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CONCERNING A CHANGE OF CLIMATE DURING RECENT DECADES IN THE ARCTIC AND SUBARCTIC REGIONS, FROM GREENLAND IN THE WEST TO EURASIA IN THE EAST, AND CONTEMPORARY BIOLOGICAL AND GEOPHYSICAL CHANGES

WITH 2 CHARTS

BY

AD. S. JENSEN

KØBENHAVN
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INTRODUCTORY REMARKS

During recent decades the hydrospheric and atmospheric changes in arctic and subarctic regions, from Greenland in the west to Eurasia in the east, have been so great, that the attention of various branches of science gradually has been directed to a closer study of the conditions; this applies not only to the hydrology and meteorology of these regions, but also to the biology and glaciology.

For my own part I have had opportunities of following certain phases of the phenomenon in the case of Greenland. To begin with, I imagined that the changes might be something special for that country; but as time went on, reports also came in from other northern areas, describing similar phenomena. Consequently, there could be no talk of special or peculiar changes in Greenland alone; these had a wider distribution. I have now decided to bring together the notes I have been making for a number of years and prepare them for publication, so that they combined with my own experiences may be of some use to others who are interested in these problems and are seeking information regarding them.

As Greenland was the original starting point of my studies, I may begin with this country before dealing with other areas.

Greenland.

In the years 1908 and 1909 I was commissioned by the Danish Home Office, then in charge of the administration of Greenland, to undertake fisheries investigations both practical and scientific in the waters of West Greenland, with the object of determining, whether the fisheries there could not be developed into an industry for the benefit of the native population, to balance the decrease of the seal fishing. During these investigations, which were carried out with the brig "Tjalfe" and which extended from Cape Farewell to Umanak (ca. 60°—71° N. L.) including the coast, fjords, offlying banks and deep sea, I obtained a good insight into the conditions. And ever since then I have kept in close touch with the fishery, inaugurated by these investigations, and have been able to see — partly from the reports forwarded yearly from the fishing stations to the Greenland Administration, partly through the practical-scientific investigations, which the Administration has directed for a number of years in Greenland — how deep-going changes have occurred in the fish fauna of Greenland in the course of the years.

Most remarkable have been changes in the occurrence of the common cod.

In the later years of last century and beginning of the present it had been well known from experience, that the Cod *(Gadus callarias)* only occurred at a few places in the

waters of South-west Greenland and only in scattered quantities. During my expedition we confirmed these experiences; the cod were only met with in number at Fiskenaesset and in the sounds near Cape Farewell. But since the year 1917 the cod has gradually appeared over much wider areas and in far greater numbers, first in the southern districts, Julianehaab and to some extent also Frederikshaab, since 1919 in the area of Godthaab Fjord, since 1922 in the Sukkertoppen district and from 1927 also in the district of Holsteinsborg. We thus see, that the distribution of the cod has gradually expanded in the direction from south to north.

This northerly trend in the occurrence of the cod was continued in the following years. In 1927 already the cod reached the southern part of the Egedesminde district, to Iginiarfik (ca. 68° 10′ N. L.), but only in small numbers. In 1928 towards the end of July shoals of cod appeared in the Egedesminde district, along the coast from Agto to Hunde Eiland in Disko Bay and Akunak (a little to the east of Egedesminde). In 1929 the cod was found everywhere in the Egedesminde district at the beginning of July; large numbers remained there during the whole summer and similarly in 1930. In 1931 the cod extended even further into Disko Bay, to Ikamiut, Akugdlet, Christianshaab and Claushavn in the Christianshaab district, and to the Ritenbenk district, even reached the Umanak district (N. of 70° N. L.).

In 1932 the following dates can be stated for the gradual advance of the cod into these northern districts: In the Egedesminde district it arrived at most places about the middle of July, at Christianshaab on July 22nd, Ritenbenk on August 24th and to the Umanak district not before the beginning of September. In the years 1933, 1934, 1935

and 1936 the cod has persisted in coming to these northern districts and in point of time earliest (middle of July) at the southernmost (Egedesminde district) and latest to the northernmost (Umanak district).

In more recent years a few isolated individuals have reached as far north as the south district of Upernavik, including the settlement of Upernavik at $72^{3}/_{4}°$ N. L., but not further north.

This increasing extension of the cod had the result, that the Greenland Administration were able to set up year by year an increasing number of stations along the west coast of Greenland, where the native population could sell and prepare the cod taken as split fish or salt fish for export; at present there are 53 of these stations, the most northerly being Umanak. Some idea of the increasing abundance of the cod can be obtained most easily from a study of the graphic representation in Fig. 1, which illustrates the great upward movement in the returns since the cod fishery began in 1911; in the years 1911—1916 the amount rose from 18 to 125 tons, 1917 to 1925 from 250 tons to 1000 tons, 1926—29 from 2000 tons to 5600 tons, culminating in 1930 with 8160 tons. In more recent years the quantity has oscillated up and down, yet always considerable, between 6125 and 8000 tons[1].

As striking evidence of the difference between the earlier conditions and the present I may give the following additional examples.

[1] The decrease in recent years need not be taken to indicate, that the cod period is beginning to ebb, it may be due to other causes than decreasing numbers of cod, e. g. sickness among the native population during the fishing season; both in 1935 and 1936, to some extent also in 1937, the people of Greenland in the cod-fishing districts were visited by a devastating form of influenza epidemic.

In 1908 during the period 11.—21. June we fished in the Godthaab Fjord with lines, hand-lines and nets, both in the inner and outer parts of the fjord, from Kornok to off the Kook Islands and took only 3 cod altogether; in 1930, when the fishery reached its culmination, the Green-

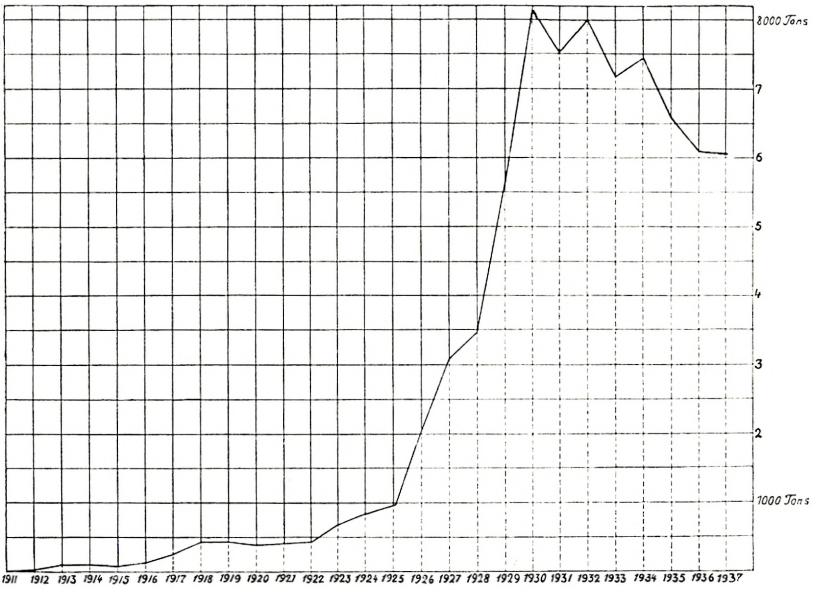


Fig. 1. Product of the cod fishery of the Greenlanders, from 1911 to 1937. Note the great increase after and including 1926 (cf. p. 34).

landers fished in this same fjord about 750,000 kg. of cod. And in Agdluitsok, also called Lichtenau Fjord (Julianehaab south district), in 1909 from 9. August to 2. September we had numerous long-lines out over the whole fjord, from the mouth right to the heads of the two arms of the fjord, without catching any cod, nor could the Greenlanders dwelling in the fjord, in spite of offers of rich rewards, obtain a single cod; in 1932, when the fishery in this fjord culminated, the Greenlanders caught 548,000 kg. of cod.

On the banks off the coast, where in poor years the cod are practically absent, the presence of this fish was noticed for the first time in 1921, some being taken in that year on Fyllas Bank off Godthaab. In the following years the numbers greatly increased on Fyllas Bank and the southern part of Lille Hellefiske Bank off Sukkertoppen and gave rise to a fishery by fishing boats from Europe, especially from the Faeroes, but also from Norway, England, France and Portugal. Good catches were made. Gradually the cod also spread more to the north and the Greenlanders, who were accustomed to carry on a halibut fishery with motor boats on the Store Hellefiske Bank off Holsteinsborg and never before had taken cod on their hooks, now caught the cod on their long lines, for the first time in 1924, later obtaining more cod than halibut. Thus, on the banks also there was a north-going movement of the cod.

With regard to East Greenland, in 1931 Johs. Schmidt published a paper[1] in which, among other things, he discussed the information he had been able to gather regarding the occurrence of the cod in the Angmagssalik District, the settlement managers Johan Petersen and A. Hedegaard being his informants. From this information and the written reports to the Greenland Administration by the latter we find, that the cod was unknown before 1912, both to the Danes and Eskimos at Angmagssalik. The cod was first observed there in 1912 and subsequently some few thin and wasted specimens were caught. It may be mentioned also, that a number of fishing experiments carried out under instructions of the Greenland Administration in 1916

[1] Johs. Schmidt: On the Occurrence of the Cod (*Gadus callarias* L.) at East Greenland. Conseil Internat. pour l'Explor. de la Mer, Rapports et Procès-Verbaux des Réunions, Vol. LXXII, V. Copenhague, 1931.

and 1917 did not find a single cod (though quantities of sharks, rays, sea-cats, Greenland halibut and Norway haddock). But about 1920 the cod began to appear in small shoals; from 1923 on it was fairly common and in the years towards 1930 it occurred almost everywhere in the district, especially in the interior of the many fjord branches, where the glaciers are not too close, and in the sounds at Cape Dan as well as round the islands there.

It must certainly, wrote HEDEGAARD to me from Angmagssalik on 11. August 1931, be regarded as a fact, that the cod has only come to this district in recent years. Since it seems but little probable, that no one among the population would have detected the fairly considerable quantities, shoals indeed, which are now reported as occurring at many places in shallow waters near the mouth of rivers, where the natives had always been accustomed to fish in kajaks, *inter alia*, for the char.

SCHMIDT concludes this part of his paper with the following summary (l. c. pp. 4—5): "In the last 5 years the cod has thus occurred in quantities in the Angmagssalik district, and it has been met with in smaller quantities since about 1912. This is the outstanding fact, but we can scarcely doubt also, that the phenomenon is of recent date in these parts of Greenland, at any rate as far as large quantities are concerned".

With this conclusion of SCHMIDT I quite agree.

