population as a whole had a seasonal variation, which was very much the same as has been recorded from north European waters, viz., with a minimum in spring, followed by a gradual increase toward a maximum in late summer or autumn (Gran 1915). Bigelow has shown how this variation in the quantity of the *Ceratium* population was accompanied by changes in the relative abundance of the various species of which it was constituted. While *longipes* was the dominant form during spring and summer time, *tripos* gained in importance during late summer and replaced *longipes* as the leading species during autumn and winter.

Our observations were taken mostly during spring and summer, and accordingly *longipes* at most stations was the predominant form. Only in the September material from the bay of Fundy was *longipes* relatively scarce.

According to our observations *tripos* may seem less abundant as compared with *longipes* than one should expect from Bigelow's data and for this reason: in our material *bucephalum* was recorded in about the same abundance as was *tripos*, while Bigelow only records this species for a few odd stations. Judging from Bigelow's illustrations of *tripos* (Bigelow 1926, figure 114), it is, however, likely that he has included *bucephalum* in *tripos*. Therefore to *tripos* in Bigelow's study has been unduly attributed a greater relative importance than its abundance should justify. Otherwise, the seasonal variation in the quantitative occurrence of the *Ceratia* was found to be in accordance with Bigelow's results. All the species, (perhaps with the exception of the rare species *C. arcticum*) had their maxima in the area during the summer. *C. longipes* reached its high numbers in the western part of the gulf as early as in June, but was very abundant over a larger area also in August.

In the bay of Fundy a similar, but somewhat more scanty *Ceratium* population was found as that in the gulf. The variation in the occurrence of the various species was found to be principally the same as in the gulf, only with such modifications as were to be expected on account of the characteristic conditions of phytoplankton production which have been discussed in another place (page 394). Thus the high numbers were found at higher levels in the turbid waters of the bay of Fundy than in the clearer waters of the gulf.

Ceratium arcticum (Ehrenberg) Cleve

The maximal number recorded from any of our samples was 420 cells per litre at station 30.23A, 75 m. It was always found in water of temperature less than 10°C.

Ceratium bucephalum Cleve

The maximal number recorded, 2,080 cells per litre, was observed at station 28.23A, 40 m. It played a much more important role in the production than would appear from Bigelow's investigations (1926) (see above).

Ceratium fusus Ehrenberg

Next to *longipes*, this was commonest of the *Ceratia*. Maximal number recorded: 760 per litre, at station 30.29, 25 m.

Ceratium lineatum Ehrenberg

This species was found scattered within the whole area from April to September 1932. Maximal number: 200 per litre at station 7, 10 m. in September. (This species was recorded by Burkholder from Frenchman's bay in the summer of 1930 (Burkholder 1933), but not by Bigelow (1926)).

Ceratium longipes (Bailey) Gran

This was the commonest of the *Ceratia* within the area, and it was found in such large quantities that it seems to be the most important of the *Ceratium*-species from a production point of view. Maximal number: 4,260 per litre, at station 23A, 40 m. in June.

Ceratium tripos O. F. Müller

The maximal number of this species was recorded for station 26, with 580 cells per litre in August, at a depth of 25 m.

McMurrich (1917) has records of *Ceratium furca* from two hauls in Passamaquoddy bay. Since this species has not been noticed in any of the many hundred samples from the bay of Fundy and the gulf of Maine, it seems likely that he has applied this name to specimens of *lineatum*, of which he does not have any records. The complete absence of *furca* in our material is striking, since this is one of the important components of the *Ceratium*-plankton on the European side of the Atlantic, which otherwise is so much like the plankton found in these waters.

DINOPHYSIS Ehrenberg

Lebour (1925), Kofoid and Skogsberg (1928) and Schiller (1931) have given descriptions of the various known species of this genus. Nevertheless, the classification of *Dinophysis* specimens is often difficult if not impossible on account of lack of knowledge of the range of variation in the various species.

The nomenclature which we have used is that of Kofoid and Skogsberg (1928) and Schiller (1931). In the descriptions of the new species, we have not given all the details as to the various measurements of the body, since on the basis of so few specimens as we have had at our disposal, we would consider it erroneous to give such measurements as characteristics of the species. They can only be given somewhat correctly, when more material is at hand, showing the range of variation in the different characters. The illustrations may preliminarily furnish the measurements of the specimens used for the description.

The following species have been listed: *acuminata, acuta, arctica ?, longialata* n.sp., *norvegica, ovum, robusta* n.sp., *sphaerica?*,

Dinophysis acuminata Claparède and Lachmann

This species is known to vary considerably and Schiller (1931) has characterized it as "eine sehr variable Art, deren Umgrenzung heute noch unklar ist". Among the forms which we have referred to this species, there are some which fall within the range of variation which seems to exist according to the literature. Others, however, are different from the illustrations given of *acuminata*. They seem to be connected with the "typical" *acuminata* forms through transitional forms and we have referred them all to *acuminata* s.l.

The specimens which we have referred to *acuminata*, vary in the shape of the body, the form of the anterior cingular lists and, like all the *Dinophysis* species, in the thickness and the structure of the cell wall. The form of the cell is egg-shaped, the greatest depth in the middle of the cell, with the posterior part of the hypotheca varying from being globular to more or less conical. The epitheca has a flattened to concave part on the dorsal side, just below the apex. Most of the specimens do not have any uneven contour at the antapex, but the very thick-walled specimens have small protuberances and these specimens also have lists which are areolated, while most of the specimens do not have any conspicuous structure in the lists.

The length of the left sulcal list is from 0.4 to 0.5 of the length of the body. Length of the cell: 33 to 51 μ.

The species occurred at all depths and as far as our observations show, all the year round. The maximal number recorded was 1,100 per litre at a depth of 10 m. in Passamaquoddy bay in September 1932.

In the course of such a quantitative study as the present one, the observations on the taxonomy of the species had to be merely occasional. We have, however, reproduced a few sketches of *acuminata* specimens from various stations (figure 47), although our observations do not suffice for a reliable limitation of this species. A special survey of the various forms of *acuminata* and the related species would seem very desirable to solve this problem.

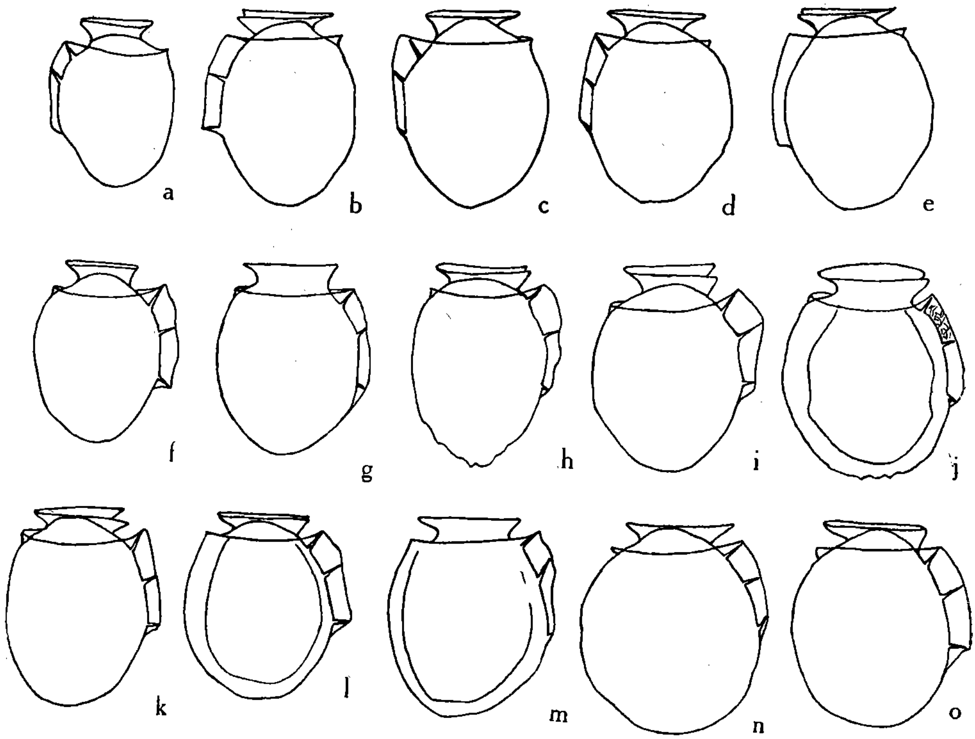


FIGURE 47. *Dinophysis acuminata.* a-f, h, and k (31 to 38 μ long) from station 30.01C; g and m (35 and 38 μ long) from station 27.36; i and j (41 μ long) from 27.37; l (36 μ long) from 26.34; n and o (38 μ long) from station N179.

Dinophysis arctica Mereschkowsky

This species has been recorded from three stations only, in April and May. They were all from water of temperature lower than 10°C.

Dinophysis acuta Ehrenberg

Rare in the Quoddy region and the western part of the gulf.

Dinophysis longi-alata n.sp.

Body in lateral view more or less egg-shaped with tapering epitheca. Dorsal and ventral contours are convex, antapical and evenly rounded. Body deepest in the middle, compressed laterally. Left sulcal list broad and extending so far down the body that the end of the lowest rib (R_3) in lateral view is further parted from apex than is antapex. The anterior cingular list has ribs. The left sulcal list may be areolated (theca smooth). Length of the two specimens which were observed: 32 and 37μ. This species was recorded from station N182, 1 m. (April 19, 1932) and station 27.29, 25 m. (May 30, 1932).

Dinophysis norvegica Claparède and Lachmann

The maximal number which was recorded for this species was 1,560 per litre at station 25, 10 m. in August. Otherwise the numbers were mostly small, but the species was regularly observed within the whole area from April to September.

Dinophysis ovum Schuett

This species was recorded only from three stations, in April, May and September. Maximal number 200 per litre.

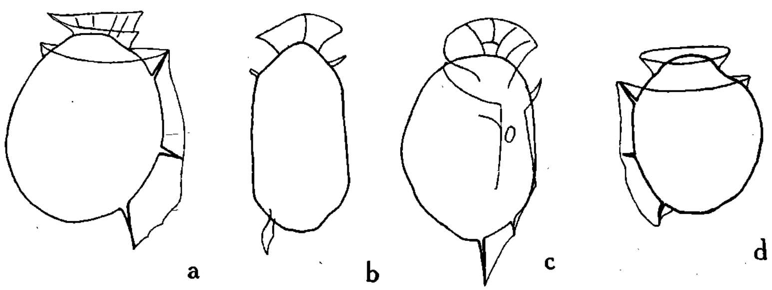


FIGURE 48. *Dinophysis longi-alata.* a, b, and c from station 27.29 (37 μ long); d from station N182 (32 μ long).

Dinophysis robusta n.sp.

Body in lateral view oval; epitheca with conical apical end; the dorsal side of the hypotheca more convex than the ventral side, which has an almost straight contour down to the lowest rib of the left sulcal list. The anterior cingular list has the same width as the posterior list and is broader. The left sulcal list broadens posteriorly (R_1 shorter than R_2 which is shorter than R_3). Its ribs are well developed, the lowest (R_3) being slightly bent towards antapex. In dorsal view the body is broadly egg-shaped broadening posteriorly, and becomes flatter towards the antapical end, which is pointed. The last feature is caused by a conspicuous dorsal elevation along the suture. Theca with poroids, of different nature according to the thickness of the wall. Cell at least as broad as deep. Length of the two specimens observed: 54μ, (thin-walled) and 62μ (thick-walled). Recorded from stations 26.26, 1 m. and 30.01C, 10 m.

Dinophysis sphaerica Stein

Recorded only from station 27.09, 1 m.

Dinophysis sp.

A. In figure 50 is given a sketch of a *Dinophysis* of which we have not sufficient material for classification. The main characteristic which is different from those of the species which have been described, is the long first rib of the left sulcal list. It exceeds the longitudinal axis of the body. The list itself is smooth. The theca is thick-walled and with conspicuous poroids. Length: 41μ. Recorded from station 27.37, 25 m.

B. The *Dinophysis* specimen which was found at station 26.34, 1 m. (fig. 51) has not been referred to any of the known species. It resembles one of Woloszynska's drawings of *D. norvegica* forms (Woloszynska 1928, VI, 11); but it is otherwise so different from the forms of *D. norvegica* found in this material

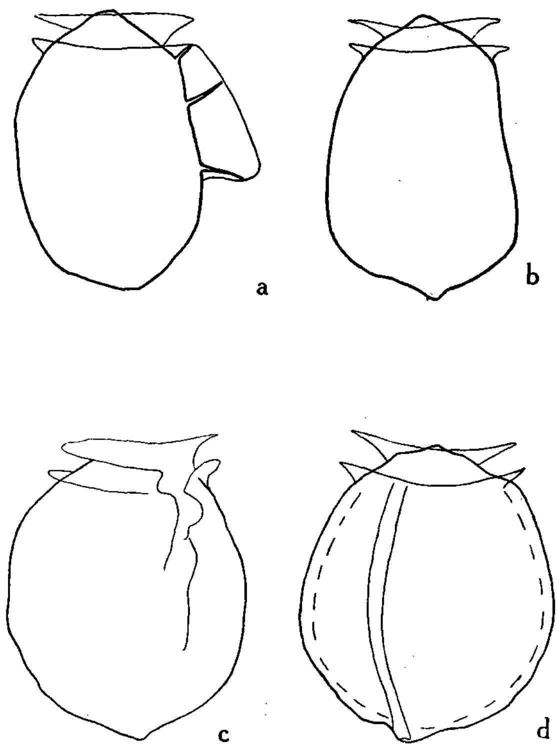


FIGURE 49. *Dinophysis robusta*. a and b from station 30.01C (54 μ long); c and d from station 26.26 (62 μ long).

that we have not found justification for referring it to this species. The main characteristics of the specimen are the rather large epitheca which in lateral view may be seen above the anterior cingular list and the almost linear contour of the ventral side of the body. Lists without conspicuous structure. Length: 48μ. (It is possible that this is a young specimen of *D. robusta*, but it does not have the antapical protuberance like the other specimens of this species).

Diplopsalis lenticula Bergh

At several stations in the bay of Fundy this species was recorded in small numbers in August. It is possible that some of them actually were specimens of *Diplopeltopsis minor*, since at the low magnification for counting, and without clearing, the distinction between them is difficult.

Exuviaella baltica Lohmann

This little dinoflagellate never occurred in very great quantities, but it formed a regular part of the phytoplankton of the whole area during the time of investigation. In April the highest number (1,000 per litre) was recorded from the waters east of Nova Scotia (station N197), while it otherwise was scanty over the area. In May there were very few specimens observed at the stations on the New Brunswick side of the bay of Fundy, while the species was rather abundant at the central and eastern stations (up to 1,000 per litre). In the gulf it was common, but not very numerous. In June it was very scanty in the bay of Fundy, like the phytoplankton as a whole, but it was fairly numerous at the stations just south of Grand Manan and in the section off Penobscot bay, where it was recorded in the maximal number for the whole area, viz., 6,600 per litre (station 28.29, 1 m.). In August it had its greatest abundance in the outer

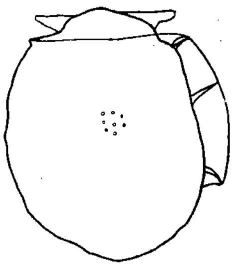


FIGURE 50. *Dinophysis sp.* A. From station 27.37 (41 μ.long).

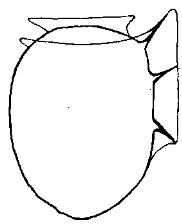


FIGURE 51. *Dinophysis sp.* B. From station 26.34 (48 μ long)

part of the bay of Fundy and, as far as our observations indicate, it had a similar distribution in September.

Since this species is so small that it passes through the nets, there are no records of it in this area previous to the present work.

Exuviaella perforata Gran

This was observed in the gulf of Maine in August, with a maximal number of 380 per litre at the surface, station 26.

Glenodinium sp.

In most of the material, but especially in spring and early summer, *Glenodinium* spp. were frequently observed, usually in small numbers only. Maximal number: 1,000 per litre at station 28.36, 10 m.

Gonyaulax spinifera (Claparède et Lachmann) Diesing.

Rare in August and September.

Gonyaulax tamarensis Lebour

This was recorded as *G. orientalis* from the gulf of Maine in August, 1932, by Gran (1933).

In figure 52 are shown some specimens of a *Gonyaulax* which we have classified as *G. tamarensis* Lebour. The plate structure is the same, but the shape of the cells is partly different and these specimens do not have antapical spines as described by Lebour (1925) for *G. tamarensis*. The variation in shape seems to be rather wide and some of the specimens (A) are so much like the drawing given by Lebour, that we have not found any reason for separating these specimens from *G. tamarensis*. Lebour describes the antapical spines as "very small". None of all the specimens which have been observed in the bay of Fundy and the gulf of Maine region had any spines. In view of the various types of cell form, which this species seems to have, the description should be modified a little:

Cell as long or longer than broad. Epitheca with convex sides. No apical horn. Girdle displaced about a girdle width, excavated, with no overhang, no lists. Ventral area with elevated margins, expanding posteriorly.

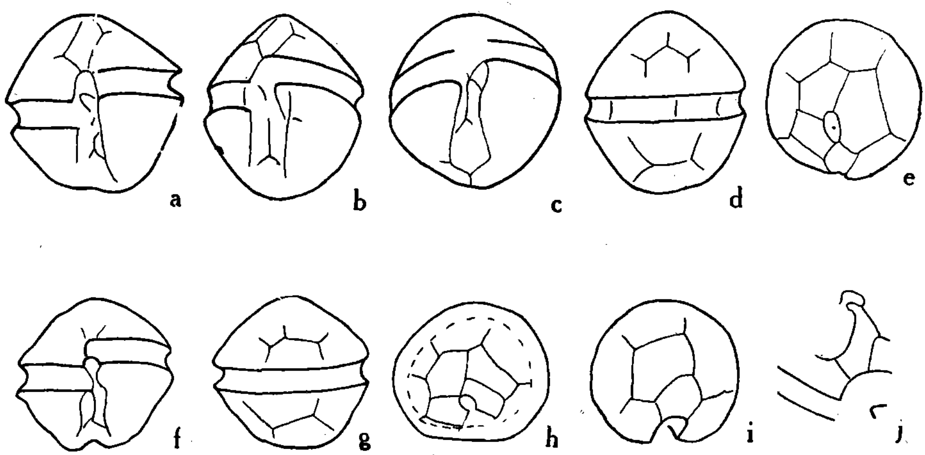


FIGURE 52. *Gonyaulax tamarensis*. a from station 30.05; b-e (36 μ long) from station SW_2, f-j from station 30.01C.

Hypotheca more or less asymmetrical or as given by Lebour, symmetrical, of variable form, from rather conical to pyramidal, in the last case with an indentation at the ventral area. Antapical spines observed in the original specimens by Lebour, but not in the American specimens. Plate formula $4'$ Oa $6''$ $6'''$ 1p $1''''$. First apical broad. Theca smooth. Forms cysts. *G. tamarensis* was found practically over the whole area. In spring it was observed at one station only in April, and in May mostly in small numbers although it was common. In June it was very scarce in the bay of Fundy like the phytoplankton as a whole. In August it reached its greatest abundance and was then common over the whole area which was studied. Its maximal number was recorded in July at station 1C in Passamaquoddy bay (2.800 per litre). Generally it was more abundant in the bay of Fundy than in the gulf. In September the observations from the Fundy stations show that it was then scarce.

Gonyaulax triacantha Joergensen

Rare in August and September.

Gymnodinium Lohmanni Paulsen

This species was recorded from the whole area in April, May and June, but after that time it was too scarce to be recorded in the centrifuge samples. The maximal number, 800 per litre, was found in water from the Quoddy passages in May 1932. Otherwise the numbers were small. The seasonal variation in abundance of this species is in agreement with what has been described from northern European waters (Gran 1915). Here it was found to be most abundant in spring and early summer, at the time of the diatom vegetation, while it was less abundant at the time when the *Ceratium*-plankton was prevalent.

Minuscula bipes (Paulsen) Lebour

This species is very common and occurs in quite a variety of forms. Most of them are easily identified, while others on account of the broader cells and shorter antapical spines are rather different from the slender forms which accompany the descriptions by Paulsen (1904) and Lebour (1925). By clearing with Javelle water they are, however, easy to identify, as the plates (especially the first apical) have a characteristic shape. In figure 53 is pictured one of the broader forms in ventral view.

Peridiniopsis rotunda Lebour

In July 1932, 39,400 cells per litre of this species were recorded at 1 m. in Passamaquoddy bay; at 10 m., 4,900 per litre; and in the deeper samples none was recorded. Besides this, the species was observed only at two stations, viz., 28.37 and 30.13, and then in small numbers (Lindemann 1928, Woloszynska 1928 and Davidson 1934).

PERIDINIUM Ehrenberg

(With regard to the number of anterior intercalaries in *Peridinium* see *P. americanum*, below)

Of this genus 29 species have been observed in our material. Since only very few observations on dinoflagellates had been made before, many of them are new for the region. Also some new species have been described. Our observations are restricted to a part of the gulf and the Fundy region and most of the net hauls have not been thoroughly examined for dinoflagellates. Therefore, our data cannot give a reliable picture of the distribution of the larger forms. The smaller forms which occur in greater numbers are caught regularly in the centrifuge samples.

Peridinium achromaticum Levander

This species was observed at two stations in the bay of Fundy in September.

Peridinium americanum n.sp.

Cell slightly longer than broad. Epitheca with convex sides ending in a more or less pronounced short apical horn. In ventral view the contour of the epitheca is uneven. The girdle is excavated, without lists, not displaced. Hypotheca has convex sides. The ventral area has two lists which line a small area which is easily seen without clearing. No antapical spines. Hypotheca is slightly dorso-ventrally flattened towards antapex. Theca smooth or punctured. Length: 43μ.

Plate formula: 4 apicals (ortho), 4 anterior intercalaries, 7 precingulars, 2 antapicals, 5 postcingulars.

The presence of 4 anterior intercalaries has never been observed in any *Peridinium* before and the diagnosis for the genus only gives 2 to 3 anterior intercalaries. The plate structure of this species was studied on several individuals and although the plates sometimes were somewhat difficult to see, the presence of the four intercalaries seems beyond doubt. Since this plate arrangement was recorded for all the specimens which were examined, it is not apt to be abnormal. Miss Karen Ringdal has kindly given us information on specimens

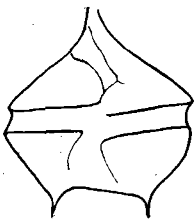


FIGURE 53. *Minuscula bipes.* From station N197 (36μ wide).

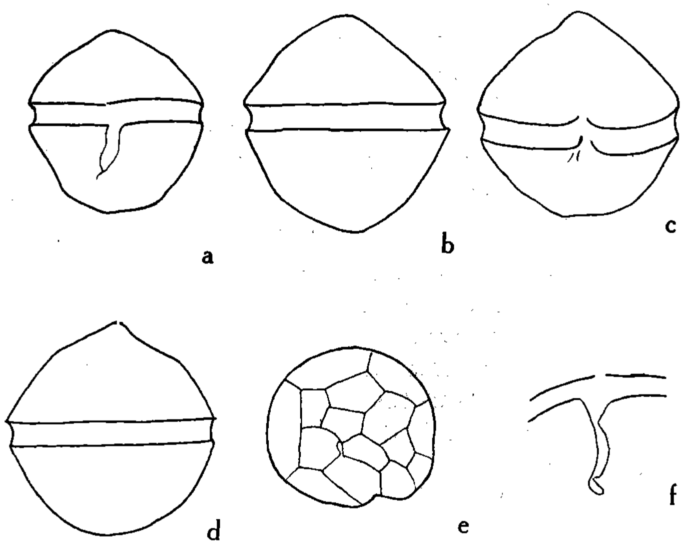


FIGURE 54. *Peridinium americanum.* a from SW_2: (35 μ long); b from 27.31; c from 27.35 (43 μ long); d-f from 27.36. a and c in ventral view; d in dorsal view, b in side view; f, the ventral area; e, diagram of plates on the epitheca.

of this species from stations west of Ireland, worked during the "Michael Sars" expedition in 1910. These individuals also had the same plate structure, with 4 intercalaries on the epitheca. Since the species except for this one character seems to agree with the diagnosis for the subgenus *Veroperidinium* Paulsen (1930), we shall preliminarily refer it to this. Thus the genus *Peridinium* will include forms with 2 to 4 anterior intercalaries.

Occurrence: stations 27.31 1 m., 27.34 25 m., 27.35 1 m., 27.36 10 m. Also recorded from the north Atlantic west of Ireland (communication from Miss Karen Ringdal).

Peridinium breve Paulsen

At some stations in the bay of Fundy and the central part of the gulf of

Maine, there occurred in May a globular *Peridinium* which we have referred to *P. breve* Paulsen. The specimens, of which sketches are found in figure 55, are more globular in shape than the illustrations of this species have shown (Paulsen 1905, Broch 1909, Paulsen 1911, Fauré-Fremiet et Puigandeau 1922). It is, however, more flattened than *P. quarnerense* (Schroeder) Broch (Paulsen 1930), and the spines are more distinct. The plate arrangement and the shape of the girdle agree with *P. breve* as it has been described by Lebour (1925). The occurrence in water of temperatures 3.84 to 6.84°C., is in agreement with the previous records which characterize this species as an arctic-neritic form. Theca was punctured. The left spine was separated from the lists (see Lebour 1925).

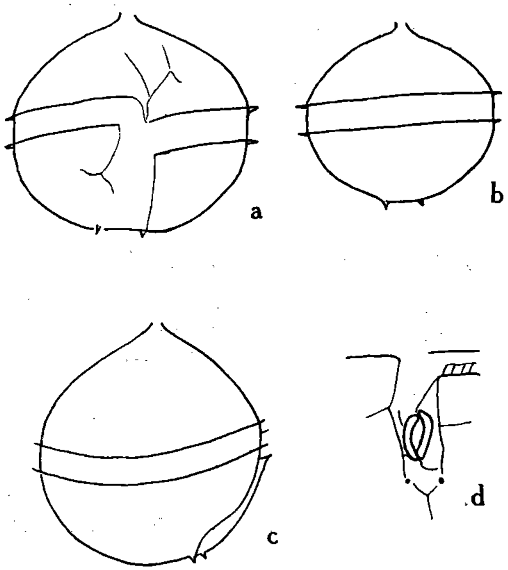


FIGURE 55. *Peridinium breve.* a and b from station N246 (43 and 35 μ wide); c and d from station 27.09 (43 μ wide).

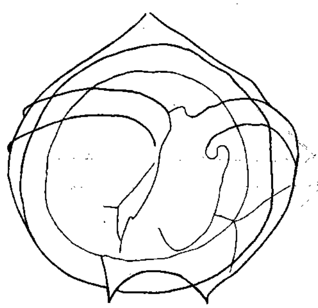


FIGURE 56. *Peridinium conicoides.* Cyst from station 26.26 (diameter 46 μ).

Except for the two records from the gulf in May, all our records of this species are for the bay of Fundy and, with one exception only, for the month of May.

Peridinium brevipes Paulsen, including **P. varicans** Paulsen

Paulsen (1908 and 1911) has described two species, *P. brevipes* and *varicans* which are only distinguished by the form of the spines, *brevipes* having parallel ones, and *varicans* divergent ones. In material from the eastern coast of Greenland, the locality from which *P. varicans* at first was described, one of us found that there was not such difference between the specimens that they could be recognized as belonging to different species (Braarud 1935). There were such variations in the shape of the spines that it seemed evident that the two types are only extreme variants of one variable species. We have, therefore, also in this material referred both types to *P. brevipes*.

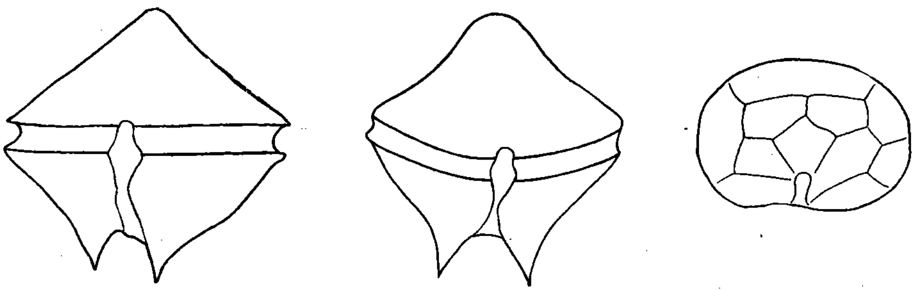
This is one of the commonest of the peridineans. It occurred all over the area and from April to September, but in small numbers only.

Peridinium cerasus Paulsen

This species was commonest in May, but also observed in April, August and September. It occurred mostly in numbers of less than 100 cells per litre.

Peridinium conicoides Paulsen

From April to September this species occurred scattered all over the area. At station 26.26, 10 m., a cyst-forming specimen was observed. The cyst was brown and inclosed in the original cell wall. The diameter of the cyst was 46μ and its wall was about 6μ thick. In the net hauls from different stations, free floating cysts were observed which had the same colour and size as the *P. conicoides* cyst figured in figure 56 and therefore probably were cysts of this species.



a b c

FIGURE 57. *Peridinium conicum* f. *Asamushi*. a from station 26.26 (51 μ long); b and c from station 27.35 (56 μ long).

Peridinium conicum (Gran) Ostenfeld and Schmidt

This species was observed from only 5 stations in April, May, June and September.

Besides the typical specimens of *P. conicum*, some individuals were recorded which had only two intercalaries on the epitheca. The plates of this species are somewhat difficult to distinguish, but in two of the specimens this dorsal structure was quite distinct. It has previously been recorded by Abè (1927), who calls this atypical form *P. conicum* (Gran) forma *Asamushi* Abè. His drawing of the cell shows that his specimen is very much like the specimens which we have found in the bay of Fundy region. The horns are, however, more pointed in our specimens (see figure 57) than in the Japanese ones (Abè 1927, figure 25A and B). We reproduce the sketches of this atypical form, since the shape of the cell is rather different from what is shown in the figures of *P. conicum* given by Paulsen (1908) and Lebour (1925). The form of the antapical horns seems to be rather variable, as well as the contours of the epi- and hypotheca (see the figures given by Paulsen and Lebour l.c.).

Peridinium curvipes Ostenfeld

Like so many of the *Peridinium* species, this one was commonest in May, but it was also observed at a couple of stations in April, always in small numbers.

Peridinium denticulatum n. sp.

This is a very characteristic *Peridinium*, belonging to the sub-genus *Archaeperidinium* (Joergensen) Lebour (1922). It is of a different type from the other species of this sub-genus, which have been recorded from northern Atlantic waters, but it is closely related to *P. Abèi* (Abè) Paulsen (1930) and *P. ventricum* Abè, described by Abè (1927) from Mutsu bay, Japan. These three species all have what Abè describes as an "apical slit-like groove", at the ventral end of which the apical pore is located. The groove extends from the first apical

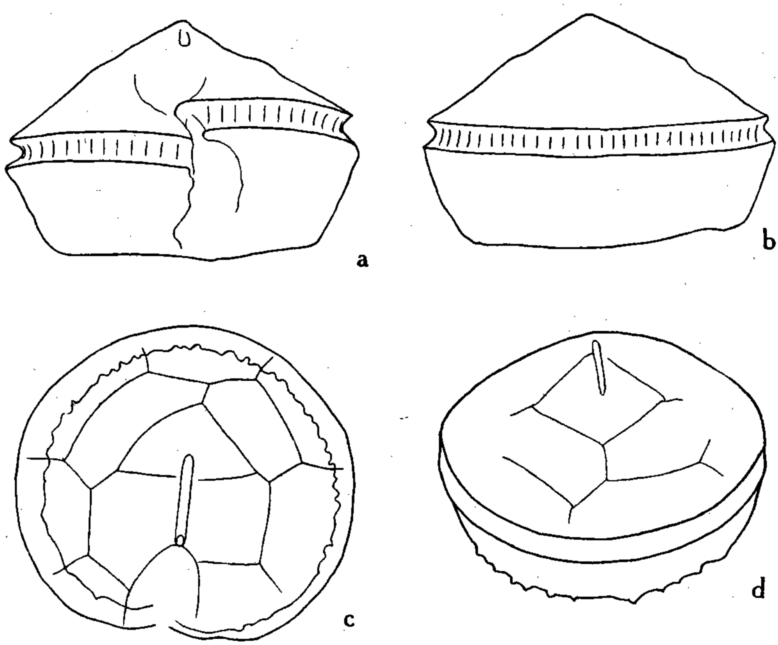


FIGURE 58. *Peridinium denticulatum.* From station 27.09 (53 μ long).

plate over to the third. Otherwise the species are rather different, the two species described by Abè being biconical and our species being flattened so the hypotheca ends in a plane part, parallel to the plane of the girdle.

