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THE HYDROGRAPHY, PRIMARY PRODUCTION, BATHYMETRY, AND "TAGSÂQ" OF DISKO BUGT, WEST GREENLAND

BY

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WITH 21 FIGURES IN THE TEXT AND 9 TABLES

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CONTENTS

Abstract

In the chapter on the hydrography, temperature variations, and to some degree the variations in the salinity of the water masses during two seasons in the exposed area of Disko Bugt and in the closed area of Disko Fjord, are described. The influence of icebergs on the vertical mixing is demonstrated.

The chapter on the primary production gives the results of the C-14 investigations made during two seasons. The total annual production is computed to be 36 g C/ m^2 / year.

In the bathymetric chapter the intricate topography of Disko Bugt is roughly described, and the influence of ice margin deposits on the formation of areas with a level bottom is demonstrated.

Chapter IV deals with the effects of the tidal waves ("Tagsâq") produced by calving glaciers on the marine fauna.

PREFACE

The present paper consists of four separate chapters which are, however, so closely associated with each other that it has been considered justified to publish the results together in one report.

The first two chapters deal with investigations planned in connection with studies on the bottom invertebrates of the area. Associated with the first two is the third chapter, the bathymetry, of which the results were not arrived at on the basis of a plan made beforehand, but which are nevertheless of significance for an understanding of the ecology of the marine bottom animals in the Disko Bugt region. The last chapter deals with the peculiar phenomena which may be encountered near productive glaciers.

Acknowledgements

The investigations recorded here could not have been carried out without the extensive help of Mr. F. Hermann, M. Sc., of the Hydrographic Laboratory, and Mr. Vagn Kr. Hansen, M. Sc., of the International Agency for C-14 determination, both of the Danish Institute for Fishery and Marine Research, Charlottenlund Slot, Denmark. Mr. F. Hermann performed the chlorine titrations of water samples collected, and the hydrographic computations, while Mr. Vagn Kr. Hansen undertook the measurements of the production on the basis of the C-14 experiments. The author is greatly indebted to these two gentlemen for their great help as well as for much valuable advice and many fruitful talks before, during, and after the field work in Greenland, and during the preparation of the present paper.

The author is, moreover, greatly indebted to the Board of the Arctic Station of the University of Copenhagen, viz. Professor M. Westergaard, Professor R. Spärck, Professor T. W. Böcher, and Dr. phil. M. Køie.

Special thanks are due to the Science Foundation of the Danish State for financial support during the preparation of this paper and for a grant, which enabled the necessary equipment for the C-14 investigation to be bought.

HYDROGRAPHY

Introduction

In connection with an investigation of marine bottom invertebrates carried out from the Arctic Station of the University of Copenhagen at Godhavn in the years 1958–1960, various hydrographic observations were made. The primary object of these investigations was to provide a picture of the temperature variations at the different depths for use in a study of the ecology of the bottom animals. Various practical difficulties prevented the investigations from being carried out as intensively as originally planned. Without discussing the difficulties in detail, it may be mentioned that Godhavn is located near a greatly exposed shore in a low-arctic region, so during rather long periods in spring and autumn (up to a couple of months) there is too much ice to allow sailing and too little ice to allow sledging. Moreover, it was not until the beginning of August, 1959, that a vessel equipped with a winch and a wire of the requisite quality needed for use with the expensive hydrographic instruments became available.

Geographically, the hydrographic measurements were distributed over three areas, viz, the area off Godhavn, where the majority of the measurements were made, Disko Fjord, where a small number of measurements were made, and finally, two stations located off glaciers in the eastern part of Disko Bugt. The map in Fig. 1 shows the position of the localities mentioned in the text.

Methods

The hydrographic measurements made at the entrance to the harbour of Godhavn were carried out in connection with the C-14 experiments by means of an insulating, non-toxic water sampler.

The other measurements were made by Nansen reversing water samplers equipped with reversing thermometers with an auxiliary thermometer. One exception to this method, however, was the measurement in Disko Fjord on November 26th 1959, where some less reliable thermometers were used.

The determinations of salinity at certain stations in Disko Fjord were made by means of an araeometer, while all remaining information

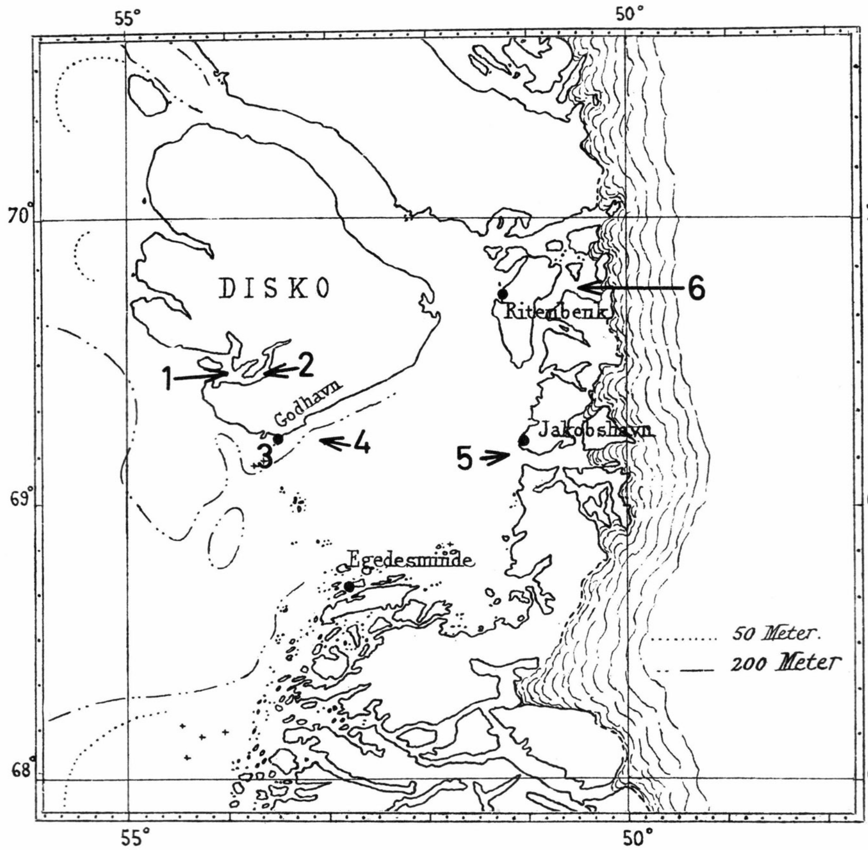

Fig. 1. Map of Disko Bugt showing the hydrographic stations. 1. Off Sioraq. 2. Off Qivitut. 3. Off Godhavn. 4. On the prawn ground. 5. Off Jakobshavns Isfjord. 6. At the head of Atâ Sund. Between Godhavn and Egedesminde lie two groups of islands called Kronprinsens Ejland (nearest Godhavn) and Hunde Ejland (nearest Egedesminde).

on the salinity is derived from chlorine titrations made at the Hydrographic Laboratory of the Danish Institute for Fishery and Marine Research.

During the winter some hydrographic measurements were carried out from the sea-ice, but the results of this operation unfortunately proved to be of no value.

Off Godhavn

Figs. 2 and 3 show the temperature distribution in the years 1959 and 1960. It will be seen from the curves that in June a warm surface layer develops, which during the course of the season attains a thickness of about 100 m. Owing to cooling of the surface layer in the autumn the highest temperatures at this time of the year are found at a depth

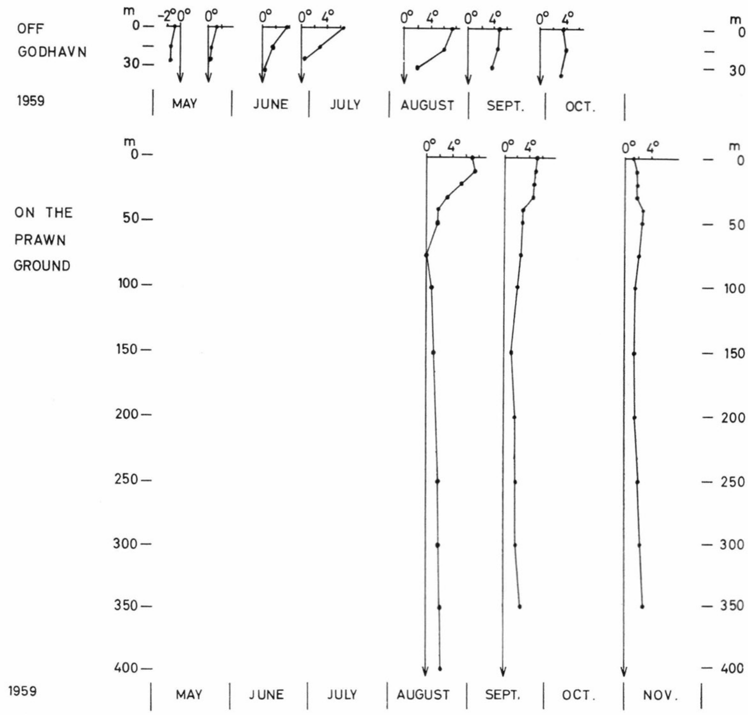

Fig. 2. Curves showing the temperature distribution according to season and depth near Godhavn in the year 1959.

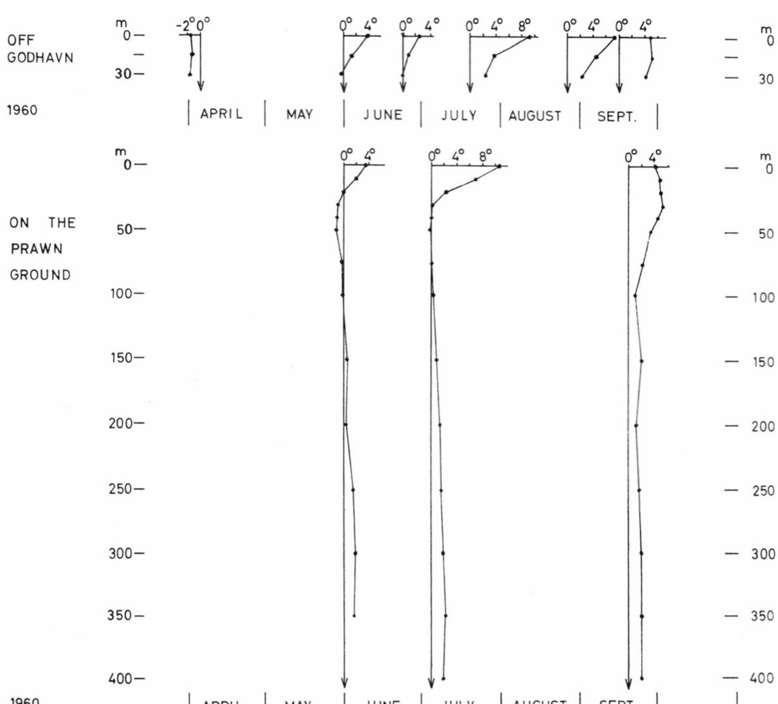

Fig. 3. Curves showing the temperature distribution according to season and depth near Godhavn in the year 1960.