As to the state of things in the Angmagssalik district since 1930, I am able to give the following information: In 1931—32 the Greenland Administration commissioned A. HEDEGAARD to carry out fishing experiments, with long-lines, hand-lines and jigger. It was then found, that in the autumn of 1931 the cod were present in some numbers at

most places in Tasiusak and in Angmagssalik Fjord, much to the domestic benefit of the natives, but nowhere in such large quantities that worth-while export could be made. From the Angmagssalik reports also for the years 1932 to 1937 it appears, that in all these years the cod fishery in the autumn has contributed to the food supplies of the population; and since seal blubber is often lacking, the oil from cod liver has been used instead in the lamps which are so important in the heating of the houses.

Thus, since 1930, there has also been cod in the Angmagssalik district and the conditions in this part of East Greenland have been in complete agreement with those in West Greenland.

It may be added, that the cod in the Angmagssalik waters occurs in summer and autumn as a rule, but according to uniform statements from the dwellers in the district the cod were present in large quantities at the settlement during the whole winter of 1930—31, as well as at most dwelling places in Angmagssalik Fjord, round Cape Dan and to some extent in Sermilik Fjord.

The question then arises: Where did these cod come from, which since 1917 have appeared in increasing quantities in the fjords and along the coasts of West Greenland and since 1926 have practically overrun the whole west coast from Cape Farewell to Holsteinsborg and even further north, right up to Disko Bay? Are these cod which have grown up at Greenland, or have they come from somewhere else?

That the cod may spawn in Greenland waters was proved by the "Dana" investigations in 1925, when the eggs and tiny fry were found near the surface over the offlying banks, from the Fiskenaes Bank off Godthaab south district to the south part of the Store Hellefiske Bank, and also in Godt-

haab Fjord[1]. Later, the fisheries biologist PAUL HANSEN[2] discovered, that the cod has a scattered spawning along the west coast in the Godthaab, Sukkertoppen and Holsteinsborg districts and good spawning grounds occur at a few places in the fjords of the same districts, thus at Kapisigdlit in Godthaab Fjord, at Atangmik in Angmagssivik Fjord and in Ikertok Fjord. One example may be cited. In the beginning of May 1936 PAUL HANSEN obtained 12,000 cod eggs in one haul of half an hour's duration with the 1m. ring trawl; this was in the mouth of the Angmagssivik Fjord (Sukkertoppen district).

The small, 1-year old cod are also frequently seen in shoals right in on the beaches, not only in the districts mentioned, but further north also (in 1935 many of the I-group were caught at Godhavn, Christianshaab and Rodebay) where they are borne in the pelagic stage by the north-going current, and also to the south (in 1937 there were unusually many of them in the districts of Julianehaab and Frederikshaab) though here not through the action of any south-going current but possibly new arrivals from Iceland. The "Dana" investigations in the waters between Iceland and Greenland have shown, that in certain years large quantities of tiny cod fry are carried from Iceland over towards East Greenland in the westgoing branch of the Irminger Current[3].

[1] AD. S. JENSEN: Investigations of the "Dana" in West-Greenland Waters, 1925. Rapports et Procès-Verbaux du Conseil Intern. pour l'Explor. de la Mer. Vol. XXXIX (pp. 85—91). Copenhague, 1926.

[2] PAUL M. HANSEN: Fiskeriundersøgelser ved Grønland. Beretninger og Kundgørelser vedrørende Styrelsen af Grønland. København, 1931—1938. — Idem: Oversigt over Fiskeriundersøgelserne ved Grønland. Det Grønlandske Selskabs Aarsskrift. København, 1937.

[3] Å. VEDEL TÅNING: Some Features in the Migration of Cod. Journal du Conseil Internat. pour l'Explor. de la Mer. Vol. XII, No. 1 (pp. 16—17). Copenhague, 1937.

That the Greenland cod has in recent years been in active reciprocal communication with the cod of Iceland, is now a well-known fact demonstrated by marking experiments. Cod taken at Iceland and liberated after marking have been recaught again in the waters of Greenland (food wanderings) and conversely (spawning migration[1]). There is every reason to believe, that these wanderings have been of very considerable dimensions, comprising many millions of cod, and that they have been of great service to the Greenland fishery[2].

If we glance back over the history of Greenland, we come upon the interesting fact, that in the previous century there were two periods of cod abundance at West Greenland, resembling greatly the present period. Dr. H. Rink, who rendered good service to the natural history of Greenland, reports for the years round 1820, that cod were present in enormous numbers in the Julianehaab district and reached as far north as Disko Bay. Thereafter cod were absent for a long series of years. The second period, according to Rink began in the forties; then also there was an abundance of cod from the southernmost parts of the west coast, shoals extending right up to Disko Bay; this gave rise from the Danish side to a commercial fishery, and English fishing vessels also took part, the results of the fishing being good for a time in the fjords, along the

[1] The principal spawning places of the cod are as is well known situated in the North Atlantic, an eastern at Norway (Lofotens), a central at the south and south-west of Iceland and a western at Newfoundland.

[2] Paul M. Hansen, Ad. S. Jensen & Å. Vedel Tåning: Cod Marking Experiments in the Waters of Greenland 1924—33. Medd. fra Kommiss. for Danmarks Fiskeri- og Havundersøgelser. Serie: Fiskeri. Bd. X, Nr. 1. København, 1935. — Å Vedel Tåning l. c. 1937.

coast and on the banks; but by 1850 the cod had become so scarce that the fishery ceased to pay. For the remainder of the nineteenth and beginning of the present century we have no certain information regarding good cod periods until we come to the present, as outlined here[1].

Other species of the cod family which have appeared at Greenland during this cod period, include the well-known European species Coalfish or Green Cod (*Gadus virens*). It had not been noticed in Greenland waters since far back in the preceding century[2], but in recent years—since 1924—it has not rarely been found among the cod shoals, in the districts of Julianehaab, Frederikshaab, Godthaab, Sukkertoppen and Holsteinsborg. The coalfish seems even to have spawned at Greenland; in addition to adult specimens of about 1 metre in length, small specimens 21—34 cm. long, belonging to the I-group, have been taken at Sukkertoppen and especially in the Frederikshaab and Julianehaab districts; at Arsuk (Frederikshaab south district) these 2-year old coalfish appeared near the shore in very great shoals in 1930 and 1932.

Then in October 1929 a 61 cm. long, thus adult, specimen of the Haddock (*Gadus aeglefinus*) was caught off Sydprøven (south district of Julianehaab). This species has never previously been known from West Greenland. And in August, September and October 1931 not a few were caught in the Sukkertoppen district (at Agpamiut and Kangamiut). In 1932 a specimen was caught at Nanor-

[1] Cf. Section: "History of the Greenland Cod Fisheries" in AD. S. JENSEN and PAUL M. HANSEN: Investigations on the Greenland Cod (*Gadus callarias*). Rapports et Procès-Verbaux du Conseil Internat. pour l'Explor. de la Mer, Vol. LXXII, 1. Copenhague, 1931.

[2] In the Copenhagen Zoological Museum are two small specimens sent down, preserved in salt, from Frederikshaab in the year 1831.

talik and one at Itivdlek in the district of Holsteinsborg. Further, in the first half of May 1937, a 77 cm. long specimen was taken in a cod-net at Holsteinsborg harbour. Lastly, 2 specimens, 58 and 75 cm. long, were taken on 29. 7. 1937 in an eel hand-net in shallow water (5—8 m.) in Sangmissok, a branch of the Kangerdluarsorujuk Fjord at Sardlok south of Julianehaab.

Previously unknown at West Greenland also was the Brosme (*Brosmius brosme*), one specimen of which was caught at the end of July 1936 in Ikertok Fjord in the district of Holsteinsborg and another on 11. 9. 1937 at Narssalik (Julianehaab district) taken on a long-line, at a depth of ca. 150 m.

The Ling (*Molva vulgaris*) was likewise unknown, but one specimen was caught in September 1928 just off the outermost islands at the outpost Narssalik in the district of Frederikshaab.

The Halibut (*Hippoglossus vulgaris*), which during the summer comes into the shallow water from the depths out in the Davis Strait, had its northern limit previously along the north edge of the Store Hellefiske Bank; in recent years it has penetrated further north and is now fished during summer and autumn in no small numbers off the Lakse Bugt at Disko (ca. 10 miles west of Godhavn), in Disko Fjord and right up to Nugssuak, Niakornat, Umanak, Ikerasak, Satut and Sermiarssuit in Umanak Bay. In recent years some few specimens have reached as far north as the Upernavik district (up to ca. $73^1/_2°$ N. L.)

The Herring (*Clupea harengus*) was formerly a rare fish in the southernmost parts of West Greenland, where in fact it only occurred in small shoals in the northern part of the Frederikshaab district (Sarfâ near Avigait). In 1909 I here

carried out fairly extensive investigations for the herring between 22. 6. and 1. 7. but the results were hardly worth mentioning, the whole catch consisting only of about a score of specimens. And in other places it was not taken at all in 1908—09. In recent years, however, the herring has appeared over more extensive areas and to some extent in greater quantities. It may be mentioned, in comparison, that on 24. July 1932 one haul with the coastal drag-seine at the just-mentioned place Sarfâ yielded over 2000 herring, on 30. June 1933 ca. 5000 herring and on 9.—10. 6. 1937 over 9000 herring in two hauls with the eel-seine. In the years 1928—1936 the herring were taken not only at several places in the Julianehaab district (specially numerous in the neighbourhood of Sardlok, where a single haul on 28. 7. 1937 yielded 4500 specimens) and noticed in Igaliko Fjord, Kangerdluarssuk and Tunugdliarfik Fjord and the Frederikshaab district (Ivigtut Fjord, Avigait and Sarfâ), but also in the Godthaab district (Fiskenaes Fjord and Godthaab Fjord). Even right up in the Sukkertoppen district, where herring had never been known before, it has occurred yearly since 1930 during the summer at Ikerasak, in southern Isortok and at the dwelling place Kangerdluarssuk, at the colony settlement and at Ikamiut as also in Evigheds Fjord; to show that the herring could occur in numbers it may be mentioned, that 3228 were taken in one haul with the eel-hand-net on 9. August 1937.

The northern movement of the herring does not stop however at Sukkertoppen district. Assistant Magnus Jensen in Upernavik informs me, that in the end of August 1934 two quite large herring were caught in a char net north of Prøven, at the head of Lakse Fjord ($72^1/_2°$ N. L.)

In 1932 (18. 8.) herring eggs were found in Tasiussak near Igdlokasik in the Julianehaab district; they were attached to algae in shallow water and the young were ready to hatch out. In the neighbourhood of Sardlok the herring were in full spawning on 8. August 1934; on hauling in the seine became full of large clumps of eggs and the water in the bay was tinged milky white with the floating sperms. It would appear, that the spawning of the herring extends throughout the whole of August and into September.