The epitheca is conical with straight to slightly convex sides. The plate arrangement is that of an *Archaeperidinium*, with a slit-like groove which from the first apical plate extends to the centre of the third apical plate. The apical pore is situated in the ventral end of the groove. The girdle is left-handed, displaced about its own width. It is excavated and the narrow lists are supported by ribs which are distinctly seen in the ventral and dorsal, as well as in apical view. The contour of the hypotheca has straight, only slightly conical sides, which abruptly pass into a flat antapical region. A little inside the margin of this flat part there is a row of irregular teeth. These cannot be seen in ventral and dorsal view, but only when the cell has a slightly oblique position can they be seen in antapical view and then they form a very conspicuous feature in the picture of the contour. Breadth of 7 specimens: 56 to 76 μ. Occurrence: stations SW_2 25 m., N192, 1 and 25 m., N197 1 m., 26.26 25 m., 27.09 25 m., 27.17 10 m., 27.37 40 m., N260 40 m., N240 10 m.

Peridinium depressum Bailey

In the centrifuge samples this species was observed in April, May and September from various localities, scattered over the whole area.

Peridinium divergens Ehrenberg

Scattered over the whole area, from April to September.

Peridinium excentricum Paulsen

A *Peridinium* specimen in a sample from Passamaquoddy bay in August was referred to this species.

Peridinium faeroense see *P. trochoideum*

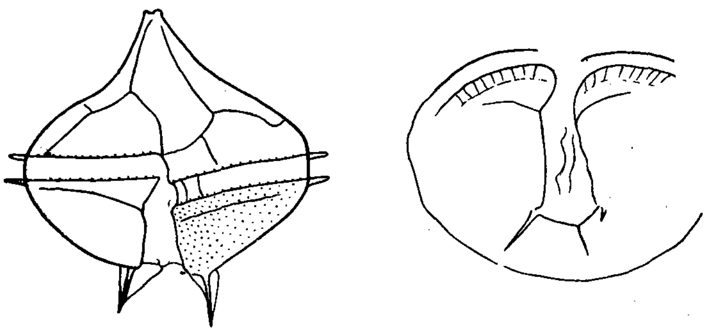


FIGURE 59. *Peridinium gracile.*

Peridinium gracile n.sp.

Among the forms which have the same plate arrangement as *P. ovatum*, is also the specimen which is pictured in figure 59. Although the forms which have been identified as *P. ovatum* have very different cell forms, ranging from the large and flattened ones of the classical type, found in Lebour's plate XXVI fig. 1 (Lebour 1925) to the more globular ones of the same shape as *P. roseum* Paulsen, it seems at present unjustifiable to refer the present form to this species. While there seem to be transitional forms between the classical *P. ovatum* and the *roseum*-type, there are no records of any intermediate forms between the hitherto known forms of *P. ovatum* and this *Peridinium* specimen. We have therefore found it most reasonable to consider it as a new species, *P. gracile.* It is possible that further records may make it justifiable to refer it to *P. ovatum* s.l.

Metaperidinium of the section *Humilia*, with second intercalary touching precingular 4. Epitheca with convex-concave sides, tapering to a conspicuous apical horn. The girdle is right-handed, not excavated, supported by spines, displaced by once its own width. Ventral area broadening towards the antapical end. Hypotheca with concave sides, ending in two long spines with wings. Theca punctured, 56 and 81μ broad, without lists.

Occurrence: station 27.27 40 m. and N246 40 m.

Peridinium Grani Ostenfeld

The *Peridinium* which in figure 60 is shown in ventral view, is a *Metaperidinium* with dorsal plate arrangement as in the section *Pyriformia*. The shape of the cell in ventral view, does not agree very well with the drawings of *P. Grani*, but as the form of the spines in this species, according to Peters (1929) is very variable, the disagreement is not so great that the specimen should not be referred to this species. The length of the cell is only 36μ, which is less than previously recorded (49 to 99μ). The present specimen may thus be a young or abnormal individual. Theca was reticulated, in accordance with the description of *P. Grani*.

Peridinium monacanthus Broch

This species has been observed in arctic waters only. In April and May it was recorded at three localities in the bay of Fundy and the gulf.

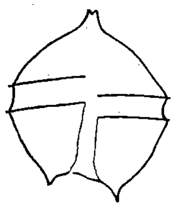


FIGURE 60. *P. Grani* (see text).

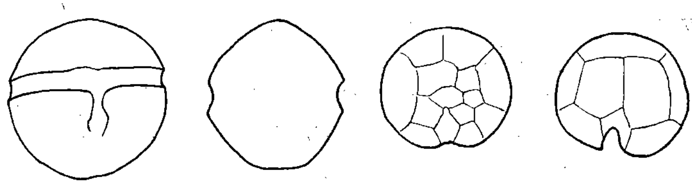


FIGURE 61. *Peridinium novascotiense.* From station N192 (33 μ long). Ventral and side view.

Peridinium novascotiense n. sp.

This minute species was only recorded from one station, viz. N192, where it occurred in the 1 m. sample (April 21, 1932)..

Body egg-shaped. In ventral view symmetric; epitheca with convex sides without apical horn. Girdle excavated without lists, slightly left-handed or not displaced. Hypotheca of the same form as epitheca, evenly rounded. The ventral area narrow, with two elevated lists which are noticeable even without clearing. Theca smooth. Plate structure that of an *Orthoperidinium* of the sub-genus *Veroperidinium* Paulsen (1930). Three anterior intercalaries of which 1a and 2a are small and pentagonal, 3a large and hexagonal and asymmetrically arranged. The intercalary 2a touches 3″ and 4″. The apical 1′ is broad and with a narrow upper part. Length: 28 to 33μ. The description is based upon only two specimens.

Peridinium ovatum (Pouchet) Schuett

P. ovatum in the bay of Fundy—gulf of Maine region, exhibits a variability in form similar to what has been recorded from other regions (Braarud 1935). The most aberrant shape from the *P. ovatum* which is given in the descriptions (e.g., by Lebour 1925) is the *P. roseum*-like form. As also observed by Lebour (l.c.) the plate arrangement is, however, in complete agreement with *P. ovatum* and there are in our material intermediate forms which seem to show that even the *P. roseum*-forms are within the range of variation of *P. ovatum*. None of the peridineans which were suspected of being *P. roseum* Paulsen had any plate arrangement different from that of *P. ovatum* Schuett, and consequently we have referred them all to *P. ovatum*.

As most of the observations were made during the quantitative study, we are not able to give any statistics of the variations. The most extreme forms which were measured, had the following proportion between the length and breadth: $46\mu/45\mu$ and $66\mu/97\mu$. The dorsal epithecal plates were symmetrically arranged in all the specimens which were examined as to the plate arrangement.

Like *brevipes*, this species is most frequent in May after the spring diatom maximium, but it was also recorded in April from many stations in the gulf and in the outer Fundy region. In summer and autumn it seems to have been scarce, since it was observed from a couple of localities only, in August and September.

Peridinium pallidum Ostenfeld

The few records of this species do not indicate any particular seasonal variation in its occurrence. The localities where it was observed are scattered over the whole area of investigation.

Peridinium pellucidum (Bergh) Schuett

Scattered records from the whole area show that this species was to be found from March to September, with a maximal frequency in May.

Peridinium pentagonum Gran

A specimen of this *Peridinium* from station 27.35, 60 m. had a more circular contour in apical view than given in Gran's original drawing (Gran 1902). The 2a intercalary was also different from what is regularly found in this species, as it touched 4″ and 5″. Length of the cell 50μ. Otherwise the form was like *P. pentagonum*, so it certainly is only a variant.

This species was observed once in May, otherwise in September only, in the bay of Fundy.

Peridinium pyriforme Paulsen

This species was observed at a few stations, in April, May, August and September, with the widest distribution in May.

Peridinium simplex n.sp.

Among the small *Peridinia* and *Glenodinia* which occur in the nannoplankton this one is fairly common in the material. We have not been able to clearly discern the plate arrangement, but we have observed that it has *Peridinium* plates and belongs to the group *Metaperidinium*. The girdle is slightly right-handed or not displaced, excavated, without distinguishable lists. The ventral area is narrow, its antapical termination not observed with certainty. The epitheca has convex sides and no apical horns. Hypotheca has slightly convex sides and a flattened antapical part. No antapical spines. Length 26 to 32μ. It was observed south of Nova Scotia in April and in May at 4 stations in the bay of Fundy and at 2 stations in the gulf.

Peridinium sub-curvipes Lebour

One specimen has been referred to this species, viz., from station 27.13, 10 m.

Peridinium subinerme Paulsen

The only two records we have of this species are both from the bay of Fundy in May.

Peridinium Steini Joergensen

Our few records of this species are all from August and September.

Peridinium Thorianum Paulsen

At various stations, scattered over the whole area, it was observed in May.

Peridinium triquetrum (Stein) Meunier

Stein (1883) referred this species to a separate genus *Heterocapsa*, but it has later been included in the genus *Peridinium* (Lebour 1925) and erroneously given the name *P. triqueta*. Its proper name ought to be *P. triquetrum*.

The records of this species from European waters indicate that it is a neritic species which often occurs in great abundance in estuaries (Paulsen 1908, Lebour

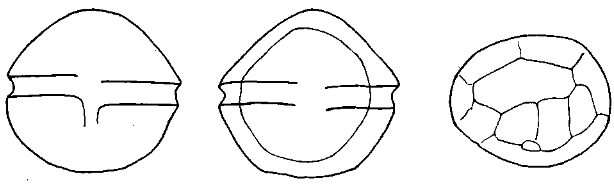


FIGURE 62. *Peridinium simplex.* From station 27.29 (33 μ wide).

1925, Marshall and Orr 1927).

In the Fundy region and the gulf of Maine it was recorded in variable quantities from March to September 1932. In August it seemed to have its greatest abundance in the bay of Fundy, where it was recorded in numbers up to 120,000 cells per litre. This is a far greater number than was recorded from the gulf, although it also seems to be a regular component of the phytoplankton communities of the gulf.

To judge from the scanty observations for the eastern outskirts of the gulf, *P. triquetrum* is here much scarcer or lacking.

Whenever the species was found in great abundance, it was in samples from the very surface or close to it (1 and 10 m. samples). The distribution in August 1932 gives an interesting picture of its occurrence in the whole area. In the bay of Fundy, the maximal numbers at each station were to be found at a depth of 1 m., only with a couple of exceptions where its maximum was at 10 m. In the gulf the maximum at the shore stations was recorded at 1 m., while at the offshore stations the maximum was found deeper, at a depth of 10 and 25 m. (See figure 41).

In view of the general conditions for phytoplankton production as discussed on page 394, this distribution would indicate that the species had its greatest abundance at each station at the depth where the general conditions of growth were most favourable.

It is difficult on the basis of the material from this region to give any definite characteristics of the species in regard to such environmental factors as salinity and temperature. Its greater abundance in the Fundy region, and the high figure for the station off the Saint John estuary, would indicate that slightly brackish water is favourable for this species. Its maximum in August, when the temperature of the surface waters of the bay is relatively high, (13 to 14°C.) similarly would indicate that it is a temperate species, but it is possible that the distribution is due more to indirect effects of these factors on the productivity rather than to the direct physiological effect upon the growth and multiplication of *P. triquetrum.*

Allen has observed the formation of zoospores in pure cultures of this species (Lebour 1925). Such spores were observed in a great number of the samples containing thecate forms of this species. In the tables no distinction is made between the thecate and the naked forms, since it was not always possible to be certain that some of the spores did not merely represent cell contents of cells which had been damaged by the shaking of the sample.

Peridinium trochoideum Stein

In his paper of 1913 Jörgensen remarks that *P. faeroense* and *trochoideum* may be identical. Lebour (1925), however, records them as separate species. As the main character in which the two species should differ, she mentions the much narrower first apical in *faeroense* and its less conspicuous apex.

In the present material specimens were observed which were easily classified as *faeroense* and *trochoideum*, but some were also observed which according to their form might be classified as non-typical specimens of either. In figure 63 is shown a specimen of *faeroense* which much resembles the *trochoideum* as to contour. After clearing, the narrow first apical necessitated its classification as a variant of *faeroense.*

Since, in counting, such doubtful specimens could not always be cleared, the classification of extreme variants of these small *Peridinia* has been a little uncertain. Therefore, we have found it necessary to treat them jointly. This seems the more reasonable since they appear to be so closely related biologically, as to seem to belong to one species. Our material does not give conclusive proof that they are identical, but we have no observations which would count against the merger of the two species.

These small brown peridineans were observed in small numbers in the bay of Fundy and at the coastal station 25A in May, but in June they were not recorded at all. In August they have their greatest distribution and abundance, since they were observed at all stations in the bay of Fundy and at station 27, 28, 29 and 30 in the gulf of Maine, although at these last stations only in small numbers. They are by far the most abundant in the bay of Fundy, where at station 37 the maximal number, viz., 6,900 per litre, was recorded. In September the population in the bay of Fundy was much more scanty than in the previous month.

Peridinium variegatum Peters

A very thick-walled *Peridinium* which had such a dark brown colour that it gave the impression of being a cyst, was found at a couple of stations in spring. On account of the thickness of the cell wall, it was difficult to see the plate arrangement accurately. The form of the cell and other characteristics as the shape of the girdle and the presence of a highly refractive ring in the ventral

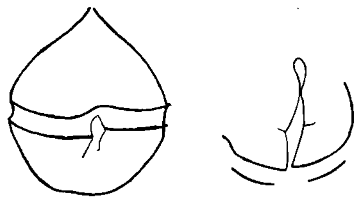


FIGURE 63. *Peridinium faeröense.* From station 30.07 (35 μ long).

area, are in accordance with *P. variegatum* Peters (1929). The classification of these specimens as *variegatum* is further supported by the identification of a thin-walled individual of that species in the net haul sample from the same station, from which one of the thick-walled specimens was recorded. This thin-walled specimen had the typical *P. variegatum* cell form with a small apical horn. The plate arrangement was hard to make out with certainty, but the first apical was like that of figure 9b by Peters (1929), a figure which in every

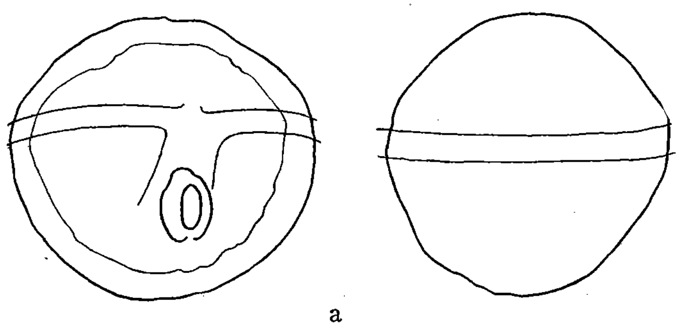


FIGURE 64. *Peridinium variegatum.* Cyst from station 27.28 (62 μ wide). a in ventral, b in side view.

respect might have been an illustration of this specimen. In the sketch of the thick-walled specimen from station 27.28, 40 m., the first apical has been drawn as in *Orthoperidinium*, but as mentioned above, the thickness of the wall made a study of the plates difficult. We do not, therefore, hesitate to classify these forms as belonging to *P. variegatum* Peters. Breadth of the cells: 52 to 62μ. Broad intercalaries. Theca punctured. (Figure 64).

Prorocentrum micans Ehrenberg

The specimen from station 26 in the gulf of Maine, had two spines, the large tooth-like one on the left valve and a smaller one at the other end of the right valve. In the description of *P. micans* by Paulsen (1908), Lebour (1925) and Schiller (1931), this character is not mentioned. This last spine is found in some of Stein's drawings (Stein 1883) and Fauré-Fremiet (1908) records that the species is found as often with the spine as without it. Martin (1929a) for the New Jersey coast has observed some specimens with the large tooth on the right valve and some without any tooth at all.

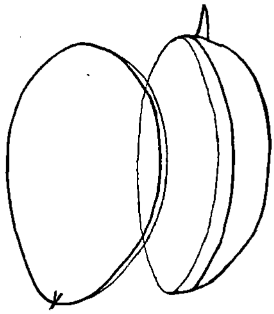


FIGURE 65. *Prorocentrum micans*. From station 26.26 (51 μ long).

COCCOLITHOPHORIDES AND OTHER PHYTOFLAGELLATES

Acanthoica acanthifera Lohmann

This oceanic species was observed in small numbers in the outer part of the bay of Fundy in September, commoner in 1931 than in 1932. Maximum: 280 per litre at the surface at station 8A, September 1931.

Calyptrosphaera oblonga Lohmann

Rare in the bay of Fundy in September.

Coccolithus pelagicus (Wallich) Schiller

This species was recorded from the whole area of investigation, from March to September, in numbers of 200 per litre or less.

Lohmannosphaera subclausa n.sp.

Cells globular, about 10μ in diameter, with the coccoliths 12μ. Coccoliths radiating in all directions, each formed as a barrel with an irregularly contoured basal plate. Their apical opening is very narrow, like a pore perforating the top of a process, situated at the centre of the slightly depressed outer membrane, which is nearly circular. Height of the coccoliths about one half of their diameter. Distinguished from *L. paucoscyphos* Schiller (1930) by the narrow central opening of the coccoliths.

This very characteristic species occurred rarely in the surface layers at offshore stations of the gulf of Maine in August and in the bay of Fundy in September. Maximum: 60 cells per litre at station 29, 10 m.

Pontosphaera Bigelowi n.sp.

Cells isodiametrical, each covered by 12 pentagonal coccoliths, forming a regular pentagon-dodeka-hedron. Coccoliths flat, relatively thick, touching each other by the margin, which is slightly prominent at the outside. Colour and cilia not seen in the preserved specimens. Diameter 16μ.

This species was observed in the surface layers at the most oceanic stations in the gulf of Maine. Maximum: 680 cells per litre at station 3, 23A, and less abundantly in the bay of Fundy.

Pontosphaera Huxleyi Lohmann

In April this species was observed at a couple of stations in the gulf, but in very small numbers. Through May and June it became commoner over the whole area and reached fairly high numbers in the western part of the gulf. In August more than 50,000 cells per litre were recorded at stations 7 and 37 in the bay of Fundy, where it was quite numerous at all stations, but generally not quite so abundant as at the gulf stations. The highest number recorded, 64,800 per litre, was, however, from station 37 in the bay of Fundy in August. In September the numbers in the bay were all smaller than 1,000 per litre.

Gran's observations (Gran 1933) show that *P. Huxleyi* was common also in the central and outer parts of the gulf in the first days of August 1932, but the numbers recorded were all smaller than 40,000 per litre. At the Atlantis station 1722, July 16, 1933, in the eastern part of the gulf, there were, however, at a depth of 18 m., 308,000 cells per litre (Braarud 1934).

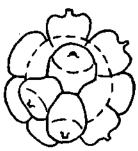


FIGURE 66. *Lohmannosphaera subclausa.* Diameter 12 μ.

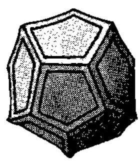


FIGURE 67. *Pontosphaera Bigelowi.* Diameter 16 μ.

Rhabdosphaera stylifera Lohmann

This Atlantic species occurred in relative abundance in the bay of Fundy in September 1931, particularly in the waters flowing in from the gulf of Maine. Its maximum was 1,420 cells per litre at station 10. In 1932 it was rare.

Syracosphaera pulchra Lohmann

Rare in the bay of Fundy in September 1931 and 1932. Maximum, 160 per litre at the surface, station 37, September 1932.

Some other species of *Syracosphaera* were observed, but not classified because the material was too scarce.

Dictyocha fibula Ehrenberg

Observed occasionally.

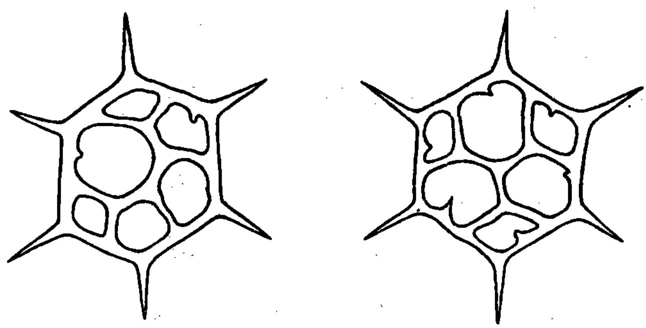
Distephanus speculum (Ehrenberg) Haeckel

According to Gemeinhardt (1930) this is by far the commonest of the silicoflagellates, and this has been found to be the case in this area too. It was found at all seasons and, except in Passamaquoddy bay, in small numbers only less than 500 cells per litre). In late summer it was a little more abundant than earlier in the year.

Passamaquoddy bay seems to be a specially favourable locality for this organism, since here it was recorded in much greater abundance than in the other localities. McMurrich (1917) observed *D. speculum* in the bay and later Davidson (1934) has records showing that it usually is very abundant there in late summer. On July 30, 1932, we found 35,200 cells per litre at a depth of 1 m. (station 29.01C), the maximal number for the whole area. In September 1931, 16,260 cells per litre were recorded from the same locality.

Since this species has such a wide distribution that it can hardly be called neritic, it is an interesting feature of its distribution that it occurs so abundantly in coastal waters. Thus Gran (1915) has reported 50,400 cells per litre from the Oslo-fjord in October. Burkholder (1933) has observed *D. speculum* in the waters of Frenchman's bay, but he does not give any information as to its abundance.

The biological background for this richness in *D. speculum* of inshore waters is yet obscure.



A B

FIGURE 68. *Distephanus speculum* f. *varians*. From station 30.07.

At the stations in the outer part of the bay of Fundy (including Passamaquoddy bay) some forms of *D. speculum* were prevailing which we have referred to as *D. speculum, forma varians* n.f. Characteristic for this form is the absence of an apical ring, while the basal ring is as in *D. speculum* (typicus). Some of the specimens, like A in figure 68, have one of the windows much larger than the others, giving the impression that it might have been formed by the fusion of the central window with one of the outer ones. Other specimens, like B in figure 68, have three evenly large and three small windows.

Schulz (1928) has described a fossil form, f. *pseudofibula*, which has a similar lack of an apical ring and 6 windows only. According to the diagnosis of the genera *Dictyocha* and *Distephanus* (Gemeinhardt 1930), the forms without any apical ring ought to be referred to the genus *Dictyocha*, but their habitus shows that they are very closely related to the known forms of *D. speculum* and naturally join them as an extension of the hitherto known range of variation in *D. speculum*.

Ebria tripartita (Schum.) Lemmermann

Observed in the bay of Fundy; common in September. Maximal number: 740 cells per litre.

Eutreptia Lanowi Steuer

In April, May and August this species was found in small numbers, at various stations. In June it formed an abundant vegetation in the central and outer parts of the bay of Fundy with numbers up to 20,680 cells per litre:

Stations	32	33	34	37	36
1m	40	2,560	980	400	3,040
10	220	220	1,880	920	20,680
25	400	60	240	200	.....
40	80	....	20	40	20

ZOOFLAGELLATES AND CILIATES

Acanthostomella norvegica (Daday) Joergensen

Fairly common during the whole season, this species never reached higher numbers than 220 cells per litre.

Bodo marina Braarud (1935)

This minute flagellate was recorded at various stations, from April to September, in numbers of 200 cells per litre or less.

Codonella sp.

Observed at station 30.09, 25 and 40 m.

Codonellopsis tuberculata (Daday) Joergensen

This species was recorded from three stations in the gulf in August. Maximal numbers: 200 cells per litre.

Corbicula socialis Meunier

Observed in April south of Nova Scotia.

Dictyocysta elegans (Ehrenberg) Kofoid and Campbell

20 cells per litre at station 30.34, 40 m.

Dictyocysta lepida (Ehrenberg) Kofoid and Campbell

20 cells per litre at station 30.33, 10 m.

Didinium parvulum Ringdal. (Ringdal unpub.)

Recorded from 4 stations in April and May.

Favella serrata (Möbius) Joergensen

The distribution of this species seems according to our records to be confined to the bay of Fundy, where it was common in August 1932. Maximal number: 840 cells per litre at station 30.07, 1 m.

Helicostomella subulata (Ehrenberg) Kofoid and Campbell

This species was very abundant in August, especially in the outer Fundy region. Maximal number: 2,900 cells per litre at station 30.37, 1 m.

Laboea Lohmann

This genus had its greatest abundance in spring and early summer, but even then its population in the bay of Fundy and the gulf proper was rather scanty, as compared with what has been recorded from north European waters (Gran 1915, Föyn 1929). At station 26.26, in April, 580 cells of *Laboea* were recorded at a depth of 10 m., and from the neighbouring station 26.28, 500 cells were recorded at the same cruise. Otherwise somewhat high figures for the *Laboea* content were recorded only for the waters off Nova Scotia (stations N197, N240, N246 and N248). At a couple of stations in the south-western part of the gulf (N259 and N260), there were also quite a few. The maximal number for the whole area was recorded for station N197 (see figure 34), viz., 800 cells per litre (consisting of *L. reticulata* only).

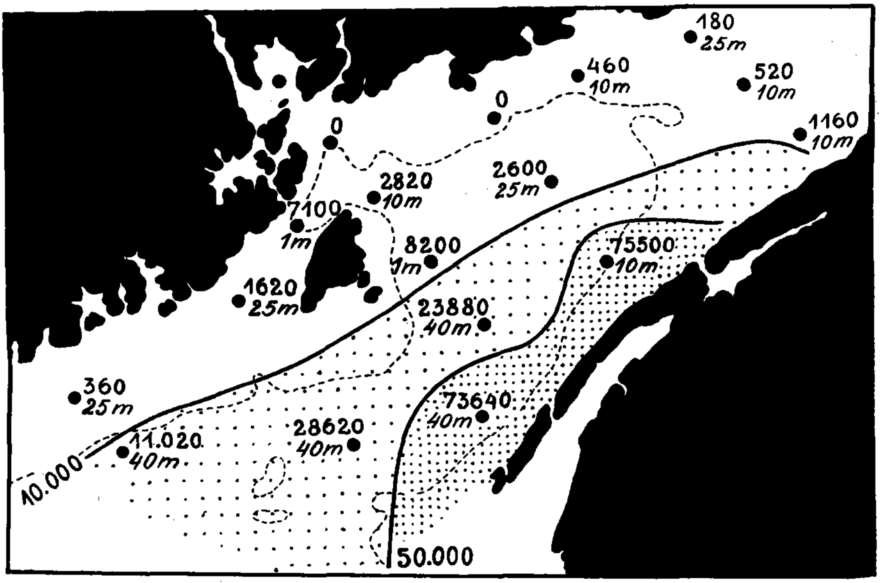


FIGURE 69. *Chaetoceros constrictus.* Maximum numbers at the stations in August, and the depths at which they occurred.

The commonest species was *conica* Lohmann, with maximal number 560 per litre at station 26.26, 10 m. A little less widely distributed were *emergens* Leegaard, *reticulata* Leegaard and *strobila* Lohmann, with maximal numbers respectively: 240 (27.27 10 m.), 800 (N197, 1 and 10 m.) and 260 (N248, 1 m.). The three species *constricta* Leegaard, *delicatissima* Leegaard and *vestita* Leegaard, were observed at only a few stations and in numbers less than 100 cells per litre.

In the classification of the species we have followed Leegaard (1915).

Lohmanniella oviformis Leegaard

This species was common in the centrifuge samples from spring and early summer, but very scarce later on. The greatest number observed was 600 cells per litre.

Lohmanniella spiralis Leegaard
Occasionally observed in numbers up to 200 cells per litre.

Mesodinium rubrum Lohmann
At station 30.37, 1,100 cells of this species per litre were recorded from 10 m., but mostly it is very scarce. Not common.

Parafavella Kofoid and Campbell
Although certainly most of the specimens which have been referred to this genus are *denticulata*, the classification of the various specimens has not been so careful, but that some other species (or variants, according to Wulff 1929) may not have been included too.

Parafavella specimens were common in the samples from the whole area, April to September, but they were not recorded in higher numbers than 200 cells per litre.

Ptychocylis obtusa (Brandt) Kofoid and Campbell
This species is scarce in spring and early summer, a little commoner in August, but even then in small numbers only. The maximal number, 600 per litre, was observed at station N197 1 m., south of Nova Scotia, outside the gulf proper.

Ptychocylis urnula (Claparède et Lachmann) Brandt
In the centrifuge samples from two stations only.

Salpingella acuminata (Claparède et Lachmann) Joergensen
Recorded from a few stations all through the season, in small numbers only.

Stenosemella Joergensen
The specimens belonging to this genus have not been assigned to any of the species, since we have not found that they fully agree with any of those described. It is probable that they may fall within the range of variation of *S. ventricosa* (Claparède et Lachmann) Joergensen (Kofoid and Campbell 1929). In spring they are scarce, but all through summer they are common in the whole area and fairly abundant. The Fundy region seems to be richer in these forms than the gulf proper, and Passamaquoddy bay particularly seems to be a favourable locality. Here 1,200 cells per litre were recorded in July, and 4,100 per litre in September 1932, the maximal number for the whole area.

Strombidium sp.
At a few stations in spring and at station 5 in September, a *Strombidium* form was observed, which was not identical with *S. acutum* Leegaard (Leegaard 1915).

Tintinnopsis spp.
From April to August, specimens of this genus were observed, but only 200 or fewer cells per litre.

Tintinnus sp.
Recorded once.

THE CORRELATION OF THE PHYTOPLANKTON WITH THE PHYSICAL AND CHEMICAL CONDITIONS

The Gulf of Maine

In the gulf of Maine our first observations in spring, from the 29th of April to the 2nd of May, show a phytoplankton dominated by *Thalassiosira Nordenskioeldi*, accompanied by a number of other species in varying quantities (*Thalassiosira gravida*, *Porosira glacialis*, *Chaetoceros debilis*, *diadema*, *compressus* and others). They are the same species as were observed by Bigelow (1926). According to his observations, *Thalassiosira Nordenskioeldi* and its associates (Cleve's "Sira-plankton") initiate the spring growth of diatoms, spreading successively from the coasts outwards in the gulf of Maine. We find the same species on those coasts of northern Europe where the minimal temperatures of the coastal waters are below 4-5°C., propagating to form a rich population just after the surface temperature has reached its minimum, when the winter vertical circulation (overturn) has come to an end. We found the maximal frequency of *Thalassiosira Nordenskioeldi* to be the same as in the Norwegian waters in spring, viz., half a million cells per litre or more.

We have observations from 5 stations, two of the southern section (26, 24A); one of the intermediate section, off Penobscot bay (28); and two of the northern, off Mount Desert island (30 and 31). At the south-western station (26), the growth of diatoms in the surface layers (1-25 m.) had already finished on the 2nd of May. *Ceratium longipes* and *bucephalum* were found in numbers up to 200 per litre, and the diatoms had nearly disappeared. *Chaetoceros compressus* was here more abundant than *Thalassiosira*, which still was present in fair numbers (92,600 per litre) at a depth of 75 m., evidently sinking.

Although no observations on nitrates and phosphates are available from this cruise, it may be concluded from the observations of the following cruise, that the surface layers at this station had already been depleted of nitrates and phosphates by the consumption of the diatoms, and that the situation characteristic of summer conditions had begun to prevail. At three of the other stations, 24A, 28 and 30, *Thalassiosira Nordenskioeldi* and its associates were still at their maximum, and at station 31 the diatoms were less abundant and more mixed. *Thalassiosira gravida* was here more frequent (104,000) than *Th. Nordenskioeldi* (57,000), and *Chaetoceros compressus*, *debilis* and *diadema* occurred in numbers nearly equal to that of *Thalassiosira Nordenskioeldi* (46,000 to 24,000). Probably this situation represented a later stage in the diatom growth than that of the stations 24A, 28 and 30.