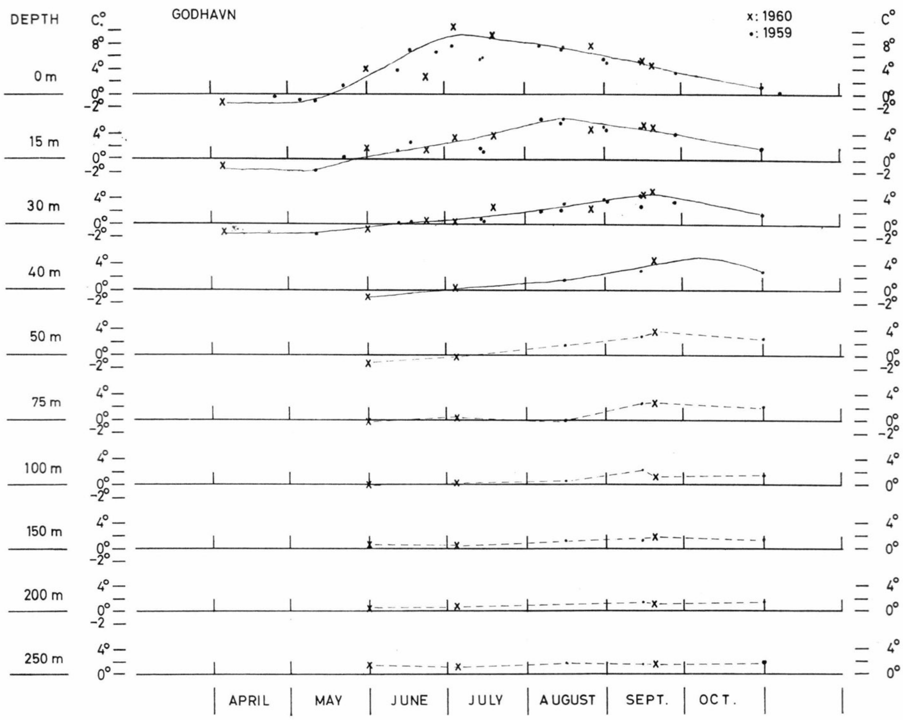

Fig. 4. Curves showing the seasonal variation of the temperature at various depths. The temperature maximum at some fixed depths occurs approximately at the following times of the year: 0 m, at the beginning of July. 15 m, at the beginning of August. 30 m, by the middle of September. 40 m, at the beginning of October. 50 m, about the middle of October.

of 30 to 50 m, an unstable condition which is probably soon obliterated by vertical mixing.

Ecologically speaking, the most important result arrived at will appear in fig. 4, where the variation of the temperature during the summer halfyear is shown for depths down to 250 m. It will be seen that the temperature maximum at the surface occurs at the beginning of July, setting in at a later and later date the deeper we go. Thus, at depths of 40 to 75 m the maximum occurs in the first half of October. At greater depths than 150 m no temperature variation of any note were observed.

On the basis of these results it is hardly possible to demonstrate any seasonal alterations of the deeper-lying water masses, such as those found off the coast of Southwest Greenland (Hachey, Hermann and Bailey 1954).

It is of interest that the surface temperatures near the harbour of Godhavn vary greatly and are generally lower than the surface temperatures farther out in Disko Bugt, viz., at the prawn ground and at

Kronprinsens Ejland. This is probably due to the fact that a great many stranded icebergs are always found near Godhavn, where they capsize throughout the summer, splitting to pieces, giving off much cold thaw-water. In this locality the thaw-water from the rivers is of very little importance in respect to the temperature, the water being heated by the air before reaching the shore.

Fig. 5 shows the variations in salinity at the entrance to Godhavn harbour. It will be seen that the salinity at the surface decreases in the course of the summer, probably owing to both the afflux of fresh water from the rivers on land and to the meltwater from the icebergs. In the

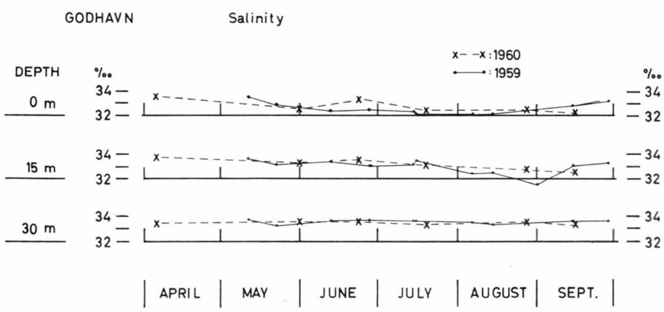

Fig. 5. Variation of the salinity during summer season off Godhavn.

autumn the salinity at the surface rises again, the supply of fresh water from land is diminished in the month of August as some of the water-courses dry out, and similarly in September, when the rivers inland begin to freeze-up. The vertical mixing, which is intensified in the autumn, likewise contributes to the increase of salinity at the surface of the sea.

For the sake of completeness an isopleth diagram of the temperature measurements made in connection with the C-14 analyses is given in fig. 6.

Disko Fjord

Hydrographic measurements were less frequently made in Disko Fjord than off Godhavn. It is true that measurements are at hand from different seasons of the year, but there are not very many from the same year. Since no great differences between the years 1959 and 1960 were ascertained on the basis of the measurements made off Godhavn, all the measurements from Disko Fjord have been treated as if they were made in the same year. The measurements in Disko Fjord were carried out from two localities, viz., one at the mouth and one in the middle of the fjord. The localities are indicated on the map in fig. 1.

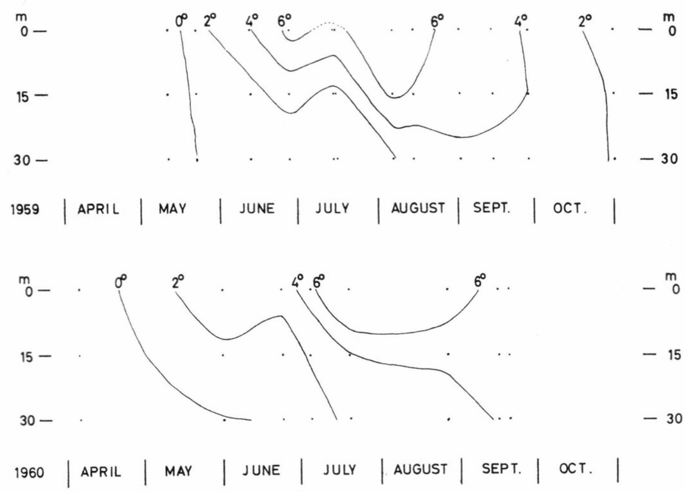

Fig. 6. Isopleth diagram of the temperature measurements from the upper 30 m.

Fig. 7 shows the temperature distribution in the water masses of the fjord, while fig. 8 gives the seasonal variations of the temperature at different depths. The results derived from these figures agree closely with those derived from the measurements off Godhavn. It is obvious how winter and summer temperatures respectively, spread to deeper water, and that the temperature maximum at the surface occurs at the beginning of July, and at a depth of 50–75 m at the beginning of October.

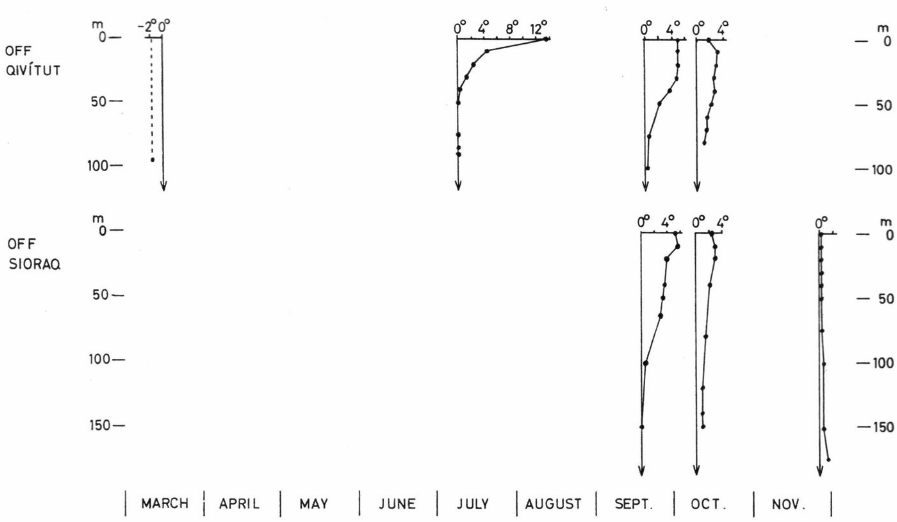

Fig. 7. Curves showing the temperature distribution according to season and depth in Disko Fjord in the years 1959 and 1960.

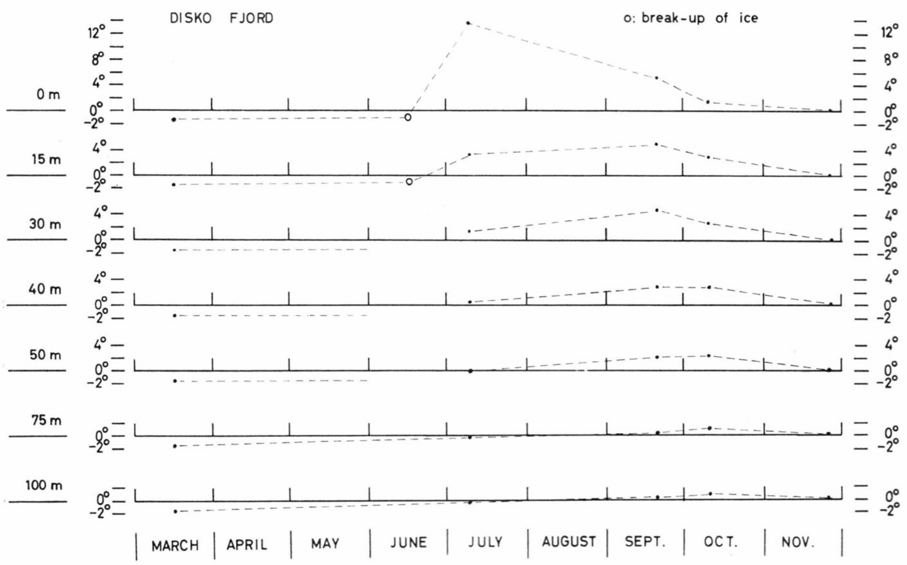

Fig. 8. Curves showing seasonal variation of the temperature at different depths in Disko Fjord. The temperature maximum at the fixed depths sets in at approximately the following times: 0 m, at the beginning of July. 15 m, at the beginning of August. 30 m, about the middle of September. 40 m, at the beginning of October.

If one is to evaluate the hydrography of Disko Fjord in relation to the differing hydrographic conditions off Godhavn the following facts should be taken into consideration:

Owing to the fjord being situated between high mountains the ice-cover is of long duration. The first sea ice appears in the fjord as early as October, and in the spring the ice does not disappear until some time in June. Icebergs are never found in the fjord itself, but at its mouth small icebergs may sometimes be encountered.

In summer Disko Fjord receives enormous quantities of thaw-water from a great many rivers both large and small, greatly polluted by suspended material, and in this way the fjord is covered with an opaque surface layer. (see Petersen 1962, fig. 5).

The innermost part of the fjord is probably separated from the outer part by a threshold extending from Qivítut to the northern shore. Although we did not succeed in ascertaining the presence of the threshold by means of the echo-sounder, various skerries do occur, which, in connection with the islands and peninsulas concentrated in the area, must impede an exchange of bottom water in the inner part of the fjord with the water outside. It may be taken for granted that during the greater part of the year the bottom animals in the interior of the fjord at depths of 75–100 m will be exposed to low temperatures, and that only during a few months in the autumn will the temperature rise above 0° C, and hardly ever above 2° C.