One peculiarity about the occurrence of the herring at Greenland is remarked upon by Paul Hansen, namely, that it comes right in on the beach in quite shallow water to lay its eggs, the highest temperature being found there[1].

Quite tiny, 1-year old herring of 5—6 cm. were taken on 4. 8. 1930 in the Tunugdliarfik Fjord (Julianehaab district). At Avigait in the Frederikshaab district large quantities of the 2- and 3-year old herring have several times been taken. We may conclude, that the herring in recent years both spawns at southern West Greenland and grows up there. At present the herring also spawns further north along the coast; among a quantity of herring taken in the beginning of August 1937 in the Sukkertoppen district (Kangerdluarssuk Fjord) there were many with ripe eggs and milt.

Paul Hansen undertook the counting of the vertebrae in samples of herring from Julianehaab, Frederikshaab and Sukkertoppen districts, to determine their race; it proved that the herring from these places had the same racial character, which agreed with that of the summer-spawning herring of Iceland[2]; he concludes, there probably is only

[1] Paul Hansen l. c. 1937, p. 50.

[2] The data for the vertebrae have been published by Dr. Tåning in his paper: The Herring Stocks of the Faeroes, Iceland and Greenland. Rapp. et Proc.-Verbaux des Réunions, Vol. C, II, p. 33. Copenhague, 1936.

this one herring race at Greenland[1]. A spring-spawning herring is not found there.

On the east coast of Greenland the herring was first observed in 1932. PAUL HANSEN[2] reports, that in that year herring shoals were seen in the neighbourhood of Cape Walløe and at Griffenfeldts Island and that a large herring had been forwarded to him taken in the Angmagssalik district.

On his expedition to East Greenland in 1933 Captain THOR IVERSEN met with herring at several places in the Denmark Strait in July, along the deep-sea ridge from Greenland to the north-west coast of Iceland. Dr. RUNNSTRÖM[3] has examined specimens of these herring and found, that in regard to number of vertebrae and age-composition they are very similar to the large herring of North Iceland, thus the same conclusion as arrived at by PAUL HANSEN in the case of the herring of West Greenland.

The Salmon (*Salmo salar*) was previously only known and only in small numbers at two places, namely, Kapisigdlit in Godthaab Fjord and Amerdlok Fjord near Holsteinsborg. But towards the end of the twenties the observation was made, that in the autumn (October and November) a migration of large salmon takes place in the Sukkertoppen district, though not very near the coast. Later, especially in 1935 and 1936, the salmon occurred in numbers from October and on into December at several places in

[1] Beretninger og Kundgørelser vedr. Grønlands Styrelse, 1934, Nr. 2, p. 241.

[2] Beretninger og Kundgørelser vedr. Grønlands Styrelse, 1933, Nr. 1, p. 42.

[3] SVEN RUNNSTRÖM: The Distribution of the Atlanto-Scandian Spring Herring. Cons. Int. p.l'Explor. de la Mer, Rapp. et Proc.-Verbaux des Réunions, Vol. 100, p. 27. Copenhague, 1936.

the Sukkertoppen district, at the dwelling place Ikerasak and in fjords round about as also at the outpost Napassok and the dwelling place Agpamiut. In the autumn of 1935 about 200 of this stately fish were caught at Ikerasak. In September 1936 a number of salmon were caught at Lichtenau, in 1935 in October several salmon were noticed at Fiskenæsset, and in September 1938 a salmon was caught in the Tasermiut Fjord.

The Piked Dogfish (*Squalus acanthias*), which earlier was a great rarity at Greenland, has been taken there in recent years (1931—36), one specimen in the Sukkertoppen district (1933), two in Holsteinsborg district (1931 and 1934) and in 1936 one at Claushavn in the Christianshaab district and one at Ikerasak in the Umanak Fjord—5 specimens in all. The sex of 4 specimens was determined and they were all females (one from Sukkertoppen contained 7 embryos and one from Holsteinsborg 4 embryos, all large). All these dogfish were taken in the summer and autumn months (June—September).

The previously known specimens, taken at long intervals, were from the Sukkertoppen and Holsteinsborg districts, like the three above-mentioned. Remarkable, therefore, is the 1936 occurrence of the two last-mentioned specimens right up in Disko Bay and Umanak Fjord.

The North Atlantic open-sea Deal-fish (*Trachypterus arcticus*), previously only noted once as having stranded at Greenland (Frederikshaab 1890), has in recent years (1923—34) been found stranded on the beach no fewer than 7 times in the southern part of West Greenland, 5 in the Julianehaab district and 2 in the Sukkertoppen district.

The Norway Haddock (*Sebastes marinus*). When I investigated the waters west of Greenland in the spring and

summer of the years 1908 and 1909, I was unable to find the fry of this fish and concluded, that the species does not spawn at West Greenland. The older pelagic young found there in the autumn I believed to have come with the marine currents from the Denmark Strait, where newly hatched fry occur in great quantities in the spring[1].

When I investigated the same waters later with the ss. "Dana" in 1925, the conditions had greatly changed. During the period 7. June to 9. July we obtained the small pelagic fry (7—17 mm.) of this species in the ring-net on no fewer than 19 stations in the Davis Strait, but nowhere north of the submarine ridge which extends right across the Strait from the level of Holsteinsborg to Cumberland in America[2]. Later investigations came to the same result.

Thus, in contrast to the earlier period, the species had now been spawning in the Davis Strait[3].

The Capelan (*Mallotus villosus*) or "Angmagssak", as it is called in Greenland, was the object of special attention during my investigations of 1908 and 1909, as it plays such an important part in the food supply of the native population. At that time it came into the fjords in enormous shoals to spawn along the beach, right from the southernmost part of the land up to Disko Bay and the middle of Vaigat. It did not normally enter the North-east Bay, but

[1] Ad. S. Jensen: *Sebastes marinus*. Vidensk. Meddel. fra Dansk naturhist. Foren., Bd. 74, p. 90. København. 1922.

[2] Ad. S. Jensen: Investigations of the "Dana" in West Greenland Waters, 1925. Conseil Internat. pour l'Exploration de la Mer, Rapp. et Procès-Verb. des Réunions, Vol. XXXIX, p. 97. Copenhague, 1926.

[3] To avoid any possible misunderstanding I wish to note expressly, that on the voyage over to Greenland in 1908 I caught a number of the small fry of the Norway Haddock in the northern parts of the Atlantic, south of the Denmark Strait, with the same apparatus as used in the Davis Strait with negative result.

might occur, though not every year, in small shoals in the southern part of the Upernavik district, whereas it was unknown in the northern part of the district. A change has now set in. The capelan now penetrates into the North-east Bay in quantities and regarding this M. P. Porsild, Director of the Danish Arctic Station in Greenland, has given me the following information. At Igdlorssuit on Ubekendte Eiland the first capelan appeared in 1927; at Ikerasak they first appeared in 1933, but only a few, in 1934 there were very large shoals, in 1935 there was abundance everywhere on the island and its surroundings; many were also taken at Uvkusigssat. In 1929 Porsild did not find any capelan at the peninsula Svartenhuk, whereas in 1935 he found many on both south and east coasts. In 1936 Paul Hansen took an enormous quantity of capelan in July in the neighbourhood of Sermiarssuit; they occurred along a considerable stretch of the coast. In near Ikerasak he caught a couple of thousand of capelan of the I-Group. In 1935 the capelan appeared for the first time and in quantities at Krauls Havn in the northern part of Upernavik district. Further, the manager Lund-Drosvad has informed me, that in that year the capelan reached right up to Igdlulik at 74° 25′ N. L., in such large quantities that they could be scooped up with a baler. In 1935 a specimen was even taken at Thule (76° 30′ N. L.) and another at the same place in 1936; both specimens—adult males—were forwarded to me by the settlement manager at Thule Hans Nielsen, who reported at the same time, that none of the natives knew this fish. In the Thule district these capelan were caught on 22. September and 13. August respectively, whereas the fish arrive in Umanak Fjord in the beginning of July and, further south, at the end of May and in June.

That the capelan may even spawn in Umanak Bay and North-east Bay is shown by the fact, that the Godthaab Expedition of 1928 captured the fry of the year with the 2 m. ring-net at the following places:

70°44′ N.,	52°16′ W.;	35 m.	wire;	4/9;	28	spec.	13—27 mm.
—	—	250 -	—	—	6	—	13—23 -
71°16′ N.,	54°17′ W.;	80 -	—	3/9;	18	—	11—20 -

In East Greenland the capelan is a well-known fish at Angmagssalik where it is eagerly sought after by the population; in fact, the district is called after this fish, the name Angmagssalik meaning that the "Angmagssak" occurs there. North of this place the capelan has not been observed; E. Bay, who knew this fish well at Angmagssalik, states expressly that it was not found at Hekla Havn or anywhere else in or north of Scoresby Sound during the East Greenland Expedition of 1891—92[1]. Things have changed in recent years. From his visit to Scoresby Sound the zoologist Alwin Pedersen brought home 6 specimens (4 ♂, 2 ♀), taken in that Sound on 19. August—3. September 1927.

Regarding the Fjord-Cod or the "Uvak" (*Gadus ogac*) at West Greenland almost the same may be said as for the capelan. At many places in South Greenland, where the fjord-cod formerly appeared in abundance it has now almost vanished. At the same time it has spread further north; in 1932 it was taken for the first time as far north as at the dwelling place Ituvsalik 74° N. L., according to written communication from the settlement manager Lembcke Otto in Upernavik. And at various places in North Greenland, where it was previously few in numbers, it is now found in great quantities, for example, in Umanak Bay.

[1] Meddel. om Grønland. 19. Hefte, p. 57. København, 1896.

I am also able to mention, that a marine mammal has extended its range from southern waters to West Greenland, namely, the Ca'ing Whale (*Globiceps melas*) so well known at the Faeroes. Since 1926 it has become a more frequent visitor in summer than in earlier years, when it had only been noted a few times on the south-west coast[1]. Thus, in the middle of September 1926 about 200 were killed at Sukkertoppen. On 24. October 1928 a shoal of 185 was surrounded and caught in the Godthaab Fjord, and almost at the same time a small shoal was seen at Sukkertoppen. At the end of September 1931 120 specimens were caught at Kangamiut, at Itivdlek 150 and at Sarfanguak 50. In August 1935 about 40 ca'ing whales were killed on the Kvane Fjord in the neighbourhood of Frederikshaab. On 5. October 1935 a shoal was chased into the Ulke Bay at Holsteinsborg and about 300 whales in all were killed. In 1935 some shoals of this whale even reached up to Disko Bay at the end of September and the inhabitants of the southern district of Christianshaab pursued them with success, for example, 35 were killed at Akugdlet. At the end of September 1936 several hundreds were seen in Hamborg Sound, some of them being shot at Agpamiut. It has happened only of recent years—something never known before—that the ca'ing whale has passed the winter at Greenland; in the winter of 1931—32, for example, when a shoal remained in the neighbourhood of the outpost Utorkarmiut in the Godthaab south district.