It is difficult to judge from these observations when the diatoms had begun to increase their numbers. According to Bigelow the surface waters of this area have their annual temperature minimum about the beginning of March, and it may be expected that the increase in diatoms takes its beginning about the same time.

The observations in **May** were taken four weeks later, from the 27th to the 31st of May. We have observations from 10 stations, four in the southern section, three in each of the others. At all stations also the oxygen and phosphate contents were determined, in the northern section also the nitrate content. (See table V).

TABLE V. Gulf of Maine, May 1932

	Off Casco bay				Off Penobscot bay			Off Mt. Desert I.		
Stations	26	23A	24A	25A	29	28	27	31	17	30
Temperature										
1 m.	9.08	9.38	7.97	8.63	7.86	6.99	8.58	6.08	5.76	6.16
10	.05	.30	.53	.80	6.09	5.86	7.39	.06	.66	.06
25	5.85	6.72	5.14	7.55	5.04	5.41	4.77	5.70	4.57	5.16
40	4.42	4.28	4.29	4.09	4.26	4.88	4.18	4.49	4.75	4.77
75	3.82	3.82	3.88	—	.88	.82	.25	.68	.71	—
Salinity										
1 m.	32.29	32.48	32.05	30.91	32.16	32.16	31.91	32.30	31.96	31.96
10	.29	.48	.03	32.14	.21	.20	.91	.36	32.00	32.00
25	.32	.47	.33	.23	.48	.34	32.12	—	.12	.05
40	.41	.56	.32	.29	.65	.52	.18	.68	.50	.18
75	.63	.70	.63	—	33.01	.75	.47	.95	.56	—
Oxygen, per cent of saturation										
1 m.	105	106	109	109.5	117	106.5	109	111	97	114
10	106	106	109.5	110	114.5	104	110	113	106	99.5
25	110	111	104.5	110	97	99	100		93	108.5
40	103.5	95	96		89.5	92.5	95	91		103
75	91	92	90.5		82	86	91	85	89.5	
Phosphates, mg. P_2O_5 per cu. m.										
1 m.	0	2	6	5	7	13	9	6	7	0
10	0	2	5	5	5	16	—	7	11	2
25	4	—	10	5	21	19	—	20	18	7
40	10	—	23	19	30	21	28	23	20	16
75	23	23	30	—	31	29	25	29	21	—
Thalassiosira Nordenskioeldi, cells per cc.										
1 m.	—	—	—	—	85	—	—	196	82	?
10	—	—	—	—	78	—	—	186	53	43
25	—	—	—	—	1	—	—	?	1	19
40	—	—	—	—	.1	.3	—	?	1	46
75	—	—	—		—	—	—	—		
Chaetoceros debilis, cells per cc.										
1 m.	—	—	—	—	24	—	—	80	17	?
10	—	—	—	—	66	.2	—	61	9	16
25	—	—	—	—	6	—	—	?	14	16
40	—	.1	—	—	1	—	1	?	1	8
75	—	1	t	—	.3	t	—	—	1	
Ceratium longipes, cells per litre										
1 m.	140	440	60	—	—	20	100	—	—	—
10	220	760	20	200	30	20	—	—	—	—
25	340	320	—	620	—	—	—		—	—
40	—	—	—	—	—	—	—		—	—
75	—	—	—	—	—	—	—	—	—	—

t means trace.

In the southern section, the waters were distinctly stratified, with a marked thermocline between 10 and 25 m., or at the innermost station (25A) between 25 and 40 m. (See sections in figure 5). The temperature of the surface layer was about 8°, at the two outer stations (26 and 23A) above 9°, while station 24A showed a relative minimum of temperature (7.96 to 7.53°). The heated surface layer had nearly the same salinity as the colder layer below (32.30 to 32.40⁰/₀₀), except close to shore, at station 25A, where it was as low as 30.91⁰/₀₀ at the surface. The phosphate content was quite low in the surface layer at all stations, below 10 mg. P_2O_5 per cu. m., and at station 26 no phosphate could be found at all. At the outermost (26) and the innermost station (25A) the phosphate content was below 10 mg. even at a depth of 25 m. The oxygen content was above that of saturation from the surface down to 25 m. at all stations, and at station 26 also at 40 m.

The diatom plankton had disappeared, leaving only scanty traces, mostly resting spores, and the phytoplankton consisted of *Ceratia*, principally *Ceratium longipes*, and *Pontosphaera Huxleyi*. The *Ceratia* were most abundant at station 23A with 760 per litre of *C. longipes* at 10 m., and had a minimum of frequency of only 60 per litre at the coldest station (24A). *Pontosphaera* had its maximum at station 26, with a frequency of about 5,000 per litre from the surface down to a depth of 25 m.

Here the change from spring to summer conditions, which a month earlier had been noticeable only at station 26, had now taken place over the whole section, resulting in stratification, depletion of phosphates in the surface layers and the replacement of the diatom plankton by *Ceratia* and *Pontosphaera*. It may be concluded that the rapidly growing diatoms had disappeared, because most of the phosphates had been consumed, and that the phosphate and possibly the nitrate content had been the limiting factors for the further growth of the diatom population, here as at many other localities, as for instance in northern European waters.

In the intermediate section, stations 27 to 29, off Penobscot bay, on the 30th of May, the development had not gone so far. The temperatures of the surface layers were about one degree lower, the increase in temperature (7 to 8°) had not yet reached as far down as in the southern section, and the thermocline was less marked (see table V). Here, too, the intermediate station (28) had a temperature about one degree lower at the surface than at the other stations. The phosphate content of the surface layers was higher than in the southern section, being 5 to 7 mg. at station 29, and at station 28 even 13 to 16 mg. The surface layer was supersaturated with oxygen down to 10 m. at all stations, and at station 29 the oxygen content was very high, the percentage of saturation being 117% at 1 m. and 114.5% at 10 m.

The diatoms had practically disappeared at station 27, were scarce at station 28, the commonest species being *Chaetoceros laciniosus*, *Nitzschia seriata* and *Thalassiosira decipiens*, but at station 29 the *Nordenskioeldi*-plankton was still fairly abundant in the surface layer (1 to 10 m.). (*Thalassiosira Nordenskioeldi* 85,000 per litre, *Chaetoceros debilis* 66,000, *Ch. compressus* 21,0000, *Ch.*

diadema 10,000, *Ch. laciniosus* 4,400 and *Nitzschia seriata* 6,700 per litre. The *Ceratia* were scarce (100 per litre of *Ceratium longipes* at station 27), as also *Pontosphaera Huxleyi.*

The northern section, off Mount Desert island, stations 30, 17, 31, worked on May 27, showed a still earlier stage of development. The temperature of the surface layer (1 to 10 m.) was only just above 6°, at the intermediate station (17) even a little colder, and the phytoplankton was quite dominated by the spring diatoms. At the innermost station (30) the phosphates were low down to the 25 m. level, at the outer stations (17 and 31) only down to the 10 m. level (table V). Of nitrates which after the winter overturn seem to have been present in quantities from 100 to 130 mg. N per cu. m. at the surface, only 17 to 19 mg. were left at 1 to 10 m. at stations 30 and 31, while the nitrate content was higher at station 17 (50 mg. at 1 m., and 38 mg. at 10 m.).

At station 31 the composition of the phytoplankton was very much the same as a month earlier at the same locality, as may be seen from the table below. *Thalassiosira Nordenskioeldi* and *Chaetoceros debilis* had increased in number, while *Th. gravida* and *Porosira glacialis* had disappeared or decreased.

At station 17 and 30 the phytoplankton was not as rich as at station 31, as may be seen by a comparison of the maximal numbers of the main species, recorded in table VI.

TABLE VI. Maximal numbers of cells per litre of the main species of diatoms at stations 30, 17 and 31

	Station 30	Station 17	Station 31	
Thalassiosira Nordenskioeldi	42,900	82,000	196,100	(56,000)
Thalassiosira gravida	60	720	0	(104,000)
Chaetoceros debilis	16,300	17,000	80,400	(24,000)
Chaetoceros compressus	7,400	3,680	35,500	(46,000)
Chaetoceros diadema	5,400	4,180	8,900	(40,000)
Chaetoceros laciniosus	4,900	2,100	5,000	(13,800)
Porosira glacialis	340	540	200	(15,200)
	V/27	V/27	V/27	IV/29

No wonder that the diatoms were decreasing at station 30, where the phosphates and nitrates of the surface layer were nearly exhausted, but it is more difficult to explain that the diatoms had not grown better at the intermediate station (17) with colder water and relatively high content of nitrate and phosphate. We met with the same question still more pronounced in the section off Penobscot bay, where station 28 with relatively cold water had a poor plankton combined with a high phosphate content. The explanation may be that at both these localities the surface waters were influenced by waters running out from the bay of Fundy, and that the biological conditions were more like those of the bay of Fundy than those of the gulf of Maine. In this section no *Ceratia* and no *Pontosphaera* were observed; there was not yet any sign of a change toward the summer conditions.

In **June** the summer situation was established over the whole gulf of Maine, with stratified waters and *Ceratium-Pontosphaera*-plankton at all offshore stations, but with a new growth of neritic diatoms along the coast of Maine (see table VII). We have observations from the same stations as in May, taken from the 28th of June to the 1st of July. Nitrates and phosphates were determined at most of the stations.

The southern section, off Casco bay, had surface temperatures above 15° at the two outer stations, decreasing shorewards to 12.46° at station 25A. The thermocline between 10 and 25 m. was very sharp. (At 75 m. the temperature was below 5°, and at 40 m. below 6° except at station 24A, where it was 6.10°). The salinity was above 32‰ except at the surface at station 23A (31.89‰) and at station 25A, where it was 29.18‰ at 1 m. and 31.89‰ at 10 m. The phosphate content of the surface layer was low (3 to 8 mg.), at the three inner stations, a little higher (9 to 10 mg.) at station 26. Here the cold waters from 25 m. downwards had a very high phosphate content (40 mg. and more) and these layers had also a low oxygen tension, only 93.3% of saturation or less, as a sign that they had been raised from greater depths.

The phytoplankton at the three outer stations (26, 23A and 24A) consisted mainly of *Ceratia* and *Pontosphaera*. *Ceratium longipes* had its maximum at station 23A; here as many as 4,260 per litre were found at 40 m., and at the same depth 2,080 of *C. bucephalum* and 680 of *C. fusus*. *C. tripos* was more abundant at the surface. At station 26 the *Ceratia* were not found below the thermocline and had their maxima at the surface, *C. longipes* with 360 per litre and *C. tripos* with 280. At station 24A *C. longipes* and *bucephalum* were dominant with their maxima at 25 m. *Pontosphaera Huxleyi* had its maximum at station 24A with 172,000 per litre at a depth of 10 m. At station 23A the maximum (37,000) was also at 10 m., just as at station 26 where only 1,340 per litre were recorded. At the innermost station (25A) neither *Ceratia* nor *Pontosphaera* was found, but here diatoms were rather abundant. *Sceletonema costatum* occurred at the surface (1 m.) with a frequency of 166,000 per litre, and only there; *Chaetoceros debilis* occurred at the surface rather scarcely (5,640 per litre), but more abundantly at 40 m., where most of the cells carried resting spores and were evidently sinking. Also at station 24A resting spores of *Ch. debilis* were found, in a number of nearly 60,000 per litre, and less frequently, resting spores of *Ch. compressus* (about 7,000 per litre).

The next section, off Penobscot bay, was worked on the 28th and 29th of June and showed similar conditions, but here the diatoms were found also farther out from the coast. The temperatures were about 11° at 1 m., 6.9° to 8.6° at 10 m. and about 6° at 25 m. (see table VII). The salinity was below 32‰ at the surface at all stations. The nitrate content was low in the surface layer, 19 to 21 mg. N per cu. m. at 1 to 10 m., but high, 105 mg. and more from 25 m. downwards. At station 29 it increased more evenly downwards, with 45 mg. at 10 m. and 70 mg. at 25 m.

The dominant diatoms were *Chaetoceros debilis* (255,000 per litre at 25 m. at station 27, and 214,000 at 25 m. at station 28) and *Ch. compressus* (102,000 at station 27, 25 m. and 81,000 at station 28, 10 m.). Both species had a great

TABLE VII. Gulf of Maine, June 1932

	Off Casco bay				Off Penobscot bay			Off Mt. Desert I.		
Stations	26	23A	24A	25A	29	28	27	31	17	30
Temperature										
1 m.	15.16	15.88	14.44	12.46	10.58	11.21	10.88	9.76	8.24	9.39
10	11.84	12.76	11.25	9.31		7.26	8.57	7.35	7.39	8.03
25	5.43	8.12	7.10	7.23		6.09	6.31	5.16	6.58	6.60
40	5.44	5.81	6.10	5.33	5.99	5.63	5.71	4.74	6.16	6.36
75	4.46	4.18	4.38		5.63	5.84	5.30	5.23	6.14	6.04
Salinity										
1 m.	32.16	31.89	32.07	29.18	31.89	31.91	31.83	32.52	32.45	32.05
10	.21	32.38	.12	31.89		32.30	32.12	.57	.48	.10
25	.30	.41	.23	32.16		.45	.29	.68	.70	.34
40	.36	.66	.48	.20	32.70	.59	.30	.74	.72	.41
75	.70	.77	.74		33.10	.88	.63	33.04	.95	.54
Oxygen, per cent. of saturation										
1 m.	103.5	105.8	109.8	107.0	114.0	107.1	110.5	109.8	98.4	126.2
10	110.0	102.9	109.8	115.8		109.2	116.8	101.1	99.4	118
25	93.3	105.8	109.4	103.2		90.8		89.9	89.6	91
40	93.3	101.5	94.0	86.6	90.5	88.5	87.8	85.2	85.7	90.5
75	88.7	82.4	81.1		80.9	83.2	82.6	76.1	81.8	87.1
Phosphate, mg. P_2O_5 per cu. m.										
1 m.	9	7	7	8					17	
10	10	4	8	3					8	9
25	44	12	21	14					25	25
40	40	27	37	43					42	21
75	45	52	59					54	44	33
***Thalassiosira Nordenskioeldi*, cells per cc.**										
1 m.	—	—	—	—	—	—	—	t	—	4
10	—	—	—	—	—	—	.2	—	—	7
25	—	—	—	—	—	13	6	—	—	2
40	—	—	—	—	—	.2	—	—	—	t
75	—	—	—	—	—	—	—	—	—	—
***Chaetoceros debilis*, cells per cc.**										
1 m.	—	—	—	6	8	2	5	t	—	70
10	—	—	—	—		31	53	t	t	708
25	t	.8[1]	1[1]	1[1]		214	255	—	—	21
40	t	1	63[1]	17[1]	.2	18	2	—	—	.3
75	—	—	—	—	—	t	1	—	—	t
***Ceratium longipes*, cells per litre**										
1 m.	360	360	—	—	820	640	620	380	200	—
10	260	100	320	—		200	80	220	140	40
25	—	780	360	—		—	—	—	40	—
40	—	4,260	—	—	—	—	—	—	—	—
75	—	—	—	—	—	—	—	—	—	—

[1] Resting spores.

number of resting spores, not included in these figures. Even at station 29 the same species were found in numbers of 8,000 to 9,000 cells per litre at the surface. *Thalassiosira Nordenskioeldi* was rather scarce, but occurred from 25 m. downwards at stations 27 and 28. *Pontosphaera* was scarce and the *Ceratia*, represented by *C. longipes*, with maximal numbers at a depth of 1 m. (at station 27, 620; at station 28, 640; and at station 29, 820 per litre), while it was not observed below 10 m.

The northern section off Mt. Desert island, worked on the 28th of June, showed peculiar conditions. The surface temperature was above 9° at stations 30 and 31, but one degree lower at the intermediate station, 17. Here both the phosphate and nitrate contents were rather high at the surface (17 mg. P_2O_5, 106 mg. N per cu. m.) and the oxygen tension was below that of saturation (98.4%).

Near to the coast, at station 30, a very rich diatom plankton had grown up, with a maximum at 10 m. (707,000 per litre of *Chaetoceros debilis* and 213,000 of *Ch. compressus*, and many other species in smaller numbers, even *Thalassiosira Nordenskioeldi* with a frequency of 7,100 per litre). At station 17 these species were nearly absent, the commonest species being *Rhizosolenia fragilissima* with 4,500 per litre at 25 m., and also at station 31 the diatom plankton was poor, and limited to the surface layer from 1 to 10 m. The commonest species was *Nitzschia seriata* with 2,480 cells per litre at a depth of 1 m. *Ceratia* were scarce at station 30, where *C. arcticum* was found to the number of 100 per litre at 10 m. At station 17 *C. longipes* had a maximum of 200 per litre at 1 m., and at station 31, 380 per litre. *Pontosphaera* was observed to the number of 2,000 per litre at the surface at station 31, quite scarce at station 17 and not at all at station 30.

TABLE VIII. Gulf of Maine, August 1932

	Off Casco bay				Off Penobscot bay			Off Mt. Desert I.		
Stations	26	23A	24A	25A	29	28	27	31	17	30
Temperature										
1 m.	19.26	18.45	16.45	16.68	16.75	13.97	12.75	15.83	12.88	11.99
10	15.20	14.56	11.05	11.79	16.45	11.62	9.13	15.36	12.57	9.50
25	9.65	8.70	8.71	9.60	11.07	8.57	9.08	9.51	9.59	8.95
40	7.59	8.57	8.15	8.05	8.41	7.64	8.23	7.96	7.02	8.79
75	6.09	5.20	6.62	7.06	5.58	6.80	7.37	5.38	5.76	8.56
Salinity										
1 m.	31.76	31.83	31.98	31.82	32.34	32.52	32.21	32.36	32.56	32.30
10	32.14	32.27	32.07	31.94	32.34	32.59	32.57	32.36	32.57	32.48
25	32.63	32.57	32.43	32.27	32.61	32.77	32.59	32.54	32.75	32.59
40	32.84	32.63	32.59	32.43	32.68	32.97	32.65	32.79	32.94	32.63
75	32.97	32.72	32.63	32.59	33.31	33.31	32.99	33.13	33.17	32.68
Oxygen, per cent of saturation										
1 m.	112.6	132.5	106.5	108.4	98.2	106.2	111.9	99.6	103.8	118.2
10	108.5	112.5	105.2	117.2	100.0	108.7	93.3	102.0	105.3	94.7
25	106.3	95.4	90.3	93.8	111.2	96.6	93.6	103.6	99.4	92.4
40	82.7	91.1	85.8	87.1	105.0	86.2	85.5	91.6	87.2	89.2
75	74.4	83.3	75.8	77.4	74.6	73.9	77.2	80.4	80.5	86.7

TABLE VIII—*Continued.* Gulf of Maine, August 1932

Phosphate, mg. P_2O_5 per cu. m.										
1 m.	7	10	8	12	7	10	14	10		10
10	10	8	34	14	7	12		12		30
25	17	32	44	25	12	23	34	22		37
40	39	47	34		21	37	40	35		30
75	54	48	48	31	35	50	37	42		35
Chaetoceros compressus, cells per cc.										
1 m.	.1	—	.4	.4	—	—	61	—	—	34
10	—	—	.1	30	—	—	—	—	—	.4
25	—	.7[1]	—	—	—	.5	—	—	t[1]	—
40	2	.2[1]	—	—	—	—	1[1]	—	t[1]	t
75	—	—	—	—	—	t	t[1]	—	t[1]	—
Rhizosolenia alata, cells per cc.										
1 m.	.4	.3	.2	.1	1.5	6.1	—	2.0	2.7	.3
10	3.8	.5	.1	.1	3.0	5.5	.4	2.0	2.3	.2
25	5.1	2.2	.3	—	3.0	2.2	1.0	.2	2.0	.4
40	.6	t	.4	.1	5.9	t	.1	t	t	.2
75	.6	t	—	—	—	t	t	—	—	.3
Ceratium longipes, cells per litre										
1 m.	—	20	300	240	—	20	200	—	—	100
10	—	60	20	120	—	20	—	20	40	40
25	40	300	40	60		120	—		40	20
40	200	520	20	20	40	100	—	40	40	20
75	160	580	40	—	1,260	20	60	1,700	440	20
Ceratium fusus, cells per litre										
1 m.	100	120	60	20	160	220	100	80	280	—
10	140	160	180	40	220	580	—	100	520	60
25	620	—	—	—	760	120	—	240	—	60
40	—	—	—	—	520	—	—	—	—	—
75	—	—	—	—	—	—	20	—	—	—

[1]Resting spores.

The conditions at station 17, where the phytoplankton was poor in spite of a high content of phosphates and nitrates in the surface water, represent a case where the occurrence of the nutrient salts cannot have acted as the limiting factor for the growth of the phytoplankton. Such cases are rare in the gulf of Maine, but commoner in the bay of Fundy. As we have mentioned above, this locality is situated just where the waters drifting out of the bay of Fundy go; our observations agree with the supposition that the surface waters here have their origin in the bay of Fundy. We shall, therefore, postpone the discussion of the peculiar life conditions in these waters, till those of the bay of Fundy are treated.

In **August** the situation was principally unchanged since June, only with slight modifications in the relative predominance of the various vegetations, although six to seven weeks had passed since the last cruise. The outermost stations in each section (26, 29 and 31) had very much the same character.

Ceratium longipes (and *bucephalum*) had nearly disappeared from the surface layer, but had accumulated at a depth of 40 and 75 m., at station 29 with numbers of 1,260 per litre, and at station 31 with 1,700 per litre (see table VIII). At the surface, as the following table shows, it was replaced by *C. fusus* and *tripos*, which require a higher temperature for their propagation. The table also shows, most clearly for *C. fusus*, that the maximum was found at a depth of about 25 m. at the outer stations (this may have been rendered possible by the high degree of transparency in the offshore waters of the gulf of Maine at this season, see Gran 1933).

Also *Pontosphaera Huxleyi* had increased in number, at station 31 to 41,000 per litre at a depth of 25 m. *Rhizosolenia alata*, which was very rare in June, was found in fair numbers with a maximum of frequency at the outer or intermediate stations, and more scarce near the shore (see table VIII).

Characteristic members of this summer vegetation of the offshore waters were also *Gonyaulax tamarensis* and *Coscinosira Oestrupi*, although they must rather be classified as neritic species.

The distribution of the oxygen clearly shows that the zone of predominant photosynthesis was deeper at the offshore stations than near the coast. The concentration of phosphates also showed low values in the photosynthetic zone and higher ones below it (see table VIII).

The coastal stations (25A, 27 and 30) were at the same time characterized by a rich and varied plankton of neritic diatoms. The species were mostly the same ones as those observed in June at the same localities, but the relative abundance had changed in correspondence with the increase in temperature. Most of them had their maxima at a depth of 1 m. *Thalassiosira Nordenskioeldi* had nearly disappeared, and *Chaetoceros debilis* decreased in number, while *Ch. compressus* had held the ground; the *Ch. constrictus* and *cinctus* populations had increased at the two northern localities, as also that of *Sceletonema costatum*. The diatom plankton, which according to Bigelow's observations (Bigelow 1926) usually keeps on growing at these localities through the whole summer, successively changes in character, the cold water species being replaced by others which are favoured by higher temperatures. From our observations at station 30 in 1932, the following sequence may be representative, with the maxima of the various species overlapping each other:

	April	May	June	August	
	Thalassiosira *Porosira glacialis* *Chaetoceros diadema*	*Ch. debbilis*	*Ch. compressus*	*Ch. constrictus*	*Ch. cinctus* *Sceletonema*
Surface temp.	3°C.	6°C.	9°C.		12°C.

The intermediate stations of each section (24A, 28 and 17) showed transitions between the corresponding outer and inner stations in the composition of the plankton as well as with regard to the depth of the photosynthetic zone.

The observations recapitulated above show that in the gulf of Maine the production of phytoplankton is generally limited by the supplies of light and of nutrient salts, in 1932 rather of phosphates than of nitrates. The light intensity determines the depth of the productive zone. In the offshore waters the balance between photosynthesis and respiration for the total population is in summer to be found below 25 m., nearer to the coast between 10 and 25 m., and at the innermost stations the transparency of the water may be so low that respiration dominates over photosynthesis, even at a depth of 10 m. The most rapid production certainly takes place in early spring, when the diatoms are predominant in relation to all other species, also to the zooplankton. At this season respiration must be slow because of the low temperature, and, therefore, the light intensity, sufficient to make photosynthesis balance respiration, may be low.

When the phosphates (or nitrates) of the illuminated zone have been reduced to a minimum, we find that the neritic diatoms can no longer propagate; they form resting spores and sink. In the offshore waters of the gulf, getting stratified by heating of the surface layers, the phosphates can no longer to any considerable extent be supplied from the lower strata by mixing. Nevertheless we find in the surface layers an increasing population. The species which grow in spite of the low phosphate content, *Ceratia*, *Pontosphaera* and *Rhizosolenia alata*, seem to have a slower rate of propagation than the neritic diatoms, and consequently must have a slower metabolism and require a lower concentration of nutrient salts for their growth. Most of them are, as a contrast to most plankton diatoms, motile and may be expected to be able to utilize the nutrient salts more completely, by locomotion from a habitat where the supply is exhausted. But when the concentration of soluble phosphates is rather constant during the summer, it may be explained by the metabolism of the zooplankton in connection with bacteria, which regenerate soluble phosphates (and nitrates) from organic compounds. The productivity of these offshore waters is, however, not high and the low concentration of the nutrient salts must undoubtedly be the limiting factor. Vertical circulation (as over Georges bank) may be sufficient to change the conditions and produce a rich growth of *Rhizosolenia alata*. Likewise a culture experiment (Gran 1933) with offshore water from the gulf, with addition of small quantities of nitrate and phosphate, gave a remarkable acceleration of the rate of propagation of the same species.

Along the coast, as at our stations 27 and 30, neritic diatoms grow continually through the whole summer, with quantitative fluctuations and with a succession of various species. Here it must be supposed that the supply of nitrates and phosphates must be quicker, as they must be continuously consumed by the rich population of diatoms. The most probable explanation may be that the tidal movements near the shore give the surface layer sufficient admixture of waters from lower levels. We have seen that the productive zone is here often less than 10 m. deep, and therefore the movements required for a sufficient supply of nutrients from below ought to be moderate.

Thus, in the gulf of Maine, the production during summer seems to be limited by the low phosphate and nitrate contents of the surface layers, and this again is caused by the stratification. Where the stratification is broken as on Georges bank, and near the coast, a richer production is possible also during the summer.

The ever varying conditions in the gulf of Maine are of course more complicated than we for the sake of simplicity have represented them to be, and we have ourselves observed and described facts which cannot be sufficiently explained by our suppositions. But after all, the general changes in the growth and decline of the phytoplankton population of the gulf of Maine, and its local variation agree with the generally adopted theories, that the quantitative variations are governed by the supplies of light and nutrient salts (phosphates and nitrates).

The Bay of Fundy

In the bay of Fundy, winter conditions were still prevailing during March. The scanty phytoplankton consisted of tychopelagic species and scarce remains of the autumn plankton of the preceding year.

For **April** we have observations from Passamaquoddy bay and from nine stations in the bay of Fundy, from the 15th to the 22nd. In the inner part of the bay of Fundy, station 10A and 12, the phytoplankton was still very poor. Through the whole water column *Melosira sulcata* was found, rather evenly distributed, as a sign of turbulence. *Thalassiosira decipiens*, a slowly growing species, also in other areas known as a characteristic winter form, was at station 10A evenly distributed from top to bottom, in numbers less than 1,000 per litre, while at station 12 a slight accumulation in the surface layer was noticeable, with a frequency of 1,400 per litre.

Within Passamaquoddy bay and just outside, at station 5, the spring growth of diatoms was going on in the surface layer (1 to 10 m.) with *Thalassiosira Nordenskioeldi* as the dominant species. At station 5, 118,000 cells per litre were recorded at a depth of 1 m. Other species, such as *Chaetoceros debilis*, *Porosira glacialis* and *Thalassiosira gravida* were quite subordinate and occurred in numbers from 2,000 to 4,000 per litre. In the central and outer parts of the bay (stations 35, 34 and 32) the spring diatoms were growing too, but except for a small area (see Prince observations, page 335) they were more evenly distributed at all depths and showed no accumulation near the surface, probably as an effect of the turbulence of the water. The temperature also was nearly even at all depths, viz., between 3 and 4°. Also here *Thalassiosira Nordenskioeldi* was the dominant species with maxima of 11,600 at station 35 and 46,000 at stations 34 and 32. Subordinate species were *Thalassiosira gravida*, *Th. decipiens*, *Porosira glacialis* and *Chaetoceros diadema*. They were all evenly distributed at all levels, except *Thalassiosira decipiens*, which showed a tendency to accumulate in deep water.

For the month of **May** we have a complete series of stations, with observations also on the oxygen, phosphate and nitrate content of the waters, made from the 18th to the 24th.

The highest numbers of diatoms were found in the Quoddy area and in Grand Manan channel (stations 5 and 14), where evidently the growth had continued since April. (*Thalassiosira Nordenskioeldi* was still dominant with

100,000 to 200,000 cells per litre at station 5 and 120,000 to 464,000 at station 14. Subordinate components of the plankton were here *Chaetoceros debilis*, *Ch. diadema*, and as an indication of turbulence, *Melosira sulcata*.) The diatoms were evenly distributed at all depths and the water was supersaturated with oxygen from the surface down to a depth of 75 m. The salinity was below $32^0/_{00}$ down to the 75 m. level at both stations, and the temperatures were lower than anywhere else except along the New Brunswick coast.

TABLE IX. Bay of Fundy, May 1932

Depth (m.)	T	Sal.	P_2O_5	Nitr. N.	*Thal.* cells per cc.
Station 5, May 19					
1	4.62	31.20	17	52	154
10	4.55	31.24		62	142
25	4.50	31.29	17	68	106
40	4.06	31.51	25	98	193
75	3.91	31.56	25		103
Station 14, May 18					
1	4.3	31.55	15	36	164
10	3.8	31.62	15	96	287
25	3.7	31.71	11	98	188
40	3.6	31.82	21	104	147
75	3.4	31.91	21	104	122

This uniformity of the waters from top to bottom, shown also in table IX, is certainly an effect of turbulence. Dr. Watson has found conditions such as these to be characteristic for Grand Manan channel, and particularly this locality (station 14) at high tide, while at low tide, waters of higher salinity are raised to a higher level, covered by a thinner layer of surface water.

TABLE X. Bay of Fundy, May 19, 1932

Depth (m.)	T	Sal.	P_2O_5	Nitr. N.	O_2%
Station 11					
1	4.30	31.74	24	118	103
10	4.04	31.73	25	116	102
25	3.99	31.73		118	101
40	3.97	31.74		106	101
75					
Station 12					
1	6.26	28.26	23	118	103
10	3.87	31.51	20	118	101
25	3.70	31.65	20	114	100
40	3.71	31.72	25	114	100
75					
Station 13					
1	6.82	26.15	16	98	104
10	3.13	31.87	23	104	99
25	3.01	31.87	23	122	98
40	2.83	31.91	25	122	98
75	2.78	32.12	25	118	97

These rich stations may best be compared with the three stations (11, 12 and 13) along the New Brunswick coast. Here too, the waters were rather uniform from top to bottom, as seen from table X, with the only exception that the very surface at stations 12 and 13 had a relatively high temperature, above 6°, and a low salinity, as an effect of the outflow from the Saint John river.

The phytoplankton was quantitatively very poor, and the nitrate and phosphate content high right up to the surface. Only at station 13, both the nitrate and phosphate contents were slightly lower at a depth of 1 m. than deeper down, possibly as an effect of the beginning increase in *Peridinium triquetrum* (500 per litre) or possibly caused by mixing with fresh water. The waters were saturated with oxygen at all depths, or slightly supersaturated at the surface.

The diatoms were very scarce. Dominant as to numbers was *Melosira sulcata*, which was equally abundant at all depths, except in the diluted surface waters at stations 12 and 13.