Off Glaciers

In the remaining part of Disko Bugt two hydrographic measurements were made, but as both of them were made in the immediate vicinity of glaciers, no general results regarding the hydrography of Disko Bugt can be derived from them.

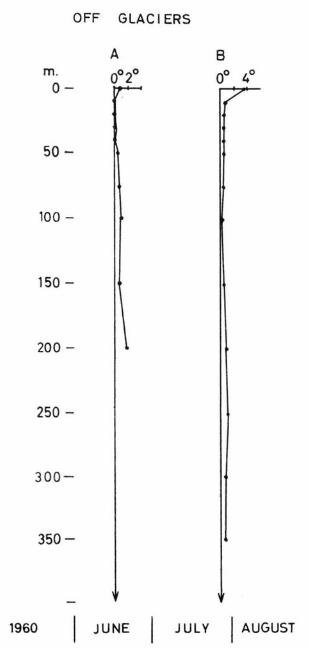

Fig. 9. Off Glaciers. Variation of temperature with depths. A. Off Jakobshavns Isfjord. B. Off Eqip sermia (Atâ Sund).

Fig. 9 shows the results of two measurements, one made off Jakobshavns Isfjeldsbanke among large icebergs, the other at the head of Atâ Sund where two glaciers descend, cf. the map in fig. 19.

If these curves are compared with measurements carried out at an earlier date on the prawn ground near Godhavn, it can be seen there is no marked temperature stratification in the water masses off the glaciers. It is remarkable that in both cases a temperature minimum at a depth of 50–75 m with temperatures below 0°C was absent. These conditions are probably explained by the considerable stirring of the water caused by the calving of the glaciers and the upsetting of the icebergs. Off the Jakobshavns Isfjord warm bottom water clearly plays a part in this process. Warm bottom water must be supplied to the head of Atâ Sund, otherwise the temperature of the bottom water mass would be still lower.

In connection with the stratification of the water masses off the glaciers it should be mentioned that there is a distinct surface layer of brackish water. Off Jakobshavns Isfjord this layer is clean and transparent, while at the head of Atâ Sund it is greatly polluted by suspended material from the various meltwater streams from the surrounding country-side.

In connection with the influence of icebergs on the hydrographic conditions Mr. FREDE HERMANN has made the following calculations of changes in the density of sea water which is in contact with icebergs:

The deeply immersed icebergs in Disko Bugt are in direct contact with the warm water layer found at depths exceeding about 150 m. Some of the deepest part of the icebergs must therefore be in the process of melting all the year round. It would be interesting to attempt an explanation of the influence this melting exerts on the density of the sea water in the immediate proximity of the icebergs.

If one gram of sea water melts a grams of ice and is mixed with the meltwater, one gets:

Temperature of sea water	t_1°
– – ice	t_2°
– – sea water and meltwater.	t_3°
Salinity of sea water....................	S_1 ‰
– – the mixed water.............	S_3 ‰

By cooling one gram of sea water from t_1° to t_3° the following amount of heat will be liberated: $1 \times (t_1 - t_3)$ cal.

By heating a grams of ice to melting point -1.8° the following amount of heat is used: $a \times 0.5 \times (-1.8 - t_2)$, the specific heat of ice being 0.5.

In order to melt a grams of ice, $a \times 80$ cal are used.

In order to heat a grams of meltwater from -1.8° to t_3°, the following amount of heat is used: $a \times (t_3 + 1.8)$.

From the above the following formula is obtained:

$$1 \times (t_1 - t_3) = a \times 0.5 \times (-1.8 - t_2) + a \times 80 + a \times (t_3 + 1.8)$$

$$t_3 = \frac{t_1 - a \times (80.9 - 0.5\, t_2)}{1 + a}$$

With regard to salinity the following formula is obtained:

$$S_1 = S_3\,(1 + a) \text{ or } S_3 = \frac{S_1}{1 + a}.$$

If $t_1 = 1.7°$ and $S_1 = 34.20$, it is possible to compute t_3, S_3, and σt_3 for various values of a and t_2. The results are given in the following table.

Table 1.

a	S_3	$t_2 = -1.°80$		$t_2 = -10.°0$		$t_2 = -20.°0$	
		t_3	σt_3	t_3	σt_3	t_3	σt_3
0.00	34.20	1.70	27.38	1.70	27.38	1.70	27.39
0.01	33.86	0.87	27.16	0.83	27.16	0.79	27.17
0.02	33.53	0.06	26.94	−0.02	26.94	−0.12	26.95
0.03	33.20	−0.73	26.71	−0.85	26.71	−1.00	26.72
0.04	32.88	−1.51	26.47	−1.67	26.48	−1.87	26.48

It will be seen from the table (1) that the melting iceberg will always cause a reduction of the specific gravity of the mixed water. As a consequence, an upward-directed vertical current will arise along the sides of the iceberg. In summer this current might be prevented from reaching the surface owing to the low density of the surface water.

In winter, however, when the density of the surface water increases because of cooling and the increasing salinity which is caused by formation of ice, it is probable that this vertical current will reach right up to the surface. As the temperature of the ascending water is above freezing point, it will delay iceforming around the iceberg.

Miscellaneous observations

Of the many miscellaneous observations made in addition to those recorded above, a few which are of interest to the hydrography will be mentioned here.

During attempts to catch seals in nets the author learned a rule from his Greenland companions. The seal nets, which are suspended below the sea ice through three holes, should be placed at right angles to icebergs frozen onto the sea ice and not grounded bergs. The latter are surrounded by tidal cracks, which one might intuitively assume to be used by the seals for breathing. However, the cracks are probably unreliable from the point of view of the seals, while bergs frozen onto the sea ice are surrounded by an upward current of mixed water composed of meltwater from the iceberg and of sea water. This upward-moving current may help the seals to keep their breathing holes free from ice. Moreover, this type of iceberg is, no doubt, of some importance for the orientation of the seal beneath the sea ice.

At the beginning of March cod are sometimes sold at Godhavn by the inhabitants of Kronprinsens Ejland, who carry the cod to Godhavn on dog sledges across the sea ice. According to information obtained, the cod were taken through holes in the ice and caught at "very great depths", most likely the deep channels found quite close to Kronprinsens Ejland, in the warm deep-sea layers of which the cod may pass the winter.

During a visit to Hareøen located northwest of Disko a great many Norwegian fish packing-cases were observed on the south coast of the island. They must have been carried there by the West Greenland current, and probably come from the fishing grounds off the southwest coast of Greenland.

Discussion

As mentioned above, the hydrographic measurements treated here were principally made with a study of the ecology of the marine bottom invertebrates in mind. In this connexion the temperature variations during the year at different depths are recorded. The depths of up to 100 m are of special interest as no seasonal collections of animals were made at greater depths than 100 m. It would be reasonable, however, to postpone a more detailed discussion of the influence of the temperature on the animals until the description of the bottom animals has been completed.

Horsted and Smidt (1956) record the results of several hydrographic measurements carried out in Greenland waters. Table 3, p. 13 in Horsted and Smidt, 1956, contains a number of hydrographic results, which may further illustrate the aforementioned phenomena encountered off glaciers. The present author's measurements on the prawn ground were made on Smidt's ground III, and were to some extent made in cooperation with Smidt. The author's measurement off the Jakobshavns Isfjeldsbanke was carried out just south of Smidt's ground II. If the figures in table 3 in Horsted and Smidt, 1956, are studied more thoroughly, e. g. by preparing curves corresponding to those used in the present paper, the result is that the temperature stability is less marked in the water masses near the Jakobshavns Isfjeldsbanke than in the water masses near prawn ground III and in the centre of Disko Bugt. The final result is that the maximum temperatures at the surface in ground II are lower than in the localities occurring at greater distances from the Isfjord, and that the minimum temperatures (most often at depths of about 100 m) are higher at ground II than at the other stations. Thus, Smidt's results support the observations recorded here, namely that icebergs and glaciers disturb the stability.

Descriptions of the various hydrographic phenomena to be encountered near glacier fronts are further found in the papers by Dunbar

(1951) and HARTLEY and DUNBAR (1938). The latter work is based on an investigation carried out in the interior of Atâ Sund.

In order to find out whether the inner parts of Disko Fjord and Atâ Sund are separated from their outer portions by a threshold, a comparison may be made between the many hydrographic measurements carried out in threshold-fjords by HORSTED and SMIDT (loc. cit.) and the author's measurements in the last mentioned two fjords. From this it may be concluded that the two fjords are not threshold-fjords proper, the temperatures in the deeper portions not being as low as in typical threshold-fjords.

The annual temperature variation found at different depths seems reasonable if compared with corresponding measurements from regions climatologically related to Disko Bugt, e. g. the waters near Baffin Island (ELLIS 1960), at Igloolik (GRAINGER 1959), in Scoresby Sund (DIGBY 1953), in the Danmarksstrædet (STEFANSSON 1962), off Godthåb (HACHEY, HERMANN, BAILEY 1954), in Southwest Greenland (HORSTED and SMIDT 1956), in the Labrador Sea (KIELHORN 1952), and in the Norwegian Sea (ØSTVEDT 1955). There are, of course, differences between the areas mentioned, but they will not be discussed at length here. It should be enough to state that the Godhavn result with temperature maximum of the surface layer in July and around 12° amplitude, and with a temperature maximum at a depth of 100 m in October and around 3° amplitude, must be regarded as fairly reliable.

PRIMARY PRODUCTION

Introduction

The purpose of investigating the gross primary production by means of the C-14 technique was to obtain a picture of the phytoplankton production in the Disko Bugt region. As the main object was to study the growth and development of the bottom invertebrates, an investigation of the production was considered a valuable supplement. The advantages of the C-14 technique were that it is easy by this means to obtain a general idea of the primary production, and that, as several investigations of the same nature had previously been carried out in Greenland waters, it would be possible to compare various areas. In order to standardize the investigations, the author studied the method in the laboratory under professor E. Steemann Nielsen, and subsequently observed it practised in the Davis Strait by Mr. Vagn Kr. Hansen on board the "Dana", and in Godthåb Fjord by Mr. Jørgen X. Nielsen of the Greenland Fisheries Investigations, on board the "Adolf Jensen". There need be no great hesitation, therefore, in comparing the results arrived at outside Godhavn with the corresponding investigations made in South Greenland and in Denmark.

Methods

The technique employed in the *in situ* experiments corresponds rather closely to that described by Steemann Nielsen (1952, 1958 a). The 10 % and 1 % depths of the blue and green light were measured by means of a submarine photometer, whose photocell was covered by the filter "Chance Coloured Optical Glass, 0 Gr 1". Water samples were taken from the individual depths by means of a nontoxic insulating water sampler, and from each sample water was taken for salinity determination and for the C-14 experiments in 100 ml bottles (Jena Geräte). The latter were suspended at the respective depths from a buoy after the addition of 1 ml radioactive solution of an activity of 4 μC.

The experiments were started when the sun was at its zenith and were stopped when the sun disappeared from the experimental locality. Immediately afterwards the contents of the bottles were filtered under pressure through a membrane filter (Membranfilter-Gesellschaft Göttingen, Stufe "Grob", Gruppe 2). As far as was possible, the experiments were carried out in fine weather. After drying the filters were sent to the International Agency for 14-C Determination, Charlottenlund, Denmark, where the final analysis was made.