In the nature of the case, as the foregoing pages indicate, changes in the marine fauna of a land like Greenland

[1] Winge gives several examples of the relative scarcity of the ca'ing whale at West Greenland in the 19th century, with exception of 1853. Cf. Herluf Winge: Grønlands Pattedyr, pp. 504—505. Meddel. om Grønland, XXI. København, 1902.

can on the whole only become known for such animals as are of economic importance and the subject of practical-scientific investigations. There is no purely scientific zoological station in Greenland and we cannot expect to be able to show corresponding changes among the invertebrate animals. Yet we have one example of an invertebrate coming within recent years into the Greenland waters from more southerly seas, namely, the jelly-fish *Halopsis ocellata*. This large craspedote medusa, belonging to the Fam. *Mitrocomidae* among the *Leptomedusae*, was first noted as occuring at Greenland by Dr. KRAMP in 1932[1]. "In 1928 I found several specimens off the west coast of Greenland as far north as the Disko Bay, about 69° N." In 1926 and 1927 Mag. PAUL HANSEN obtained this medusa in the plankton nets in the Sukkertoppen district, especially in the southern parts round Napassok. He also observed it in the boat harbour at Ivigtut in 1927, in Karssorssat harbour in 1929; in 1937 he saw many specimens at Julianehaab, where it was then the most common jelly-fish, and it was very abundant in the harbour at Sydprøven.

Since 1926, therefore, this medusa has been found along the west coast, from Sydprøven (60°25′ N.) to Disko Bay (69° N.).

It is quite inconceivable, that this fair-sized medusa (it measures 60—70 mm. in diameter) could have been overlooked, if it had occurred at West Greenland formerly. It is not given as Greenlandic in any earlier paper where its distribution is noted and we may conclude, that it has only come to West Greenland in recent years. On the east coast

[1] P. L. KRAMP: A Revision of the Medusae belonging to the Family Mitrocomidae. — Vidensk. Meddel. Dansk Naturh. Foren. Bd. 92 (p. 355). København, 1932.

of North America *Halopsis ocellata* is distributed from Grand Manan to Cape Cod; further, it occurs in the waters of north-western Europe, from the south-west of Ireland to the south coast of Iceland and western Norway up to Tromsø[1]. In relation to West Greenland, therefore, this species has a southern distribution and its occurrence there in recent years may be viewed in the light of changed climatic conditions.

Another invertebrate has in recent years become common in South-west Greenland, namely, the Common Starfish (*Asterias rubens*). This echinoderm is well-known from the lusitanian and boreal waters of Europe—in the north it reaches to the White Sea and Iceland—and was first taken, in 1895, by the Ingolf Expedition in the innermost part of Ameragdla, an inner branch of the Ameralik Fjord south of Godthaab. In 1926 Paul Hansen saw it right up in Angmagssivik in the Sukkertoppen district, and in 1927 he found it in large numbers in shallow water in Kapisigdlit, an inner arm covered with Zostera of the Godthaab Fjord. In recent years Paul Hansen has also found, that *Asterias rubens* is now very common from Julianehaab up to Holsteinsborg. Dr. Th. Mortensen, who has determined his material, gives as new localities: Sydprøven, Julianehaab harbour, Ikertok Fjord and off Holsteinsborg harbour[2]. As several naturalists had made large collections in South-west Greenland at earlier periods, it is difficult to believe, that they could have overlooked this large and obvious starfish.

As *Asterias rubens* earlier, in contrast to the present, was a great rarity and only found in a single locality, I am

[1] P. L. Kramp: Craspedote Medusen. 3. Teil. Leptomedusen. Nordisches Plankton, Bd. XII, p. 567. Kiel u. Leipzig, 1933.

[2] Th. Mortensen: Echinoderms (The Godthaab Expedition 1928). Meddel. om Grønland, Bd. 79, Nr. 2, p. 23. København, 1932.

most inclined to believe, that it is not really an immigrant, but a "relict", persisting since the warm period which prevailed in Greenland in postglacial times[1]. The species has survived the subsequent deterioration of the climate by retiring to the innermost branch of a fjord; and now that the conditions have become more favourable, it begins again in quite recent years to spread along the south-west coast of Greenland with great rapidity, almost like the results of an explosion.

In preceding pages it has been noted for West Greenland, how some forms of animal life (*Gadus aeglefinus, Brosmius brosme, Molva vulgaris, Halopsis ocellata*), unknown earlier there, have appeared on this coast in recent times; and how other forms (*Gadus callarias, G. virens, Clupea harengus, Salmo salar, Squalus acanthias, Trachypterus arcticus, Globiceps melas, Asterias rubens*), which previously had been comparatively rare and local in occurrence, have extended their distribution along the coast and at the same time in some cases (*Gadus callarias, Clupea harengus*) have enormously increased in numbers; further, some (*Hippoglossus vulgaris, Mallotus villosus*), which were previously common but now distributed further north than before; and lastly, one species (*Sebastes marinus*) which has only spawned at West Greenland in recent years.

On the other hand, we have the experience at the same time, that arctic forms have kept away from, or shortened

[1] Ad. S. Jensen: On Greenland's fossil Mollusc-Fauna from the quaternary time. Meddel. om Grønland, Bd. 29, p. 301, 1905. København, 1909. — Ad. S. Jensen & Poul Harder: Postglacial Changes of Climate in Arctic Regions as revealed by Investigations on Marine Deposits. Postglaziale Klimaveränderungen, p. 399. Stockholm, 1910.

their stay in South-west Greenland. The White whale, also called Whitefish (*Delphinapterus leucas*), which lives far to the north in summer but migrates south in the autumn to pass the winter along the west coast about the Polar Circle, has not arrived at Sukkertoppen in recent years before the middle of November and has again turned northwards already in January, according to information sent me by Mr. N. L. Nielsen, who has directed the white-fish fishery for the government during the past 25 years. In earlier years it came down to Sukkertoppen in the middle of October and did not depart before April and early May; in recent times indeed the white whale has almost disappeared here in the south in winter, but has been observed to prolong its stay in the north. And the capelan (*Mallotus villosus*), which used to come each year in enormous numbers close to the coast to spawn, from Disko Bay right down to the south point of the land, has for some years failed to appear at several of the earlier fishing places in the waters of South Greenland. On the other hand, the capelan has extended its area and even spawned further north than before (cf. pp. 19—21). And the fjord-cod (*Gadus ogac*) has become more numerous in North Greenland, but rarer in south-western Greenland. It should be noted further, that the arctic flatfish, the Greenland halibut (*Reinhardtius hippoglossoides*) has occurred during recent years in much smaller quantities than previously in the fjords of the most south-western Greenland (cf. pp. 30—31).

Review of the hydrographic conditions with some examples of the change in fish-fauna with the temperature of the sea.

If we should ask now, what can be the cause of these deep-going changes in the animal life at Greenland, the

answer must be, that we should seek for it in changed physical conditions, such as marine currents, ice conditions, temperature and conditions affecting productivity and so on.

We may consider first of all the marine currents, which must be discussed rather more closely, for the sake of other areas to be mentioned later.

Along the east coast of Greenland there runs a cold, ice-filled current from north to south. It comes from the Polar Sea and is in fact the principal outlet of this Sea to the south. The Polar Sea receives water first and foremost from the Norwegian Sea (Gulf Stream), but the large rivers, which open into it from the neighbouring continents, also bring water which sooner or later must find its way to the south. Owing to the deflecting force of the earth's rotation the descending Polar Current is restricted mainly to the East Greenland shelf, whilst out over the deeper parts of the Greenland Sea—the sea west of Spitzbergen and Jan Mayen—there is warmer water of Atlantic origin at corresponding depths. At one place, however, in the neighbourhood of 70° N.L., the Polar Current gives off a branch towards the south-east over towards North and East Iceland, but the great mass of it continues southward as far as the south point of Greenland, where it changes direction and runs northwards along the west coast of Greenland; here it gradually loses its force.

This ice-bearing current provides the reason, why the whole of East Greenland, and to some extent also South-west Greenland, is so unfavourably situated by comparison with West Norway, though it lies in the same latitude. It is only on the west coast, that a branch of the Gulf Stream brings some mitigation.

Whilst the Polar Current comes from the north, from

the Polar Sea, the Gulf Stream (more correctly called the "North Atlantic Current") comes from the south-west, from the Atlantic, passing up through the Faeroe-Shetland Channel and on to West Norway (Norwegian Atlantic Current), where the mild climate is due to this warm current combined with prevailing south-westerly winds. To the north of Norway the Gulf Stream sends branches into the Polar Sea, eastwards to the Barents Sea (North Cape Current) and northwards to the west coast of Spitzbergen (Spitzbergen Atlantic Current), where it keeps the water free of pack-ice in summer[1].

An arm of this Spitzbergen Atlantic Current flows northward into the Polar Basin[2]. Another flows westward into the Greenland Sea, where it comes to lie under and outside the East Greenland Polar Current; this relatively warm and salt stream, which was first detected just here and its Atlantic origin rightly indicated by Ryder, can be followed down along the coast of East Greenland as far as the submarine ridge, which extends from Iceland to Greenland

[1] Knipowitsch has drawn a schematic chart of the finger-like prolongations of the Gulf Stream in the European Polar Sea; it shows in broad lines, where the branches come to the surface and where they continue below the cold covering layers. Cf. N. Knipowitsch: Ichthyologische Untersuchungen im Eismeer, II, chart p. 38 with explanation pp. 39—40. Mem. de l'Acad. Imp. des Sciences, Cl. Phys.-Math. Vol. XXII, No. 4. St. Pétersbourg. 1908.

[2] This warm Atlantic water under the cold Polar water has been found by the recently concluded Russian North Polar investigations right up under the North Pole itself and the investigators were able to follow it down to off North-east Greenland at 75° N. North of 86° N. L. the surface layer with negative temperatures was 250 m. thick, the layer below with positive temperatures was 500 m. thick with maximum of 0.77° C.; further south, between 86° and 85° the cold layer was 200 m. thick, the warm layer 750 m. and its temperature 0.88° to 1° C.; still further south the Atlantic layer became more extensive and the temperature rose to 1.72° C.. P. Shirshov & E. Fedorov: Scientific Work of the Drifting North Polar Station. Nature, Vol. 141, p. 629. London, 1938.

across the northern part of the Denmark Strait; where the current goes thereafter is a matter of doubt, but in any case it does not affect Greenland any more. It is replaced by a very warm and mighty branch of the Gulf Stream, which has separated from the main stream in the Atlantic and flows northward towards the south coast of Iceland and further on along the west coast. This branch is called the Irminger Current after its discoverer, the Danish Admiral IRMINGER.