TABLE XI. Bay of Fundy, May 19, 1932

Depth (m.)	*Melosira sulcata*, cells per litre Station 11	Station 12	Station 13
1	1,300	—	100
10	1,860	2,960	3,480
25	1,370	1,140	460
40	780	600	2,040
75			920

As mentioned before, this species does not belong to the phytoplankton proper, but it is often washed out from the shores. When occurring regularly as on this occasion, it gives a sure indication of the turbulence of the waters. Of true pelagic species small numbers were observed of *Thalassiosira Nordenskioeldi*, *Chaetoceros debilis*, *compressus* and *diadema*, and *Porosira glacialis*. All of them are characteristic representatives of the spring plankton of diatoms of our area, but they were all quite scarce. It can be postulated with certainty that the waters running along the New Brunswick coast in the middle of May had not yet carried a population of diatoms comparable to the rich growth characteristic of most other parts of our area.

The same can be said of the waters flowing into the bay of Fundy along the Nova Scotian coast, represented by our station 8A (table XII). Here the oxygen tension was below saturation at all depths, the phosphate and nitrate content high, and the diatom plankton still poorer than along the coast of New Brunswick.

TABLE XII. Bay of Fundy, May 23, 1932

Depth (m.)	T.	Sal.	P_2O_5	Nitr. N.	O_2, % of sat.
Station 8A					
1	5.30	32.45	23	108	85.5
10	5.10	32.47	23	101	95.5
25	5.16	32.50	23	101	94.5
40	5.09	32.52	23	107	–
75	5.10	32.52	26	118	94.5

At the other stations in the central and inner parts of the bay of Fundy, the surface waters were more or less stabilized, with a fairly rich diatom plankton and with a marked indication of oxygen production at a depth of 1 m., partly also at 10 m., and with minimum values for phosphates and nitrates at the surface; but from 10 m. downwards the same quantities of *Melosira sulcata* were found as at the stations along the coast of New Brunswick. These layers were also still very cold, with temperatures below 4°. The rich plankton of the surface at station 6 had the same character as that of the Quoddy area and may have floated out from there.

The rest of the stations in the central and inner parts of the bay of Fundy, stations 35, 37 and 9 along the Nova Scotian coast, and stations 7, 36 and 10A along the central axis of the bay, were sufficiently like each other to be treated together. All of them had the waters well stabilized, with temperatures above 6° at the surface (except at station 35, where at 1 m. the temperature was 5.97°). At all of them the surface water was supersaturated with oxygen and had low phosphate and nitrate contents, as an indication of a very active photosynthesis and growth of the phytoplankton.

At the two innermost stations, 9 and 10A, the phosphate content was only 4 mg. per cu. m., the lowest value we have observed in the bay of Fundy.

The phytoplankton was not very rich in quantity, but contained a great number of various species, as *Thalassiosira Nordenskioeldi, Chaetoceros debilis, diadema, compressus* and *laciniosus* in about equal numbers. (See table XIII).

Resting spores were rather abundant, and the maximum of the vegetation was found somewhat below the surface, most often at 10 m. These facts indicate that the maximum of abundance and growth had already passed, and that the situation at the two inner stations, 9 and 10A, represented a later stage in the development than that of the other stations. It may be concluded that the whole of this area had been populated by a normal, rich spring growth of diatoms, which had reached its maximum one or two weeks before our observations were made (21st to 23rd of May).

TABLE XIII. Bay of Fundy, central and inner part, May 21 to 23, 1932

Stations	7	35	36	37	10A	9
Temperature						
1 m.	6.67	5.97	7.16	7.93	7.58	7.99
10	5.80	5.71	5.91	5.47	6.71	6.47
25	4.47	5.09	4.68	5.18	4.53	5.79
40	4.49		3.98	5.14	4.37	5.51
75	4.41	4.87[1]	3.84	4.93		

TABLE XIII—*continued*. Bay of Fundy, central and inner part. May 21 to 23, 1932

Stations	7	35	36	37	10A	9
Salinity						
1 m.	31.64	31.98	30.82	30.57	29.16	30.62
10	31.94	31.98	31.24	31.96	30.93	31.55
25	32.30	32.45	32.23	32.09	32.00	31.80
40	32.34		32.39	32.14	32.01	31.82
75	32.65	32.77[1]	32.39	32.27		
Oxygen, per cent of saturation						
1 m.	113	106	114	107	107	102
10	99.5	103	112.5	103	101	101.5
25	96	97	100	100	97	101
40	96		93.5	99.5	97.5	100
75	89	78[1]	93	99		
Phosphate, mg. P_2O_5 per cu. m.						
1 m.	6	13	19	8	4	4
10	23	13	23	21	10	40
25		23	25	22	22	26
40			25	20	22	
75	29	37[1]	23	20		
Nitrate, mg. N. per cu. m.						
1 m.	19	24	20	24	24	25
10	25	36		80	50	75
25	115	94		88	104	50
40	122		130	98	74	94
75		129[1]	122	98		
Chaetoceros debilis, resting spores not included. Number of cells per cc.						
1 m.	13	7	11	.5	4	8
10	23	6	27	5	2	5
25	12	.3	13	1	1	3
40	7.1		1	4	—	1
75	.1	—	2	2		
Thalassiosira Nordenskioeldi, cells per cc. Resting spores not included.						
1 m.	16	9	17	—	.4	—
10	27	15	37	4	.7	.4
25	12	.4	27	1	1.4	.2
40	15		1	2	—	.4
75	1		3	4		
All diatoms, resting spores included. Number of cells per cc.						
1 m.	75	30	45	10	12	29
10	93	29	86	20	8	23
25	69	1	71	15	5	18
40	52		12	34	—	9
75	11	1[1]	17	32		

[1]At 60 m.

The stations at the mouth of the bay of Fundy (32, 33 and 34) had a plankton of a similar character to that farther in, with regard to the species present as well as to their numbers. The phytoplankton was more evenly distributed at all depths, probably as an effect of turbulence. The physical and chemical observations too, indicated a strong turbulence of the waters, particularly at station 34. Here the temperature was uniformly low at all depths down to 75 m., between 4.38 and 4.41°, the phosphate and nitrate contents were high at all depths (24 to 26 mg. P_2O_5 and 114 to 122 mg. N per cu. m.). The water was subsaturated with oxygen at all depths, even at the surface. At station 33 the surface waters also were thoroughly mixed from 1 to 40 m., and had the same character as at station 34, while at 75 m. the water had the character of the oceanic deep water of the gulf of Maine, with a high temperature (6°) and salinity (33.77$^0/_{00}$), low oxygen content (73% of saturation) and high values for phosphate and nitrate contents (47 and 192 mg.). At station 32 the effect of turbulence was slightly less than at the two other stations.

The situation had not changed much in this area since April. We found at station 34, on the 22nd of April, the same diatom plankton as in May, distributed evenly at all depths, and also low and even temperatures (3.6 to 4°). The strong turbulence had evidently during spring kept the diatom growth at a moderate level, by preventing the diatoms from accumulating near the surface.

For the month of **June** we have observations from the same stations as for May, taken within a week, from the 20th to the 26th of June. The results gave a great surprise. The phosphate and nitrate contents were high from the deep layers up to the surface. At most of the stations the phosphate content at a depth of 1 m. was 20 mg. P_2O_5 per cu. m. or higher, only two stations showing lower values (13 mg. at station 6 and 17 mg. at station 7). The nitrate content at 1 m. was 33 mg. N per cu. m. at station 36, 50 in Passamaquoddy bay and 55 at station 8A, but elsewhere it was 60 mg. or higher. In spite of this, the phytoplankton was exceedingly poor at most of the stations. Only in Passamaquoddy bay a rich diatom plankton was found, consisting of *Chaetoceros debilis* as the predominant species with 151,000 cells per litre at 1 m. One might have doubted whether the centrifuge method had given an adequate picture of the situation, if the results had not been corroborated by the observations on the oxygen. Only at one single station (36), were the surface waters slightly supersaturated with oxygen, and here also a slight maximum of phytoplankton was found. Everywhere else the oxygen values were below saturation, even at the surface.

The stations in the Quoddy area (5 and 14) were the poorest ones of all. The total numbers of diatoms were 500 per litre or less, *Thalassiosira decipiens* being the commonest species of all. Not much richer were the stations along the New Brunswick shore (11, 12 and 13). Here too, *Thalassiosira decipiens* was the dominant species, rather evenly distributed at all depths in numbers of 1,000 to 3,000 per litre. *Melosira sulcata* was also relatively common, and small numbers were observed of *Eutreptia Lanowi* and *Exuviaella baltica*.

At the stations near the entrance (33, 34, 8A and 35) and in the centre of the bay of Fundy (7 and 36), a *Ceratium*-plankton like that of the gulf of Maine had appeared. *Ceratium longipes* was fairly abundant particularly at station 8A (see table XIV). *Pontosphaera Huxleyi* had a similar distribution.

Together with these oceanic species, some neritic diatoms occurred, evidently introduced from the gulf of Maine, forming a maximum in the moderately stabilized waters in the centre of the bay, at station 36, the only locality showing supersaturation in oxygen at the surface. The species were: *Rhizosolenia fragilissima*, *Nitzschia seriata*, *Eucampia recta*, *Detonula confervacea* and *Leptocylindrus minimus*. The green flagellate *Eutreptia Lanowi* and the brown peridineans *Peridinium triquetrum* and *Exuviaella baltica*, were members of the same vegetation (table XIV, where as examples the itemized records are given for some of them). The surplus in oxygen at station 36 was evidently produced mainly by *Eutreptia*, *Detonula* and *Peridinium triquetrum*, while *Rhizosolenia*, *Nitzschia*, *Ceratium longipes* and *Pontosphaera* were dominant at the outer stations (33, 34 and 8A).

At the two innermost stations, 9 and 10A, the phytoplankton was very poor. At station 10A about the same species were found as at station 36, but in much smaller numbers. The stability of the water layers was low, particularly at station 9, and the nitrate and phosphate contents high from bottom to surface, although the nitrate content in these shallow waters (63 mg. N per cu. m. at station 9 and 73 mg. at station 10A) had not been regenerated to reach the high values as for instance at the stations 32 and 34 (105 to 109 mg. N).

TABLE XIV. Bay of Fundy, June 21 to 26, 1932

Stations	33	34	8A	7	35	36	37
Temperature							
1 m.	7.39	7.99	8.02	8.83	7.76	9.46	7.66
10	6.95	8.42	7.15	7.21	7.38	8.86	7.40
25	6.42	6.28	6.93	6.47	6.07	6.74	7.21
40	6.96	6.11	6.88	5.17	6.26	6.23	7.18
75	6.24	6.28	6.38	5.36	5.97	5.93	7.16
Salinity							
1 m.	32.20	31.91	32.56	31.78	31.92	31.98	32.41
10	32.41	32.57	32.59	32.21	32.32	31.98	32.50
25	32.48	32.57	32.68	31.25	32.32	32.29	32.50
40	32.48	32.66	32.70	32.50	32.41	32.65	32.50
75	32.48	32.94	32.99	31.92	32.86	32.75	32.50
Oxygen, per cent. of saturation							
1 m.	95.4	97.4	98.3	90.3	96.7	102.0	95.6
10	92.6	90.0	93.7	97.1	95.2	100.8	96.7
25	91.1	89.5	93.0	—	91.0	92.6	94.2
40	94.4	87.1	93.4	88.3	90.0	89.6	94.2
75	76.2	87.0	86.4	82.7	84.1	86.4	93.5

TABLE XIV—*Continued.* Bay of Fundy, June 21 to 26, 1932

Stations	33	34	8A	7	35	36	37
P_2O_5, mg. per cu. m.							
1 m........	25	24	20	17	22	25	31
10	28	—	20	27	28	25	36
25	45	45	27	30	40	31	32
40	—	32	29	40	52	33	32
75	56	45	46	50	39	27	32
Nitrate, mg. N. per cu. m.							
1 m........	109	109	55	62	76	33	73
10	116	60	55	66	77	58	75
25	109	120	88	80	110	78	63
40	105	182	80	110	106	113	70
75	190	109	106	150	150	116	63
Rhizosolenia fragilissima, cells per litre							
1 m........	300	60	4,640	—	—	—	80
10	280	8,280	5,400	—	40	—	480
25	1,460	40	860	60	—	—	440
40	6,500	160	2,680	—	80	100	160
75	960	4,840	1,160	40	80	180	280
Detonula confervacea, cells per litre							
1 m........	260	320	—	—	—	12,960	580
10	280	3,240	—	—	—	8,560	1,640
25	960	400	—	—	—	6,440	640
40	2,940	140	—	—	—	480	640
75	80	1,160	—	—	—	80	760
Eutreptia Lanowi, cells per litre							
1 m........	2,560	980	—	—	—	3,040	400
10	220	1,880	—	—	—	20,680	920
25	60	240	—	—	—	—	200
40	20	20	—	—	—	20	40
75	—	—	—	—	—	—	120
Ceratium longipes, cells per litre							
1 m........	—	—	300	20	20	80	—
10	60	760	120	20	160	80	—
25	60	—	140	—	—	—	—
40	180	—	160	—	20	—	—
75	20	—	20	—	—	40	40
Pontosphaera Huxleyi, cells per litre							
1 m........	200	200	360	—	—	240	—
10	—	5,400	840	20	—	1,040	240
25	640	40	—	—	—	320	80
40	3,540	20	—	20	—	—	40
75	60	1,820	—	—	—	20	—

As a general result of the June observations it may be concluded with certainty that the poor growth of the phytoplankton in the bay of Fundy at this season had not been limited by the lack of nitrates or phosphates in the surface layers.

On the other hand there are indications that the growth of the phytoplankton population had been checked by the strong turbulence of the waters. The few localities where a fair growth was observed, viz., Passamaquoddy bay and the central parts of the bay of Fundy (station 36), were characterized by more stabilized waters than were found elsewhere in the bay of Fundy.

For the month of **August** we have observations made at the same stations as in June, most of them worked within a week, from August 15 to 21. Only two stations, 14 and 15, in Grand Manan channel and just outside, were worked a week earlier, on the 8th of August.

All the stations showed a considerable rise in temperature, and all stations in the bay of Fundy except the outermost ones, bordering the gulf of Maine, showed at the same time a marked increase in stability. Only at the innermost station on the Nova Scotian side (9), the difference in density between the 25 m. and the 1 m. samples was very small (0.06) and in the Quoddy area (stations 5 and 14) the waters were also less stable than elsewhere (difference in density between the 25 and the 1 m. samples 0.17 and 0.35, see table XV). Over the whole central and inner part of the bay of Fundy, except the Quoddy area and at station 9, the surface temperature was above 12°.

In the Quoddy area, the phytoplankton was poor at station 5, with only up to 7,000 diatoms per litre, evenly distributed at all depths, *Sceletonema costatum* being the dominant species. The oxygen content was below that of saturation at all depths, and the phosphate and nitrate high. At this locality no considerable growth can have taken place during the weeks immediately preceding the observations. At station 14 the phytoplankton was rich, with a frequency of up to 415,000 diatoms per litre, of which *Sceletonema costatum* and *Asterionella japonica* were the dominant species. The diatoms were evenly distributed at all depths, but the waters were supersaturated with oxygen only at the surface (102.3% of saturation at 1 m., 98.2% at 10 m.), and the phosphate and nitrate contents were high at all depths (of phosphates 22 mg. P_2O_5 or more, of nitrate 73 mg. or more). A similar accumulation of water layers, rich in phytoplankton, was observed at the same locality, on the 18th of May.

TABLE XV. Differences between the densities at the 25 m. and 1 m. levels (+ means an increase, and − a decrease, compared with the previous cruise)

Stations	Cruise 27	Cruise 28		Cruise 30		Cruise 32	
5	0.18	0.14	−	0.17	+	0.29	+
6	1.30	0.18	−	0.77	+	−	
7	0.77	0.69	−	1.37	+	0.07	−
8	0.06	0.25	+	0.44	+	0.07	−
9	1.21	0.04	−	0.06	+	0.01	−
10A	2.58	0.23	−	1.54	+	0.03	−
11A	0.02	0.06	+	0.78	+	0.18	−
12	2.64	0.85	−	1.20	+	0.23	−
13	4.90	0.06	−	1.65	+	0.38	−
14	0.16	0.05	−	0.35	+	0.31	−

TABLE XV—*Continued.* Differences between the densities at 25 m. and 1 m. levels

Stations	Cruise 27	Cruise 28	Cruise 30	Cruise 32
17	0.26	0.43 +	1.27 +	
23A	0.38	1.83 +	2.52 +	
24A	0.57	1.39 +	1.84 +	
25A	1.18	3.16 +	1.75 −	
26	0.48	1.72 +	2.68 +	
27	0.66	1.03 +	0.95 −	
28	0.36	1.19 +	1.44 +	
29	0.82	1.31 +	1.38 +	
30	0.19	0.62 +	0.83 +	
31	0.49 (1-40 m.)	0.77	1.35 +	
32	0.28	0.31 +	0.24 −	
33	0.07	0.28 +	0.28	
34	0.05	0.74 +	0.07 −	
35	0.48	0.53 +	1.22 +	0.16 −
36	1.41	0.64 −	1.25 +	0.26 −
37	1.54	0.13 −	0.82 +	0.31 −
1C (IV/25)	0.51	0.78 +	1.26 +	0.22 −

Along the New Brunswick coast the diatom plankton was poor, with only 10,000 to 17,000 cells per litre, consisting of the *Sceletonema*-society, mixed with the oceanic species *Rhizosolenia alata. Peridinium triquetrum* occurred abundantly at the surface, with a maximum of 122,000 per litre at station 12, and *Ceratia* were fairly abundant, with a maximum of 500 *C. fusus* per litre at station 13, 1 m. Even *Pontosphaera Huxleyi* was rather common at the surface, with a maximum of 42,000 at station 13, 10 m. At all these three stations the water was supersaturated with oxygen at the surface. The phosphate and nitrate contents were lower at the surface than in the deeper layers, but not very low except at station 11, where the phosphate content was as low as 9 mg. and the determination of nitrates gave a negative result (see table XVI below).

TABLE XVI. Bay of Fundy, August 19 to 21, 1932

	Station 13	Station 12	Station 11
Phosphate, mg. P_2O_5 per cu. m.			
1 m.	20	23	9
10	30		29
25	35	35	29
40	40	35	37
Nitrate, mg. N. per cu. m.			
1 m.	30	60	0
10	73	72	75
25	82	84	—
40	118	98	82

It is difficult to explain the low content of nutrients at station 11. It can hardly have been caused by the consumption by the phytoplankton present at this locality at the time of observation.

The inflowing waters at station 8A were characterized by a fairly rich diatom plankton, consisting of *Chaetoceros constrictus*, accompanied by smaller numbers of *Cerataulina Bergoni*. *Ch. constrictus* had many resting spores, and its maximum was found at a depth of 40 m., as a sign that the diatoms were already sinking. *Ceratia*, *Pontosphaera* and *Rhizosolenia alata*, the oceanic species of the gulf of Maine, and also *Peridinium triquetrum* were present, but not very abundant. The surface temperature was rather low, 10.6°, and the phosphate and nitrate contents high (20 mg. P_2O_5 and 60 mg. N. per cu. m. at 1 m.) The waters were supersaturated with oxygen only at the very surface. The stratification was not very marked.

Nearly the same conditions were found at the two stations farther west, 33 and 34. Here *Chaetoceros constrictus* was less abundant, but the oceanic species (*Ceratia*, *Pontosphaera* and *Rhizosolenia*) were more numerous. The waters were just saturated with oxygen (station 34) or slightly supersaturated at depths of 1 and 10 m., and the phosphate and nitrate contents high right up to the surface. The surface waters were even less stabilized than at station 8A, particularly at station 34.

The conditions in the central and inner parts of the bay of Fundy, except those on the New Brunswick side, already treated above, are shown in table XVII. At all stations except station 9, the waters were well stabilized with temperatures above 12° at the surface. At station 9 the water must have been thoroughly mixed, as the salinity was high even at the surface, the temperature uniform at all depths (10.12° to 10.48°) and the nitrate and phosphate contents uniformly high. The phytoplankton was here much poorer than at the other stations.

At all the other stations the surface waters with temperatures above 11° had phosphate contents below 20 mg. and nitrate contents below 60 mg. As far as our observations go, the same surface layers were supersaturated with oxygen, while the layers below had a deficit in oxygen. Only in the warm surface layer, the oxygen production of the phytoplankton had been intensive enough to surpass the consumption by respiration, and only here had a heavy consumption of nitrates and phosphates taken place. In the table we have marked by a line the lower limit of the heated surface layer, characterized by temperatures above 11°, supersaturation in oxygen, phosphate contents below 20 mg. and nitrate contents below 60 mg. Some photosynthesis may also have taken place in the waters below this limit, although it had been insufficient to make the oxygen content increase above saturation.

The thickness of this very productive layer was less than 10 m. at the inner stations (10A and 37), between 10 and 25 m. at the outer stations, and at station 7 it was even more than 25 m. deep. These variations may have been caused by differences in the transparency of the water, but it is also possible or even probable that winds and currents may have accumulated a thicker surface layer at one place (station 7) and brought deep water nearer to the surface at other localities. At station 9 the light and warm surface layer may have been completely removed by currents. Such hydrographical changes are well known from other areas, as for instance from the Oslo fjord (Gran and Gaarder 1918).

The distribution of the phytoplankton was somewhat complicated, partly because the various species had a different hydrographical origin, and partly because the diatoms particularly have a tendency to sink below the level where they have been produced. The characteristic societies described on page 346, were more or less mixed, but after all with a clear differentiation correlated with their hydrographical origin and their biological character, as shown in table XVII.

(1) The *constrictus*-society (neritic), introduced from the north-eastern part of the gulf of Maine, had its maximum along the eastern side of the bay (stations 35 and 37), and was practically limited to the colder layer below the thermocline. *Chaetoceros constrictus* had already formed many resting spores.

(2) The neritic *Sceletonema*-society had its maximum on the western side and was predominant near Grand Manan (station 6) and at the outer stations 7 and 35.

(3) The *triquetrum*-society (neritic) was more abundant along the eastern side (stations 35 and 37) than along the central axis of the bay (stations 7 and 36).

(4) The oceanic *Ceratium-Pontosphaera-Rhizosolenia*-society was more evenly distributed over the whole area and most abundant at the outer stations 7 and 35.

All societies, except the *constrictus*-society had a distinct maximum in the warm surface layer.

The general results of the observations in the bay of Fundy in August, may be summarized as follows:

(1) The heating from the surface had made a certain stratification possible; a marked thermocline divided a warm surface layer of more than 11° from the colder waters below.

(2) A fairly rich production of phytoplankton was limited to this surface layer, and only here were the waters supersaturated with oxygen, and had the greater part of the phosphates and nitrates been consumed. The consumption had not been rapid enough to remove all the nutrient salts from the surface layers. At two stations only, 11A and 10A, the nitrates, but not the phosphates had completely disappeared from the upper layers. Both these localities were situated in the inner part of the bay, where much organic detritus is usually suspended in the waters, and the temperature was very high (14.53 and 15.13°). Therefore, this extraordinary case may possibly be explained as an effect of nitrate reduction by bacteria. It must also be taken into account that the determination of nitrate may have given too low values, if organic compounds were present in a considerable quantity.

TABLE XVII. Bay of Fundy, August 17 to 19, 1932

Stations	6	7	35	36	37	10A	9
Temperature							
1 m........	12.25	12.98	12.93	13.24	13.60	15.13	10.48
10	12.08	12.40	11.90	11.37	10.46	10.46	10.26
25	10.35	11.86	9.77	8.83	10.46	9.69	10.18
40	9.30	9.15	8.78	7.96	9.14	9.60	10.12
75	8.63	7.44	7.55	7.23	9.03		

TABLE XVII—*Continued.* Bay of Fundy, August 17 to 19, 1932

Stations	6	7	35	36	37	10A	9
Salinity							
1 m........	31.71	31.78	31.87	32.12	32.34	32.30	32.63
10	31.73	32.07	32.10	32.29	32.63	32.57	32.65
25	32.25	32.18	32.72	32.72	32.63	32.66	32.65
40	32.32	32.66	32.88	32.95	32.83	32.68	32.65
75	32.63	33.10	33.30	33.40	32.86		
Oxygen, per cent. of saturation							
1 m........	107.1	–	113.7	110.5	123.1	–	94.3
10	–	113.9	108.0	104.2	–	–	93.3
25	95.3	–	96.3	89.7	97.9	–	93.8
40	–	–	88.6	82.0	–	–	92.6
75	86.5	78.6	80.6	74.7	89.4		
Phosphate, mg. P_2O_5 per cu. m.							
1 m........	15	9	9	10	11	10	33
10	17	12	9	19	24	27	35
25	35	13	26	36	22	34	32
40	36	35	35	34	37	35	36
75	40	34	43	52	38		
Nitrate, mg. N per cu. m.							
1 m........	42	30	43	43	50	0	72
10	30	42	46	30	63	70	82
25	82	40	73	113	72	75	62
40	98	88	120	140	93	82	82
75	118	145	125	113	95		
Chaetoceros constrictus, cells per cc.							
1 m........	1.6	8.2	.6	–	.6		.2
10	2.8	4.0	6.2	1.7	75.5	.5	1.1
25	.2	1.6	23.9	2.6	26.2	–	.7
40	.4	2.6	7.9	.8		.2	1.2
75	.6	.1	.5	.3	.7		
Sceletonema costatum, cells per cc.							
1 m........	243	527	504	17.1	–		1
10	491	319	517	57.1	12.6	.1	3
25	52	59	31	35.6	2.9	.3	1
40	4	34	16	2.5		–	1
75	6	1	.5	.9	3.6		
Rhizosolenia alata, cells per litre.							
1 m........	340	2,840	1,240	2,700	800		180
10	200	4,020	2,120	1,600	1,300	3,080	280
25	560	1,840	880	280	880	1,020	100
40	–	440	440	40		520	260
75	100	60	–	60	20		
Ceratium fusus, cells per litre							
1 m........	160	560	520	100	100		20
10	80	380	200	100	100	160	20
25	20	300	40	–	180	–	20
40	–	–	–	–	–	160	60
75	–	–	–	–	–		

TABLE XVII—*Continued.* Bay of Fundy, August 17 to 18, 1932

Stations	6	7	35	36	37	10A	9
Peridinium triquetrum, cells per cc.							
1 m........	6	30	29.5	14.3	85		6
10	7	14	22.4	18.4	7	6	3
25	–	28	8.8	.1	6.7	1	1
40	–	–	–	–	–	1	1
75	–	–	–	–	.1		
Pontosphaera Huxleyi, cells per cc.							
1 m........	–	17	15	12	65		2
10	–	42	22	26	26	14	.6
25	–	51	4	1	31	6	.3
40	–	1	–	–		5	.2
75	–	–	–	–	.3		

(3) Where no warm surface layer was differentiated, and the waters were not stratified, the phytoplankton was poor, except at station 14, in the Grand Manan channel, where a rich diatom plankton was found evenly distributed from surface to bottom. But as here the oxygen tension was below that of saturation, everywhere except at the 1 m. level, and the nitrate and phosphate contents were evenly high, it may be supposed that the diatoms had not propagated at the depths where they were found. According to Watson's observations, it is a regular phenomenon in this locality, that a thick layer with the character of surface water is accumulated by high tide, while the conditions at low tide are different (Watson unpub.). A sufficient explanation of these special facts can not be given from the observations available.

This extraordinary case does not, however, disprove the general conclusion that in August the stabilization of the surface waters had conditioned a summer maximum in the phytoplankton of the bay of Fundy.

For the month of **September** we have observations taken at 10 stations in the bay of Fundy, most of them from the 14th to the 16th; only two, viz., for station 5 and 14 are from September 26.

Since August the phytoplankton had strongly decreased in quantity, but its composition with regard to species was not much changed. The temperature of the surface layers had decreased, and the salinity was high, at most stations above $32.5^0/_{00}$. No marked thermocline was found, and the stability had decreased everywhere where the waters in August had been stratified (see table XV). The surface waters were saturated with oxygen only at station 7, and at the stations 9, 10A and 37, the percentage of saturation at the surface was even below 87%. At the three innermost stations, 9, 10A and 11A the temperature and salinity were nearly uniform from top to bottom, as an indication that the waters had been thoroughly mixed. At the same stations, the phosphate and nitrate contents were high even at the surface, viz., 33 to 35 mg. P_2O_5 and 102 to 103 mg. N per cu. m., corresponding to the "normal" maximal content of the surface waters of the bay of Fundy. At the stations situated farther out in the bay, the phosphate and nitrate contents of the surface waters down to 40 m. or less, were still below the normal value, and lowest at the outermost stations, 7 and 35 (see table XVIII, where are combined the observations from the same stations as those represented in the table for August).

The phytoplankton showed a general tendency towards an even distribution at all depths, evidently as an effect of vertical mixing. Of the societies represented in August, the *constrictus*-society had disappeared, but the others were still represented by the same species as in August. Only *Rhizosolenia alata* had decreased in number to such an extent that only single specimens were observed. *Sceletonema costatum*, which in August had its maximum of frequency at station 7, with 527,000 cells per litre, had in September its maximum at the same station, with only 7,000 to 9,000 cells per litre. The *Ceratia* also had their maxima at station 7, with 160 per litre of each of the two species *C. tripos* and *C. fusus*. *Pontosphaera Huxleyi* was observed in numbers up to 860 per litre, most abundantly at stations 7 and 35. *Peridinium triquetrum* occurred with maxima from 2,000 to 5,000 per litre, most abundantly at stations 7, 36 and 37.

The general decrease in the phytoplankton of the bay of Fundy from August to September cannot have been caused only by the decrease in sunlight, following the seasonal change. In northern Europe even in October and November a rich phytoplankton has been found growing at higher latitudes, in Skagerack at a latitude 10° higher than that of the bay of Fundy. The content of phosphates and nitrates of the surface waters had at the same time rather increased than decreased and seemed to be present in sufficient quantities for a good growth. We can find no other explanation of the decrease in phytoplankton, than that the stability which had been established in August by the high temperature of the surface water, had been diminished in September by cooling from the surface and by the influence of the currents, with the result that, as in June, the phytoplankton was prevented from accumulating in the surface layers, where the light might still be sufficient for its growth and photosynthesis.

The observations made in September 1931, gave a similar picture of the situation. The decrease in phytoplankton had that year not gone quite so far. The *Sceletonema-Asterionella* population was in September 1931 at station 6 still fairly rich, not only in the beginning of the month, on the 11th, but also on the 22nd. At the Nova Scotian side, the waters influenced from the gulf of Maine contained a fairly rich growth of *Peridinium triquetrum*, *Gonyaulax tamarensis* and of *Ceratia*, principally of *Ceratium bucephalum* and in the beginning of the month there was a considerable inflow of visitors from the ocean, such as *Rhabdosphaera stylifera* and other southern coccolithophorides. Such variations from year to year may always be expected, and as a whole these observations corroborate the general conclusions we have drawn from the observations made in 1932.