In 1959 experiments were made with light-bottles only, while in 1960 experiments with both light-bottles and dark-bottles were carried out at each depth. The dark-bottles were covered by tin-foil.

The majority of the experiments were carried out during that part of the season when the sea-ice presented no problems. Those made in April and May, however, deserve detailed mention owing to the special circumstances under which they were made.

In the experiment carried out on April 5th, 1960, the bottles were suspended from the ice edge, which then lay about 3 km south of the shore off the Arctic Station. A large area of open water was found south of the ice edge, but judging from the movements of the ice during that period it could hardly be considered open water but rather a large lead in the ice.

In both 1959 and 1960 the experiments in the month of May were carried out in the ordinary way, but the ice conditions presented so many obstacles that the *in situ* method must be characterized as unsuitable in this locality during the first part of the period of production. Thus, it was very difficult to find a suitable anchoring place for the buoy, fast-ice was present in the sheltered places, and in the more exposed localities the buoy was greatly threatened by drifting ice-floes. Moreover, the depths in these places often exceed 100 m, thus making anchoring difficult. In May 1959 the necessary experimental equipment was transported in a jolly-boat which was dragged across the ice to the ice-edge, and from there it was sailed to a suitable anchorage. However, because it was melting, the ice was not quite safe. In May 1960 a channel was made through the ice, whereby it became possible to force a passage past the ice-floes in the powerful motorboat of the Arctic Station, "Porsild". However, this is not a procedure to be reccmmended. These conditions are mentioned in order to point out that it would have been preferable to employ other methods, e. g. the *imitated in situ* method (Steemann Nielsen 1958 a).

Description of the locality

Fig. 10 is a map of the area, which is situated about 69°15′ N., 53°33′ W. The experiments were carried out near the Hvidfiskeøer, where the bouy was sheltered from wind and ice. Owing to the prevalent easterly winds the locality is fairly well sheltered from icebergs and floes. However, icebergs are often found at the entrance to the harbour

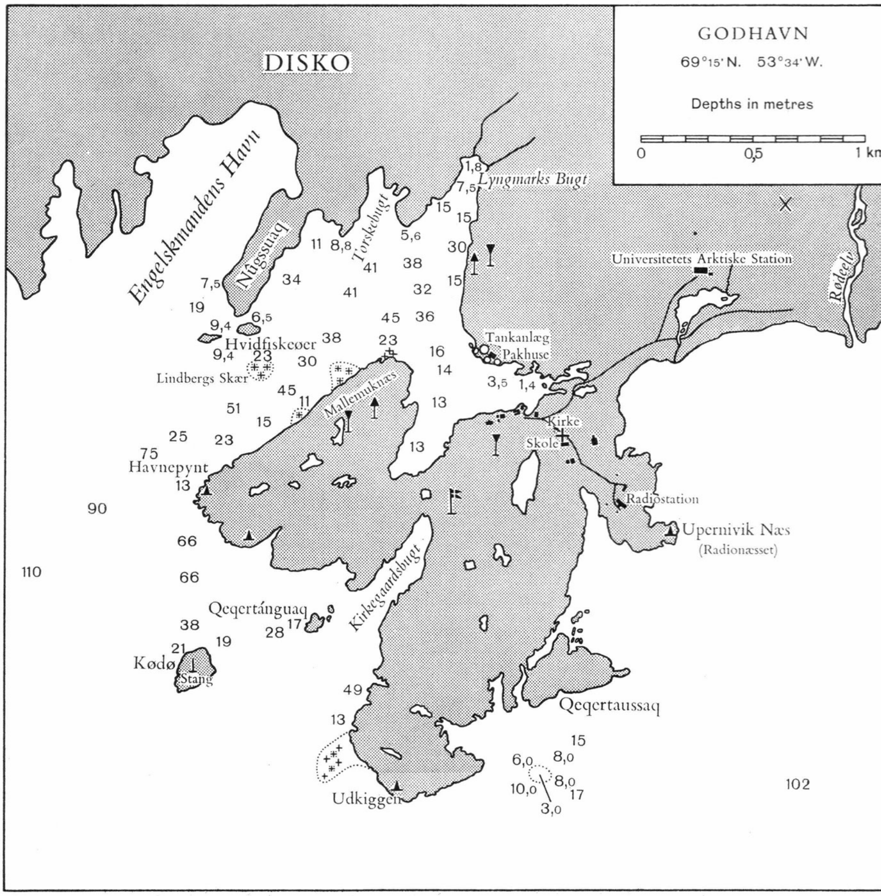

Fig. 10. Detailed map of Godhavn. The *in situ* measurements were made near Hvidfiskeøer. The photograph in fig. 11 shows the area seen from a position located almost at X.

of Godhavn, and they may even occur in the harbour proper. The depth varies greatly, and the sea bottom may most adequately be described as flooded skerries. As a rule, the buoy was anchored at a depth of 40–60 m. Compared with other suitable localities in the neigbourhood, this area recieves only small quantities of fresh water, which come from small rivers on the north coast of the entrance of the harbour.

The photograph shown in fig. 11 illustrates the special conditions found in the experimental locality. The icebergs had on that day drifted into the east-facing bays.

Results

The results arrived at will appear from figs. 12–14 and from table 9. The values obtained from dark-bottle experiments have been dis-

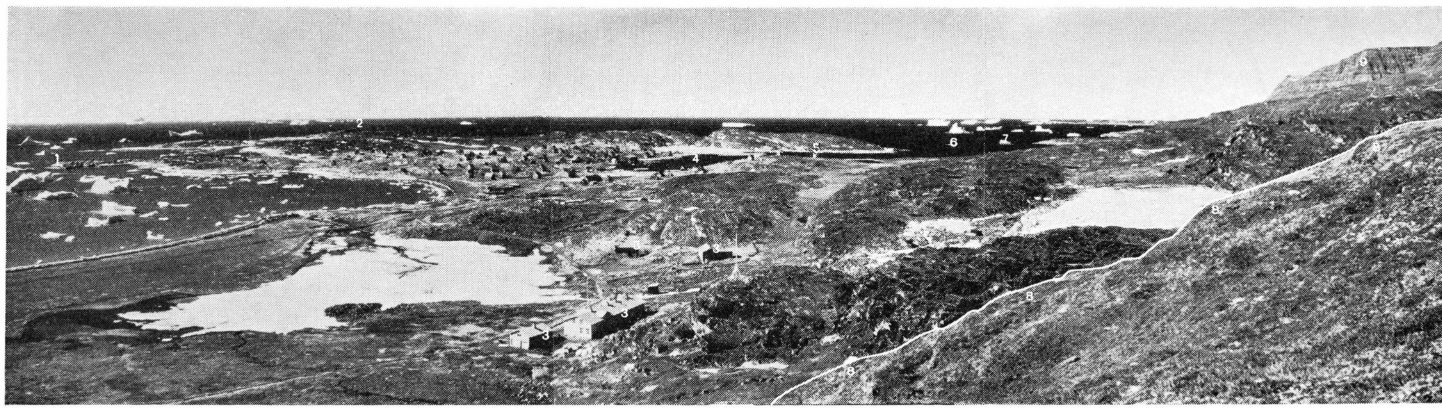

Fig. 11. Photograph showing the position of the locality in which the measurements of the phytoplankton-production were made. 1. Radionæsset. 2. Udkiggen. 3. The Arctic Station of the University of Copenhagen. 4. The harbour of Godhavn. 5. The Oil Tank. 6. Lindbergs Skær. 7. Hvidfiskeøer. 8. The edge of Østerlien. 9. The mountains which obscure the midnight sun. 30-5-1959.

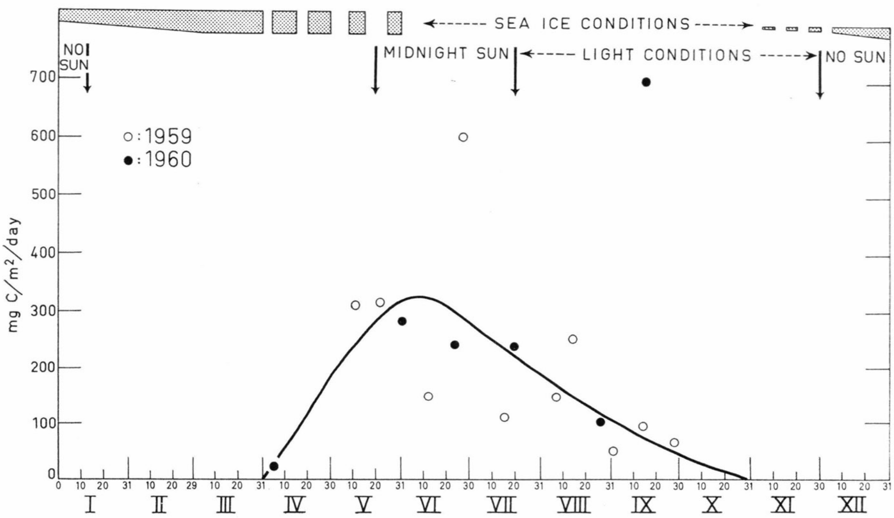

Fig. 12. Gross primary production off Godhavn. The curve represents the average production in 1959 and 1960. The points indicate the individual observations. The diagram includes information on the midnight sun and the ice conditions. The average total annual production for the two years is 36 g C /m² / year.

regarded in the calculations; they are so high that they are probably erroneous. Fig. 12 gives the variation of the gross primary production per diem in the years 1959 and 1960. It will be seen that there is good agreement between the results from these two years. The largest production takes place in the spring, in May-June, and decreases gradually in the course of the summer, probably because the nutritive salts in the surface layer have been used up. In addition the graph gives information on the sea-ice conditions and the light conditions.

The production period is assumed to last from around April 1st to around November 1st. The reasons for this assumption will be given on page 24.