West of Iceland the Irminger Current divides into two arms, detected by MARTIN KNUDSEN on the Ingolf Expedition 1895—96, an east-going arm along the north coast of Iceland and a western, which continues in a southerly direction accompanying the East Greenland Polar Current. Some of this west-going water of the Irminger Current probably returns from East Greenland towards the south-east and east, in the great circulatory system between Iceland and Greenland[1], but a powerful part goes on round Cape Farewell like the Polar Current and is then turned northward by the earth's rotation along the west coast of Greenland. The major part of the water which flows north along the west coast of Greenland, thus consists in part of the East Greenland Polar Current and in part of the Irminger Current; they are however already well mixed along the east coast. As the currents gradually spread up along the west coast, they decrease in strength and importance, tending little by little out towards the west in the Davis Strait. Yet the warm current can still be traced at some depth (ca. 500 m.) through Baffin Bay.

[1] Dr. Å. VEDEL TÅNING informs me, that current bottles liberated from the "Dana" in 1931—34 on the west side of the Denmark Strait, stranded in large numbers on the west and south-west coasts of Iceland.

In the southern waters of Greenland there is therefore a conflict going on between the cold water of the Polar Current and the warm from the Atlantic Current; and according as to which obtains the upper hand, it is influencing the fauna, as the various examples mentioned in the foregoing have shown.

As a concrete example of the extent to which the fish fauna may change according to the temperature of the sea, I may mention the following:

The temperature of the water in Agdluitsok (Lichtenau Fjord) south of Julianehaab was measured in 1909 by Dr. phil. J. N. Nielsen and in 1934 by Cand. mag. Paul Hansen; comparing the results we have the following:

Agdluitsok Fjord

22. 8. 1909		16. 8. 1934
m.	°C.	°C.
0	3.85	5.20
10	1.45	3.65
25	0.52	2.52
50	0.62	1.36
75	0.44	..
100	0.07	1.09
125	0.38	..
200	0.61	1.50
275	..	2.19
300	0.59	..
390	0.58	..

We see that the column of water was throughout warmer in 1934 than in 1909. The fish fauna had also quite a different appearance; during the "cold period" of the fjord it was an arctic species, the Greenland halibut (*Reinhardtius hippoglossoides*), which dominated; in August 1909 I had long-lines laid out in the fjord and 808 Greenland halibut were caught on 4860 hooks, thus one Greenland

halibut on every 6th hook; on the other hand, not a single cod (*Gadus callarias*) was taken, neither on these lines nor in attempts with hand lines. In the "warm period" of Agdluitsok, on the other hand, it was the boreal *Gadus callarias* which dominated; in 1934 533,679 kg. of this fish were caught, whereas the arctic *Reinhardtius hippoglossoides* had become very scarce, as was shown by the experimental fishings of the biologist PAUL HANSEN in 1929, 1930 and 1932 at the same places where I had set out the lines in 1909[1].

An example from middle Greenland may also be given, namely, Godthaab Fjord.

In the cod-poor years (cf. p. 7) the following temperatures were measured by Dr. phil. J. N. NIELSEN.

Mouth of Godthaab Fjord

20. 6. 1908

m.	°C
0	0.75
25	0.60
50	0.62
100	0.58
200	0.61
385	0.54

Off Sardlok inside Godthaab Fjord

15. 6. 1908

m.	°C
0	1.90
25	0.82
50	0.64
100	0.24
200	0.29
300	0.56
400	0.85

[1] It should be noted, however, that the decline of the Greenland halibut might be due, though hardly to any great extent, to the fact, that quantities are taken out in the Davis Strait. As I have shown, this halibut does not spawn in the fjords and bays of West Greenland where the Greenlanders fish for them, but out in the deeper parts of the Davis Strait, south of the submarine ridge which extends about 67° N. L. from Greenland to America (AD. S. JENSEN: The Greenland Halibut (*Reinhardtius hippoglossoides*), its Development and Migrations. Kgl. Danske Vidensk. Selsk. Skrifter; Naturv. og Math. Afd., 9. Række, VI, 4. København, 1935). In recent years the waters out here have been fished by large fleets after the halibut (*Hippo-*

In the rich cod period (cf. p. 7) Cand. mag. Paul M. Hansen obtained the following temperatures:

Mouth of Godthaab Fjord		Off Sardlok inside Godthaab Fjord			
11. 6. 1935		8. 6. 1936		26. 6. 1937	
m.	°C.	m.	°C.	m.	°C
0	4.35	0	3.10	0	3.30
10	3.62	10	2.81	10	2.76
25	2.65	25	2.22	25	2.69
50	2.00	50	2.00	50	2.47
100	1.31	100	1.68	100	2.36
200	1.14	200	1.26	200	2.04
300	1.10	300	1.11	300	1.98

We see here again, that the water is considerably warmer in the rich cod years than in the poor period.

These are examples from the most southerly and central parts of Greenland; another may be added from the most northern occurrence of the cod. As mentioned previously, in 1931 the cod reached up to the Umanak district at 71° N. L. and in such large numbers, that a beginning was made of an export industry, and this has repeated itself each year since then. In this connection it is of interest, therefore, that Dr. Fritz Loewe[1], who carried out hydrographical investigations in the Umanak Bay in 1932, measured there temperatures of about 2° C. in the core of the warmer water-masses (400 m.), which surpasses by 0.6° to 0.7° the values found by the "Godthaab" (1928), whilst the salinity was 0.1 ‰ higher, certainly a small amount but clearly significant owing to its frequent recur-

glossus vulgaris), and during this fishery many Greenland halibut are taken on the hooks. (cf. Årsberetning vedkommende Norges Fiskerier 1935, No. IV, p. 112 and 1936, Nr. V, p. 132. Bergen, 1937).

[1] Fritz Loewe: Hydrographische Untersuchungen in Fjorden Westgrönlands. Arctica, No. 3, 1935, p. 69. Leningrad.

rence. By comparison with the measurements of the "Tjalfe" also (1908), the corresponding temperatures measured by him were 0.7° higher. It is reasonable to conclude, says Dr. LOEWE, that a connection exists between the appearance of the cod up here in Umanak Bay and the rising temperature, which has risen above the lower temperature limit (minimum) for the more abundant occurrence of the cod[1], a view which I quite agree with.

With regard to the conditions on the banks lying off the Southwest Greenland coasts, we find there in summer along their outer side a conflict prevailing between the cold water of the Polar Current and the warm Atlantic undercurrent; taken in conjunction with the heating of the surface water in summer, this conflict determines whether the watermasses over the banks in any year will be warm or not. In a work not yet published but already in manuscript, which he has kindly placed at my disposal, Mag. sci. A. KIILERICH has discussed the conditions on the banks very fully[2]. In these investigations KIILERICH found, among other things, that the Polar Current makes its strongest onslaught in the neighbourhood of the banks (Fyllas Bank) about the first of July, in some years very strongly, in others so feebly that it has but little influence. And KIILERICH comes to the conclusion, that the warm years, which began in the second half of the decade 1920—30, have continued up to the present without noteworthy interruption.

[1] Dr. LOEWE refers here to the investigations of AD. S. JENSEN & PAUL M. HANSEN, and of BEAUGÉ.

[2] A preliminary paper has been published: A. KIILERICH: Svingninger i de hydrografiske Forhold ved de vestgrønlandske Fiskebanker. Nordiska (19. Skandinaviska) Naturforskarmötet i Helsingfors den 11.—16. Augusti 1936, p. 317. Helsingfors, 1936.

This is in good agreement with the statistics which show, that it was from and including the year 1926 that the Faeroese and foreigners, especially Norwegian, French, English and Portuguese, have made good catches of cod on the West Greenland banks. — It will also be seen from the graphic representation in fig. 1 (p. 7), that it was from and including the year 1926, that the really big increase occurred in the returns of the cod fishery of the Greenlanders.

Air temperature.

It is not only in the sea-water that temperatures have risen, the air has also become warmer. At Upernavik, Jakobshavn, Godthaab and Ivigtut the winters have become milder in recent years than formerly. As a concrete example of this, we may consider the conditions at Jakobshavn.

In a paper on the coastal climate of Greenland the Danish State Meteorologist Helge Petersen has drawn up a table showing the variations of temperature in Jakobshavn (69° 13′ N. L.) during the period 1876 to 1932[1]. On the basis of this table Dr. Scherhag of the Weather Bureau (Reichsamt für Wetterdienst), Berlin, has compiled the temperature variations for the true winter months (January to March and November to December) during the last 50 years, and arranged them in 10-year periods so as to determine the deviations from the normal during the period 1876—1925[2]. It will be seen from the table 1, that the amelioration in the winter conditions at Jakobshavn has made steady progress from 1883 to 1922 and has advanced by almost 2° C.. Then

[1] Helge Petersen: Klima der Küsten von Grönland. Handbuch der Klimatologie von W. Köppen und R. Geiger, Bd. II, Teil K, Tabelle 25, pp. 62—63. Berlin, 1935.

[2] R. Scherhag: Die Erwärmung der Arktis. Journal du Conseil, Vol. XII (p. 263). Copenhague, 1937.

the temperature rises further with a jump and the winters at Jakobshavn during the period 1923—1932 have been more than 5° C. warmer than those registered 50 years ago.

Table 1. Deviations of temperature from the mean for 1876—1925 at Jakobshavn in winter (from SCHERHAG)

	1883—1892	1893—1902	1903—1912	1913—1922	1923—1932
°C	— 1.1	— 0.7	— 0.2	0.6	4.0

The summers have also become warmer, though the rise in summer has been considerably less than in winter. As will

Table 2. Deviations of the annual temperature from the normal (from SCHERHAG)

Year	Jakobshavn	Angmagssalik	Jan Mayen	Bear Island	Spitzbergen
1923...	1.7	0.5	0.7	2.3	2.9
1924...	1.06	— 0.3	1.4	1.9	2.5
1925...	0.9	0.3	1.3	2.2	1.9
1926...	2.2	1.7	1.1	0.6	0.8
1927...	2.0	1.6	0.6	0.8	0.3
1928...	4.0	2.3	1.1	1.4	0.7
1929...	4.0	2.5	1.5	0.6	— 0.4
1930...	2.8	1.0	2.0	2.8	2.5
1931...	2.3	0.5	1.1	2.6	2.9
1932...	3.1	2.4	1.1	1.3	1.3
1933...			1.9	3.3	3.0
Mean .	2.5	1.3	1.3	1.8	1.7

be seen from the table 2 the annual average temperature for the period 1923—1932 was 2.5° C. above the normal.[1]

[1] R. SCHERHAG: Eine bemerkenswerte Klimaänderung über Nordeuropa. Annalen der Hydrographie und Meteorologie, 64. Jahrg., Heft III (p. 97 and Table 4). Berlin, 1936. — Cf. also F. LOEWE: A Period of warm winters in Western Greenland and the Temperature See-Saw between Western Greenland and Central Europe. Quart. Journ. Royal Meteorological Society, Vol. LXIII, No. 271. London, 1937.