TABLE XVIII. Bay of Fundy, September 14 to 16, 1932

Stations	7	35	36	37	10A	9
Temperature						
1 m.	11.69	11.99	10.82	10.67	10.26	10.30
10	11.60	11.97	10.91	9.71	10.13	10.34
25	11.50	11.41	10.90	9.38	10.09	10.28
40	10.97	10.77	8.92	9.35	10.09	10.27
75	8.94	9.55	8.66	9.23		
Salinity						
1 m.	32.56	32.43	32.70	32.72	32.77	32.81
10	32.56	32.43	32.81	32.75	32.77	32.81
25	32.61	32.50	32.83	32.81	32.77	32.81
40	32.72	32.63	32.97	32.83	32.77	32.81
75	32.92	32.86	33.08	32.86		
Oxygen, per cent of saturation						
1 m.	101.2	97.9	95.9	86.4	86.0	86.3
10	101.1	97.9	91.8	91.1	85.5	86.9
25	100.2	94.7	91.0	88.3	85.7	86.4
40	98.2	91.4	84.7	88.2	90.3	86.4
75	84.2	87.0	82.8	87.2		
Phosphate, mg. P_2O_5 per cu. m.						
1 m.	13	12	29	22	33	32
10	18	13	31	29	41	36
25	15	19	34	33	34	37
40	22	27	37	33	35	36
75	34	34	35	34		
Nitrate, mg. N per cu. m.						
1 m.	19	26	48	60	103	102
10	20	27	60	78	103	102
25	20	36	83	86	104	79
40	36	106	110	86	106	102
75	110	135	111	102		
Sceletonema costatum, cells per cc.						
1 m.	7	.2	2	1.1	—	.2
10	6	—	1.6	1.7	.6	.2
25	9	.6	2.5	.3	.5	.6
40	6	1.3	.4	1.1	.2	.2
75	3	2.3	.2	1.1		
Peridinium triquetrum, cells per litre						
1 m.	3,620	320	2,020	4,920	—	—
10	3,620	300	60	200	40	20
25	2,740	300	120	60	20	—
40	360	140	—	40	60	—
75	—	—	—	40		

General Discussion of the Conditions of Production

The study of the phytoplankton conditions in the bay of Fundy and the gulf of Maine in relation to the physical and chemical factors naturally leads to the consideration of the following two problems: (1) how is the growth of the phytoplankton and the general productivity of our area influenced by the distribution of the nutrient salts, principally the phosphates and the nitrates; and (2) how does the extraordinary turbulence conditions in the bay of Fundy influence the productivity, directly by carrying the productive population downwards from the surface to levels where photosynthesis and propagation are retarded or stopped, and indirectly by carrying nutrient salts from the deeper layers up to the illuminated zone? Therefore, we shall consider these problems at some length.

It is difficult to measure directly the rate of growth of the phytoplankton. No method in use gives accurate determinations of the quantitative occurrence of all species, and even if this were possible, the various species living together in the same population are so different in size and in their rate of growth and metabolism, that it is impossible to estimate how much each takes part in the total production. Our method allows us to determine within rather wide limits of accuracy the occurrence of the dominant species, and fortunately the fluctuations are so large that even rough methods can give a characteristic picture of them. But these quantitative measurements cannot be used to determine the total quantity of plant substance present or the production of the phytoplankton under given conditions.

The production of organic matter yielded by the phytoplankton can also be estimated by the quantity of oxygen liberated by its photosynthesis or by the quantities of phosphates and nitrates consumed by its assimilation. Where the waters are supersaturated in oxygen, the surplus of oxygen must have been produced by photosynthesis except that, particularly in spring, saturated surface waters may be supersaturated by heating. As a rule, however, supersaturation gives a certain indication that a rich phytoplankton is or has recently been present and that the photosynthesis of the phytoplankton has been predominant over the respiration of the total population of plankton and bacteria. We have seen that supersaturation is only found in the illuminated zone, and that the lower limit of the supersaturated layers may approximately coincide with the depth of compensation, in places where the phytoplankton is rich and predominant. In such cases we have also found the phosphates and nitrates being partially consumed by the phytoplankton.

Where no nitrates or phosphates have been consumed, the surface layers of our area with a salinity below $32^0/_{00}$ have regularly a phosphate content of about 33 mg. P_2O_5 and a nitrate content of 100 mg. N per cu. m. or slightly more. In waters of higher salinity, both values are regularly higher, but such layers are only found at greater depths and are rarely raised as high as to 40 m. below the surface.

On the other hand, where a rich phytoplankton is growing, and the water is supersaturated in oxygen, we have found the phosphate content to be less than 20 mg. and the nitrate content less than 60 mg. Thus, we have seen that for August in the bay of Fundy the limits of the water masses with a temperature of 11° and with an oxygen percentage of 100% coincide with those for waters with 20 mg. P_2O_5 and 60 mg. N per cu. m. or more. The relation between the amounts of phosphates and nitrates which are consumed within the illuminated layer, viz., at least 13 mg. P_2O_5 and 40 mg. N per cu. m., correspond to the same values found in other localities: $P_2O_5/N = 1/3$ (Gran 1930). This agreement between the variations in the nitrate and the phosphate contents indicates that the denitrification or nitrate reduction is not as a rule of any importance in relation to the nitrate consumption of the phytoplankton.

Only on a few occasions our observations show the nutrient salts being completely consumed. In May at our most southern station in the open gulf (26) no phosphates were found at the surface (see page 395). In August at two stations in the inner part of the bay of Fundy (10 and 11), no nitrates were found in the surface water, which still contained 9 mg. P_2O_5 per cu. m. Here it is possible that nitrate reduction by bacteria may have taken place, favoured by the organic substances of the sediments, which at these localities are relatively abundant. But if organic matter has been present in more than ordinary quantities, the nitrate determinations may have been less accurate.

In the gulf of Maine we have found on the whole that during summer, after the spring growth has reduced the nutrient content of the illuminated zone to low values and the waters have become well stratified by heating from above, the productivity is here restricted by the low contents of phosphates and nitrates. The exceptions confirm the rule. Over Georges bank a fairly rich diatom plankton can be produced by the effect of the turbulence in the waters flowing over the shallow bank, and near the coast of Maine continuous growth of neritic diatoms is going on through the whole summer, because nutrient salts are brought to the surface by the tidal currents in shallow water. In a culture experiment, carried out at Woods Hole, August 6 to 11, 1932, with water from the open gulf of Maine, *Rhizosolenia alata* increased without addition of nutrient salts to 5 times the original number, but with addition of nitrate and phosphate, to 67 times as many as before the experiment (Gran 1933, p. 172).

In the tongue of relatively cold water observed in the first part of the summer in the northern part of the gulf of Maine, exceptional conditions may be found, as at our station 17 off Mount Desert island on the 28th of June, between the coast and the offshore waters. Here conditions were prevailing similar to those found in the bay of Fundy at the same season, with high contents of nitrates and phosphates from top to bottom, and at the same time with a very poor phytoplankton. These waters are undoubtedly originating from the bay of Fundy and their biological conditions are determined by the factors characteristic of this area.

In the Bay of Fundy the conditions are more complicated than in the gulf. Contrary to what was found in the gulf, the largest population of phytoplankton was not to be found in the most turbulent waters, but where the waters were moderately stratified. Where the waters were thoroughly mixed by turbulence, the phosphate and nitrate contents were high right up to the surface, but nevertheless the phytoplankton was poor. It may be stated that the lack of nitrates and phosphates is here never, or only exceptionally, the principal factor limiting the growth of the phytoplankton. Our most important problem is, therefore, to find the cause of these extraordinary conditions.

When we consider this problem, we shall use the observations from the month of June as an example. We then found a rich diatom plankton only in Passamaquoddy bay, where a numerous population of *Chaetoceros debilis*, in accordance with Davidson's observations from other years, had just succeeded the *Thalassiosira*-plankton of the spring. Everywhere else in the bay the phytoplankton was poor.

The temperature at this season ought to be quite favourable for the growth of *Ch. debilis* over the whole bay of Fundy, and the supply of nutrient salts seems to have been more than sufficient.

The question may be raised, whether the growth might have been prevented because living cells, able to utilize the prevailing life conditions, had not been present within the area. Only a month earlier, however, *Chaetoceros debilis* had been distributed over the whole bay, with a maximum as high as 27,000 cells per litre (station 36, May 22), and even in June it was not totally absent. At station 8A, representing the waters flowing into the bay along the Nova Scotian coast, the frequency was as high as 200 cells per litre, and at station 37, 500 per litre. For a species living in chain-formed colonies, numbers less than 100 cells per litre have little chance to be observed by our method. It must also be expected that resting spores of this common species will always be present at the bottom. According to culture experiments, under favourable conditions *Chaetoceros debilis* undergoes at least one division per day. Therefore, if the growth were not prevented by some limiting factor, a rich population ought to have chances to develop in a few days.

The same can be said with regard to other species, for instance *Ch. compressus* which in May also was present at all stations (maximum 7-8,000 cells per litre at station 36), and in June was found in the inflowing waters (stations 8A and 37) in numbers up to 900 per litre. Therefore, it may be concluded with certainty that even in June the waters of the bay of Fundy contained enough germs of various species sufficiently fitting to the prevailing conditions of temperature and nutrition to enable good growth.

Another factor is the consumption of phytoplankton by the pelagic animals, particularly copepods, feeding on diatoms and other plankton algae. The influence of this factor is, unfortunately, very difficult to determine quantitatively. It must be considerable, but we have not data to calculate its effect. We can only say that according to the zooplankton observations (Fish and Johnson unpub.) the zooplankton of the bay of Fundy is on the whole less abundant than in the gulf of Maine, and therefore the consumption is certainly not sufficient in itself to explain the extreme poverty of the phytoplankton of the bay of Fundy as compared with the gulf, particularly in June.

Thus only one factor seems to remain to explain the extraordinary biological conditions in the bay of Fundy: the extraordinarily high degree of turbulence of the waters. We have in the bay of Fundy at all seasons found the phytoplankton to be poorest in the most turbulent waters. Along the coast of New

Brunswick (stations 11, 12 and 13) the waters are as a rule uniform in character from the surface down to the bottom, as an effect of the turbulence caused by the extreme tides at the head of the bay, and here the plankton was found to be poor at all seasons, even in May, when the rich *Thalassiosira* population yielded a rich production everywhere else. On the other hand, in the areas where the surface waters were moderately stratified, we found the richest parts with regard to phytoplankton. Furthermore, the peculiar summer minimum in June coincides with a minimum in stabilization for the surface waters. At that time it was only in Passamaquoddy bay the phytoplankton was rich, and only here the waters were moderately stratified. A slight stabilization was found also in the central part of the bay of Fundy, where also a very slight maximum of the phytoplankton was found.

As a contrast to these conditions, on the other hand, we have seen that in the gulf of Maine a permanent stratification may cause a depletion of phosphates and nitrates in the surface layers and prevent the development of a rich diatom plankton during summer, and that turbulence may stimulate the growth of the diatoms by carrying nitrates and phosphates to the surface from the deep waters.

In turbulent waters we find the phytoplankton, and particularly the diatoms, more or less evenly distributed from the surface down as far as the waters have been thoroughly mixed by the turbulence. A part of the phytoplankton may be carried down below the level where photosynthesis and propagation is possible, and another part will be exposed to light intensities below the optimum, and their photosynthesis and propagation must be proportionally reduced.

Thus, the question, whether violent turbulence may make the phytoplankton increase or decrease, must to a large extent depend on the thickness of the productive layer and thus on the light conditions. On Georges bank in August 1932 (Gran 1933) the favourable effect of the turbulence was evidently predominant. Here the light supply for photosynthesis was sufficient as far down as to a depth of 35 m., as shown by the oxygen values, and even at 43 m. effective photosynthesis seems to have been possible. As the total depth was only 60 m., about two thirds of the whole water column were sufficiently illuminated for an active photosynthesis, and the stimulating effect of the vertical circulation of nutrient salts could be predominant.

The depth of compensation between photosynthesis and respiration of the phytoplankton must be dependent on the following factors:

(1) the illumination at the surface;
(2) the transparency of the water;
(3) the biological character of the plankton present;
(4) the temperature;

(1) From the observations of Dr. Klugh, Dr. Sawyer and Mr. Herbert Kimball, and from meteorological observations published, Sawyer (unpub.) calculated that the total radiation at the surface in the bay of Fundy in 1932 was between 2/3 and 3/4 of the amount at the same time in the gulf of Maine, and that in both areas it had its maximum in May, decreasing in June to half

the value in May and decreasing further, but very slowly in July and Augus with a more rapid decline in September (see page 319).

(2) The transparency of the waters we have only been able to estimate from some observations on the turbidity and from some few Secchi disc records by Graham (unpub.). The observations show that the waters of the gulf of Maine were more transparent than those of the bay of Fundy, where the turbidity was high particularly along the New Brunswick coast, as a result of the washing out of silt from the Saint John river and the rivers in the Quoddy area, and by the turbulence in the estuaries at the head of the bay, raising organic and inorganic detritus from the bottom, as proved by the regular occurrence of *Melosira sulcata*. The influence from these sources was still to be observed in the Quoddy area and around Grand Manan, but not so much in the eastern and central parts of the bay of Fundy.

(3) Not so much can be said about the light requirements of the various species of which the phytoplankton is composed. It may be supposed that slowly propagating species as *Thalassiosira decipiens* have a less rapid respiration than, *e.g.*, the neritic *Chaetoceros*-species with their relatively large specific surface, and that their compensation point may be found at a lower light intensity. But such representatives of Schimper's "shade flora" are not abundant in our area. The bulk of the diatom plankton consists of rapidly growing species, as *Thalassiosira Nordenskioeldi*, *Chaetoceros* spp. and *Sceletonema costatum*.

(4) We have no observations in regard to the photosynthesis and respiration of the plankton algae in relation to temperature; but it may be supposed that their respiration has a higher temperature coefficient than that of their photosynthesis and that at low temperatures a lower light intensity would be sufficient to give balance between photosynthesis and respiration than at higher temperatures. For this reason the growth conditions may be more favourable in April-May than during summer.

The quantitative effect of all these factors can not as yet be calculated from the observations available. It would, therefore, be very desirable to get further information regarding these very interesting problems, and it should be possible to reach important results by culture experiments combined with observations in nature.

At present, we can only try to estimate the effect of the light conditions in the various parts of the area, from the observations on the amount of dissolved oxygen and the consumption of phosphates and nitrates at different depths. In the offshore waters of the gulf of Maine we have seen that an active photosynthesis in summer must take place down to depths of about 40 m. or slightly more. When we approached the coasts, the point of compensation was found nearer to the surface, and near the coast we found it as high up as about 10 m. below the surface.

We have from the bay of Fundy one assimilation experiment, in Passamaquoddy bay on August 2, 1932, made on a clear day, covering six hours in the middle of the day (see page 326). At that occasion the point of compensation was found to be between 15 and 20 m. When the respiration during the night is taken into account, the compensation point for 24 hours will be at 10 m. or even less. From our observations in August in the central parts of the bay of Fundy, the compensation point probably may have been slightly below 10 m.

To get a rough calculation of the possible effect of the turbulence on the phytoplankton, we suppose that a water column of 50 m. depth is in continuous vertical circulation, and that the point of compensation is found at a depth of 10 m. The phytoplankton then will be suspended within the illuminated zone only for one fifth of its life time, and only during part of this time the conditions for photosynthesis will be optimal. If they are just optimal at the surface, the average photosynthesis of each cell will be only one tenth of the full value of optimal conditions, that is if the cell has been continuously at the surface. As a rule the light conditions may be optimal one or two metres below the surface, and therefore, the value 1/10 will be too low, and the correct value will in our case be between 1/5 and 1/10.

The question, whether the phytoplankton during its stay in the lighted zone can accumulate sufficient energy for its further growth, must therefore depend upon the relation between its photosynthesis and respiration. In our example, if the respiration is more than 1/8 of the assimilation, the propagation will stop, and the population will soon be consumed by the zooplankton.

The data published as yet on the respiration of the plankton algae are not plentiful. Steemann Nielsen (1932) made some experiments on the photosynthesis and respiration of phytoplankton at the Danish coast during summer at various light intensities. Bottles with sea water with its natural content of plankton were suspended at various depths. Each experiment lasted exactly 24 hours. For a series of experiments Steemann Nielsen found the coefficient $\frac{\text{photosynthesis}}{\text{respiration}}$ never higher than 5.2 (at a depth of 0.2 to 2 m.), and at 5 m. about half of that at 2 m. For our purpose we have to consider that the quantities of oxygen consumed by respiration partly may have been absorbed by animals and bacteria, and that if this error could be excluded, the coefficient would be higher.

TABLE XIX.

		Photosynthesis mg. oxygen produced Maximum	Respiration mg. oxygen consumed
(1)	12.30 a.m. to 3.00 a.m.	0.05	0.10
(2)	3.00 a.m. to 6.00 a.m.	1.18 (0 m.)	0.08
(3)	6.50 a.m. to 8.50 a.m.	0.81 (2 m.)	0.17
(4)	9.00 a.m. to 11.55 a.m.	0.90 (1 m.)	0.38
(5)	12.00 noon to 2.57 p.m.	0.99 (6 m.)	0.20
(6)	3.00 p.m. to 5.55 p.m.	1.02 (2 m.)	0.24
(7)	6.00 p.m. to 8.53 p.m.	0.95 (1 m.)	0.09
(8)	8.57 p.m. to midnight	0.11 (0 m.)	0.16
	per 24 hours	6.01 mg.	1.42 mg.

This gives a coefficient $\frac{\text{photosynthesis}}{\text{respiration}} = 4.2$

From most of the well known experiments by Marshall and Orr (1928) coefficients of the same order of magnitude can be calculated. Some of the experiments give higher values, but most of these lasted for such a short time (3 hours) that the values found for the respiration were too small to be accurately determined. Marshall and Orr used persistent cultures of *Coscinosira polychorda*, in which only bacteria might take part in the metabolism besides the diatoms.

One experiment may be quoted; it lasted from noon on June 9 to noon on June 10, divided into a series of 8, each lasting 3 hours. The sun was shining for 15 hours and 5 minutes, and the bottles contained 3,600 cells of *Coscinosira* per cc.

The few observations yet available are of course quite insufficient for drawing general conclusions, but they are sufficient to show that the daily respiration of the phytoplankton is relatively high compared with its photosynthesis. If the photosynthesis of a diatom cell is reduced to one tenth of the normal or perhaps even only to one fifth, it will consume as much of organic matter as it can produce, and its propagation must come to a standstill. In that case the population will in shorter or longer time be consumed by the zooplankton, and we have seen by an example, that such a situation easily may occur in turbulent waters as in the bay of Fundy during June. It will depend on the interrelation between many factors, whether the phytoplankton population shall increase or decrease, and the factors having a tendency to reduce the increase must be the following ones: turbulence, low transparency of the water, reduced illumination at the surface, feeding of the zooplankton and the passive sinking of the immotile diatoms. The turbulence, on the other hand, may promote the production by carrying nutrient salts to the surface, and this favourable effect may be predominant by good light conditions.

The combined effect of all these variable factors, together with the temperature variations and the effect of the horizontal currents carrying the phytoplankton from one place to another, may of course vary in a very complicated way, and it may be difficult to explain the observed facts in each case. We have tried to find out whether the extraordinary conditions observed in the bay of Fundy, particularly in June, can possibly be explained by interaction of the known factors, and we have come to the conclusion that this is possible. The principal factor in this area producing a quite unique effect must be the turbulence caused by the tidal currents.

To recapitulate the data referred to above, we would emphasize the most characteristic points in the development of the phytoplankton of the gulf of Maine and the bay of Fundy.

(1) In the gulf of Maine a rich diatom (*Thalassiosira*) plankton grows in April and May, representing the richest production of the whole year. In the offshore waters, the diatoms are succeeded by oceanic species as *Ceratium longipes* and later *C. tripos* and *fusus*, *Pontosphaera Huxleyi* and *Rhizosolenia alata*. The change occurs as soon as the greatest part of the phosphates and nitrates of the surface layer has been consumed by the diatoms and the waters get stratified, with the consequence that no considerable quantities of these salts can be brought up from deep waters. A moderate production of phyto-

plankton is going on continuously through the whole summer, limited by the relatively small quantities of phosphates and nitrates present, and liberated by the metabolism of plankton and bacteria. The point of compensation in the offshore waters lies at a depth of about 40 m., but nearer to the coast it is found at higher levels, and in the coastal zone its depth may be 10 m. or less. A rich population of neritic diatoms may grow continuously through the whole summer in the coastal waters, where the tidal currents give a moderate turbulence carrying nutrient salts from deeper waters. Similar conditions may be found at Georges bank, where the currents meeting the slopes of the bank produce a vertical mixing of the waters, populated by such species as *Rhizosolenia alata* (and in other years *Guinardia flaccida*), evenly distributed from the surface to the bottom.

(2) In the bay of Fundy the turbulence is much more marked, particularly along the coasts. Here, also, a rich diatom plankton grows in April and May over the whole bay except along the New Brunswick coast, where the turbulence seems to prevent a rich growth even in spring. In May the light conditions are better than at any other season, the low temperature will give a favourable relation between photosynthesis and respiration, and the production of phytoplankton has, without comparison, its maximum at this season.

In June the situation is quite changed and shows a striking contrast to that of the gulf of Maine. In Passamaquoddy bay, where the waters are well stabilized, the diatom plankton is still rich, with *Chaetoceros debilis* predominating, but elsewhere the waters are nearly barren. A scanty plankton of some small species of neritic diatoms, together with the green flagellate *Eutreptia* has a slight maximum in the centre of the bay. The *Ceratium*-plankton of the gulf of Maine is represented but are few in numbers. The nitrate and the phosphate contents are high even at the surface, and the surface waters are insufficiently stabilized. The turbulence causing this situation must also be the principal cause of the poorness of the phytoplankton.

The facts observed in August confirm this conclusion. The surface waters are stabilized after the considerable increase in temperature, producing a marked thermocline, mostly between a depth of 10 and 25 m., and just the surface layer above this thermocline is productive. The phosphate and nitrate content of this layer is reduced by the metabolism of the phytoplankton, but not totally consumed, except that no nitrates were found at the surface at two stations in the inner part of the bay.

In September the stability has been reduced by cooling of the surface, and the phytoplankton decreased, while the phosphate and nitrate content of the surface water has increased by the turbulence.

While during summer the production of phytoplankton in the surface layers in the gulf of Maine is mainly limited by the low contents of phosphate and nitrate, caused by a marked stratification, we find quite the inverse situation in the bay of Fundy. Here, the phosphates and nitrates are, particularly in June, present in excess, but the phytoplankton is nevertheless poorer than in the gulf of Maine, and in June extremely poor. The only possible explanation of this seems to be that the phytoplankton is prevented by the turbulence from accumulating in the illuminated zone. As this zone is shallower than in the gulf of Maine, because of the weaker illumination and the turbidity of the waters, the photosynthesis of the plankton algae, moving up and down with the turbulent waters, may be insufficient to counterbalance their respiration or to give a surplus sufficient to cover the consumption by animals.

In Passamaquoddy bay the phytoplankton is rich from May till the end of July, as described from observations through a series of years by Davidson (1934). In August and September the quantity of the phytoplankton decreases as a rule. The waters are during spring and summer more or less stratified, but the phosphate and nitrate contents of the surface water seem never to be exhausted. The regular decline of the phytoplankton in August may perhaps have some connection with the very rich population of copepods (*Acartia*), which according to the zooplankton observations (Fish and Johnson, unpub.) is propagating in the bay in late summer (see recent observations by Harvey 1934).

With regard to the problem placed before the experts by the International Passamaquoddy Fisheries Commission, we must, according to the results of this survey, conclude that a closing of the entrances to Passamaquoddy bay as projected will not reduce the general productivity of the waters outside the dams. Even if, in the Outer Quoddy region, the turbulence should be essentially reduced by the building of the dams, this change would rather be expected to be favourable for the production of phytoplankton than unfavourable.

SUMMARY

1. At 27 standard stations, 17 in the bay of Fundy and 10 in the gulf of Maine, samples were collected for studying the phytoplankton by the centrifuge method (see figure 15). These stations were worked during the months of April, May, June and August, and those in the bay of Fundy also in September 1932. At each station a series of samples was taken from the following depths: 1 m., 10 m., 25m., 40 m. and 75 m., occasionally also some samples from greater depths. This material was supplemented with local observations at other seasons.

2. At most stations and depths where phytoplankton samples were collected, observations were made on temperature, salinity and on the phosphate, nitrate and oxygen contents of the sea water. The standard methods now generally used in oceanography were applied.

3. The observations on temperature and salinity corroborate Bigelow's results with regard to the general circulation of the waters.

The values for phosphate were high at the lower levels (50-60 mg. P_2O_5 per cu. m.), decreasing towards the surface in correlation to the salinity distribution and on account of the consumption by the phytoplankton in the illuminated zone. The phosphate content of the surface waters was during summer generally higher in the bay of Fundy than in the gulf of Maine. The variations in the nitrate content were parallel to those in the phosphate content.

The oxygen content of the deeper layers of Atlantic origin was low (about 70%). The surface waters of the gulf of Maine during spring and summer

generally were supersaturated with oxygen, as far down as the photosynthesis of the phytoplankton was predominant, viz., to a depth of about 40 m. in the offshore waters and to lesser depths near the shore. In the bay of Fundy, the surface waters during the same period of time were often subsaturated in oxygen, particularly in June.

4. In the centrifuged samples the following numbers of species were recorded: 78 diatoms, 57 dinoflagellates, 8 coccolithophorides, 2 silicoflagellates, 1 green flagellate (*Eutreptia*), 19 zooflagellates and ciliates. For each species remarks on their general frequency in the area and on their biological conditions were given. The following numbers of new species were described: 1 diatom, 7 dinoflagellates, 2 coccolithophorides. For some critical species remarks were made on their taxonomy and variation.

5. During winter the phytoplankton of the bay of Fundy was quantitatively poor, consisting of oceanic species and some littoral diatoms, washed out from the shores. In April-May the phytoplankton in the whole area had its annual quantitative maximum. It consisted of boreal and arctic-neritic diatoms, a *Thalassiosira Nordenskioeldi* vegetation with a great number of species as subordinate components. Only along the New Brunswick coast this rich spring growth of diatoms was never observed.

In the offshore waters of the gulf of Maine this diatom vegetation was succeeded by dinoflagellates, with *Ceratium longipes* and *bucephalum* as dominants in May and June, these later succeeded by *C. fusus* and *tripos*, accompanied by *Pontosphaera Huxleyi* and *Rhizosolenia alata*. This change began in the south-western part of the gulf and gradually extended northwards. Along the coast populations of neritic diatoms prevailed during the whole summer, successively changing their composition in response to the rise in temperature.

In the bay of Fundy the phytoplankton in June was very poor, except in Passamaquoddy bay, where *Chaetoceros debilis* and its associates prevailed. In August the plankton had increased. It was composed of the following societies: (*a*) a *Chaetoceros constrictus*-society, in the waters flowing in from the gulf of Maine; (*b*) a *Sceletonema*-society along the New Brunswick coast, with a pronounced maximum around Grand Manan; (*c*) a *triquetrum*-society of neritic, minute dinoflagellates prevailing along the coasts; (*d*) a *Ceratium-Pontosphaera*-society, dominant in the centre of the bay and corresponding to the summer plankton of the offshore waters of the gulf of Maine.

In September the same societies were found, except the first one (*a*), but then less abundant. At this season, visitors from the Atlantic, particularly oceanic coccolithophorides, were found in relatively great numbers, and more abundantly in 1931 than in 1932.

6. In the gulf of Maine the general changes in the growth and decline of the phytoplankton population, and its local variations agree with the theories of Brandt and Nathansohn, that the quantitative variations are governed by the light intensities and the supply of nutrient salts (phosphates and nitrates). The spring increase in diatoms occurs, as in North European waters, after the waters have been vertically mixed during winter, so that sufficient supplies of phosphates and nitrates have been brought to the surface from the deep strata.

As soon as the surplus of nutrients has been consumed by the diatoms, and the waters are stratified (by heating and freshening), the growth of the phytoplankton in the surface layers is limited by the lack of nitrates and phosphates, which through the whole summer are present in small quantities only, just sufficient to maintain a moderately rich population of *Ceratia* and coccolithophorides. Only along the coast the tidal currents cause turbulence, sufficient to supply nutrient salts for the growth of neritic diatoms through the whole summer.

7. In the bay of Fundy the conditions are more complicated. Here the tidal currents, because of the great tidal range, up to 52 feet (16 metres), produce a high degree of turbulence, particularly along the coasts. and the phosphate and nitrate contents through most of the year are relatively high from the bottom to the surface. However, this rich supply is not to any great extent consumed by the phytoplankton. Particularly in June, the phytoplankton was here very poor, except in Passamaquoddy bay, where the waters were moderately stabilized. In August the surface waters were again more stabilized, particularly in the central parts of the bay, and then these surface waters were populated by a fairly rich vegetation, which had consumed part of the phosphates and nitrates and produced supersaturation in oxygen in the illuminated zone.

These extraordinary conditions, so different from those found in the gulf, tentatively have been explained as an effect of the higher degree of turbulence in the bay of Fundy as compared, for instance, with the gulf of Maine, preventing the diatoms from accumulating in the surface layers where they can reproduce. In estimating the effect of the high degree of turbulence in the Fundy region, the following facts have to be considered.

(*a*) The light conditions, as calculated from Dr. Sawyer's records of the radiation and from the relative numbers of foggy days, are less favourable in June to September than in May, and for the whole year the total radiation is in the Fundy region about 25% less than in the gulf.

(*b*) The waters of the bay of Fundy are very turbid, because of detritus washed out with the large fresh water contributions from rivers, and on account of the extraordinary tide conditions, from the estuaries at the head of the bay.

(*c*) An experiment on the photosynthesis and respiration of the plankton in Passamaquoddy bay indicates that the point of compensation may not be lower than at a depth of 10 m.

(*d*) Experiments by Steemann Nielsen and by Marshall and Orr, show that the respiration of the plankton diatoms is as high as about one fifth of their photosynthesis. Therefore, if the total illumination of each diatom cell is reduced by the moving up and down by the turbulence, to one fifth of the optimum light intensity, no surplus of energy can be stored, no reproduction can take place, and the diatoms must soon be consumed by the animals feeding upon them.

Although our material is insufficient for accurate calculations, we have come to the conclusion that for these reasons the extraordinary turbulence and turbidity conditions of the bay of Fundy waters are the main factors for limiting their production of phytoplankton. No other explanation could be found, as the surface waters at the least productive seasons, as in June, contain a surplus of nutrient salts, and the zooplankton feeding upon the phytoplankton is not as rich in the bay of Fundy as in the gulf of Maine.

8. If the entrances to Passamaquoddy bay were closed by the projected dam, this would not be expected to have any noticeable effect on the productivity of the bay of Fundy outside the Quoddy region. In the Outer Quoddy region, an increase in stability during the summer season, as would possibly be the effect of the dams, rather should tend to increase than to reduce the phytoplankton production in these waters.

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TABLES

Only some of the phytoplankton tables are published here. Typewritten copies of the rest are deposited at the following three localities: the Biological Board of Canada, University of Toronto, Toronto, Canada; the Woods Hole Oceanographic Institution, Woods Hole, Mass., U.S.A.: the Botanical Laboratory of the University, Oslo, Norway.

TABLE XX. Station 1C, September 12, 1931

Depth	1	10	25	40
Temperature	12.95	12.18	11.86	11.71
Salinity, per mille	31.51	31.80	32.07	32.18
σt	23.73	24.09	24.37	24.47
Phosphate, mg. P_2O_5 per cb. m.	45.0	47.7	50.4	49.6
Number of cc. examined	25	50	50	50
Chaetoceros constrictus	120	—	—	—
simplex	740	180	120	—
Coscinodiscus excentricus	80	40	60	100
Guinardia flaccida	460	—	—	—
Melosira sulcata	380	340	140	1 340
Pleurosigma Normanni	120	20	40	180
Rhizosolenia imbricata	280	—	—	—
Sceletonema costatum	—	580	680	2 080
Thalassionema nitzschioides	220	80	—	140
Thalassiosira decipiens	60	—	80	60
Dinophysis acuminata	120	40	—	—
norvegica	40	40	20	—
Distephanus speculum	16 260	340	360	40
Ebria tripartita	140	—	—	—
Helicostomella subulata	240	60	100	160
Mesodinium rubrum	180	—	—	—

Actinocyclus Ehrenbergi 40 m., 20. *Coscinodiscus centralis* 1m., 40; 25 m., 20. *Navicula distans* 25 m., 40; 40 m., 80. *Nitzschia closterium* 1 m., 20. *N. delicatissima* 25 m., 40. *Rhizosolenia fragilissima* 1 m., 40, 40 m., 40. *Thalassiosira* sp. 10 m., 80; 25 m., 60.

Ceratium lineatum 1 m., 40. *C. longipes* 1 m., 60. *C. tripos* 1m., 40. *Peridinium brevipes* 10 m., 20. *P. pentagonum* 1 m., 40. *P. Steini* 1 m., 20; 25 m., 20. *P.* sp. 1 m., 20. *Prorocentrum micans* 1 m., 20.