Only one of the measurements was entirely different, viz. that made on September 15th, 1960. The measurement in the surface layer was extraordinarily high, but since this applies to both the light-bottle and the dark-bottle, it can hardly be due to an error of measurement, but rather to extraordinary circumstances. In the background of the high dark-fixation measured, the following two special circumstances should be mentioned in this connection. A factory ship preparing fillets of cod and catfish had been stationed in the harbour of Godhavn for about one month prior to the experiment. In consequence the harbour was greatly polluted by fish offal during that period. (The preparation of fish products does not normally take place in the harbour, but at a plant

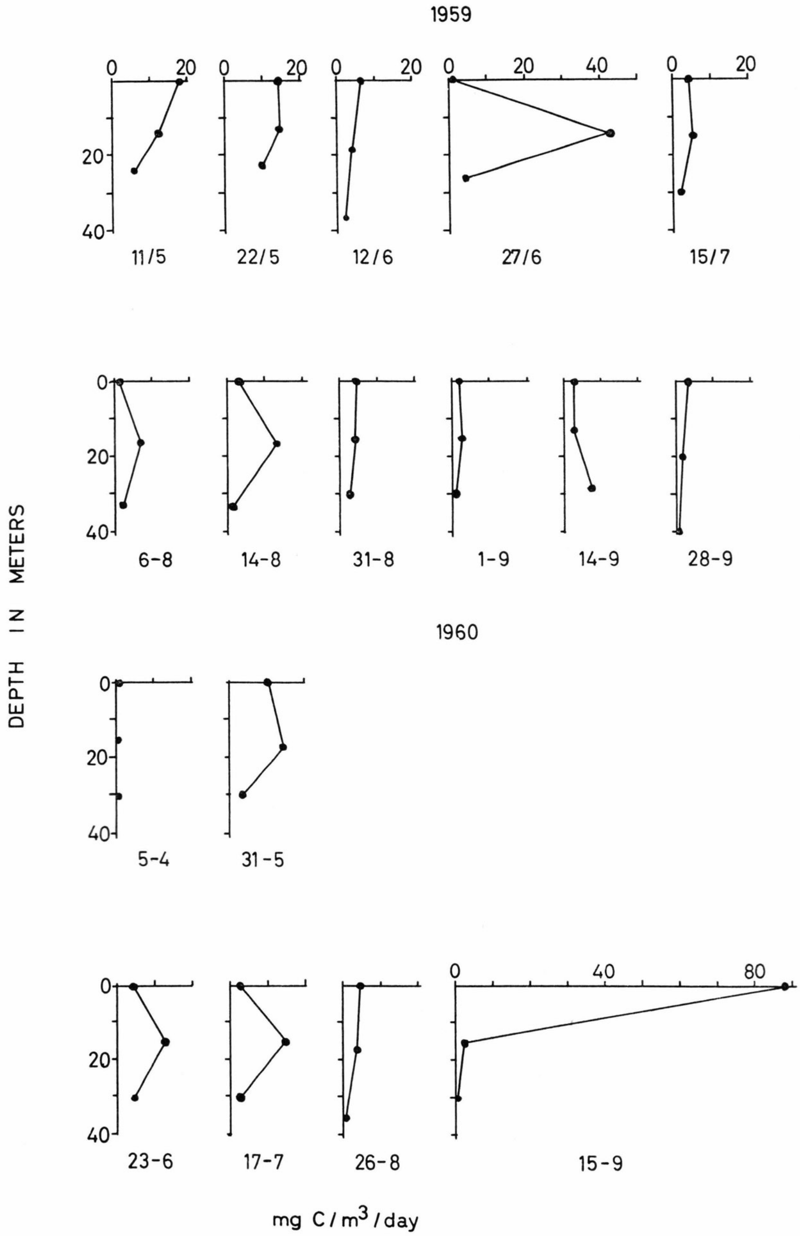

Fig. 13. Gross production at the light-depths 100 %, 10 %, and 1 %.

situated in a bay at the southeastern side of the land area around Godhavn). In addition a sperm whale was taken into the harbour for flenching in August, but the greater part of the whale was left to decay on the beach below the oil tank (see figs. 10 and 11). These two circumstances giving rise to a heavy and abnormal amount of pollution, may have produced an unusually high bacterial activity in the surface layer, which could explain the high production measured.

Fig. 13 shows the vertical distribution of the production computed as mg C per cubic metre per day.

The relation between production and the 1 °/₀ depth (fig. 14) agrees with that recorded by V. Kr. Hansen (1961).

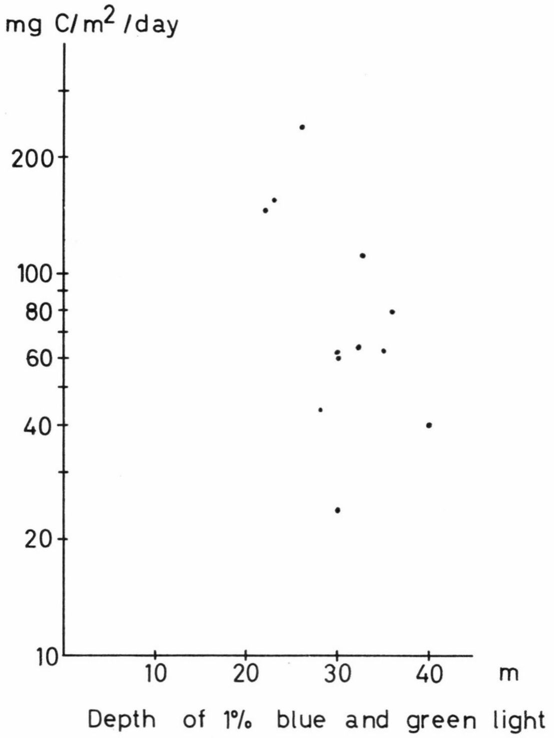

Fig. 14. Depth of 1 °/₀ green light plotted against gross production. Semilogarithmic scale.

Discussion

As the results found are derived from experiments made in a locality near the shore, it is questionable as to what extent they may be regarded as being representative of the waters around Disko. The factors important to the production will be discussed here, special regard being given to the extraordinary conditions prevailing in the area, both in the waters around Disko and in the experimental locality.

Illumination

The light energy which penetrates below the surface of the sea is determined by the length of the day, the altitude of the sun, the degree of cloudiness, and ice covering. In winter light is the limiting factor, in the first place because the sea is covered with ice, but also, of course, because light is sparse. For example, in the period from December 2nd to January 13th the sun does not rise above the horizon.

Even after the equinox, March 21st, when day becomes longer than night, light is still the limiting factor until the end of May owing to the ice covering. In estimates of the annual production the duration and the extent of the ice covering constitute the most doubtful factors. The first part of the curve in fig. 12 must therefore be regarded with some reservation as it is possible that a maximum, not ascertained during the *in situ* experiments, may occur in April-May. About April 1st the ice begins to break in the waters west and south of Godhavn. During this process, gales, currents, and swell constitute the most significant factors, while the melting of the ice apparently plays a subordinate role. During the period from April 1st to the end of May both large and small floes constantly break off from the fixed sea-ice and drift away, the ice edge thus gradually approaching the shore. In this way the light of the sun penetrates through an increasing area of sea surface, providing conditions for a larger and earlier production than shown in fig. 12. This, without doubt, must be the case in the waters west and south cf Godhavn, e. g. over the Disko Banke. An indication of the correctness cf this assumption is furnished by plankton samples secured by vertical hauls through holes in the ice, samples from the end of April contained large quantities of phytoplankton which had drifted in below the ice from ice-free areas farther away from the shore. However, as the study of these samples has not yet been completed, it is not intended to discuss the observations in greater detail here. In regard to Disko Bugt as a whole, where the ice in the inner parts disappears about a week or two later than the ice at Godhavn, the results shown in fig. 12 will probably apply.

In summer the midnight sun is in the sky from around May 20th to around July 20th, and as the ice does not disappear till the end of May, there will be abundant light during a very long period of the day and night as soon as the ice disappears. About June 21st there will probably be sufficient light for assimilation all during the day and the night. This phenomenon, however, has not been studied as in actual fact there is no midnight sun in the experimental locality or at Godhavn on the whole owing to the presence of some high mountains (700–1000 m) north of the town, which obscure the midnight sun. In the experimental locality at the entrance to the harbour of Godhavn the sunlight lingers only untill around 1800 hours, irrespective of the date. The distribution of the production during twenty-four hours with midnight sun ought, of course, to be studied. However, this is not feasible off Godhavn by the *in situ* method, depths of 200–400 m and often many drifting icebergs are found outside the area shaded by the mountains. This study is, nevertheless, possible e. g. at Kronprinsens Ejland, a group of islands located ca. 30 km south of Godhavn, but it was impossible to include such an investigation in the planned programme, and only one single experiment was carried out at Kronprinsens Ejland.

During practically the whole period in which it was possible to carry out *in situ* experiments the illumination was more favourable in the off-shore areas than in the experimental locality. In that respect, therefore, the results should be minimum values. On the other hand, the experiments were always, as far as possible, made in fine, clear weather. As the weather in this area is often foggy and cloudy during the summer, the results will show a better average than the actual average for the locality.

In the autumn the experiments were interrupted at the end of September in 1959 owing to rough and cloudy weather in the month of October. They were interrupted in 1960 when the return journey was made. Considering the light-conditions it is reasonable to regard November 1st as the end of the productive period, in the first place the sun disappears rapidly after the autumnal equinox (disappearing entirely below the horizon on December 2nd), and secondly, the weather in autumn is often very cloudy and rough.

Stabilisation

It will be seen from figs. 2 and 3 that a stabilisation of the surface water owing to heating sets in already at the end of May. During the greater part of the period of production the stabilised surface layer extends to a depth of 30–40 m or almost the same depth as the compensation depth, thus providing good conditions for the phytoplankton production (Sverdrup 1953). The cooling process setting in in August–September breaks down the stabilised surface layer in October–November. It will be seen from fig. 5 that the low salinity of the surface layer likewise contributes to the stabilisation in the spring. The low salinity is due to the afflux of meltwater from the land, from icebergs, from sea-ice, and from snow which accumulates on the ice in the course of the winter. In spring and autumn the salinity at the surface is of the same order of magnitude as at greater depths. Marshall (1958) showed that in the Barents Sea the stabilisation (because of decreasing salinity of the surface layer during the melting of the ice) is of importance for the production-wave following upon the retreat of the ice edge in spring.

It will be seen that the period in which the conditions of stabilisation are favourable for the production coincides with the period with favourable conditions of illumination.

Nutritive salts

No measurements of the contents of nutritive salts were made, but there is reason to assume that a supply takes place from the deeper layers to the euphotic zone, in addition to that caused by vertical currents in winter. The many icebergs found in the area (see fig. 11) will probably give rise to a vertical mixing both owing to the mechanical stirring caused by the upsetting of the bergs and to the instability caused by the melting of the more deeply immersed parts of the bergs, which may extend to depths of 100–200 m.

A certain amount of vertical stirring probably also takes place during the passage of a branch of the West Greenland Current across the broken bottom of Disko Bugt, this current entering the southern half of the bay and passing out along the south coast of Disko (a part of the current will pass out along the north coast of Disko).

The supply of dissolved nutritive salts from the land is probably of subordinate importance as the affluents of fresh water which enter the experimental area are small and clean.

Pollution

As will be seen from table 9, the values derived from the dark-bottle experiments are relatively high. This may be due in part to the use of imperfectly light-tight dark-bottles, but this is hardly a sufficient explanation. It is also quite possible that a lively bacterial activity is in some measure responsible for the high dark-fixation found. On several occasions large quantities of dead plankton organisms were observed drifting at the surface in the experimental locality; these had obviously been killed by fresh water as a thin layer of fresh water could be distinctly seen to form the upper few centimetres. At spring tides the surface layer was sometimes observed to be polluted with cast-off skins from crustaceans such as barnacles and amphipods. It should be added that the streams which carry water to the entrance of the harbour of Godhavn do not pollute the experimental area by washed up material, as is the case with many other areas off river mouths, e. g. the area east of Godhavn (Holmquist 1959, pp. 122–126). It is probable, also, that organic material from the land is of importance for the bacterial activity, branches and leaves of terrestrial plants have often been found in bottom samples taken near the experimental locality. Pollution from the town of Godhavn, however, is probably of subordinate importance considering the location of the houses and the special sanitary conditions. An extraordinary amount of harbour pollution is mentioned on page 22. A further discussion of the general problems in connection with the dark-fixation is found in papers by Steemann Nielsen (1960) and Thomas and Simmons (1960).

Duration of the period of production

As mentioned above, there is a possibility that the first part of the productive period has been underestimated. Owing to practical difficulties it was impossible to make experiments by the *in situ* method earlier in the season. Judging from the ice and stabilisation conditions, the production must be assumed to start late in April in the areas west of Godhavn and late in May in the interior of Disko Bugt. The result arrived at must be fairly representative of the Disko Bugt area. It would be natural, therefore, to make a comparison with some other areas with a more or less arctic location when information on the length of the productive period is available.