The east coast of Greenland has also enjoyed a milder climate in recent years. At Angmagssalik the annual average temperature lay 1.3° C. above the normal in the period 1923—32 (cf. table 2); and all winters from 1921 to 1934 have been warmer than the mean for 1895 to 1925[1].

It may be added, that according to Loewe the mean temperature in Upernavik was—5.6° C. in 1926 to 1931 against—8.6° C. in the 50-year period; hence the difference amounted to the large dimension of 3° C.. During the period 1926 to 1931 Godthaab had on an average a positive deviation from the mean of 1.9° C.[2].

Ice conditions.

It was to be expected, that the favourable temperature conditions in the air and sea would affect the ice conditions at Greenland, and there is evidence that this has actually been the case.

In a paper on the ice conditions in the Davis Strait the Danish State Meteorologist, Commander Speerschneider has described his investigations[3] and come to the conclusion, that apart from certain irregularities the period 1820—1860 was poor in ice, the period 1860—1900 was rich in ice and then again a period poor in ice from 1900—1930—the year in which the work was concluded—or pro tem. a period of 30 years while the two former periods each lasted forty years. From 1910 to 1930 the "Storis" (pack-ice) did not reach so far westward as before 1910. In the years 1910—1929 the pack-ice in the Davis Strait did not

[1] Helge Petersen: l. c. Tab. 25. p. 64. — Loewe, l.c. p. 365.

[2] Fritz Loewe, l.c. 1935, pp. 69—70.

[3] C. H. I. Speerschneider: The state of the ice in Davis Strait 1820—1930. Publications from the Danish Meteorological Institute. Meddelelser Nr. 8, København, 1931.

reach beyond 55° W. L., whereas in the years 1890—1909 it not rarely reached 56°—57° W. L., once even to 58°—59° W. L. In the period 1880—1899 the pack-ice reached rather far northward, after 1910 not so far north in the Strait as before 1910. In half of the years before 1910 the ice in the Strait reached to Godthaab (64° 10′ N.) or further northward, while after 1910 Fiskenaesset (63° 05′ N.) seems to be the normal northward limit of the pack-ice.

Along the east coast of Greenland the favourable ice years culminated in 1931, 1932 and 1933, according to the Danish Nautical-Meteorological Annuals. In August 1932 the coast from Cape Farewell to Scoresby Sound was almost free of polar ice. During all the 34 years in which the Danish Meteorological Institute has gathered information concerning the ice, the conditions for navigation have hardly in any other year been so favourable as during the summer of 1933, when in August the sea was free of ice over the whole distance from Cape Farewell to Scoresby Sound; during this month a vessel worked her way up to Lat. 79°, a feat that had never before been accomplished here. In 1934 and especially in 1935 the ice conditions seem to have become worse, but in 1936 in August the Denmark Strait and Greenland Sea up to about 75° N. were free of ice except for some small patches of pack-ice, which constituted no hindrance to navigation.

Iceland.

As mentioned in the foregoing, the south and west coasts of Iceland are washed by the Atlantic Current, whereas the north and east coasts come under the influence of the Polar Current. The considerable difference in the temperature of the sea resulting from this has a great influence on the

fauna, which in general has an arctic character to the north and east of Iceland, boreal to the west and south.

In recent years, however, numerous cases have occurred which indicate, that considerable changes have taken place in the animal life, especially the fish. Our information comes from the Icelandic Government's fisheries consultant, Dr. phil. Bjarni Sæmundsson, who has called attention to these changes, and I attach special importance to his judgment, for he has been untiring in his study of the animal life at Iceland and in the waters round about for the past 40 years and knows the conditions there better than any one. From his paper I take the following[1].

Cod (*Gadus callarias*). The great fishery based on the spawning cod takes place usually along the warmer coasts of Iceland (south and south-west) in the early spring (March-May), whilst this period is mostly a dead period for the fishery on the opposite, colder north coasts. But in most years since 1924, large shoals of mature cod have been met with at North Iceland in the spawning time, resulting in large catches there; and many of these cod were ripe with fully developed eggs and milt.

Here I may add some information received from Dr. Vedel Tåning. During the investigations with the "Dana" in the years 1924—38 the eggs and tiny fry of the cod were constantly obtained both on the north and east coasts, though in fairly small quantities. The conditions have thus changed since the beginning of the century, when neither cod eggs nor fry were found on North or East Iceland, according to Schmidt's classic investigations[2].

[1] Bjarni Sæmundsson: Probable influence of changes in temperature on the marine fauna of Iceland. Rapp. et Procès-Verb. du Conseil Internat. pour l'Explor. de la Mer, Vol. LXXXVI, 1. Copenhague, 1934.

[2] Johs. Schmidt: Fiskeriundersøgelser ved Island og Færøerne i

As to the Capelan (*Mallotus villosus*) B. SÆMUNDSSON writes, that it formerly used to visit the south and south-west coasts, to spawn almost every year in March-May; on the more northern and eastern coasts it spawned later, in May-July. But in the period from 1928 to 1935 very few capelan have appeared on the south and south-west coasts; at the same time they have appeared in great numbers on the north coast earlier in the year than previously[1].

The Herring (*Clupea harengus*) spawns under usual conditions on the south and south-west coasts, like the cod; but in 1926 and 1929 BJARNI SÆMUNDSSON was able to prove that considerable spawning had occurred on the east and north-west coasts, where previously such a spawning had been unknown. Later (1935) Mag. sci. FRIÐRIKSSON has also found summer-spawning at various places on North Iceland[2].

This change noted in the occurrence of the three common fishes mentioned, has according to B. SÆMUNDSSON also been noticed in the case of some of the rarer species. The Witch (*Pleuronectes cynoglossus*) and the Turbot (*Rhombus maximus*), which earlier only occurred on the south and west coasts, have spread in this period respectively to the north and east coast. Further, some of the southern species, which can only be regarded as stragglers in Icelandic waters, have on the one hand appeared in greater numbers than before, and on the other have found their way to the previously unvisited north and east coasts; for example, the Basking

Sommeren 1903. Skrifter udg. af Kommissionen for Havundersøgelser, No. 1 (pp. 59, 72 & 77). København, 1904.

[1] BJARNI SÆMUNDSSON: Fiskirannsóknir. Andvari, 62. Ár, p. 35. Reykjavík, 1937.

[2] ÁRNI FRIÐRIKSSON; Síld hrygnir við Norðurland. Aegir, XXVIII Ár, p. 206. Reykjavík, 1935.

Shark (*Selache maxima*), Tunny (*Orcynus thynnus*), Mackerel (*Scomber scombrus*), Skipper (*Scombresox saurus*), Sunfish (*Orthagoriscus mola*) and the Sudid *Paralepis Krøyeri*.

In later papers Dr. B. Sæmundsson was able to add three species of southern fish, which were previously not known from Iceland, but which have wandered up there in recent years, namely, the Six-gilled Shark (*Notidanus griseus*), Swordfish (*Xiphias gladius*) and the Horse Mackerel (*Caranx trachurus*)[1]. The subject is further discussed in a still later paper[2], which gives new information regarding the frequent occurrence of fish of southern origin at Iceland.

Bjarni Sæmundsson also mentions three species of common North-European Gulls (*Larus ridibundus, L. fuscus* and *L. argentatus*), which were previously rare but have become fairly abundant in recent years. He also notes, that certain Invertebrates, the large Sea-urchin (*Echinus esculentus*) and the well-known Polychaete, the Sea-mouse (*Aphrodite aculeata*), earlier known only from the south and south-west coasts, have now spread to the north coast. In a later paper[3] he adds the Stone-crab (*Lithodes maja*); previously this was only known from the south and west coasts, but in later years it has spread to the north coast. Further, the giant Polychaete *Nereis virens*, unknown earlier at Iceland was found in 1934 at Reykjavik and in the Dyra Fjord[4].

[1] Cf. Skýrsla um hið Islenzka Náttúrufraeðisfélag Félagsárin 1933 & 1934, p. 41; 1935 & 1936, p. 33. Reykjavik, 1935 & 1937. Nátturufraeðigurinn, VII Árg. p. 120. Reykjavik, 1937.

[2] Bjarni Sæmundsson: Zoologiske Meddelelser fra Island, XVII. Vidensk. Meddel. Dansk Naturh. Foren., Bd. 102, pp. 183—212. 1938—39.

[3] Bjarni Sæmundsson: Icelandic Malacostraca in the Museum of Reykjavik. Societas Scientiarum Islandica, XX. Reykjavik, 1937.

[4] Skýrsla um hið Islenzka Náttúrufraeðisfélag Félagsárin 1935 & 1936, p. 34. Reykjavik, 1937.

The cause of these changes in the animal life at Iceland is found by BJARNI SÆMUNDSSON in the increased temperature of the sea and air during the last 10—15 years. In the first place the polar ice or drift ice which often comes down on the north-west, north and east coasts, has been practically absent, except in the year 1929 when a lot of ice was about in July and August. At the same time the winters have been extraordinarily mild, especially in February and March, when the mean temperature was some 4° to 7° C. above normal. The high winter temperatures at Iceland in these years and the great scarcity of ice in these northern waters were due first and foremost to the higher temperature in the sea round Iceland, combined with the prevailing southerly winds during this period. The surface temperature has risen 0.5°—4° C. above normal, being higher on the east and north-east coasts, lower on the south and west coasts. The increase must be considered due to a stronger Irminger Current than usual, for this high temperature was not restricted to the surface, but penetrated down into the deeper layers (200—400 m.). Roughly speaking the temperature of the sea on the north and east coasts was very nearly the same as in the corresponding depths off the south and south-west coasts, where the water is usually warmer than on the other coasts of Iceland.

In connection with BJARNI SÆMUNDSSON's observation of the occurrence of spawning herring on the east coast, Dr. Å. VEDEL TÅNING makes the following remark on the summer-spawning herring at Iceland. The fact that a considerable spawning has taken place at south-east Iceland during the present period (1924—34), whereas anything of the kind was not known in the earlier period (1903—09),

may also be taken as a sign of a change produced by the present warmer period in the waters of Iceland[1].

An interesting feature mentioned by Dr. Runnström (l. c. pp. 25—26) may also be referred to in this connection. He found that the number of vertebrae in the herring of Iceland at present (1931—33) is lower than that found by A. C. Johansen in his racial investigations on the herring for the years 1900—1924; this result is in full agreement with the well-known phenomenon, that higher temperatures lower the average numbers of vertebrae.