Favella serrata, 10 m., 40. *Laboea crassula* 10 m., 20. *L. strobila* 1 m., 20, *Stenosemella* sp. 25 m., 80.

TABLE XXI. Station 6, September 11, 1931

Depth	1	10	25	40	75
Temperature	13.35	13.61	12.59	10.36	9.17
Salinity, per mille	31.67	31.73	31.85	32.38	32.95
σt	23.75	23.77	24.05	24.79	25.48
Phosphate, mg. P_2O_5 per cb m.	39.2	41.7	47.6	44.5	50.8
Asterionella japonica	6 760	13 760	14 900	200	340
kariana	160	—	320	80	—
Chaetoceros affinis	980	680	200	—	—
constrictus	320	1 280	1 660	560	—
debilis	120	—	—	—	—

TABLE XXI—*Continued*

Chaetoceros decipiens	180	760	360	80	—
didymus	80	—	100	—	—
laciniosus	480	240	300	560	—
radicans	300	880	200	—	—
Coscinodiscus excentricus	100	160	80	40	20
Ditylum Brightwelli	660	1 420	880	40	40
Leptocylindrus minimus	—	—	120	—	—
Melosira sulcata	—	240	620	120	240
Nitzschia closterium	—	160	180	20	—
delicatissima	2 100	9 560	4 960	—	—
seriata	—	120	380	—	—
Rhizosolenia imbricata	—	—	—	100	—
Sceletonema costatum	88 860	145 440	34 300	360	880
Thalassionema nitzschioides	1 260	2 200	1 720	—	—
Thalassiosira decipiens	2 120	4 220	1 840	400	220
sp.	2 980	5 440	2 340	60	80
Gonyaulax tamarensis	220	40	—	—	—
Distephanus speculum	100	280	40	—	—
Laboea conica	100	40	—	—	—
strobila	400	160	—	—	—
Mesodinium rubrum	240	80	60	—	—

Actinoptychus undulatus 40 m., 20. *Biddulphia alternans* 40 m., 80. *Chaetoceros simplex* 25 m., 20. *Rhizosolenia fragilissima* 25 m., 40. *R. setigera* 1 m., 40.

Ceratium bucephalum 1 m., 40. *C. fusus* 1 m., 20. *C. tripos* 1 m., 20. *Dinophysis acuminata* 1 m., 40. *D. norvegica* 1 m, 20.. *Gymnodinium Lohmanni* 1 m., 20. *Peridinium triquetrum* 1 m., 80.

Eutreptia Lanowi 1 m., 80; 10 m., 40. *Coccolithus pelagicus* 75 m., 20. *Rhabdosphaera stylifera* 1 m., 20. *Ebria tripartita* 10 m., 40.

Favella serrata 10 m., 40. *Helicostomella subulata* 10 m., 40; 25 m., 20. *Laboea crassula* 1 m., 20. *L. vestita* 1 m., 40. *Lohmanniella oviformis* 25 m., 20. *L. spiralis* 10 m., 40; 75 m., 20. *Tintinnopsis* sp. 1 m., 20.

TABLE XXII. Station 8A, September 11, 1931

Depth	1	10	25	40	75
Temperature	11.58	10.49	10.07	9.14	8.28
Salinity, per mille	32.32	32.32	32.32	32.72	32.94
σt	24.55	24.83	24.97	25.34	25.63
Phosphate, mg. P_2O_5 per cb m.	40.7	43.0	49.1	54.5	60.5
Asterionella japonica	860	—	1 580	—	—
Chaetoceros constrictus	320	—	300	—	—
decipiens	1 140	—	140	—	—
laciniosus	—	160	100	—	180
radicans	160	—	320	—	—
Coscinodiscus excentricus	—	20	60	—	40
Ditylum Brightwelli	40	40	20	—	—
Leptocylindrus minimus	1 080	—	—	—	—
Melosira sulcata	—	—	—	—	300
Nitzschia closterium	20	100	100	—	—
delicatissima	540	100	480	—	—
seriata	240	—	180	—	—
Rhizosolenia imbricata	620	—	—	—	—
Sceletonema costatum	4 420	820	3 040	380	1 160

TABLE XXII—*Continued*

Thalassionema nitzschioides	80	–	620	–	60
Thalassiosira decipiens	100	160	1 260	160	60
sp.	200	40	20	–	–
Exuviaella baltica	1 100	–	40	–	–
Gonyaulax tamarensis	21 980	–	–	–	–
Oxytoxum gracile	160	–	–	–	–
Peridinium triquetrum	cc.	–	–	–	–
Acanthoica acanthifera	280	–	–	–	–
Coccolithus pelagicus	180	100	60	20	–
Eutreptia Lanowi	2 040	–	–	–	–
Pontosphaera Huxleyi	260	40	60	40	20
Rhabdosphaera stylifera	1 120	–	120	–	–
Syracosphaera sp.	2 320	–	40	–	–
Lohmanniella oviformis	40	–	40	20	–

Actinocyclus Ehrenbergi 10 m., 40. *Cerataulina Bergoni* 10 m., 20. *Chaetoceros affinis* 25 m., 60. *Ch. didymus* 25 m., 60. *Corethron hystrix* 1 m., 60. *Rhizosolenia fragilissima* 1 m., 40; 40 m., 40. *R. setigera* 25 m., 20.

Ceratium bucephalum 1 m., 20; 10 m., 40. *C. fusus* 1 m., 20; 10 m., 20. *C. lineatum* 10 m., 20; 75 m., 40. *C. longipes* 1 m., 20., *C. tripos* 75 m., 20. *Dinophysis acuminata* 1 m., 20. *Peridinium brevipes* 1 m., 20.

Distephanus speculum 1 m., 60. *Syracosphaera pulchra* 1 m., 20.

Acanthostomella norvegica 1 m., 20. *Helicostomella subulata* 1 m., 60; 40 m., 20. *Laboea conica* 1 m., 20. *L. strobila* 1m., 20. *Parafavella denticulata* 1 m., 20.

TABLE XXIII. Station 11A, September 10, 1931

Depth	1	10	25	40
Temperature	12.47	12.35	11.94	11.64
Salinity	32.14	32.16	32.20	32.21
σt	24.30	24.33	24.36	24.50
Phosphate, mg. P_2O_5 per cb. m.	44.4	44.5	44.8	46.4
Asterionella japonica	–	160	200	440
kariana	–	200	–	–
Biddulphia regia	–	20	80	40
Cerataulina Bergoni	80	–	80	–
Chaetoceros affinis	–	180	–	–
didymus	–	100	–	–
laciniosus	100	240	120	240
radicans	–	360	–	–
Coscinodiscus excentricus	80	80	80	60
Ditylum Brightwelli	200	240	120	240
Melosira sulcata	–	80	80	400
Nitzschia delicatissima	80	–	60	100
Rhizosolenia imbricata	100	60	–	–
Sceletonema costatum	7 940	7 400	6 040	3 040
Thalassionema nitzschioides	180	80	80	80
Thalassiosira decipiens	160	120	340	40
sp.	280	360	400	700
Laboea strobila	40	40	40	–

TABLE XXIII—*Continued*

Amphiprora alata 10 m., 20; 40 m., 20. *Biddulphia alternans* 10 m., 80. *Chaetoceros compressus* 10 m., 80. *Navicula distans* 10 m., 40. *Nitzschia closterium* 25 m., 20. *Pleurosigma Normani* 1 m., 20. *Rhizosolenia fragilissima* 40 m., 20. *R. setigera* 1m., 20; 25 m., 20. *Streptotheca thamesis* 10 m., 20.

Ceratium bucephalum 1 m., 20. *Gonyaulax tamarensis* 25 m., 20.

Eutreptia Lanowi 1 m., 20. *Distephanus speculum* 1 m., 40.

Helicostomella subulata 25 m., 20. *Mesodinium rubrum* 1 m., 40; 40 m., 20.

TABLE XXIV. Station A (44°50′N. lat., 65°51 1/2′ W. long.), September 10, 1931

Depth	1	10	25	40	75
Temperature	12.69	11.84	10.78	10.78	10.29
Salinity, per mille	32.23	32.29	32.43	32.47	32.61
σt	24.35	24.55	24.84	24.88	25.06
Phosphate, mg. P_2O_5 per cb. m.	38.1	38.1	46.7	52.6	51.3
Chaetoceros borealis					
borealis f. concavicornis	—	400	—	—	—
constrictus	460	880	—	160	—
decipiens	820	1 940	480	—	—
radicans	560	—	—	—	—
Corethron hystrix	—	100	—	—	—
Coscinodiscus excentricus	20	—	20	60	—
Melosira sulcata	60	—	100	—	20
Rhizosolenia semispina	40	160	—	—	—
imbricata f. Shr.	660	80	60	—	—
Sceletonema costatum	80	—	440	240	—
Thalassiosira decipiens	—	20	140	200	60
Ceratium bucephalum	180	220	—	20	—
longipes	100	40	—	—	—
Gonyaulax tamarensis	1 500	100	20	—	—
Peridinium triquetrum	cc.	cc.	—	—	—
Eutreptia Lanowi	220	—	—	—	—
Coccolithus pelagicus	160	140	200	60	40
Pontosphaera Huxleyi	20	—	20	40	20
Rhabdosphaera stylifera	760	1 140	20	—	—

Asterionella japonica 25 m., 80. *Coscinodiscus centralis* 40 m., 20. *Nitzschia closterium* 1 m., 20. *N. seriata* 1 m., 80. *Pleurosigma Normani* 75 m., 20. *Rhizosolenia fragilissima* 25 m., 20. *Thalassionema nitzschioides* 25 m., 40; 75 m., 80.

Ceratium fusus 1 m., 80; 10 m., 60. *C. tripos* 1 m., 40; 10 m., 80. *Gonyaulax spinifera* 1 m., 20; 10 m., 20. *Peridinium pallidum* 1 m., 20; 10 m., 60. *Prorocentrum micans* 1 m., 20; 10 m., 20.

Acanthoica acanthifera 1 m., 20. *Calyptrosphaera oblonga* 1 m., 20; 10 m., 20. *Syrachosphaera* sp. 25 m., 40. *Distephanus speculum* 1 m., 20; 75 m., 20.

Helicostomella subulata 1 m., 60; 75 m., 20. *Laboea vestita* 1 m., 20.

TABLE XXV. Station 25.05. March 5, 1932

Depth	10	25	40	75
Temperature	1.41	0.89	1.62	1.93

TABLE XXV—*Continued*

Number of cc. examined	50	50	50	50
Actinoptychus undulatus	–	–	40	20
Asterionella japonica	–	240	–	–
Biddulphia aurita	–	–	160	–
Chaetoceros compressus	–	–	–	160
debilis	–	120	440	–
Lauderia borealis	200	–	–	–
Navicula sp.	300	80	140	100
Nitzschia closterium	60	20	–	20
seriata	300	40	60	20
Rhizosolenia styliformis	180	–	–	–
Sceletonema costatum	2 400	640	540	800
Thalassiosira bioculata	–	–	100	60
decipiens	320	440	40	140
gravida	–	–	–	120
Nordenskioeldi	–	320	140	160

Cocconeis sp. 40 m., 20. *Coscinodiscus radiatus* 75 m., 20. *C.* sp. 75 m., 20. *Ditylum Brightwelli* 75 m., 40. *Fragilaria* sp. 40 m., 40. *Navicula distans* 40 m., 20; 75 m., 20. *Nitzschia delicatissima* 40 m., 40. *Pleurosigma* sp. 10 m., 40; 75 m., 20. *Rhizosolenia semispina* 40 m., 20 *Thalassionema nitzschioides* 75 m., 100.

Ceratium lineatum 40 m., 20. *Exuviaella baltica* 25 m., 20. *Gymnodinium* sp. 10 m., 20; 40 m., 20. *Peridinium faeroense* 10 m., 20. *P.* sp. 10 m., 20.

Distephanus speculum 75 m., 20. *Lohmanniella oviformis* 75 m., 20.

TABLE XXVI. Station 26.26. May 2, 1932

Depth	1	10	25	75
Temperature	6.1	5.5	5.4	4.4
Salinity	32.89	32.72	32.90	–
Number of cc. examined	50	50	50	10
Chaetoceros compressus	440	7 660	2 120	1 500
–resting spores	–	–	–	200
convolutus	–	120	120	–
borealis f. concavicornis	–	–	–	300
debilis	–	720	–	14 700
–resting spores	–	–	–	1 700
decipiens	–	–	–	200
diadema	–	300	100	1 900
–resting spores	–	–	–	200
didymus	80	–	240	–
furcellatus, resting spores	–	–	–	500
laciniosus	–	420	100	1 600
–resting spores	–	40	–	400
Coscinosira Oestrupi	940	860	200	2 500
Endictya oceanica	20	20	–	100
Fragilaria oceanica	–	–	–	5 000
Navicula sp	–	–	–	700
Nitzschia seriata	340	2 320	1 280	1 000
Porosira glacialis	–	–	40	4 800
Rhizosolenia semispina	–	–	20	450
Thalassionema nitzschioides	–	160	–	–

TABLE XXVI—*Continued*

Thalassiosira bioculata	20	–	20	100
decipiens	–	–	–	10 600
gravida	60	–	–	26 300
Nordenskioeldi	140	1 340	1 300	92 600
—resting spores	620	–	40	17 900
Ceratium bucephalum	100	40	120	–
fusus	80	40	180	–
lineatum	40	20	40	–
longipes	60	140	200	–
tripos	20	40	60	–
Dinophysis acuminata	–	60	40	–
norvegica	40	40	100	–
Exuviaella baltica	600	820	580	–
Gymnodinium Lohmanni	40	60	40	–
sp.	100	20	100	–
Peridinium brevipes	60	80	20	–
depressum	20	20	100	–
pallidum	60	–	100	–
triquetrum	700	3 080	440	100
Coccolithus pelagicus	40	20	200	–
Pontosphaera Huxleyi	20	100	–	–
Acanthostomella norvegica	160	220	20	–
Laboea conica	–	560	–	–

Coscinodiscus cinctus 1 m., 40. *Nitzschia closterium* 10 m., 20; 25 m., 80. *Rhizosolenia alata* 25 m., 30. *R. fragilissima* 10 m, 40; 25 m., 80. *R. styliformis* 10 m, 20.

Dinophysis robusta 1 m., 20. *Glenodinium* sp. 25 m., 20. *Gonyaulax triacantha* 1 m., 20; 25 m., 40. *Peridinium americanum* 1 m., 20. *P. cerasus* 25 m., 40. *P. conicoides* 1 m., 20; 10 m., 40. *P. conicum f. Asamushi* 1 m., 20. *P. divergens* 25 m., 20. *P. monacanthus* 25 m., 20. *P. ovatum* 1 m., 40; 25 m., 20. *P. pyriforme* 25 m., 20. *P. roseum* 1 m., 80; 25 m., 40. *P.* sp., 10 m., 20; 25 m., 60. *Prorocentrum micans* 10 m., 20.

Syracosphaera sp. 1 m., 20; 25 m., 60. *Distephanus speculum* 1 m., 20.

Laboea emergens 25 m., 20. *L. strobila* 10 m., 20. *Lohmanniella oviformis* 10 m., 20; 25 m., 20. *L. spiralis* 1 m., 40. *Parafavella denticulata* 10 m., 80, 25 m., 60.

TABLE XXVII. Station 26.30, April 29, 1932

Depth	1	10	25	40	70
Temperature	3.6	3.4	3.4	3.4	–
Salinity	32.02	31.87	31.92	32.01	32.42
Number of cc. examined	5	5	10	10	10
Asterionella japonica	2 000	–	–	–	–
Biddulphia aurita	–	–	300	–	1 600
Chaetoceros compressus	–	400	–	–	–
convolutus	–	–	–	–	400
debilis	17 200	7 400	8 000	19 700	1 000
decipiens	200	–	200	–	600
diadema	7 400	3 200	3 000	16 600	–
furcellatus	3 000	8 400	22 800	5 100	700
laciniosus	–	200	200	–	400
radicans	–	–	–	1 700	–

TABLE XXVII—*Continued*

Coscinodiscus centralis	—	400	—	—	—
Coscinosira polychorda	—	—	—	300	—
Melosira sulcata	400	—	—	—	—
Navicula sp	400	600	400	300	—
Nitzschia closterium	—	—	100	300	100
delicatissima	—	—	400	200	—
Porosira glacialis	17 600	11 200	11 800	7 100	2 900
Rhizosolenia fragilissima	—	200	100	300	—
semispina	—	—	—	—	150
Thalassiosira decipiens	4 400	1 200	4 200	2 500	800
gravida	5 800	6 000	4 300	—	3 000
—resting spores	—	6 800	2 200	—	—
Nordenskioeldi	610 400	431 600	694 900	411 900	34 500
Exuviaella baltica	400	—	100	—	—
Gymnodinium sp	—	—	400	—	—
Peridinium brevipes	200	—	100	—	—
pyriforme	—	200	—	—	—
triquetrum	600	200	—	—	—
Distephanus speculum	—	—	200	—	—
Lohmanniella oviformis	200	—	—	—	—

Chaetoceros borealis f. concavicornis 25 m., 100. *Eucampia zoodiacus* 25 m., 100. *Navicula distans* 25 m., 100. *Thalassiothrix longissima* 70 m., 100.

Peridinium ovatum 40 m., 100.

TABLE XXVIII. Station 26.31, April 29, 1932

Depth	1	10	25	40	75
Temperature	4.3	4.1	3.9	3.6	5.2
Salinity	32.41	32.46	32.46	32.60	33.26
Number of cc. examined	5	5	5	25	25
Asterionella japonica	—	—	1 000	—	—
Biddulphia aurita	—	—	1 600	—	—
Chaetoceros borealis f. concavicornis	—	1 600	600	120	—
compressus	21 200	46 000	26 800	800	—
convolutus	600	—	—	1 640	80
debilis	15 800	24 000	11 000	1 880	240
—resting spores	—	—	—	40	—
decipiens	600	1 400	—	—	—
diadema	20 660	20 800	40 000	960	—
—resting spores	2 000	—	800	520	—
furcellatus	—	—	—	160	—
laciniosus	10 000	13 800	9 800	920	—
—resting spores	—	—	600	120	—
radicans	—	—	600	—	—
Corethron hystrix	200	—	200	120	—
Coscinosira Oestrupi	18 200	9 800	5 200	880	—
Eucampia zoodiacus	—	2 200	—	120	—
Fragilaria sp. chains	600	200	600	600	80
Navicula sp	200	—	400	560	80
Nitzschia closterium	200	600	200	40	40

Table XXVII—*Continued*

Nitzschia delicatissima	—	200	1 000	160	—
seriata	1 200	—	3 200	960	—
Porosira glacialis	3 400	12 200	15 200	14 800	440
—resting spores	—	—	—	40	240
Rhizosolenia alata	200	—	—	—	—
fragilissima	200	400	1 200	300	—
semispina	300	300	100	320	—
Thalassionema nitzschioides	—	—	—	480	—
Thalassiosira bioculata	600	—	400	—	120
decipiens	800	5 200	9 200	11 760	1 240
gravida	40 400	74 400	104 000	17 760	—
—resting spores	—	—	—	1 360	—
Nordenskioeldi	18 400	35 200	56 800	29 800	2 560
—resting spores	3 000	3 400	6 000	14 360	2 480
Dinophysis ovum	200	—	200	—	—
Exuviaella baltica	400	400	—	—	—
Gymnodinium Lohmanni	—	200	—	160	—
Peridinium brevipes	—	400	—	80	—
conicoides	200	200	—	—	—
triquetrum	400	600	200	40	—
Syracosphaera sp.	200	800	—	—	—
Lohmanniella spiralis	200	—	200	—	—

Chaetoceros socialis 1 m., +. *Minuscula bipes* 1 m., 200. *Peridinium roseum* 75 m., 40. *Didinium parvulum* 40 m., 40; 75 m., 40. *Lohmanniella oviformis* 1 m., 200. *Salpingella acuminata* 40 m., 40. *S.* sp. 25 m., 200. *Parafavella denticulata* 10 m., 200. *Tintinnopsis* sp. 1 m., 200.

Table XXIX. Station 26.35, April 21, 1932

Depth	1	10	25	40	75
Temperature	4.2	3.8	—	3.2	3.7
Salinity	32.39	32.42	32.46	32.59	32.64
Number of cc. examined	25	25	50	50	50
Biddulphia aurita	—	—	100	—	40
Chaetoceros borealis f. concavicornis	—	—	60	60	180
compressus	—	—	240	—	—
convolutus	—	—	400	80	—
debilis	160	80	180	—	—
decipiens	—	200	—	—	—
diadema	280	80	700	200	—
didymus	160	—	40	—	—
laciniosus	40	—	300	—	—
Coscinosira Oestrupi	1 360	2 560	1 300	580	320
Melosira sulcata	—	—	—	200	640
Nitzschia seriata	—	—	240	—	—
Porosira glacialis	2 080	2 400	2 960	880	440
Rhizosolenia fragilissima	280	120	—	—	—
semispina	100	80	20	20	—
Thalassionema nitzschioides	520	—	280	—	260
gravida	3 720	1 520	5 100	2 120	880
—resting spores	—	160	440	—	—

TABLE XXIX—*Continued*

Thalassionema hyalina	640	—	—	80	120
Nordenskioeldi	6 960	10 400	11 640	3 920	960
—resting spores	—	—	160	—	—
Exuviaella baltica	40	40	100	—	—
Gymnodinium sp.	—	40	60	—	20
Peridinium brevipes	—	160	40	—	—

Chaetoceros atlanticus 25 m., 60. *Ch. radicans* 10 m., 40; 25 m., 20. *Coscinodiscus centralis* 25 m., 20. *C. curvatulus* 25 m., 20. *Fragilaria* sp. 75 m., 20 chains. *Navicula* sp. 1 m., 40. *Nitzschia closterium* 10 m., 80. *N. delicatissima* 1 m., 80. *Rhizosolenia alata* 40 m., 60.

Peridinium cerasus 25 m., 20. *P. curvipes* 10 m., 40. *P. ovatum* 10 m., 40; 40 m., 20. *P. pellucidum* 10 m., 40; 25 m., 20. *P. pyriforme* 25 m., 20. *P. roseum* 10 m., 40; 25 m., 20. *P. triquetrum* 10 m., 80; 40 m., 20.

Distephanus speculum 10 m., 40. *Syracosphaera* sp. 25 m., 20. *Strombidium* sp. 10 m., 40.

TABLE XXX. Station N.192, April 21, 1932

Depth	1	10	25
Temperature	2.8		
Number of cc. examined	10	10	10
Achnanthes taeniata, chains	—	100	300
Bacterosira fragilis	2 300	—	—
Biddulphia aurita	1 100	1 400	—
Chaetoceros compressus	32 500	60 500	16 000
—resting spores	500	—	200
debilis	1 100	1 400	1 500
—resting spores	—	200	—
decipiens	300	1 300	1 200
diadema	9 200	9 900	6 300
—resting spores	900	600	800
didymus	—	2 500	1 000
laciniosus	1 600	2 700	4 800
—resting spores	600	200	—
radicans	—	—	1 500
Coscinosira Oestrupi	7 200	1 600	2 400
Fragilaria oceanica, resting spores	3 400	—	—
Navicula sp	400	500	2 500
Nitzschia closterium	300	100	300
seriata	2 100	2 700	1 500
Porosira glacialis	1 600	1 900	1 700
—resting spores	—	—	100
Rhizosolenia fragilissima	—	300	—
semispina	50	—	150
Sceletonema costatum	700	1 100	800
Thalassionema nitzschioides	1 900	6 400	1 000
Thalassiosira bioculata	—	100	200
decipiens	400	—	—
gravida	8 200	8 600	13 900
—resting spores	1 100	600	1 400
hyalina	2 700	—	5 600
Nordenskioeldi	5 500	6 100	8 800
—resting spores	13 200	5 500	19 100

TABLE XXX—*Continued*

Exuviaella baltica	700	400	—
Gymnodinium Lohmanni	100	200	100
Lohmanniella oviformis	300	300	100

Dinophysis acuminata 10 m., 100. *Glenodinium* sp. 1 m., 100. *Gymnodinium* sp. 1 m., 100; 25 m., 100. *Minuscula bipes* 10 m., 100. *Peridinium brevipes* 10 m., 100. *P. conicoides* 1 m., 100. *P. denticulatum* 1 m., 100. *P. pallidum* 10 m., 100. *P. pellucidum* 1 m., 100. *P. novascotiense* 1 m., 100. *P. Thorianum* 1 m., 100.

Distephanus speculum 1 m., 100. *Laboea conica* 1 m., 100. *L. emergens* 1 m., 100. *Salpingella* sp. 1 m., 100. *Stenosemella* sp. 10 m., 100. *Strombidium* sp. 10 m., 100.

TABLE XXXI. Station Nova 197, April 23, 1932

Depth	1	10	25	40	75
Number of cc. examined	5	5	5	5	10
Achnanthes taeniata	—	800	600 ch.	800 ch.	4 200
Bacterosira fragilis	800	1 600	2 400	—	—
Biddulphia aurita	—	1 000	—	—	800
Chaetoceros borealis f. concavicornis	—	—	—	600	—
compressus	16 200	9 000	28 400	27 200	—
—resting spores	200	—	2 600	400	—
convolutus	—	400	—	—	—
debilis	9 400	600	22 600	45 600	2 500
decipiens	400	—	1 800	—	—
diadema	11 600	3 200	12 200	13 000	600
didymus	—	—	—	4 400	500
furcellatus	—	—	—	2 800	—
laciniosus	1 800	400	1 600	800	—
radicans	—	—	—	7 000	—
socialis	—	—	2 400	35 800	—
sp.	—	—	—	—	800
Coscinosira Oestrupi	5 200	3 800	4 400	9 400	1 100
Fragilaria oceanica	12 000	14 400	10 000	96 600	3 300
—chains			400		
—resting spores	—	—	1 600	—	—
Melosira sulcata	—	—	—	—	300
Navicula Vanhoeffeni	—	2 000	—	6 200	1 700
sp.	—	200	600	1 400	200
Nitzschia closterium	1 000	600	—	200	—
seriata	1 000	1 200	1 400	400	200
Porosira glacialis	1 200	1 000	2 600	12 000	4 500
—resting spores	—	—	—	—	1 000
Rhizosolenia fragilissima	200	200	1 000	+	—
semispina	400	—	200	1 000	100
Sceletonema costatum	—	—	—	20 600	—
Thalassionema nitzschioides	4 000	5 000	4 400	—	2 200
Thalassiosira bioculata	—	200	400	—	100
decipiens	600	—	—	1 200	600
gravida	10 400	28 000	30 400	51 200	7 300
—resting spores	800	—	—	800	—
hyalina	—	4 400	17 400	55 000	4 800

TABLE XXXI—*Continued*

Thalassiosira Nordenskioeldi	43 800	42 400	21 800	180 000	9 000
—resting spores	400	1 000	2 000	15 800	500
Dinophysis acuminata	200	—	—	—	—
Exuviaella baltica	1 000	400	800	—	—
Gymnodinium Lohmanni	—	—	400	—	200
sp.	200	200	1 600	2 400	200
Minuscula bipes	—	200	200	—	—
Peridinium curvipes	200	—	400	—	—
Corbicula socialis	—	—	—	2 000	—
Acanthostomella norvegica	—	—	—	200	200
Laboea reticulata	800	800	600	—	—
Lohmanniella oviformis	200	—	600	—	—
Ptychocylis obtusa	600	—	200	—	—
Strombidium sp.	—	200	200	200	100

Peridinium brevipes 1 m., 200. *P. pellucidum* 25 m., 200. *P. roseum* 1 m., 200. *P.* 1 m., 200. *Coccolithus pelagicus* 40 m., 200. *Bodo marina* 25 m., 200. *Lohmanniella spiralis* 25 m., 200. *Parafavella denticulata* 25 m., 200.

TABLE XXXII. Station 01C, April 25, 1932

Depth	1	10	25
Temperature	3.7	3.29	3.02
Salinity	30.23	30.41	30.79
σt	24.04	24.23	24.55
Number of cc. examined	5	5	5
Bacterosira fragilis	4 000	—	—
Biddulphia aurita	1 600	1 400	600
Chaetoceros debilis	400	800	7 400
diadema	—	—	400
furcellatus	3 400	57 600	70 400
Coscinosira Oestrupi	—	400	800
Melosira sulcata	4 000	3 800	—
Navicula sp.	200	800	—
Porosira glacialis	400	1 200	400
Thalassiosira decipiens	1 200	1 200	1 400
gravida	1 200	800	200
Nordenskioeldi	237 400	498 600	377 200
Gymnodinium Lohmanni	200	200	—
Peridinium pellucidum	—	400	—
Lohmanniella oviformis	400	600	—
Strombidium sp.	—	—	600
	—	800	200

Navicula distans 25 m., 200. *Rhizosolenia setigera* 25 m., 100. *Diplopeltopsis minor* 25 m., 200. *Gonyaulax* sp. 1 m., 200.

TABLE XXXIII. Station SW_2, May 4, 1932

Depth	1	10	25	40	100
Temperature	3.13	2.89	2.79	2.42	1.88
Salinity	31.53	31.67	31.58	31.85	31.94
σt	25.13	25.27	25.20	25.44	25.55
Number of cc. examined	5	5	10	10	25
Chaetoceros debilis	15 200	11 800	4 300	5 300	360
diadema	10 000	1 400	5 500	1 600	—
furcellatus	—	1 000	1 400	400	1 360
radicans	8 000	10 000	16 400	11 400	—
Coscinosira Oestrupi	—	400	—	—	80
Melosira sulcata	—	—	800	1 500	4 800
Navicula distans	—	—	200	600	120
Nitzschia closterium	—	—	100	100	—
Porosira glacialis	200	1 200	1 300	400	360
Sceletonema costatum	—	600	800	—	—
Thalassiosira bioculata	200	400	200	100	—
decipiens	2 400	200	700	800	680
gravida	600	—	1 900	900	—
—resting spores	400	—	—	200	—
Nordenskioeldi	415 000	266 800	334 100	145 600	7 800
—resting spores	—	—	600	200	120

Actinoptychus undulatus 100 m., 40. *Corethron hystrix* 40 m., 100. *Distephanus speculum* 25 m., 100. *Strombidium acutum* 40 m., 100.

TABLE XXXIV. Station 27.05, May 19, 1932

Depth	1	10	25	40	75
Temperature	4.62	4.55	4.50	4.06	3.91
Salinity	31.20	31.24	31.29	31.51	31.56
σt	24.73	24.77	24.81	25.03	25.09
Oxygen, cc./1	8.23	8.16	8.07	7.86	7.94
Oxygen, per cent of saturation	111	110	108.5	105	106
Nitrate, mg. N./cb. m.	52	62	68	98	—
Phosphate, mg. P_2O_5/cb. m.	17	—	17	25	20
Number of cc. examined	10	10	10	10	50
Chaetoceros compressus	—	1 300	400	1 700	200
debilis	7 000	11 500	9 000	10 300	4 780
—resting spores	—	—	—	100	—
decipiens	—	500	600	—	—
diadema	2 900	2 300	3 000	5 200	2 400
—resting spores	—	100	—	300	180
didymus	300	—	—	—	—
furcellatus	3 500	2 700	1 600	4 500	1 260
—resting spores	2 000	8 800	5 800	13 000	5 240
laciniosus	700	1 000	100	500	960
socialis	—	—	—	300	720
Coscinosira Oestrupi	700	1 700	3 000	3 400	740
Eucampia zoodiacus	—	400	—	—	—
Melosira sulcata	—	1 500	—	800	—
Navicula sp	—	200	—	—	100

TABLE XXXIV—*Continued*

Porosira glacialis	500	500	—	500	540
Sceletonema costatum	—	200	—	—	540
Thalassiosira bioculata	—	300	200	—	—
decipiens	1 700	1 400	200	—	500
gravida	—	—	—	800	260
Nordenskioeldi	153 600	142 000	106 000	193 200	103 020
—resting spores	29 300	40 300	32 000	79 100	69 760
Lohmanniella oviformis	—	100	—	100	60

Coscinodiscus centralis 75 m., 20. *C. curvatulus* 75 m., 20. *C.* sp. 25 m., 100. *Licmophora* sp. 10 m., 100. *Nitzschia delicatissima* 75 m., 80. *N. seriata* 75 m., 20.