In South Greenland investigations of the production have been made off Narssaq and off Godthåb. In both these localities the production starts in March–April, to die out in November (Steemann Nielsen 1958 b).

In the Labrador Sea the production starts late in March, reaching a spring maximum in early June (Holmes 1956).

In the Norwegian Sea (Halldal 1953), off Tromsø (Gaarder 1938), and near the Lofoten (Føyn 1929), the spring production starts in March.

Bursa (1961 p. 608) gives a table of the biological seasons in various arctic localities. It is true that the present investigation is not directly comparable to those used in Bursa's tables as the methods employed are different, but the productive period off Godhavn seems very much like that found by Bursa at Igloolik. The two localities are situated at about the same latitude and with about the same conditions of illumination. The ice conditions, however, are more severe at Igloolik than at Godhavn, and accordingly the season is a little longer at Godhavn than at Igloolik.

Amount of production

A comparison of the annual production in various localities is made below. As regards the many factors to be taken into consideration concerning measurements of the phytoplankton production, the reader is referred to Strickland (1960).

Steemann Nielsen (1958 b) gives the following list of the annual production in various Danish and South Greenland localities:

	g C / m² / year.
Denmark	
Great Belt (Halskov Rev)	60
Kattegat (Anholt Nord)	61
Sound (near Elsinore)	39
Limfjord (Venø Bugt)	105
Isefjord (Inner Broad)	1175
Dybsø Fjord	6
South Greenland	
Outside Narssaq	29
Mouth of the Godthåb Fjord	98
Inner part of the Godthåb Fjord	95
North Greenland	
Godhavn (present paper's result)	36

The results arrived at in the present paper concerning annual production agree reasonably well with the above list.

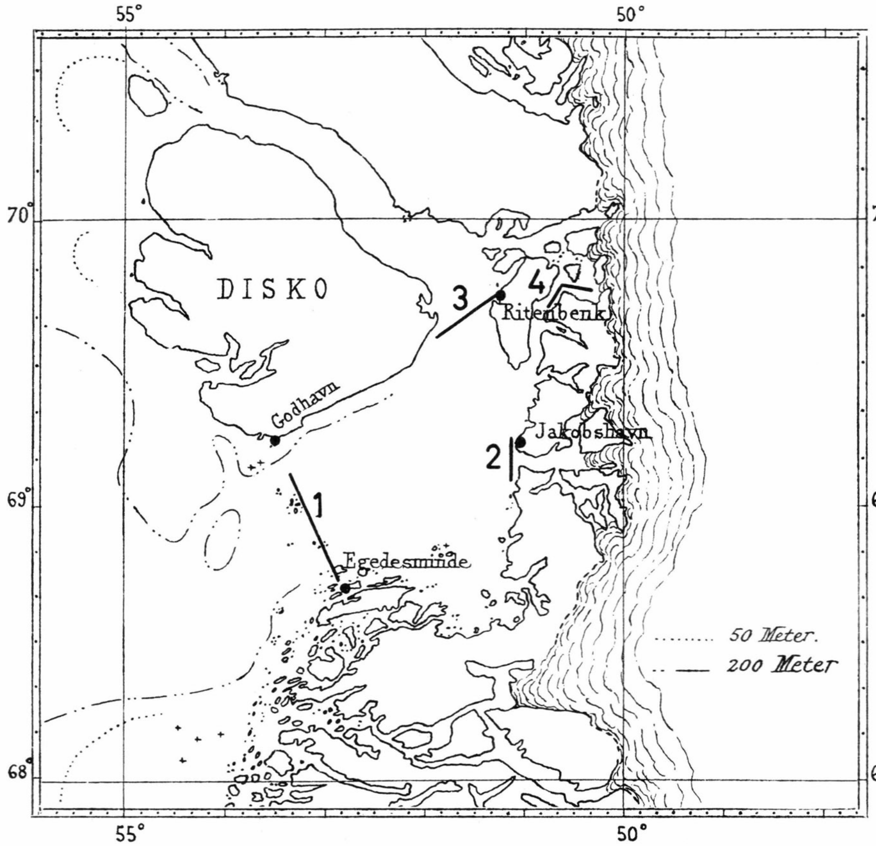

Fig. 15. Map of the Disko Bugt area, showing the various sections of echo-soundings mentioned in the text. 1: Godhavn-Egedesminde. 2: Off Jakobshavns Isfjord. 3: Nûk-Ritenbenk. 4: Atâ Sund.

BATHYMETRY

A great improvement of the marine-biological investigations carried out from the Arctic Station on Disko was made when in 1959 the University of Copenhagen bought the motorboat "Porsild", which is extremely well fitted, i. a., with an echo sounder. By means of this instrument many particulars concerning the topography of the bottom were gradually secured on trips in Disko Bugt, the most important of which will be dealt with below. The echograms themselves, which are furnished with indications of locality and depth, are used as illustrative material. The distances, however, are not stated, neither the speed nor the course having been registered with any particular degree of accuracy during the trips. By comparing the echograms with the map in fig. 15, in which the individual sections are inserted, an idea of the topography is obtained.

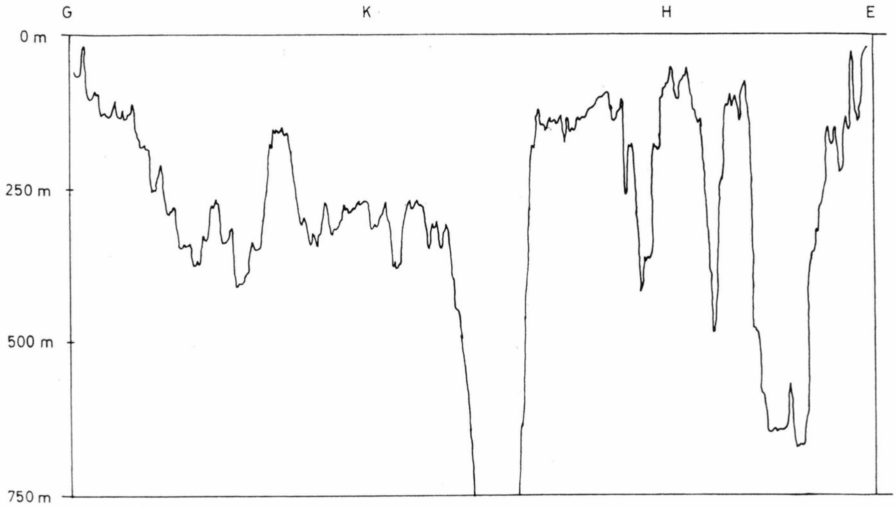

Fig. 16. Echogram from the section Godhavn-Egedesminde. G. Godhavn. K. Off Kronprinsens Ejland. H. Off Hunde Ejland. E. Egedesminde. The distance covered from G to E constitutes about 60 km. The depth of the channel between K and H is about 900 m.

In this connection the topography was of the greatest importance, while the records of locality and depths were not, of course, sufficiently accurate for navigational purposes.

The Godhavn-Egedesminde section

Along the stretch from Godhavn to Kronprinsens Ejland (a group of islands situated midway between Godhavn and Egedesminde), the bottom may most adequately be described as flooded skerries, similar to the skerries in the Egedesminde district. Midway between Kronprinsens Ejland and Egedesminde lies the group of islands called Hunde Ejland, which is surrounded on the north and south by deep channels, the walls of which descend steeply from depths of 50–100 m to more than 900 m. The bottom configuration in these channels corresponds to that of the remaining part of the flooded skerries, the bottom not being level as is otherwise the case at great depths. Fig. 16 shows a section of the echogram from a voyage across the channels. The bottom configuration of the channels is found on other echograms which, however, are not suitable for reproduction. As a level bottom probably most often originates from sedimentation, the broken ground at the bottom of the channels is presumably an indication of a strong current passing along at these depths.

Off Jakobshavns Isfjord

Stranded icebergs are found here in an area called the Jakobshavns Isfjeldsbanke. This bank is regarded by some to be built up of material carried there by the icebergs. Some time was spent sailing around the area among the icebergs in order to find the comparatively low depths indicated on the chart. This operation proved to be unsuccessful owing to the large number of icebergs. However, from comparisons of the echograms from this voyage with those from other trips, it appears that the Jakobshavns Isfjeldsbanke should be defined as a series of regular skerries or perhaps a moraine, north of which lies the so-called Hellefiskebanke with a fairly level bottom at a depth of about 200–250 m. It is true that the bottom material found in grab-samples from Jakobshavns Isfjeldsbanke is a very fine-grained light grey clay, probably transported across the skerries by the bergs. However, when one has seen thousands of perfectly clean icebergs and only a few sullied by unimportant quantities of morainic material, it is natural to assume that the rôle of the icebergs in transporting this kind of material has been generally overestimated.

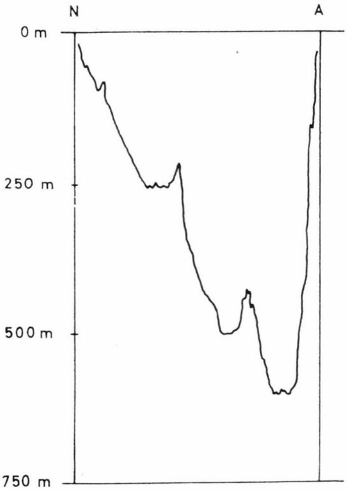

Fig. 17. Echogram from Nûk (N) on the eastern cape of Disko to Ritenbenk on Arveprinsens Ejland (A). The distance covered from N to A was about 20 km.

Nûk - Ritenbenk

On only one occasion there was a possibility of crossing this stretch of water. Fig. 17 shows the echogram made during the passage. It will be seen that the bottom descends from Nûk, the easternmost point of Disko, to a depth of about 450 m, then suddenly comes a channel about 600 m deep, from which Arveprinsens Ejland rises in the form of a very steep wall.