Dr. Tåning[2] writes further, that larvae of the Capelan (*Mallotus villosus*) in recent years have occurred on the whole in much smaller numbers at most of the Icelandic coasts than in the beginning of the century. This agrees with the diminution in quantities of this fish and changes in its biology at Iceland within recent years, as described by Bjarni Sæmundsson.

The hydrographer Helge Thomsen has recently published a paper on the variations of the surface temperature at Selvogsbanki, Iceland, during the years 1895—1936[3], and summarises the results of his investigations as follows: "It is very striking that the period 1895—1912 contains three abnormal years only, while cold and warm years otherwise change; the period 1913—1925 on the other hand seems cold, 6 years definitely cold even, while the period 1926—1936 has been warm, 6 of the years definitely warm". This

[1] Å. Vedel Tåning: Distribution of postlarval stages of herring in Icelandic Waters 1924—34. Cons. Intern. p. l'Explor. de la Mer, Rapp. et Procès-Verbaux des Réunions, Vol. XCIX, VI, p. 17. Copenhague, 1936.

[2] Ibid. 1936.

[3] Rapports et Procès-Verbaux des Réunions, Vol. CV, X, p. 51. Copenhague, 1937.

falls in line with BJARNI SÆMUNDSSON's statement, that the surface temperature of the sea has risen since 1926[1].

Jan Mayen.

Captain IVERSEN has published an interesting report on the investigations he was able to carry out near and on this island[2].

From his account of the fishing experiments it appears, that in 1930 and 1931 both Cod (*Gadus callarias*) and Herring (*Clupea harengus*) were found at Jan Mayen, in no small quantities, though insufficient for a commercial fishery; this was also found to be the case in 1929, likewise from the Norwegian side.

Captain IVERSEN notes at the same time, that in 1900 during the fisheries investigations at Jan Mayen from the "Michael Sars" under the direction of JOHAN HJORT, no food-fishes were found though all sorts of fishing apparatus were used.

These changes in the occurrence of cod and herring at Jan Mayen, according to IVERSEN, must be ascribed to the great variations in the temperature of the water in this area, which lies on the borders of the drift ice; the comparison below shows what a different picture is shown by the hydrographical data for the years 1900 and 1930:

Jan Mayen

	8. 8. 1900	8. 8. 1930
m.	°C.	°C.
0	4.20	7.07
10	..	6.87
20	2.21	..
25	..	6.73

[1] Cf. agreement with South-west Greenland (p. 34, above).

[2] THOR IVERSEN: Sydøstgrønland, Jan Mayen. Fiskeridirektoratets Skrifter, Serie Havundersøgelser, Vol. V, Nr. 1, pp. 101—171. Bergen, 1936.

m	8. 8. 1900 °C.	8. 8. 1930 °C.
50	0.89	4.44
70	0.80	..
75	..	1.57
100	0.41	1.37
145	..	0.40

Further information given by Capt. Iversen includes, that in the period 1924—33 there was extremely little ice round Jan Mayen, in contrast to 1882—83 (the year when the Austrian Expedition stayed the winter there) which belonged to a period with much ice, severe winter and cold summer, by comparison with the years 1924—33. In the summer months (June—September) the average temperature was 4.7° C. in 1924—33 against 2.6° C. in 1882—83; for the whole year the mean temperature was 0.1°C. in 1924—33 against —2.3° C. in 1882—83 (cf. pp. 146—147, Fig. 109 and Tab. III in Iversen).

In this same paper (p. 116) Captain Iversen brings forward evidence to show, that the cod at Jan Mayen comes from Iceland. Both in 1930 and 1931 he found hooks of Icelandic origin in cod taken at Jan Mayen; and from marking experiments made in 1930 he found, that cod migrate from Jan Mayen to Iceland. The migration to Jan Mayen is explained as a wandering after food, whilst the return to Iceland is for the purpose of spawning.

Barents Sea, Murman Coast, White Sea, Novaya Zemlya, Kara Sea.

For these areas we have reports from a number of Russian observers, that the temperature of the sea has risen during recent years as the result of a strong inflow of warm,

Atlantic water; in consequence, great changes have come about in the fauna, both plankton and benthos, a number of new forms of boreal character having penetrated into the areas from the warmer waters lying to the west (North Norway).

Among the investigators who have occupied themselves with the conditions discussed here, Professor KNIPOWITSCH should be first mentioned and we may attach special importance to his statements, for his investigations and studies over many years have given him an intimate knowledge of the hydrological and biological conditions in the European Arctic Ocean, both as they were at the beginning of the present century and also later.

KNIPOWITSCH has shown[1], that a warmer period has prevailed in the south-western part of the Barents Sea from the year 1921 than in the beginning of the century. At a series of hydrographic stations ($69^1/_2°$—$72^1/_2°$ N. L.) along the Kola meridian (33° 30′ E.) the temperature at depths of 0—200 m. was 1.06° to 3.48° C. higher at the end of May 1921 than at the same date in the years 1900 and 1901 ; the mean difference was 1. 9° C.. After the year 1921 there were certainly considerable fluctuations in the temperature of the sea water, but on the whole we must regard this period as relatively warm.

It was possible to show, that simultaneously with the rise in temperature of the sea considerable changes occurred in the composition and distribution of the fauna. Food-fishes of Atlantic origin were caught in large quantities farther to the east and north-east than in earlier years; thus, in the

[1] N. M. KNIPOWITSCH: Hydrologie und Fischerei. Explorations des Mers d'U. R. S. S., Fasc. II, 1930, p. 33. — Idem: Rasche Veränderungen hydrologischer und biologischer Verhältnisse im Barents-Meer. Bulletin de la Commission pour l'Etude du Quaternaire, 1931, No. 3, p. 19. Leningrad.

autumn of 1921 the Cod (*Gadus callarias*) was found in large numbers in the south-eastern part of the Barents Sea, considerably farther east than previously[1]. Further, in the plankton of the Kola Fjord Knipowitsch found the colony-forming Radiolarian *Collozoum* several times in May 1921 already, although this form had not previously been taken east of Finmark. In the following years a number of animal forms were found on the Murman Coast (*Gibbula tumida*[2], *Acera bullata*) which were previously unknown there, and

[1] During the "cold" period something happened, which was diametrically opposite to what occurred in the following "warm" period. In the years 1902 and 1903 arctic animals, such as the Greenland Seal (*Phoca groenlandica*), the Ringed Seal (*Phoca foetida*) and the White Whale (*Delphinapterus leucas*), whose mass-wanderings are otherwise restricted to purely arctic regions, came down in enormous schools to the northern coasts of Norway and farther also along the west coast. Previously the fixed ice-boundary had advanced farther west and south than any one could remember; even in May 1902 it extended as a continuous wall from Spitzbergen and Bear Island down towards the Murman Coast, not far from Varanger Fjord, presumably owing to the prevailing northerly and easterly winds over Spitzbergen and the Barents Sea. The temperature of the sea and air was noted as low. The special meteorological and hydrographical conditions in conjunction with the advance of the ice were taken to be the cause of the mass-incursion of arctic animals to Norway. At the same time the great cod fisheries in the northern districts of Norway were a failure and the fishermen believed, that the arrival of the seals had driven the cod from the coast. It might be questioned, however, whether it was not the changed natural conditions, which enabled the arctic seals and whales to thrive on the northern coasts of Norway, which had the opposite influence on the boreal cod and forced them to go elsewhere. — Detailed reports on these remarkable occurrences are given by Alf Wollebaek: Über die Biologie der Seehunde und die Seehundjagd im Europäischen Eismeer, hauptsächlich nach norwegischen Quellen, pp. 20—24. Rapports et Procès-Verbaux, Vol. VIII. Copenhague, 1907. And by R. Collett: Norges Pattedyr, pp. 391—392, 399—404 and 660—664. Kristiania, 1911—1912.

[2] Interestingly enough shells of this gastropod were found earlier on the Murman Coast in marine deposits of interglacial age, the molluscan fauna in which shows indications of having lived in a warm period of distinctly oceanic character.

for which the eastern boundary had been Finmark; other species, rare before, had now become common (e. g. *Cardium edule* and *Echinus esculentus*).

In a paper published at the same time DERJUGIN deals with the same theme[1] and comes to similar results. In addition to the animal forms mentioned by KNIPOWITSCH as penetrating to the Murman Coast from western areas, DERJUGIN notes *Galvina* and *Cuthona* among the nudibranchs and the Hermit Crab (*Eupagurus bernhardus*) among the crustaceans. Referring to investigations carried out by professional specialists, DERJUGIN also mentions a number of plankton organisms, belonging to both the zoo- and phytoplankton, which were of more western, Atlantic origin but since 1921 had been observed in the warm currents of the open sea.

TANASIJCUK[2] mentions from the Kola Fjord a number of boreal species, which had not previously been known from this fjord, but were found in the years 1921—28: *Primnoa resedaeformis, Poraniomorpha hispida, Amphipholis murmanica*[3], *Lamellidoris bilamellata, Acera bullata, Munida rugosa*[4], *Eupagurus bernhardus, Goniada maculata* and *Nereis virens*. All the forms mentioned—writes TANASIJCUK—are so conspicuous, that we can hardly believe they could have been

[1] K. M. DERJUGIN: Hydrologie und Biologie. Explorations des Mers d'U. R. S. S., Fasc. II, 1930, p. 44.

[2] N. TANASIJCUK: Über den Einfluss des Nordkapstromes auf die Fauna des Kola-Fjords. Travaux de la Station Biologique de Murman, Vol. III, No. 1, p. 24. Murmansk, 1929.

[3] TANASIJCUK considers this species, first described as new in 1929, as a boreal species for the reason that it belongs to the family *Amphiuridae*, which lives mainly in warmer waters.

[4] Is presumably the same as *Munida Sarsii;* cf. AUGUST BRINKMANN: Die nordischen Munidaarten und ihre Rhizocephalen, p. 9 et seq. Bergens Museums Skrifter Nr. 18. Bergen, 1936.

overlooked by previous observers, especially as they are all (with exception of *P. hispida*, *M. rugosa* and *N. virens*) found in fairly large numbers at several places. Further, some boreal species (*Echinus esculentus*, *Cardium edule*), previously rare, have now spread and become common. Tanasijcuk explains this phenomenon in the following manner: It is evident, that the fauna of the fjord is changing with an enrichment of the boreal elements and that this enrichment has been produced by the special character of the hydrological conditions in the Barents Sea during the years 1921—27. Comparing the hydrological graphs from the seasonal cruises along the Kola meridian (33° 30′ E. L.) in the years 1900—1906 with those of the years 1921—27, we find that the temperature of the waters of the Barents Sea was lower in the first than in the second period. This was the period of the so-called depression in the tension of the North Cape Current. The waters were characterized not only by the lower temperature, but also by the reduction in the quantity of warm water which flowed into the Barents Sea from the Atlantic Ocean. In addition, the largest branch of the North Cape Current (Murman Current) was more distant from the Murman coast than in the years 1921—27. These later years we may call years of increase in the tension of the North Cape Current. In two tables (pp. 10—11) Tanasijcuk gives a summary of the differences in the bottom temperatures in the periods 1900—1906 and 1921—26, partly at the stations in question and partly in the Murman Current itself; in the second period the mean temperature in the Murman Current was for May 0.98°, for August 1.05°, for the whole period 1.01° above the corresponding temperatures in the period 1900—1906.