TABLE XXXV. Station 27.23A, May 31, 1932

Depth	1	10	25	40	75
Temperature	9.38	9.30	6.72	4.28	3.82
Salinity	32.48	32.48	32.47	32.56	32.70
σt	25.11	25.12	25.49	25.84	25.99
Oxygen, cc./1	7.05	7.02	7.79	7.00	6.04
Oxygen, per cent of saturation	106	106	111	95	92
Phosphate, mg. P_2O_5/cb. m.	2	2	—	—	23
Number of cc. examined	50	50	50	50	50
Chaetoceros borealis	—	—	—	—	100
debilis	—	—	—	100	1 120
Thalassiosira decipiens	—	—	—	20	100
Ceratium bucephalum	—	60	20	—	—
fusus	120	120	20	—	—
longipes	440	760	320	—	—
tripos	140	40	20	—	—

Chaetoceros borealis f. concavicornis 75 m., 80. *Corethron hystrix* 40 m., 20. *Nitzschia seriata* 25 m., 60.

Exuviaella baltica 75 m., 20. *Peridinium pellucidum* 75 m., 20. *P. pyriforme* 1 m., 20. *Coccolithus pelagicus* 40 m., 20. *Lohmanniella oviformis* 25 m., 40.

TABLE XXXVI. Station 27.26, May 31, 1932

Depth	1	10	25	40	75
Temperature	9.08	9.05	5.85	4.42	3.82
Salinity	32.29	32.29	32.32	32.41	32.63
σt	25.00	25.01	25.48	25.71	25.95
Oxygen, cc./1	7.00	7.06	7.88	7.61	6.77
Oxygen, per cent of saturation	105	106	110	103.5	91
Phosphate, mg. P_2O_5/cb. m.	0	0	4	10	23
Number of cc. examined	50	50	50	50	50
Ceratium bucephalum	20	100	—	—	—
fusus	20	20	40	—	—
longipes	140	220	340	—	—
Exuviaella baltica	—	—	240	1 420	—

TABLE XXXVI—*Continued*

Peridinium spore	100	–	–	–	–
Coccolithus pelagicus	–	–	20	140	20
Pontosphaera Huxleyi	5 380	2 700	5 200	1 420	–

Chaetoceros furcellatus resting spores 1 m., 40.

Diplopeltopsis minor 75 m., 20. *Minuscula bipes* 75 m., 20. *Peridinium brevipes* 75 m., 20. *P. ovatum* 1 m., 20.

Laboea constricta 75 m., 20. *L.* sp. 25 m., 20. *Lohmanniella* sp. 10 m., 20. *Parafavella denticulata* 75 m., 20.

TABLE XXXVII. Station 27.30, May 27, 1932

Depth	1	10	25	40	150
Temperature	6.16	6.06	5.16	4.77	
Salinity	31.96	32.00	32.05	32.18	
σt	25.16	25.20	25.35	25.49	
Oxygen, cc./1	8.10	7.09	7.86	7.54	
Oxygen, per cent of saturation	114	99.5	108.5	103	
Nitrate, mg. N./cb. m.	17	19	39	98	
Phosphate, mg. P_2O_5/cb. m.	0	2	7	16	
Number of cc. examined		10	10	50	50
Chaetoceros affinis		–	1 100	–	–
borealis f. concavicornis		–	500	–	40
compressus		7 400	1 700	1 600	–
—resting spores		–	–	–	40
convolutus		–	–	–	120
debilis		16 200	16 300	7 700	–
—resting spores		–	–	400	–
decipiens		–	1 600	100	–
diadema		2 700	5 400	440	–
—resting spores		–	–	180	–
furcellatus		800	–	–	20
—resting spores		200	1 400	2 040	–
laciniosus		–	4 900	1 600	–
Coscinosira Oestrupi		300	500	680	–
Eucampia zoodiacus		–	400	1 000	–
Nitzschia closterium		–	200	–	–
delicatissima		–	400	80	–
seriata		–	2 400	360	–
Porosira glacialis		–	–	340	40
Rhizosolenia fragilissima		–	300	140	–
Thalassiosira bioculata		100	–	–	100
decipiens		–	600	900	60
Nordenskioeldi		42 900	18 500	31 900	–
—resting spores		600	–	14 500	–
Glenodinium sp.		–	–	220	40
Exuviaella baltica		100	–	20	40
Minuscula bipes		100	100	–	20
Peridinium brevipes		–	–	40	100
curvipes		–	100	–	–
ovatum		100	–	60	20
roseum		100	100	–	60

TABLE XXXVII—*Continued*

Chaetoceros radicans 40 m., 60. *Coscinodiscus curvatulus* 150 m., 20. *Rhizosolenia semispina* 40 m., 60. *Thalassionema nitzschioides* 40 m., 60. *Thalassiosira gravida* 40 m., 60.

Gonyaulax tamarensis 40 m., 20; 150 m., 20. *Peridinium conicoides* 40 m., 20. *P. divergens* 10 m., 100. *P. Thorianum* 10 m., 100. *P. triquetrum* 40 m., 20; 150 m., 20. *P. cerasus* 150 m., 20.

Coccolithus pelagicus 150 m., 20. *Lohmanniella oviformis* 40 m., 80.

TABLE XXXVIII. Station 27.31, May 27, 1932

Depth	1	10	25	40	75
Temperature	6.08	6.06	5.70	4.49	4.68
Salinity	32.30	32.36	—	32.68	32.95
σt	25.43	25.49	—	25.92	26.11
Oxygen, cc./1	7.91	8.00	—	6.67	6.17
Oxygen, per cent of saturation	111	113	—	91	85
Nitrate, mg. N./cb. m.	17	17	107	128	—
Phosphate, mg. P_2O_5/cb. m.	6	7	20	23	29
Number of cc. examined	10	10			50
Chaetoceros borealis f. concavicornis	500	—			—
compressus	35 500	16 900			—
convolutus	400	200			100
debilis	80 400	60 500			—
—resting spores	—	—			360
decipiens	500	—			—
diadema	8 600	8 900			100
—resting spores	—	200			—
furcellatus, resting spores	800	400			120
laciniosus	4 100	5 000			—
radicans	9 700	7 700			—
Eucampia zoodiacus	1 400	1 600			—
Nitzschia delicatissima	200	100			—
seriata	2 800	2 400			40
Porosira glacialis	—	200			—
Rhizosolenia fragilissima	—	800			—
Thalassiosira decipiens	800	—			180
Nordenskioeldi	196 100	186 200			—
—resting spores	1 600	1 300			—
Dinophysis ovum	100	100			100
Exuviaella baltica	500	600			80
Glenodinium sp	100	300			—
Pontosphaera Huxleyi	200	—			—

Thalassiosira bioculata 75 m., 40. *Minuscula bipes* 75 m., 40. *Peridinium americanum* 1 m., 100. *P. brevipes* 10 m., 100; *P. divergens* 10 m., 100.

Lohmanniella oviformis 10 m., 100; 75 m., 20. *Parafavella denticulata* 1 m., 100; 75 m, 20.

TABLE XXXIX. Station 27.35, May 23, 1932

Depth	1	10	25	60	135
Temperature	5.97	5.71	5.09	4.87	4.73
Salinity	31.98	31.98	32.45	32.77	32.84

TABLE XXXIX—*Continued*

σt	25.19	25.22	25.67	25.95	26.02
Oxygen, cc./1	7.54	7.40	7.02	5.69	6.35
Oxygen, per cent of saturation	106	103	97	78	87
Nitrate, mg. N./cb. m	24	36	94	129	150
Phosphate, mg. P_2O_5/cb. m	13	13	23	37	—
Number of cc. examined	50	50	50	50	50
Chaetoceros borealis f. concavicornis	—	160	20	—	—
compressus	5 260	3 900	—	—	—
—resting spores	20	—	40	20	60
debilis	6 840	5 580	320	—	—
—resting spores	—	—	—	80	140
decipiens	480	80	—	—	—
diadema	4 300	2 180	40	—	40
—resting spores	20	—	—	—	180
furcellatus, resting spores	420	120	80	40	320
laciniosus	400	280	80	40	—
radicans	760	—	—	—	220
Eucampia zoodiacus	200	—	—	—	—
Melosira sulcata	—	—	—	—	520
Rhizosolenia fragilissima	220	620	160	100	20
semispina	60	—	—	20	20
Sceletonema costatum	—	—	80	—	120
Thalassiosira decipiens	380	200	60	280	120
Nordenskioeldi	9 180	14 920	360	—	100
—resting spores	1 420	840	100	140	1 680
Exuviaella baltica	600	160	60	20	—
Peridinium conicoides	180	40	—	—	—
roseum	20	20	—	—	20
triquetrum	380	120	—	—	20
sp.	120	—	—	—	—
sp., spore	160	—	40	20	—

Actinoptychus undulatus 60 m., 20. *Chaetoceros convolutus* 1 m., 40; 10 m., 20. *Coscinodiscus curvatulus* 25 m., 20. *Coscinosira Oestrupi* 135 m., 20. *Nitzschia closterium* 1 m., 20. *N. delicatissima* 1 m., 80. *Porosira glacialis* 10 m., 20; 60 m., 20. *Thalassiosira bioculata* 60 m., 20.

Dinophysis acuminata 10 m., 60. *D. norvegica* 1 m., 40. *Diplopeltopsis minor* 1 m., 20. *Glenodinium* sp. 10 m., 20. *Gonyaulax tamarensis, cystae* 1 m., 20; 10 m., 20. *Peridinium brevipes* 60 m., 20; 135 m., 40. *P. conicum f. Asamushi* 25 m., 20. *P. curvipes* 1 m., 20. *P. depressum* 10 m., 40; 25 m., 20. *P. faeroense* 1 m., 20; 10 m., 20. *P. monacanthus* 135 m., 40. *P. pellucidum* 1 m., 40; 10 m., 40. *P. pentagonum* 60 m., 20. *P. simplex* 135 m., 20.

Eutreptia Lanowi 1 m., 40. *Pontosphaera Huxleyi* 1 m., 20. *Dictyocha fibula v. spinosa* 135 m., 20. *Distephanus speculum* 1 m., 20; 60 m., 20.

Didinium parvulum 10 m., 20. *Lohmanniella oviformis* 1 m., 20; 60 m., 40. *Parafavella denticulata* 1 m., 20; 60 m., 20. *Ptychocylis obtusa* 25 m., 20.

TABLE XL. Station 28.01C, June 20, 1932

Depth	1	10	25
Temperature	8.88	7.30	7.23
Salinity, per mille	30.82	31.35	31.51
σt	23.89	24.52	24.67
Oxygen, cc./1	6.11	6.85	6.75

TABLE XL—*Continued*

Oxygen, per cent of saturation	90.4	98.4	97.1
Nitrate, mg. N./cb. m.	50	80	94
Phosphate, mg. P_2O_5/cb. m.	29	20	27
Chaetoceros debilis	151 200	136 900	11 480
diadema	1 500	2 700	–
simplex	100	–	–
teres	900	–	–
Melosira sulcata	–	–	480
Pleurosigma Normani	100	100	80
Rhizosolenia fragilissima	200	1 100	80
Sceletonema costatum	–	800	–
Thalassiosira decipiens	–	–	200
Distephanus speculum	100	–	100

Biddulphia aurita 25 m., 80. *Navicula distans* 25 m., 40.

TABLE XLI. Station 28.08A, June 23, 1932

Depth	1	10	25	40	75
Temperature	10.02	7.15	6.93	6.88	6.38
Salinity, per mille	32.56	32.59	32.68	32.70	32.99
σt	25.38	25.53	25.63	25.64	25.94
Oxygen, cc./1	6.67	6.72	6.46	6.50	6.07
Oxygen, per cent of saturation	98.3	97.0	93.0	93.4	86.4
Nitrate, mg. N./ cb. m.	55	55	88	80	106
Phosphate, mg. P_2O_5/cb. m.	20	20	27	29	46
Chaetoceros compressus	–	–	–	100	–
convolutus	–	–	–	120	–
debilis	–	80	160	60	–
diadema	80	–	–	–	180
furcellatus, resting spores	–	340	–	–	–
radicans	120	60	–	–	–
Eucampia recta	40	–	20	20	–
Leptocylindrus danicus	–	400	260	–	–
minimus	920	1 040	120	920	–
Melosira sulcata	–	–	60	60	80
Nitzschia delicatissima	140	100	–	60	–
seriata	80	580	700	60	160
Rhizosolenia fragilissima	4 680	5 400	860	2 680	1 160
semispina	180	140	160	220	20
Thalassionema nitzschioides	–	200	–	–	80
Thalassiosira gravida	680	500	500	420	340
Ceratium bucephalum	60	60	60	–	–
longipes	300	120	140	160	20
Pontosphaera Huxleyi	360	840	–	–	–

Actinocyclus Ehrenbergi 25 m., 20. *Chaetoceros laciniosus* 75 m., 60. *Ch. teres* 25 m., 20. *Rhizosolenia setigera* 40 m., 20. *Thalassiosira decipiens* 10 m., 80.

Ceratium fusus 1 m., 40. *C. tripos* 1 m., 40. *Dinophysis acuminata* 40 m., 20. *D. norvegica* 75 m., 20. *Peridinium depressum* 40 m., 40. *P. Steini* 1 m., 20; 25 m., 20.

Stenosemella sp. 25 m., 20; 40 m., 20.

TABLE XLII. Station 28.12A, June 21, 1932

Depth	1	10	25	40
Temperature	7.86	7.49	6.79	6.64
Salinity, per mille	30.75	30.86	31.65	31.89
σt	23.99	24.12	24.84	25.04
Oxygen, cc. per 1	6.70	6.74	6.81	6.60
Oxygen, per cent of saturation	97.0	96.7	96.9	93.7
Nitrate, mg. N./cb. m	106	96	62	60
Phosphate, mg. P_2O_5/ cb. m	21	29	—	31
Eucampia recta	40	20	20	—
Melosira sulcata	160	—	—	2 220
Nitzschia closterium	20	100	20	120
seriata	20	80	—	20
Sceletonema costatum	—	40	—	200
Thalassiosira decipiens	1 540	1 630	1 100	1 420
gravida	—	20	20	20
Exuviaella baltica	140	100	—	—
Peridinium triquetrum	140	40	20	—

Chaetoceros decipiens 1 m., 40; 40 m., 20. *Ch. furcellatus*, resting spores 25 m., 40; 40 m., 60. *Navicula distans* 1 m., 40; 25 m., 20. *N.* sp. 1 m., 20; 10 m., 20; 40 m., 160. *Nitzschia delicatissima* 1 m., 20. *Pleurosigma* sp. 40 m., 20. *Thalassionema nitzschioides* 25 m., 60. *Thalassiosira bioculata* 40 m., 20. *T. Nordenskioeldi*, resting spores 10 m., 20; 40 m., 20.

Gymnodinium sp. 25 m., 20.

Eutreptia Lanowi 1 m., 60.

Acanthostomella norvegica 1 m., 40. *Laboea conica* 1 m., 40. *Lohmanniella oviformis* 40 m., 40. *Mesodinium rubrum* 1 m., 20. *Stenosemella* sp. 10 m., 20.

TABLE XLIII. Station 28.25A, July 1, 1932

Depth	1	1	10	25	40
Temperature		12.46	9.31	7.23	5.33
Salinity, per mille		29.18	31.89	32.16	32.20
σt		22.02	24.66	25.18	25.44
Oxygen cc./1		6.80	7.73	7.15	6.26
Oxygen, per cent of saturation		107.0	115.8	103.2	86.6
Phosphate, mg. P_2O_5/cb. m		8	3	14	43
Cerataulina Bergoni		200	620	40	80
Chaetoceros constrictus		320	—	—	—
debilis		5 640	—	780	7 260
—resting spores		—	—	80	9 660
diadema		—	180	—	—
Leptocylindrus minimus		—	—	1 620	—
Rhizosolenia fragilissima		40	—	20	140
setigera		60	20	20	—
Sceletonema costatum		166 000	—	—	—
Thalassionema nitzschioides		360	120	40	140
Thalassiosira decipiens		120	—	—	—

Nitzschia seriata 40 m., 80. *Rhizosolenia semispina* 1 m., 20; 25 m., 20. *Thalassiosira gravida* 10 m., 80.

Ceratium fusus 25 m., 20. *Dinophysis acuminata* 25 m., 40. *D. norvegica* 1 m., 20; 10 m. 40.

Distephanus speculum 25 m., 20. *Helicostomella subulata* 10 m., 20.

TABLE XLIV. Station 28.26, July 1, 1932

Depth	1	10	25	40	75	120
Temperature	15.16	11.84	5.43	5.44	4.46	4.35
Salinity, per mille	32.16	32.21	32.30	32.36	32.70	32.97
σt	23.79	24.48	25.51	25.56	26.32	26.55
Oxygen, cc./1	6.14	6.93	6.71	6.71	6.51	5.67
Oxygen, per cent of saturation	103.5	110.0	93.3	93.3	88.7	77.1
Nitrate, mg. N./cb. m	20	21	–	–	–	–
Phosphate, mg. P_2O_5/cb.m	9	10	44	40	45	57
Melosira sulcata	–	–	200	–	–	–
Thalassiosira decipiens	–	–	200	980	60	–
Thalassionema nitzschioides	–	–	20	120	–	–
Ceratium bucephalum	20	160	–	–	–	–
fusus	40	20	–	–	–	–
longipes	360	220	–	–	–	–
tripos	280	20	–	–	–	–
Peridinium achromaticum	20	–	20	20	–	–
Pontosphaera Huxleyi	580	1 340	–	–	–	–

Actinocyclus Ehrenbergi 75 m., 20. *Chaetoceros borealis* 75 m., 20. *Ch. debilis*, resting spores 25 m., 80; 40 m., 40. *Nitzschia closterium* 25 m., 20. *N. seriata* 10 m., 20. *Rhizosolenia alata* 10 m., 20; 75 m., 40. *Thalassiosira gravida* 120 m., 20.

Ceratium arcticum 1 m., 20. *Dinophysis acuminata* 1 m., 20. *Exuviaella baltica* 1 m., 20. *Gonyaulax tamarensis, cyste* 10 m., 20. *Peridinium triquetrum* 1 m., 60; 10 m., 20.

Coccolithus pelagicus 25 m., 20.

Parafavella denticulata 1 m., 40. *Stenosemella* sp. 1 m., 40.

TABLE XLV. Station 28.30, June 28, 1932

Depth	1	10	25	40	75
Temperature	9.39	8.03	6.60	6.36	6.04
Salinity, per mille	32.05	32.10	32.34	32.41	32.54
σt	24.77	25.02	25.39	25.48	25.62
Oxygen, cc./1	8.36	8.06	6.44	6.38	6.17
Oxygen, per cent of saturation	126.2	118.2	91.7	90.5	87.1
Nitrate, mg. N./cb. m	21	30	113	109	125
Phosphate, mg. P_2O_5/cb. m	–	9	25	21	33
Actinocyclus Ehrenbergi	–	–	40	–	–
Chaetoceros compressus	28 500	213 500	5 760	100	–
constrictus	680	3 200	–	–	–
debilis	69 500	707 500	20 800	320	60
decipiens	80	300	300	–	–
diadema	2 120	16 500	640	–	–
furcellatus	–	2 400	–	–	–
laciniosus	1 380	13 000	1 400	20	100
radicans	120	15 500	380	–	–
similis	–	300	–	–	–
teres	100	200	40	–	–
Coscinosira polychorda	80	600	–	–	–
Lauderia glacialis	80	200	–	–	–

TABLE XLV—*Continued*

Leptocylindrus danicus	680	2 900	40	—	—
minimus	800	8 100	840	—	—
Nitzschia delicatissima	40	600	100	—	40
seriata	1 480	3 000	340	—	—
Rhizosolenia alata	20	100	—	—	—
fragilissima	2 440	12 400	920	—	—
Sceletonema costatum	—	200	240	—	—
Thalassiosira decipiens	120	200	1 060	60	80
gravida	1 060	1 400	100	20	20
Nordenskioeldi	3 700	7 100	2 160	20	—
Ceratium arcticum	—	100	20	—	—
Peridinium achromaticum	—	100	—	—	—
ovatum	—	100	—	—	—
Eutreptia Lanowi	20	100	—	—	—

Cerataulina Bergoni 1 m., 80. *Chaetoceros simplex* 1 m., 40. *Melosira sulcata* 25 m., 80. *Pleurosigma Normani* 25 m., 20. *Nitzschia closterium* 10 m., 100. *Rhizosolenia semispina* 1 m., 40. *Ceratium bucephalum* 1 m., 20. *C. longipes* 1 m., 40; 25 m., 60. *Peridinium Steini* 25 m., 20. *Distephanus speculum* 1 m., 40.

TABLE XLVI. Station 28.36, June 26, 1932

Depth	1	10	25	40	75
Temperature	9.49	8.86	6.74	6.23	5.93
Salinity, per mille	31.98	31.98	32.29	32.65	32.75
σt	24.70	24.80	25.34	25.69	25.81
Oxygen, cc./1	6.75	6.75	6.48	6.33	6.14
Oxygen, per cent of saturation	102.0	100.8	92.6	89.6	86.4
Nitrate, mg. N./cb. m	33	58	78	113	116
Phosphate, mg. P_2O_5/cb. m	25	25	31	33	27
Chaetoceros compressus	—	—	180	40	40
Corethron hystrix	160	80	20	—	—
Detonula confervacea	12 960	8 560	6 440	460	80
Eucampia recta	2 720	1 600	320	40	—
Leptocylindrus minimus	—	160	100	40	60
Melosira sulcata	—	—	—	—	360
Nitzschia closterium	120	—	120	—	—
delicatissima	360	—	40	—	—
seriata	120	40	40	80	160
Rhizosolenia fragilissima	—	—	—	100	180
semispina	—	40	140	80	—
Sceletonema costatum	2 640	2 840	2 000	40	—
Thalassionema nitzschioides	—	—	240	80	60
Thalassiosira decipiens	—	—	480	160	200
sp.	—	80	20	20	—
Ceratium longipes	80	80	—	—	40
Exuviaella baltica	1 080	400	2 600	20	—
Glenodinium sp.	40	1 080	100	—	20
Gymnodinium Lohmanni	—	240	20	140	60
sp.	40	—	760	—	—
Minuscula bipes	—	80	80	20	—

TABLE XLVI—*Continued*

Peridinium pellucidum	160	40	–	–	20
triquetrum, spores	–	7 440	–	–	–
sp., spores	640	–	–	180	200
Eutreptia Lanowi	3 040	20 680	–	20	–
Pontosphaera Huxleyi	240	1 040	320	–	20
Lohmanniella oviformis	40	240	60	40	–

Chaetoceros densus 40 m., 20. *Ch. diadema* 40 m., 40. *Ch. furcellatus*, resting spores 40 m., 80; 75 m., 40. *Ch. laciniosus* 25 m., 40. *Ch. radicans* 40 m., 40. *Coscinodiscus* sp. 25 m., 20. *Navicula* sp. 25 m., 40. *Thalassiosira bioculata* 75 m., 20.

Ceratium fusus 10 m., 40. *Dinophysis acuminata* 25 m., 40. *D.* sp. 10 m., 40. *Oxytoxum* sp. 40 m., 20. *Peridinium breve* 40 m., 20. *P. brevipes* 25 m., 20. *P. conicum* 40 m., 20. *P. conicum f. Asamushi* 75 m., 40. *P. depressum* 40 m., 20. *P. gracile* 40 m., 20; 75 m., 20. *P. ovatum* 25 m., 20. *P. roseum* 25 m., 80; 75 m., 60.

Coccolithus pelagicus 75 m., 40. *Acanthostomella norvegica* 10 m., 80; 25 m., 20; 40 m., 20. *Laboea* sp. 10 m., 80.

TABLE XLVII. Station 29.01C, July 30, 1932

Depth	1	10	25	40
Temperature	10.58	–	10.15	–
Salinity	30.55	31.69	31.74	–
σt	23.41	–	24.40	+
Oxygen, cc./1	6.76	6.36	6.31	–
Oxygen, per cent of saturation	103.6	–	96.5	
Phosphate, mg. P_2O_5/cb. m	15	33	32	–
Number of cc. examined	5	10	2.5	10
Asterionella japonica	–	–	2 400	700
Cerataulina Bergoni	16 200	1 600	2 000	–
Chaetoceros affinis f. Willei	–	–	–	600
compressus	–	–	–	2 100
debilis	–	–	2 800	–
decipiens	–	1 500	4 000	400
diadema	–	800	–	2 000
laciniosus	800	800	9 600	4 500
radicans	–	2 500	–	1 200
simplex	–	400	800	100
Corethron hystrix	–	–	400	–
Leptocylindrus danicus	5 000	400	–	900
minimus	2 200	–	–	–
Nitzschia closterium	400	1 800	2 000	2 300
delicatissima	200	400	400	1 200
Pleurosigma sp	–	100	–	100
Sceletonema costatum	5 200	397 300	780 000	522 000
Thalassiosira decipiens	600	2 300	8 000	5 600
Dinophysis norvegica	–	200	–	–
sp	200	800	–	–
Exuviaella baltica	600	400	–	200
Glenodinium sp	200	–	–	–
Gonyaulax tamarensis	2 800	–	–	–

TABLE XLVII—*Continued*

Peridiniopsis rotundata	39 400	4 900	—	—
Peridinium ovatum	200	—	—	—
pellucidum	600	—	—	—
triquetrum	15 200	1 900	—	900
Distephanus speculum	35 200	14 500	3 600	1 700
Pontosphaera Huxleyi	—	—	400	—
Stenosemella sp	1 200	—	—	—

Coscinodiscus sp. 10 m., 100. *Detonula confervacea* 10 m., 100. *Eucampia zoodiacus* 40 m., 100. *Rhizosolenia alata* 10 m., 100.

Ceratium longipes 40 m., 100. *Peridinium trochoideum* 40 m., 100, *Lohmanniella oviformis* 100 m, 100.

TABLE XLVIII. Station 30.06, August 16, 1932

Depth	1	10	25	40	75
Temperature	12.25	12.08	10.35	9.30	8.63
Salinity	31.71	31.73	32.25	32.32	32.63
σt	24.00	24.05	24.77	25.00	25.34
Oxygen, cc./1	6.72	—	6.12	—	5.81
Oxygen, per cent of saturation	107.1	—	95.3	—	86.5
Nitrate, mg. N./cb. m.	42	30	82	98	118
Phosphate, mg. P_2O_5/cb. m.	15	17	35	36	40
Asterionella japonica	45 000	40 000	7 300	2 140	480
Cerataulina Bergoni	—	240	—	—	—
Chaetoceros affinis	—	—	280	—	—
compressus	240	—	760	—	—
constrictus	1 580	2 820	220	440	620
convolutus	60	20	—	20	40
debilis	—	640	—	—	—
decipiens	—	—	240	—	200
diadema	—	180	—	—	—
laciniosus	—	—	160	—	—
radicans	240	—	—	—	—
Corethron hystrix	20	20	20	—	—
Coscinodiscus excentricus	60	100	40	—	—
Coscinosira polychorda	500	160	40	160	—
Ditylum Brightwelli	960	1 000	620	160	20
Melosira sulcata	—	—	360	100	—
Nitzschia delicatissima	520	500	300	100	—
seriata	120	—	100	—	—
Rhizosolenia alata	340	200	560	—	100
setigera	80	20	20	—	20
Sceletonema costatum	243 000	490 500	52 480	3 600	5 500
Thalassionema nitzschioides	280	80	180	220	—
Thalassiosira decipiens	1 080	2 640	600	240	140
gravida	3 040	11 500	760	60	20
Nordenskioeldi	40	40	—	40	—
Ceratium fusus	160	80	20	—	—
longipes	80	80	20	—	20
tripos	20	100	20	—	—

TABLE XLVIII—*Continued*

Dinophysis acuminata	100	160	–	20	–
norvegica	100	140	–	20	–
Peridinium triquetrum	6 160	7 000	–	20	–
trochoideum	220	280	–	–	–
sp	300	160	–	–	–
Distephanus speculum	200	440	80	20	20
Helicostomella subulata	240	300	60	20	–
Stenosemella sp	60	300	420	20	20

Actinoptychus undulatus 40 m., 20. *Chaetoceros atlanticus* 75 m., 60. *Coscinodiscus concinnus* 1 m., 20; 10 m., 80. *Navicula distans* 10 m., 20; 75 m., 20. *Nitzschia closterium* 1 m., 40; 25 m., 40. *Pleurosigma Normani* 75 m., 20. *Rhizosolenia fragilissima* 1 m., 20; 10 m., 60. *R. imbricata* 1 m., 40; 10 m., 20.

Ceratium bucephalum 1 m., 20; 10 m., 20. *Gonyaulax Tamarensis, cystae,* 1 m., 40; 10 m., 20. *G. triacantha* 1 m., 40; 10 m., 40. *Peridinium conicum* 10 m., 20. *P. depressum* 1 m., 20. *P. ovatum* 10 m., 20. *P. pellucidum* 10 m., 20. *P. Steini* 1 m., 20; 10 m., 20.

Favella serrata 1 m., 20; 10 m., 80.

TABLE XLIX. Station 30.07, August 17, 1932

Depth	1	10	25	40	75	115
Temperature	12.98	12.40	11.86	9.15	7.44	7.30
Salinity, per mille	31.78	32.07	32.18	32.66	33.10	33.19
σt	23.92	24.26	24.45	25.29	25.88	25.98
Oxygen, cc./1	–	7.10	–	–	5.40	5.38
Oxygen, per cent of satur.	–	113.9	–	–	78.6	78.4
Nitrate, mg. N./cb. m.	30	42	40	88	145	145
Phosphate, mg. P_2O_5/cb. m.	9	12	13	35	44	43
Asterionella japonica	18 440	4 720	200	–	80	–
Cerataulina Bergoni	200	–	240	560	–	–
Chaetoceros affinis	–	–	280	160	–	60
cinctus	–	–	–	400	–	–
compressus	320	–	–	–	–	–
constrictus	8 200	4 020	1 580	2 640	80	200
decipiens	320	–	300	180	–	–
diadema	–	–	–	280	–	–
laciniosus	560	580	220	–	–	–
Coscinosira polychorda	80	40	–	140	–	–
Ditylum Brightwelli	760	260	60	–	–	–
Leptocylindrus danicus	–	–	–	100	–	–
minimus	–	–	–	240	–	–
Melosira sulcata	–	–	–	–	20	220
Nitzschia delicatissima	1 600	200	100	–	–	–
seriata	–	160	140	100	–	–
Rhizosolenia alata	2 840	4 020	1 840	440	60	60
imbricata	–	40	280	40	–	–
Sceletonema costatum	527 000	318 520	59 240	33 980	1 020	700
Thalassionema nitzschioides	160	40	80	–	–	–
Thalassiosira decipiens	80	360	40	–	60	20
gravida	2 520	960	340	200	80	160
Ceratium bucephalum	120	40	60	40	–	–

TABLE XLIX—*Continued*

Ceratium fusus	560	380	300	–	–	–
longipes	80	20	100	–	–	–
tripos	80	300	160	–	–	–
Dinophysis acuminata	40	80	120	–	–	20
norvegica	160	340	100	–	–	–
Diplopsalis lenticula	80	40	80	–	–	–
Exuviaella baltica	880	480	940	–	80	–
Gonyaulax tamarensis	160	140	60	20	–	–
triacantha	40	80	120	–	–	–
Peridinium pallidum	40	40	20	–	–	–
triquetrum	29 720	13 840	27 640	20	–	–
trochoideum	560	520	60	20	–	–
sp	160	20	320	–	20	–
Pontosphaera Bigelowi	–	60	80	60	–	–
Huxleyi	16 560	41 980	50 760	600	–	–
Distephanus speculum f. varians	840	480	40	100	–	–
Favella serrata	840	180	20	–	–	–
Helicostomella subulata	640	1 820	1 080	–	–	–
Stenosemella sp	40	220	200	40	40	–

Chaetoceros borealis 40 m., 60. *Ch. convolutus* 1 m., 80; 40 m., 20. *Ch. debilis* 40 m., 80. *Corethron hystrix* 1 m., 40; 40 m., 20. *Coscinodiscus excentricus* 40 m., 20. *Coscinosira Oestrupi* 10 m., 20; 40 m., 20. *Guinardia flaccida* 25 m., 20. *Nitzschia closterium* 10 m., 80; 25 m., 40. *Rhizosolenia fragilissima* 10 m., 80. *R. setigera* 1 m., 40.