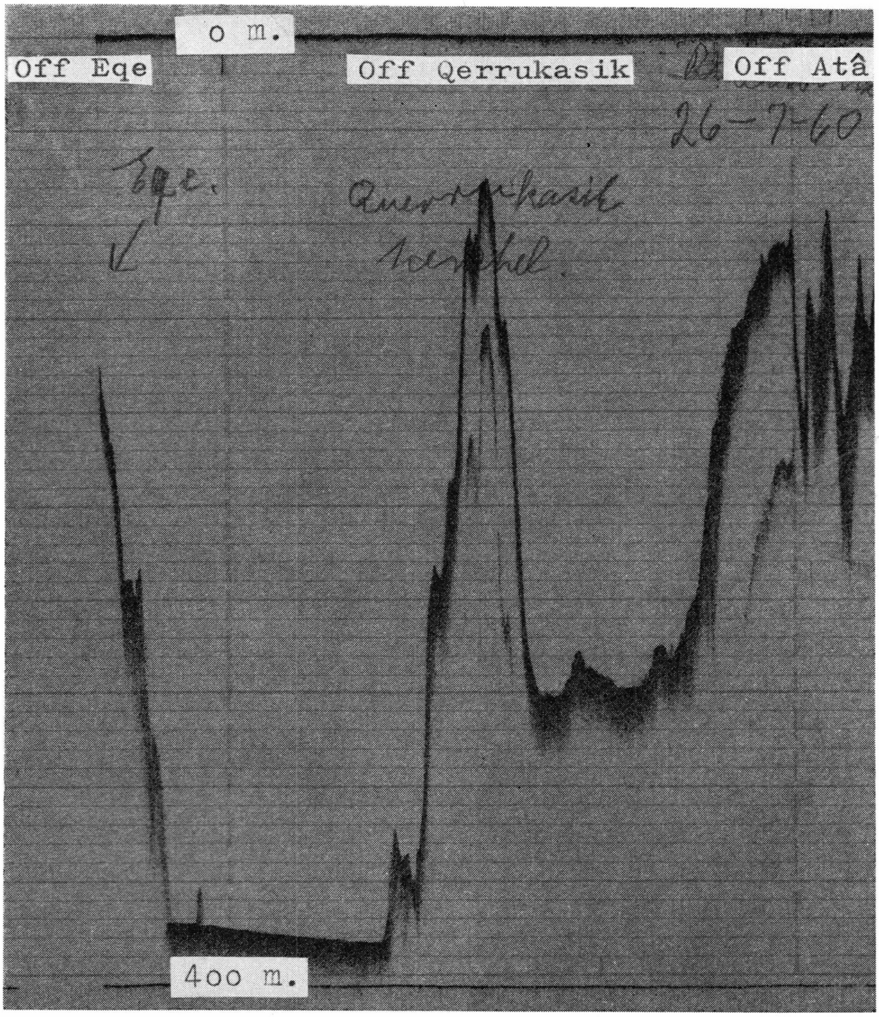

Fig. 18. Echogram from the innermost part of Atâ Sund. Owing to irregular courses it is impossible to give accurate distances covered, but the figure is prepared in such a way as to give an approximately correct idea of the bottom conditions during a straight course.

The rather evenly rising slope east of Nûk offers ideal conditions for sampling from different depths, which might very likely form the basis of the picture given by Ellis (1960, fig. 13), but it would not be typical of the Disko Bugt region.

Atâ Sund

In the outer three-fourths of Atâ Sund a bottom topography similar to that normally found in the Disko Bugt region is met with, viz. a

Fig. 19. Map of the interior of Atâ Sund, section from map sheet 69 V 2 Jakobshavn, of the Geodetic Institute, Copenhagen 1953.

greatly broken bottom, corresponding to the topography of the surrounding country. However, in the interior of the bay, from a line Qerrukasik – Igdluluarssuit toward the glaciers as far as to the small island Qeqertánguaq, an entirely level bottom, though with occasional tops (the highest rising about 20 m above the bottom) was found at a depth of 360–390 m.

Fig. 18 shows the echogram from the area, while fig. 19 is a detailed map of Atâ Sund giving the names used in the text. Curiously enough, the broken bottom occurred again at a position closest to the glacier Eqip sermia, e. g. in the section Qeqertánguaq-Qingârssuaq. The presence of the plane-bottom is probably best explained as being caused by an earlier more extensive distribution of the inland ice, and by the assumption that such large quantities of material were deposited in the area of the level bottom that the irregularities of the "originally broken bottom" were gradually filled until the bottom became smooth.

Delta Morphology

The deltas in the Disko Bugt region are, as a rule, shaped according to fig. 20 where a typical delta is outlined. The delta slopes evenly from H. W. M., where a coastal cliff is generally found, out to an edge situ-

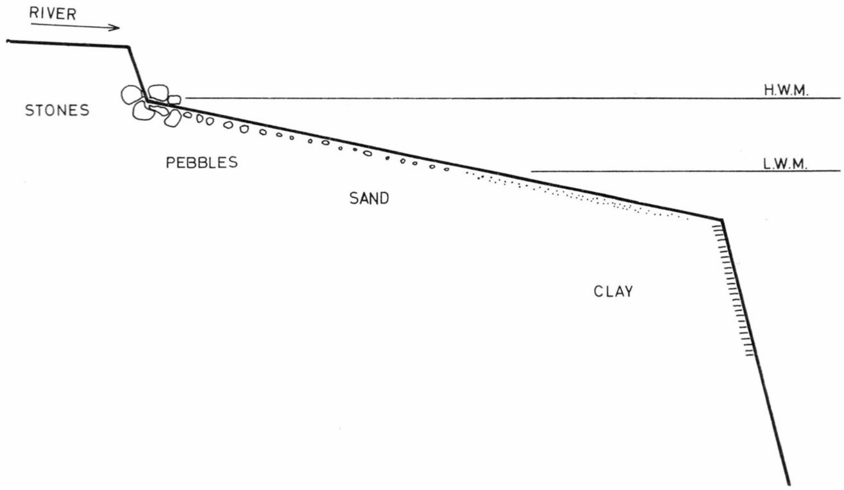

Fig. 20. Diagrammatic representation of a delta typical of the Disko Bugt region.

ated about 2 m below L. W. M., from here the bottom descends steeply to greater depths which usually range between 50 and 150 m depending on the locality. The bottom material near H. W. M. consists of large stones. Around L. W. M. the bottom is made up of sand, while clay is found on the steep slope. The most important feature of the delta to a marine biologist is the very steep delta front, which is apparently as steep as the material permits. This cliff was observed from a jolly-boat in the autumn, when the water off the river mouths is clear. Owing to a land freeze-up the rivers do not carry enough material to pollute the water off the deltas. Moreover, the cliff is distinctly indicated on the echogram, though the edge is not shown, it being impossible for the large boat to penetrate into such low water.

Discussion

It is not the intention to give here a detailed geological explanation of the intricate bathygraphy of Disko Bugt, which is, moreover, described by RIIS CARSTENSEN (1948). It is natural to assume, however, that the level bottom found in the interior of Atâ Sund is in some way associated with ice-margin deposits. HORSTED and SMIDT (1956) give descriptions and maps of a large number of prawn grounds in West Greenland fjords. The location of these prawn grounds are, apart from the occurrence of prawns, characterized by a level bottom where trawls may be used. The location also shows that the conditions in Atâ Sund are not unique, leading one to the supposition that level fjord bottoms indicate the presence of ice margin deposits. Judging from the maps published by HORSTED and SMIDT (1956, figs. 7, 12 and 23), the distribution of the level-bottom in the fjords possibly indicates two systems of ice margin deposits, as two rows of level-bottom are found viz., one very near the head, the other farther out in the fjords, some 30 to 50 km from the inner row. It might be supposed that these two rows are associated with two different main stationary lines of the ice margin, but a more detailed argumentation of this line of thought falls outside the scope of the present paper, and the reader is referred to WEIDICK (1963), where two ice margins from South Greenland are mentioned.

As a matter of course, not all the prawn grounds can be systematized in this way, e. g., the large prawn ground east of Godhavn is probably a basin of tectonic origin in connection with the fault lines by which the sea bottom is intersected. A thorough understanding of the bathymetric conditions will require a more detailed geological investigation, of course, and the above explanations are mentioned only because it is of some importance for a marine biologist to have a certain working hypothesis regarding the conditions of the sea bottom when selecting localities for investigation.

The information obtained from echo soundings by the method employed here is, of course, not sufficiently accurate for either the purposes of surveying or navigation, but they do give a picture of the bottom conditions which is not necessarily obtained merely by a study of the sea chart. On the whole, the bottom conditions of Disko Bugt may be summed up as follows:

The skerries at Egedesminde extend northwards to Godhavn and are also found in Disko Fjord, i. a., at Qivítut. They are marked on the chart by groups of islands and skerries and are on the echograms characterized by the very broken appearance they present. Just east of Godhavn these flooded skerries are replaced by a basin which extends along the south coast of Disko, presenting an abrupt northern wall towards Disko; while to the west, towards the skerries, the basin is bounded by a more gradual slope. The basin is connected with the channel west of Arveprinsens Ejland and with the channels between Kronprinsens Ejland and Egedesminde archipelago. The basin has a rather level bottom at depths of around 400 m.

"TAGSÂQ", TIDAL WAVES ORIGINATING FROM GLACIERS

During the investigation in 1960 of the marine fauna of the tidal zone and its relations to fresh water some excursions were made to fjord systems at the head of Disko Bugt and Umanak Fjord, both places with productive glaciers. On these excursions various observations were made in addition to those which constituted the object of the trips, and which are partially described in G. Høpner Petersen (1962, pp. 19–21).

On July 26th and 27th an excursion was made through Torssukátak to de Quervains Havn and Atâ Sund (see map in fig. 19). Although neither of the two glaciers, Kangilerngata sermia and Eqip sermia (both of which terminate at the head of Atâ Sund), appear to produce actual icebergs, the ice blocks which frequently broke off from the front of the glacier Eqip sermia caused such a great stir of water that there seemed little possibility of getting ashore from the jolly-boat. However, between the swells the water was quite calm and it was possible to get ashore.

The most interesting observation was made in a rockpool situated just above the high-water mark and about 800 m from the glacier proper (see fig. 21). In this pool, in which the greatest depth was about 20 cm, many large living animals were found which must have been washed onto the rocks shortly before our visit. The fishes and crustaceans were all alive. On seizing the animals with bare hands it was observed that a layer of warm water was present below a cold surface layer. The upper layer was around 2 cm thick and its temperature 14° C. It consisted of brackish water, the boundary between the two layers being distinctly visible. The temperature of the lower water layer was 20° C. Only *Mysis oculata* (O. Fabricius) was seen in the upper colder water layer, while all the other animals were found in the warmer layer below.

In the cold surface layer the following animals were collected:

Four specimens of *Mysis oculata* (O. Fabricius), 1.0, 1.1, 1.2, and 1.4 cm long.

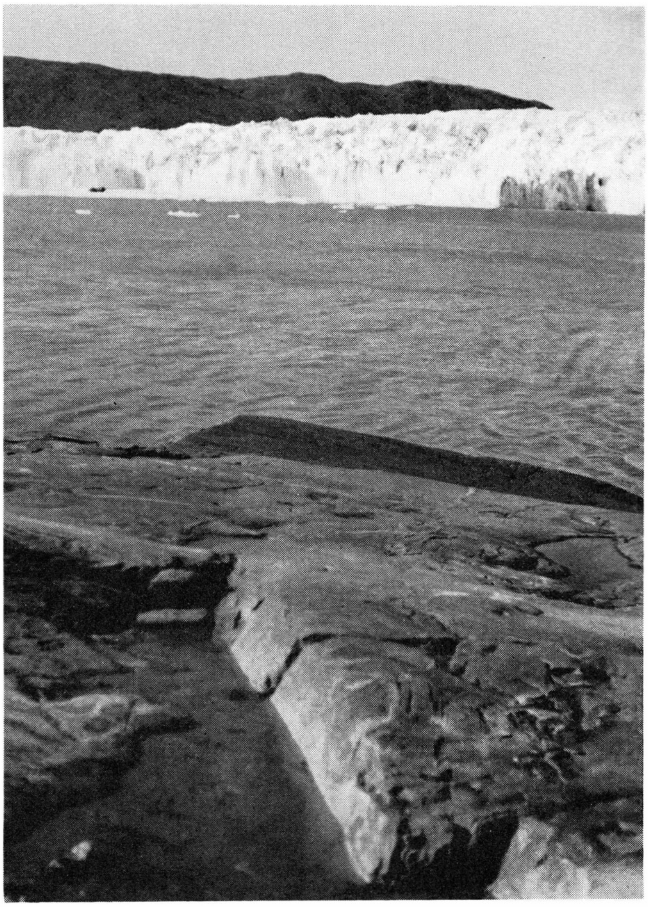

Fig. 21. Foreground, the rock-pool (mentioned in the text), situated immediately above the high-water mark. Background, the glacier Eqip sermia.