Ceratium lineatum 10 m., 40. *Peridinium brevipes* 10 m., 20; 25 m., 80. *P. depressum* 10 m., 20. *P. ovatum* 10 m., 20. *Ptychocylis obtusa* 1 m., 40; 40 m., 40.

TABLE L. Station 30.08A. August 17, 1932

Depth	1	10	25	40	75	105
Temperature	10.60	9.85	8.55	8.99	8.41	7.05
Salinity	32.57	32.72	32.72	32.86	33.01	33.48
σt	24.98	25.22	25.42	25.47	25.67	26.24
Oxygen cc./1	6.69	6.42	5.84	6.11	5.93	5.09
Oxygen, per cent of satur	103.9	98.3	87.2	92.2	88.1	73.9
Nitrate, mg. N./cb. m.	60	72	120	–	95	–
Phosphate, mg. P_2O_5/cb. m.	24	24	39	33	36	–
Cerataulina Bergoni	400	3 500	160	1 660	40	–
Chaetoceros cinctus	–	400	–	–	–	–
compressus	–	300	–	80	–	–
constrictus	1 800	17 900	2 520	73 640	5 460	1 500
convolutus	–	–	80	740	–	–
decipiens	–	–	–	120	160	–
diadema	–	–	–	120	–	–
laciniosus	–	600	–	260	20	–
Corethron hystrix	–	200	120	20	–	–
Leptocylindrus danicus	–	–	–	200	–	–
minimus	–	1 400	–	–	–	–
Melosira sulcata	–	–	760	360	160	460
Nitzschia delicatissima	200	–	400	–	–	–
seriata	–	600	40	1 200	280	–

TABLE L—*Continued*

Rhizosolenia alata	600	100	160	140	80	60
fragilissima	–	400	–	–	–	–
imbricata	100	–	200	480	100	–
Sceletonema costatum	30 100	38 800	9 720	2 560	360	580
Thalassiosira gravida	100	100	–	20	–	–
Nordenskioeldi	–	100	560	–	–	–
Ceratium fusus	200	–	–	40	20	–
lineatum	100	–	–	20	–	–
longipes	100	200	–	80	20	20
tripos	–	100	–	–	20	–
Dinophysis acuminata	300	–	–	–	–	–
norvegica	100	–	–	20	–	–
Exuviaella baltica	1 700	1 100	–	120	–	–
Peridinium achromaticum	100	–	–	20	–	–
brevipes	–	100	–	40	–	–
depressum	100	–	–	60	–	–
triquetrum	11 900	4 100	120	80	–	–
trochoideum	300	400	–	120	–	–
sp.	200	200	–	60	–	–
Pontosphaera Huxleyi	7 000	5 600	–	20	60	20
Distephanus speculum	100	–	40	60	40	–
Helicostomella subulata	–	800	–	20	–	20
Stenosemella sp.	–	200	40	80	20	–

Actinoptychus undulatus 25 m., 40. *Chaetoceros borealis* 75 m., 40; 105 m., 40. *Coscinosira Oestrupi* 10 m., 100. *Navicula distans* 40 m., 20. *Nitzschia closterium* 1 m., 100. *Pleurosigma Normani* 105 m., 20. *Rhizosolenia semispina* 40 m., 20; 75 m., 20. *R. styliformis* 105 m., 20. *Thalassionema nitzschioides* 40 m., 60. *Thalassiothrix longissima* 40 m., 20.

Gonyaulax triacantha 10 m., 100. *Peridinium pallidum* 10 m., 100. *P. Steini* 40 m., 20.

TABLE LI. Station 30.12, August 20, 1932

Depth	1	10	25	40
Temperature	13.31	12.02	10.94	9.68
Salinity	31.22	31.96	32.20	32.48
σt	23.43	24.25	24.63	25.06
Oxygen, cc./1	6.35	–	6.08	5.92
Oxygen, per cent of saturation	102.9	–	94.8	90.0
Nitrate, mg. N./cb. m.	60	72	84	98
Phosphate, mg. P_2O_5/cb m.	23	–	34	35
Asterionella japonica	680	1 100	1 080	360
kariana	–	–	140	–
Chaetoceros affinis	120	–	–	–
constrictus	–	460	–	–
decipiens	40	–	–	160
laciniosus	340	–	–	–
Coscinodiscus centralis	60	20	–	–
excentricus	–	40	80	40
Ditylum Brightwelli	40	240	360	200
Melosira sulcata	–	160	680	700
Navicula distans	20	–	–	120

TABLE LI—*Continued*

Nitzschia closterium	40	20	40	20
delicatissima	40	160	200	40
Rhizosolenia alata	1 300	2 020	20	440
fragilissima	—	—	160	—
Sceletonema costatum	3 060	5 060	7 620	2 660
Thalassionema nitzschioides	80	140	120	70
Thalassiosira decipiens	—	40	160	40
Nordenskioeldi	40	240	560	40
Ceratium fusus	140	80	—	60
longipes	20	—	20	20
tripos	100	—	—	—
Dinophysis acuminata	140	—	20	—
Exuviaella baltica	300	—	—	—
Gonyaulax tamarensis	440	140	—	20
Peridinium triquetrum	121 800	1 240	180	900
trochoideum	2 680	180	20	140
Pontosphaera Huxleyi	13 400	4 620	40	40
Distephanus speculum var	40	100	40	—
Favella serrata	160	60	20	40
Helicostomella subulata	460	240	20	80

Actinocyclus Ehrenbergi 10 m., 20. *Biddulphia aurita* 40 m., 20. *Chaetoceros compressus* 10 m., 80. *Ch. densus* 10 m., 60; 25 m., 60. *Ch. diadema* 1 m., 80. *Coscinosira Oestrupi* 1 m., 20; 10 m., 20. *Pleurosigma Normani* 1 m., 20; 25 m., 20. *Rhizosolenia setigera* 25 m., 20.

Ceratium bucephalum 10 m., 20. *Dinophysis norvegica* 1 m., 40; 40 m., 20. *Gonyaulax spinifera* 1 m., 40. *Peridinium achromaticum* 1 m., 60. *P. brevipes* 1 m., 20; 40 m., 20. *P. pallidum* 10 m., 20.

Pontosphaera Bigelowi 10 m., 20. *Stenosemella* sp. 10 m., 20.

TABLE LII. Station 30.23A, August 11, 1932

Depth	1	10	25	40	75	130
Temperature	18.45	14.56	8.70	8.54	5.20	4.55
Salinity	31.83	32.27	32.57	32.63	32.72	32.97
σt	22.77	23.99	25.29	25.35	25.87	26.14
Oxygen, cc./1	7.44	6.73	6.39	6.12	6.02	5.39
Oxygen, per cent of saturation	132.5	112.5	95.4	91.1	83.3	73.6
Nitrate, mg. N./cb. m.	48	46	73	126	126	250
Phosphate mg. P_2O_5/cb. m.	10	8	32	47	48	65
Cerataulina Bergoni	—	20	140	—	—	—
Chaetoceros affinis	—	—	100	—	—	—
atlanticus	—	—	60	60	20	—
borealis	—	—	60	20	20	—
compressus	—	—	680[1]	200[1]	—	—
constrictus	120	—	6 700	1 260[1]	—	—
debilis	—	—	9 920	280	—	—
decipiens	—	—	480	360	—	—
densus	—	—	280	—	—	—
diadema	—	—	3 100	—	—	—
laciniosus	—	—	1 260	60	80	—
Corethron hystrix	—	—	180	60	—	—

TABLE LII—*Continued*

Coscinosira Oestrupi	40	60	680	560	40	—
polychorda	60	100	600	19 180	60	40
Nitzschia seriata	20	20	2 800	400	—	—
Rhizosolenia alata	260	480	2 200	20	20	—
fragilissima	—	—	120	—	—	—
imbricata	—	100	680	20	20	—
Sceletonema costatum	—	—	880	—	—	—
Thalassiosira decipiens	—	—	180	13 980	840	20
Ceratium arcticum	—	—	—	80	420	—
bucephalum	—	40	160	320	40	—
fusus	120	160	—	—	—	—
longipes	20	60	300	520	580	—
tripos	120	140	—	—	—	—
Dinophysis acuminata	20	80	—	20	—	—
Exuviaella baltica	260	240	—	60	—	—
perforata	280	120	—	20	—	—
Gonyaulax tamarensis	20	60	280	—	—	—
Peridinium achromaticum	—	40	—	20	—	20
triquetrum	20	220	—	—	—	—
trochoideum	40	380	—	—	—	—
Coccolithus pelagicus	—	—	—	120	—	—
Pontosphaera Bigelowi	320	680	—	40	—	—
Huxleyi	580	14 640	—	—	—	—
Distephanus speculum	—	40	220	40	—	—
Parafavella denticulata	—	40	20	40	—	—
Ptychocylis obtusa	—	—	80	80	—	—

Guinardia flaccida 25 m., 40. *Nitzschia closterium* 25 m., 80. *Rhizosolenia semispina* 1 m., 20; 25 m., 20. *Thalassionema nitzschioides* 40 m., 60. *Thalassiothrix longissima* 25 m., 60.

Dinophysis norvegica 10 m., 40. *Gonyaulax spinifera* 25 m., 20. *Peridinium brevipes* 10 m., 60. *P. conicum* 25 m., 20. *P. Grani* 25 m., 20. *P. ovatum* 75 m., 40. *P. Steini* 10 m., 60. *Acanthostomella norvegica* 75 m., 20; 130 m., 20. *Helicostomella subulata* 10 m., 60. *Salpingella acuminata* 25 m,, 20. *Stenosemella* sp. 75 m., 40; 130 m., 20.

[1]With resting spores.

TABLE LIII. Station 30.26, August 11, 1932

Depth	1	10	25	40	75	120
Temperature	19.26	15.20	9.65	7.59	6.09	5.60
Salinity	31.76	32.14	32.63	32.84	32.97	33.37
σt	22.51	23.75	25.19	25.66	25.96	26.33
Oxygen, cc./1	6.23	6.44	6.98	5.66	5.26	5.04
Oxygen, per cent of saturation	112.6	108.5	106.3	82.7	74.4	70.8
Nitrate, mg. N./cb. m.	43	43	43	126	136	155
Phosphate, mg. P_2O_5/cb. m.	7	10	17	39	54	54
Chaetoceros affinis	—	160	300	—	—	—
compressus	120	—	—	2 200	—	40[1]
constrictus	—	—	—	1 780[1]	—	—
debilis	—	—	—	800	—	—
decipiens	—	—	—	660	100	—
densus	—	—	—	440	—	—

TABLE LIII—*Continued*

Chaetoceros diadema	–	–	+	500	–	–
laciniosus	–	80	140	260	–	–
Corethron hystrix	–	–	20	80	20	–
Coscinosira Oestrupi	20	160	120	–	–	–
Nitzschia seriata	–	40	600	200	20	20
Rhizosolenia alata	400	3 760	5 120	580	20	–
Sceletonema costatum	80	–	+	80	–	3 700
Ceratium bucephalum	–	20	+	580	–	–
fusus	100	140	620	–	–	20
longipes	–	–	40	200	160	20
tripos	120	100	580	–	–	–
Exuviaella baltica	860	560	+	–	–	+
perforata	380	140	+	–	–	–
Gonyaulax tamarensis	100	200	740	20	–	–
Peridinium triquetrum	60	120	220	–	–	40
trochoideum	–	180	220	–	–	+
sp.	–	60	60	–	–	20
Pontosphaera Bigelowi	600	300	+	–	–	–
Huxleyi	4 260	16 920	120	–	–	–
Distephanus speculum	–	–	–	20	20	100

Chaetoceros borealis 40 m., 60. *Ch. cinctus* 40 m., 20. *Coscinodiscus excentricus* 40 m., 20. *Guinardia flaccida* 25 m., 20. *Nitzschia closterium* 40 m., 20. *Rhizosolenia imbricata* 10 m., 80; 40 m., 40. *R. semispina* 40 m., 20. *R. setigera* 10 m., 20; 120 m., 20. *R. styliformis* 10 m., 20. *Thalassiosira gravida* 10 m., 20; 25 m., 40. *Thalassiothrix longissima* 40 m., 40.

Ceratium arcticum 40 m., 20. *C. lineatum* 1 m., 20. *Dinophysis acuminata* 25 m., 20. *D. norvegica* 10 m., 20; 25 m., 60. *Peridinium achromaticum* 25 m., 20. *P. conicum* 40 m., 20. *P. brevipes* 25 m., 20; 40 m., 20. *P. depressum* 25 m., 20. *P. Grani* 75 m., 20. *P. Steini* 25 m., 60.

Coccolithus pelagicus 120 m., 20. *Acanthostomella norvegica* 10 m., 20; 25 m., 40. *Helicostomella subulata* 25 m., 20. *Parafavella denticulata* 10 m., 20. *Stenosemella* sp. 1 m., 60.

[1]With resting spores.

TABLE LIV. Station 30.30, August 14, 1932

Depth	1	10	25	40	75
Temperature	11.99	9.50	8.95	8.79	8.56
Salinity, per mille	32.20	32.48	32.59	32.63	32.68
σt	24.44	25.09	25.27	25.32	25.39
Oxygen, cc./1	7.43	6.24	6.16	5.96	5.82
Oxygen, per cent of saturation	118.2	94.7	92.4	89.2	86.7
Nitrate, mg. N./cb. m.	32	–	93	93	116
Phosphate, mg. P_2O_5/cb. m.	10	30	37	30	35
Asterionella japonica	–	–	80	1 600	–
Cerataulina Bergoni	2 300	820	80	260	500
Chaetoceros affinis	2 100	–	–	–	–
brevis	300	–	–	–	–
cinctus	259 700	18 580	580	2 460	–
compressus	34 200	360	–	40[1]	–
constrictus	11 800	8 660	4 460	5 320	3 140
debilis	8 400	4 620	820	–	120
decipiens	3 600	820	480	360	–
diadema	500	–	–	–	260

TABLE LIV—*Continued*

Chaetoceros laciniosus	2 700	300	300	140	80
Coscinosira polychorda	—	240	140	120	—
Leptocylindrus danicus	—	280	240	120	—
minimus	—	—	—	—	220
Melosira sulcata	—	—	—	—	200
Nitzschia closterium	100	60	80	20	—
delicatissima	—	140	80	140	40
seriata	—	—	40	80	200
Porosira glacialis	100	100	—	—	—
Rhizosolenia alata	300	200	360	240	340
fragilissima	2 500	1 740	40	360	20
imbricata	—	—	180	100	—
Sceletonema costatum	200	6 240	10 040	14 920	4 420
Thalassionema nitzschioides	—	—	—	40	180
Thalassiosira decipiens	—	180	720	620	420
sp.	—	240	340	380	280
Ceratium fusus	—	60	60	—	—
longipes	100	40	20	20	20
tripos	100	—	—	—	—
Dinophysis acuminata	100	40	—	—	—
Exuviaella baltica	300	—	—	—	—
Gonyaulax spinifera	100	—	—	—	—
Peridinium triquetrum	2 000	120	—	—	—
trochoideum	100	20	20	—	—
Pontosphaera Huxleyi	—	40	20	20	—
Distephanus speculum	400	100	20	20	20
Stenosemella sp.	—	40	20	40	20

Actinocyclus Ehrenbergi 25 m., 20. *Corethron hystrix* 25 m., 60; 75 m., 20. *Coscinodiscus excentricus* 25 m., 20; 75 m., 60. *C. radiatus* 25 m., 20. *Ditylum Brightwelli* 25 m., 20; 40 m., 20. *Thalassiothrix longissima* 75 m., 20.

Helicostomella subulata 75 m., 20. *Ptychocylis obtusa* 75 m., 20.

[1]Resting spores.

TABLE LV. Station 30.36, August 18, 1932

Depth	1	10	25	40	75
Temperature	13.24	11.37	8.83	7.96	7.23
Salinity, per mille	32.12	32.29	32.74	32.95	33.40
σt	24.14	24.62	25.39	25.70	26.15
Oxygen, cc./1	6.79	6.64	5.99	5.63	5.14
Oxygen, per cent of saturation	110.5	104.2	89.7	82.9	74.7
Nitrate, mg. N./cb. m	43	30	113	140	113
Phosphate, mg. P_2O_5/cb. m	10	19	36	44	52
Asterionella japonica	1 000	—	—	—	60
Cerataulina Bergoni	—	100	20	—	—
Chaetoceros constrictus	—	1 700	2 600	760	320
decipiens	—	—	280	+	120
laciniosus	—	400	—	—	—
Corethron hystrix	200	—	40	—	20
Coscinodiscus radiatus	—	100	—	—	20

TABLE LV—*Continued*

Coscinosira polychorda	—	300	120	20	—
Ditylum Brightwelli	—	—	20	60	20
Leptocylindrus minimus	—	700	—	—	—
Melosira sulcata	—	—	—	—	140
Nitzschia closterium	200	300	120	—	—
Rhizosolenia alata	2 700	1 600	280	40	60
fragilissima	—	300	—	—	—
imbricata	—	400	160	—	—
Sceletonema costatum	17 100	57 100	35 600	2 520	900
Thalassiosira decipiens	100	—	120	80	—
Nordenskioeldi	—	100	260	60	40
Ceratium bucephalum	100	100	—	—	—
fusus	100	100	—	—	—
longipes	—	100	20	—	—
tripos	—	200	—	—	—
Dinophysis acuminata	100	200	—	—	—
norvegica	—	300	—	—	—
Diplopsalis lenticula	100	300	—	—	40
Exuviaella baltica	1 500	1 400	20	20	—
Gonyaulax Tamarensis	—	100	—	—	—
Peridinium achromaticum	200	100	—	20	—
Steini	100	—	—	—	—
triquetrum	14 300	18 400	120	20	—
trochoideum	1 000	2 400	—	—	—
Pontosphaera Bigelowi	300	—	—	—	—
Huxleyi	12 300	25 800	1 180	20	—
Distephanus speculum	—	400	—	—	—
Favella serrata	200	—	—	—	—
Helicostomella subulata	300	500	20	—	—
Stenosemella sp	—	900	40	60	40

Coscinosira Oestrupi 25 m., 60; 40 m., 40. *Eucampia recta* 25 m., 40. *Nitzschia delicatissima* 25 m., 40. *Rhizosolenia semispina* 75 m., 20. *Thalassiosira gravida* 25 m., 20.

Peridinium conicum 40 m., 40. *Parafavella denticulata* 40 m., 20. *Ptychocylis obtusa* 25 m., 20.

TABLE LVI. Station 31.01C, September 12, 1932

Depth	1	7	20	35
Temperature	12.74	12.33	11.77	11.53
Salinity	32.12	32.12	32.18	32.23
σt	24.24	24.32	24.46	24.55
Oxygen, cc./1	5.71	5.84	5.55	5.54
Oxygen, per cent of saturation	92.2	93.7	87.7	87.4
Nitrate, mg. N./cb. m	48	48	58	53
Number of cc. examined	10	10	10	10
Asterionella japonica	700	2 700	5 900	16 400
Chaetoceros compressus	—	—	1 500	400
constrictus	—	800	—	1 600
—resting spores	—	—	—	200
debilis	—	—	500	—

TABLE LVI—*Continued*

Chaetoceros decipiens	–	500	–	200
laciniosus	–	400	–	600
radicans	–	–	–	800
simplex	1 000	100	200	100
socialis	–	–	6 100	2 300
subtilis	–	–	200	200
sp.	–	300	–	–
Ditylum Brightwelli	–	100	–	100
Guinardia flaccida	300	1 200	300	200
Nitzschia closterium	800	100	700	100
delicatissima	–	600	1 300	700
seriata	–	100	–	400
Pleurosigma sp	100	100	–	–
Rhizosolenia imbricata	650	2 050	250	300
Sceletonema costatum	1 400	2 200	12 700	23 900
Thalassionema nitzschioides	100 600	67 500	52 300	12 500
Thalassiosira decipiens	300	500	3 200	2 000
Ceratium fusus	–	200	100	–
lineatum	200	–	100	–
tripos	–	200	–	–
Dinophysis acuminata	200	400	–	–
norvegica	–	200	–	–
Exuviaella baltica	700	400	400	–
Gonyaulax tamarensis	300	–	–	–
Peridiniopsis rotundata	100	200	–	–
Peridinium conicoides	–	100	100	–
ovatum	–	200	–	–
triquetrum	200	900	100	–
trochoideum	400	–	100	–
Distephanus speculum	2 300	2 900	900	–
Helicostomella subulata	300	100	100	–
Lohmanniella oviformis	–	100	100	–
Stenosemella sp	500	4 100	100	100

Corethron hystrix 7 m., 100. *Coscinodiscus excentricus* 20 m., 100. *Leptocylindrus minimus* 20 m., 200. *Melosira sulcata* 35 m., 300. *Rhizosolenia setigera* 1 m., 100.

Ceratium longipes 7 m., 100. *Peridinium cerasus* 7 m., 100. *Pontosphaera Huxleyi* 7 m., 200. *Halosphaera viridis* 1 m., 200.

TABLE LVII. Station 31.05, September 12, 1932

Depth	1	7	20	75
Number of cc. examined	10	10	10	10
Asterionella japonica	21 200	89 400	40 100	36 800
Cerataulina Bergoni	–	500	200	–
Chaetoceros affinis v. Willei	–	–	600	–
constrictus	–	–	700	400
—resting spores	–	100	100	–
debilis	–	3 100	1 000	500
decipiens	900	600	–	–

TABLE LVII—*Continued*

Chaetoceros diadema	1 500	2 000	3 300	–
—resting spores	–	–	400	–
laciniosus	300	–	–	–
Ditylum Brightwelli	200	1 100	800	500
Guinardia flaccida	–	200	–	100
Melosira sulcata	–	–	500	500
Nitzschia closterium	200	1 900	400	100
delicatissima	200	1 600	700	100
seriata	400	400	800	300
Rhizosolenia imbricata	–	450	–	100
Sceletonema costatum	10 500	127 300	68 900	68 600
Thalassionema nitzschioides	1 500	5 100	5 100	1 300
Thalassiosira decipiens	100	5 800	3 500	4 400
Ceratium tripos	–	100	100	–
Dinophysis acuminata	300	100	–	–
norvegica	100	100	–	–
Exuviaella baltica	3 200	300	100	–
Glenodinium sp.	–	–	100	100
Peridinium triquetrum	3 300	300	200	–
Distephanus speculum	100	100	100	–
Eutreptia Lanowi	300	–	–	–
Pontosphaera Huxleyi	1 600	–	–	–
Lohmanniella oviformis	–	100	–	100
Stenosemella sp.	–	–	–	400

Corethron hystrix 75 m., 100. *Coscinodiscus cinctus* 7 m., 100. *C. excentricus* 75 m., 100. *Leptocylindrus minimus* 7 m., 200. *Navicula distans* 20 m., 100. *Rhizosolenia alata* 75 m., 100. *R. setigera* 7 m., 100.

Ceratium fusus 75 m., 100. *Gymnodinium Lohmanni* 75 m., 100. *Peridinium globulus* 20 m., 100.

Helicostomella subulata 1 m., 100. *Laboea conica* 7 m., 100. *L. strobila* 7 m., 100. *Strombidium* sp. 20 m., 100.

TABLE LVIII. Station 32.05, September 26, 1932

Depth	1	10	25	40	75
Temperature	12.06	11.99	11.69	10.92	9.86
Salinity	32.00	32.09	32.29	32.48	32.75
σt	24.27	24.36	24.56	24.86	25.24
Oxygen, cc./1	5.92	5.81	5.76	5.36	5.35
Oxygen, per cent of saturation	94.3	92.5	91.0	83.7	81.9
Asterionella japonica	440	2 000	–	–	–
Chaetoceros constrictus	380	420	–	–	–
decipiens	160	–	100	–	–
Ditylum Brightwelli	160	260	60	20	–
Melosira sulcata	–	–	–	240	–
Nitzschia closterium	20	40	20	–	60
delicatissima	120	80	–	–	–
Sceletonema costatum	3 080	1 080	800	–	280
Thalassionema nitzschioides	–	160	–	120	300
Thalassiosira decipiens	–	–	–	180	320

TABLE LVIII—*Continued*

Thalassiosira sp.	160	40	20	20	–
Peridinium triquetrum	260	60	–	–	20
trochoideum	120	–	–	–	–
sp.	80	40	–	20	–

Coscinodiscus centralis 1 m., 20; 25 m., 20. *C. excentricus* 75 m., 20. *C. radiatus* 1 m., 20. *Coscinosira polychorda* 40 m., 20. *Guinardia flaccida* 75 m., 140. *Navicula distans* 40 m., 20. *Pleurosigma Normani* 25 m., 20. *Rhizosolenia imbricata* 75 m., 20. *R. setigera* 25 m., 40.

Ceratium lineatum 1 m., 80. *C. tripos* 1 m., 20; 10 m., 20. *Dinophysis acuminata* 10 m., 20. *D. norvegica* 1 m., 60; 10 m., 20. *Gonyaulax tamarensis* 1 m., 20.

Distephanus speculum 10 m., 40; 25 m., 20. *Parafavella denticulata* 1 m., 20. *Stenosemella* sp. 40 m., 20.

TABLE LIX. Station 32.07, September 14, 1932

Depth	1	10	25	40	75	140	175
Temperature	11.69	11.60	11.50	10.97	8.94	7.57	7.59
Salinity	32.56	32.56	32.61	32.72	32.92	33.42	33.44
σt	24.78	24.79	24.85	25.03	25.52	26.12	26.13
Oxygen, cc./l	6.39	6.38	6.35	6.26	5.58	5.05	5.08
Oxygen, per cent of satur.	101.2	101.1	100.2	98.2	84.0	74.0	74.5
Nitrate, mg.N/cb.m.	19	20	20	36	110	240+	240+
Phosphate, mg.P_2O_5/cb.m.	13	18	15	22	34	50	50
Asterionella japonica	2 320	640	2 120	1 860	2 080	–	–
Chaetoceros decipiens	20	220	220	–	240	–	–
diadema	320	–	–	–	–	–	–
laciniosus	180	–	–	–	100	–	–
Coscinosira polychorda	20	40	20	40	–	–	–
Guinardia flaccida	120	–	–	–	–	–	–
Leptocylindrus minimus	–	360	140	–	–	–	–
Melosira sulcata	–	–	–	–	–	100	120
Nitzschia closterium	100	60	80	80	20	–	–
delicatissima	–	140	40	80	240	–	–
Rhizosolenia alata	40	80	–	20	–	–	–
Sceletonema costatum	6 560	5 520	8 620	5 680	3 040	820	380
Thalassiosira decipiens	–	–	–	–	180	–	–
sp.	460	180	440	300	200	20	40
Ceratium fusus	160	60	60	60	–	–	–
lineatum	80	200	120	20	–	–	–
longipes	20	40	60	60	–	–	–
tripos	140	120	160	100	–	–	–
Dinophysis acuminata	60	–	20	20	–	–	–
norvegica	40	20	40	–	–	–	–
Exuviaella baltica	1 740	420	440	140	–	–	–
Peridinium triquetrum	3 620	3 620	2 740	360	–	20	–
trochoideum	260	160	480	–	–	–	–
Eutreptia Lanowi	360	80	80	140	–	–	–
Coccolithus pelagicus	60	20	20	40	–	–	–
Pontosphaera Huxleyi	860	80	440	60	60	–	–
Distephanus speculum var.	–	40	40	40	–	20	–
Ebria tripartita	460	540	520	–	–	–	–
Helicostomella subulata	–	20	40	–	–	20	20

TABLE LIX—*Continued*

Biddulphia regia 140 m., 40. *Chaetoceros convolutus* 1 m., 60. *Ch. debilis* resting spores 140 m., 40; 175 m., 20. *Corethron hystrix* 1 m., 40. *Coscinodiscus excentricus* 175 m., 60. *Coscinosira Oestrupi* 1 m., 20; 25 m., 40. *Ditylum Brightwelli* 1 m., 20; 10 m., 20. *Nitzschia seriata* 75 m., 80. *Rhizosolenia fragilissima* 140 m., 20. *Thalassionema nitzschioides* 1 m., 80.

Ceratium bucephalum 10 m., 20; 25 m., 20. *Gonyaulax spinifera* 1 m., 20. *G. triacantha* 10 m., 20; 25 m., 20. *Peridinium achromaticum* 40 m., 20. *P. brevipes* 10 m., 60. *P. depressum* 140 m., 20; 175 m., 20. *P. pallidum* 25 m., 20. *Prorocentrum micans* 40 m., 20.

Lohmannosphaera subclausa 10 m., 20.

Favella serrata 25 m., 20. *Parafavella denticulata* 75 m., 20. *Stenosemella* sp. 75 m., 40.

TABLE LX. Station 32.35, September 15, 1932

Depth	1	10	25	40	75	115
Temperature	11.99	11.97	11.41	10.67	9.55	7.72
Salinity	32.43	32.43	32.50	32.63	32.86	33.40
σt	24.62	24.63	24.78	25.01	25.37	26.08
Oxygen, cc/1	6.15	6.15	6.00	5.87	5.72	5.11
Oxygen, per cent of saturation	97.9	97.9	94.7	91.4	87.0	75.0
Nitrate, mg. N./cb. m.	26	27	36	36	106	135
Phosphate, mg. P_2O_5/cb. m.	12	13	19	27	34	42
Asterionella japonica	580	280	260	1 300	200	—
Chaetoceros constrictus	—	160	—	140	360	40
decipiens	—	260	—	—	—	—
laciniosus	—	—	—	240	—	—
Coscinosira Oestrupi	40	—	140	—	20	—
Ditylum Brightwelli	20	40	—	20	20	—
Melosira sulcata	60	—	—	—	80	160
Nitzschia closterium	—	40	40	20	—	—
delicatissima	—	—	20	80	80	—
Rhizosolenia alata	40	20	—	20	20	—
Sceletonema costatum	160	40	640	1 340	2 260	80
Thalassionema nitzschioides	40	20	40	40	40	—
Thalassiosira decipiens	—	—	—	60	120	40
sp	100	120	100	260	120	40
Ceratium fusus	20	20	80	—	—	—
tripos	40	80	40	—	20	—
Exuviaella baltica	300	360	200	40	—	—
Peridinium brevipes	—	—	20	20	20	—
triquetrum	320	300	320	140	—	—
sp	—	—	20	40	20	—
Coccolithus pelagicus	—	—	100	60	—	—
Pontosphaera Huxleyi	—	—	120	60	40	—
Distephanus speculum var	20	40	—	20	20	—
Ebria tripartita	740	300	460	20	20	—

Cerataulina Bergoni 25 m., 20. *Chaetoceros convolutus* 75 m., 20. *Ch. densus* 10 m., 80; 40 m., 60. *Corethron hystrix* 25 m., 20. *Coscinosira polychorda* 75 m., 40. *Guinardia flaccida* 25 m., 80. *Rhizosolenia imbricata* 25 m., 40.

Ceratium bucephalum 25 m., 20. *C. lineatum* 25 m., 40; 40 m., 40. *C. longipes* 10 m., 40; 25 m., 40. *Dinophysis acuminata* 1 m., 20; 40 m., 20. *D. norvegica* 10 m., 40; 25 m., 40. *Diplopsalis lenticula* 25 m., 20. *Gonyaulax triacantha* 25 m., 20. *Peridinium pallidum* 75 m., 20.

Syracosphaera sp. 25 m., 40; 40 m., 20.

Helicostomella subulata 40 m., 20. *Favella serrata* 75 m., 40.