In the warm lower water layer the following animals were collected:

1 sp.	of *Pholis fasciatus* (Bloch)	24 cm long
1 –	– *Cottus scorpius* (Linné)	15 cm long
1 –	– *Balanus crenatus* (Bruguiere) .... in addition to several shells of this species.	4.1 cm high
1 –	– *Spirontocharis groenlandica* (J. C. Fabricius) ...	12 cm long
1 –	– *Acmæa testudinalis* (O. F. Müller)	1.5 cm long
2 spp.	of *Margarita helicina* (Phipps)	0.5 cm high
1 sp.	– *Macoma calcarea* (Chemnitz)	1.0 cm long
4 spp.	– *Mya truncata* (L.). Length: in cm: 6.2, 4.9, 1.1, 1.0	
8 –	– *Hiatella arctica* (L.). Length: 0.8–2.6 cm.	
4 –	– *Cistenides granulata* (L.) Length: 2–3 cm, largest empty tube 4.8 cm long.	

These animals must have been washed up by heavy tidal waves. It is possible that some of the deep digging bottom animals had been removed from the bottom by overturning ice floes.

It was not possible to make investigations of any length on the spot, and consequently, the peculiar hydrographic conditions of the pool could not be studied. As a provisional explanation it must be assumed that the cold surface layer was formed by melting ice fragments lying on the rocks or in the pool, (although ice fragments were not observed). It is fantastic that the lower water layer should nevertheless have had a temperature of 20°C though the insolation, on account of the very fine weather, was strong. A hydrographic measurement at the head of Atâ Sund showed the maximum temperature of the surface layer to be 3°C. Until more thorough investigations are possible, no further explanation can be attempted.

During excursions on foot along the shore in the area between the glacier and Qingmilivik several large accumulations of dead and living *Mya truncata* of varying sizes were observed in rock fissures found up to 1–2 m above the high-water mark; all the specimens had apparently been washed up by waves precipitated by the glacier.

On August 13th a trip was made to Qarajaqs Isfjord at the head of Umanak Fjord. The Qarajaq glacier discharges large icebergs into the fjord.

Salt deposits were observed on the Nûgârssuk peninsula at an altitude of 12–15 m above the high-water mark, and at altitudes of 4–5 m several marine bottom animals were found, e. g. *Hiatella arctica*, *Mya truncata* and various polychaete tubes. See also G. Høpner Petersen 1962, fig. 7. On account of the dangerously exposed position of the boat it was necessary to leave the location before any further collections or investigations could be made.

As will appear from the above, very peculiar conditions can be expected to occur on the shore near a productive glacier. It is conceivable that the very heavy forces released by the calving of glaciers may be factors of great ecological significance for marine animal life near the glaciers, in both shallow and deep water. Of interest to Quaternary geologists it may perhaps be of importance to know that this possibility of "faunal pollution" in shore sediments may be present in certain localities.

There is neither a Danish nor an English word to adequately describe the phenomena considered here. The present author would suggest the Greenlandic word "Tagsâq" to describe those water movements resulting from the calving of icebergs from glaciers and from the breaking up of the individual icebergs.

TABLES

Table 1 see page 15.

Table 2. *Hydrography on the Prawn Ground.*

Depth in m	15-8-1959 t°	14-9-1959 t°	31-10-1959 t°	31-5-1960 t°	4-7-1960 t°	19-9-1960 t°	19-9-1960 0/00
0	7.10	5.19	1.18	3.31	10.47	4.26	32.51
10	7.38	4.85	1.77	2.00	6.91	4.89	32.76
20	5.23	4.80	1.87	−0.03	2.39	5.00	32.90
30	3.20	4.67	1.85	−0.96	0.22	5.25	33.17
40	1.72	3.01	2.74	−1.01	0.13	4.55	33.49
50	1.65	2.87	2.69	−1.19	−0.08	3.53	33.58
75	0.00	2.66	2.09	−0.23	0.19	2.26	33.84
100	0.71	2.13	1.45	−0.17	0.23	1.07	33.84
150	1.17	1.20	1.32	0.49	0.78	1.92	33.93
200	– –	1.63	1.68	0.38	1.33	1.19	34.06
250	1.92	1.74	1.99	1.32	1.52	1.55	34.17
300	1.98	1.87	2.25	1.89	1.78	1.77	34.22
350	2.04	2.08	2.38	1.69	2.12	1.77	34.26
400	2.24	– –	– –	– –	1.94	1.84	34.28

Table 3. *Hydrography off Godhavn.*

Data from C-14-experiments 1959.

Depth in m	t°	0/00	Depth in m	t°	0/00	Depth in m	t°	0/00
	11-5-1959			22-5-1959			12-6-1959	
0	−1.0	33.49	0	1.5	32.98	0	3.9	32.47
14	−1.7	33.67	13	0.5	33.16	19	1.4	33.41
23	−1.7	33.67	22	0.0	33.25	36	0.4	33.58
	27-6-1959			14-7-1959[1])			15-7-1959[1])	
0	6.5	32.56	0	5.6	32.32	0	5.9	32.20
14	2.8	33.12	15	1.8	33.39	15	1.0	33.50
26	0.5	33.62	30	0.8	33.58	30	0.5	33.58
	6-8-1959			14-8-1959[1])			31-8-1959[1])[2])	
0	7.5	32.09	0	6.9	32.19	0	5.4	32.84
16	6.2	32.44	16	5.8	32.48	15	5.2	32.98
32	2.0	33.42	32	2.2	33.36	30	4.0	33.38
	1-9-1959			14-9-1959[1])			28-9-1959	
0	4.8	32.46	0	4.9	32.94	0	3.7	33.14
15	4.6	31.65	13	4.6	33.07	20	4.0	33.28
30	3.7	– –	28	2.9	33.65	40	3.4	33.58

[1]) not used in fig. 2.
[2]) station off Kronprinsens Ejland.

Table 4. *Hydrography off Godhavn.*
Data from C-14-experiments 1960.

Depth in m	5-4-1960		Depth in m	31-5-1960		Depth in m	23-6-1960	
	t°	0/00		t°	0/00		t°	0/00
0	-1.5	33.53	0	3.8	32.53	0	2.6	33.29
15	-1.2	33.61	17	1.5	33.29	15	1.1	33.47
30	-1.4	33.45	30	-0.1	33.53	30	0.1	33.62
	19-7-1960			26-8-1960			15-9-1960	
0	9.3	32.48	0	7.3	32.42	0	5.0	32.25
15	3.9	33.12	17	4.7	32.97	15	5.3	32.79
30	2.4	33.38	35	2.2	33.49	30	4.2	33.40

Table 5. *Observations of surface temperatures off Godhavn.*

Date:	22-9-1958	25-4-1959	5-5-1959	10-5-1959	17-6-1959	3-7-1959	7-11-1959	3-9-1960
t°:	2.2	-0.3	-1.0	-0.2	7.0	7.5	0.5	8.0

Table 6. *Hydrography off Sioraq.*

Depth in m.	18-9-1958		9-10-1958		26-11-1959
	t°	0/00[1])	t°	0/00[1])	t°
0	5.0	--	2.5	32.2	0.2
10	5.6	32.2	3.04	32.3	0.3
20	3.94	32.2	2.97	32.7	0.3
30	--	--	--	--	0.3
40	3.61	32.8	2.19	32.9	0.4
50	3.44	33.9	--	--	0,3
65	3.10	33.7	--	--	--
70	--	--	--	--	--
75	--	--	--	--	0.4
80	--	--	1,50	34.0	--
100	0.07	34.2	--	--	0.5
120	--	--	0.87	33.7	--
140	--	--	0.82	33.7	--
150	0.00	34.2	1.01	33.7	0.4
175	--	--			1.4

[1]) salinity measured with araeometer.

The measurements on 26-11-1959 were carried out with thermometers of a simple construction, and the results are not exact.

Table 7. *Hydrography off Qivitut.*

Depth in m.	10-10-1958		16-3-1960	9-7-1960	20-9-1960	
	t°	0/00[1]	t°	t°	t°	0/00
0	1.8	32.2	—	13.95	5.17	31.97
10	2.96	32.7	—	4.69	5.10	32.59
20	3.04	32.7	—	2.63	5.10	32.60
30	2.72	32.8	—	1.46	4.88	32.82
40	2.69	32.7	—	0.39	3.88	33.19
50	2.12	32.6	—	0.00	2.13	33.54
60	1.59	33.4	—	— —	— —	— —
70	1.32	33.6	—	— —	— —	— —
75	— —	— —	—	-0,02	0.53	33.69
80	1.19	33.7	—	— —	— —	— —
85			—	-0.05	— —	— —
90			—	-0.05	— —	— —
95			-1.60		— —	— —
100			—		0.39	33.74

[1]) Salinity measured with araeometer.

Table 8. *Hydrography off glaciers.*

Depth in m	Jakobshavn 16-6-1960 t°	Atâ Sund 27-7-1960 t°
0	1.09	2.65
10	0.28	0.73
20	0.21	0.69
30	0.25	0.61
40	0.27	0.55
50	0.62	0.58
75	0.81	0.50
100	0.88	0.36
150	0.72	0.53
200	1.72	0.85
250	— —	0.90
300		0.77
350		0.79

Table 9.

Gross primary production, mg C/m³/day, at the surface, at the 10 % depth and the 1 % depth of the green light and the production summed up for the water column given in mg C/m² of the surface/day. All the experiments were carried out off Godhavn with the exception of the experiment on 31-8-1959, which was made near Kronprinsens Ejland, 30 km south of Godhavn.

Date	mg C/m³/day			mg C/m²/day	
depths:	100%	10%	1%		
11-5-1959	18.6	12.7	6.2	313	
22-5-1959	18.8	21.6	12.3	448	318
”	9.6	7.3	7.8	187	
12-6-1959	5.7	7.0	11.0	193	145
”	7.2	0.9	0.8	96	
27-6-1959	1.0	25.0	3.4	352	605
”	2.0	62.2	5.4	857	
15-7-1959	4.0	4.8	1.6	113	
6-8-1959	1.9	7.1	2.5	149	
14-8-1959	3.2	13.5	1.6	255	
31-8-1959	4.4	4.4	2.1	107	108
”	4.9	3.9	2.7	109	
1-9-1959	1.8	2.4	0.4	50	
14-9-1959	2.6	2.6	7.0	97	
28-9-1959	3.0	1.9	0.1	69	
5-4-1960	0.8	0.7	0.3	18	21
”	0.4	1.1	0.3	23	
31-5-1960	10.3	14.8	3.6	284	
(dark fix.)	(5.2)	(1.7)	(0.9)	(71)	
23-6-1960	4.5	12.9	4.9	245	
(dark fix.)	(1.7)	(2.5)	(1.5)	(56)	
19-7-1960	2.1	14.3	2.7	240	
(dark fix.)	(1.4)	(1.3)	(0.5)	(39)	
26-8-1960	4.8	3.9	0.3	104	
(dark fix.)	(1.2)	(0.8)	(0.02)	(33)	
15-9-1960	88.8	2.3	0.5	702	
(dark fix.)	(23.4)	(1.0)	(0.02)	(175)	

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