In connection with these observations TANASIJCUK states, that SV. RUNNSTRÖM has proved experimentally, that the embryonic development only proceeds normally within very restricted temperature limits; change of temperature to 1—2° higher or lower than certain critical points brings about the anormal development of the fertilised eggs. TANASIJCUK is of the opinion then, that hydrological factors would approximate more to the optimum for boreal species in the years when the tension of the North Cape Current had increased. Hence we should have either a mass-occurence of such boreal species or a considerably larger number of their representatives or both together.

Regarding the Murman Coast it is reported by RASS[1], that his investigation of the fishes taken in the Kola Fjord in the summer of 1926 revealed but few specimens of the arctic species *Leptagonus decagonus* (2 spec.) and *Gymnacanthus tricuspis* (1 spec.), whilst they were taken earlier in larger quantities; and, on the other hand, they obtained such species as *Zeugopterus* (*Scophthalmus*) *norvegicus* and *Chirolophus galerita*, the usual distribution of which only extends from the British Isles to Northern Norway. These observations, writes RASS, may indicate an increase of the more seldom, boreal forms and a reduction of the arctic forms in the Kola Fjord, which probably is connected with the greater heating of the water-masses in the Kola Fjord in 1925—26.

According to BERG[2] (pp. 6—7), in the autumn of 1931

[1] THEODOR RASS: Übersicht der Fische, welche von der Biologischen Station an der Murman-Küste während des Sommers 1926 gesammelt wurden. Travaux de la Station Biologique de Murman, Vol. III, 7, p. 26. Murmansk, 1929. — Cf. also ibid., Vol. II, p. 76. Murmansk, 1926.

[2] LEO S. BERG: Rezente Klimaschwankungen und ihr Einfluss auf die geographische Verbreitung der Seefische. Zoogeographica, Bd. 3, Heft 1. Jena, 1935.

considerable numbers of the Haddock (*Gadus aeglefinus*) were found in the White Sea, where none previously had been noticed at any time. Further, in the same year large quantities of the Coalfish (*Gadus virens*) also appeared in the White Sea and this had not been known since the middle of last century.

Awerinzew has also stated, in 1935[1], that during the last 20 years some warm-water forms had appeared in the White Sea and Barents Sea, which had not been observed there earlier. In 1924—26 he himself had observed the Mackerel (*Scomber scombrus*) in catches from the White Sea, and on the Murman Coast shoals of mackerel had been encountered, yielding catches of 300—400 kg.; twenty to thirty years ago nothing was known of a mass-occurrence of herring in the gulfs of the Murman Coast, such as one may observe nowadays. Awerinzew adds, that according to his earlier experiences in the years 1904—06 one could not rely upon catching large quantities of the cod and other food-fishes with the otter-trawl in the waters round Bear Island, whereas it is common knowledge that the area between Spitzbergen and Bear Island is now teeming with these fishes (cf. similar reports from the Norwegian side, pp. 52—53).

Berg[2] quotes statements from various Russian investigators which dwell upon the fact, that cod have been found in recent years, partly in enormous quantities, on the coasts of Novaya Zemlya. The cod was undoubtedly observed earlier and right back into the last century on the coasts of Novaya Zemlya, but we may believe, that in recent years

[1] S. Awerinzew in Journ. du Conseil Internat. pour l'Exploration de la Mer, Vol. X, No. 1, pp. 73—74. Copenhague, 1935.

[2] l. c. pp. 2—3.

especially its numbers have increased. At the island of Kolgujew, which lies to the south of Novaya Zemlya, an expedition sent out by the Arctic Institute in 1932 found, according to JESSIPOW[1], a fairly large number of Herring (*Clupea harengus*), a fish previously unknown there. Later, AGAPOV and TOPORKOV have reported[2], that they discovered for the first time the following boreal species during their 1936 investigations along the west coast of Novaya Zemlya: Herring (*Clupea harengus*), Mackerel (*Scomber scombrus*) and Coalfish (*Gadus virens*). And they add: "The appearance of these fishes, aliens to the Arctic, is caused by the same factor as the appearance of the cod and some other fishes in the Kara Sea, namely the general warm spell of the past few years".

Here these authors refer to the information given by LEO S. BERG (l.c. p.2), that PROBATOV in the year 1932 caught ripe Herring (*Clupea harengus*) as well as Cod (*Gadus callarias*) in the Kara Bay; further, Salmon (*Salmo salar*) in the River Kara, which flows into the southern end of the Kara Sea;—all fishes that had not previously been recorded so far to the east.

Spitzbergen, Bear Island, Franz Joseph Land and Northern Land.

At Spitzbergen, the northern limit for the cod, the Norwegian sealers found by chance in 1873 that cod were present there in large quantities. Instigated by this discovery, 3 fishing vessels sailed up there in 1874 and brought

[1] Arctica, No. 2, 1934, p. 168. Leningrad.

[2] I. D. AGAPOV and G. N. TOPORKOV: Some data concerning the Fishes of Novaya Zemlya. Problems of the Arctic. 2. Leningrad, 1937, p. 108 (Arctic Institute of the USSR.).

home 37,500 cod. From then onwards there was a general participation from Norway in this fishery on the west coast of Spitzbergen, up to and including the year 1882, and the catches landed each year at Tromsø and Hammerfest alone amounted to between 147,000 and 595,000 cod. But in 1883 all the vessels returned without a catch; the total was 3 cod—the fishing period at Spitzbergen was at an end. A detailed account of this short-lasting cod fishery at Spitzbergen has been given by the fisheries adviser Iversen[1].

Later attempts at a Spitzbergen cod fishery in 1898 and 1901 from German and Norwegian sides gave a negative result. It was not until in 1923 and 1924 that the investigations were renewed, by the Norwegians, and the cod were again found, though but few. In 1925 both cod and haddock were plentiful, and good catches of both were made in trial fishings in 1926, 1930, 1931 and 1932[2]. In consequence of these investigations a commercial fishery was started on the banks west of Spitzbergen in 1934; in 1935 about 200 vessels with 1500 men took part and the catch amounted to about 4,500 tons, by far the most part consisting of cod and haddock, with a value of ca. 1.2 million kroner, according to Orvin. Several shoals of herring were also observed[3]. In 1936 again the cod fishing was carried on by Norwegian line-fishermen on the west coast of Spitzbergen from the beginning of July. The Faeroese took part for the first time in this fishery and returned with

[1] Thor Iversen: Torskefiske ved Spitsbergen i gamle Dage. Norsk Fiskeritidende, 42. Aargang. Bergen, 1923.

[2] Thor Iversen: Some Observations on Cod in Northern Waters. Report on Norwegian Fishery and Marine Investigations, Vol. IV, No. 8, pp. 6—8. Bergen, 1934. — Årsberetning vedk. Norges Fiskerier 1937, Nr. 4, pp. 87—89. Bergen, 1937.

[3] K. Anders Orvin, in Norsk Geografisk Tidsskrift, Bind V, p. 472. Oslo, 1935.

very good catches, taken on hand-lines. The trawlers also made a good fishery[1].

Bear Island, south from Spitzbergen, belongs like the latter group of islands to the boundary zone where warm Atlantic and cold Polar waters contend for the mastery. Like Spitzbergen Bear Island had also its cod period during last century, but for a long period of years (1898—1914) trial fishings only gave unfavourable results. In 1925 however good catches of cod were obtained and since then the cod fishery has been carried on each year at Bear Island, not only by Norwegian but also by foreign vessels[2].

According to IVERSEN the spawning of the cod in these northern waters seems to be so insignificant, that it cannot form the foundation for the great masses of every age-group, which now occur there. The cod stock frequenting Bear Island and Spitzbergen (and also the Barents Sea) is probably mainly connected with the spawning grounds off the coast of Norway (Lofoten). Marking experiments carried out by the Norwegians and Russians seem also to verify this[3].

So far as I am aware, no scientific publication has yet appeared dealing with the very extensive hydrographical material, which has been collected in recent years by the Norwegian investigations. From a paper not yet published Prof. AHLMANN states, however, that MOSBY's investigations

[1] Årsberetning vedk. Norges Fiskerier 1936, Nr. V, pp. 127—28. Bergen, 1937.

[2] THOR IVERSEN, l. c. 1934, pp. 4—5.

[3] JOHAN HJORT: Fluctuations in the year-classes of important food-fishes. Journal du Conseil Internat. pour l'Explor. de la Mer, Vol. I, No. 1, 1926 (p. 8).—E. MESSIATZEVA: Chief results of the Fishery Research in the Barents Sea in 1930 by GOIN. Rapports et Procès-Verbaux des Réunions, Vol. LXXXI (p. 147). Copenhague, 1932.—THOR IVERSEN l. c. 1934 (p. 11.)

during the Swedish-Norwegian Arctic Expedition in 1931 showed higher temperatures and salinities than any observation from former years. North of Spitzbergen he found that both temperature and salinity had obviously decreased from 1910 to 1912; from 1912 to 1922, in 1923 and in 1931 there was on the whole an increase[1].

We have the information that the temperature of the air has risen, from B. J. Birkeland, O. V. Johansson and R. Scherhag. From Scherhag, who has also cited the two first-mentioned authors, we take the following brief extracts[2].

At Spitzbergen and Bear Island the annual temperature during the period 1923—33 was on an average 1.7° C. and 1.8° C. above the normal (cf. Table 2, p. 35 in the present paper).

The accompanying table 3, from Scherhag, shows the mean temperatures at Spitzbergen in the winter months (January to March and November to December), arranged in 5-yearly groups for the period 1911—1935:

Table 3. Mean winter temperature at Spitzbergen (from Scherhag).

	1911—1915	1916—1920	1921—1925	1926—1930	1931—1935
°C.	— 17.6	— 17.6	— 12.5	— 13.9	— 8.6

We see that in the third 5-year period an amelioration has set in of 5° C.; and in the period 1931—1935 the mean temperature of the winter has been even 9° C. higher than in the period 1911—1920.

"Such a change of temperature as we have experienced

[1] The Geographical Review, Vol. XXVIII, p. 436. New York, 1938.

[2] R. Scherhag: Eine bemerkenswerte Klimaänderung über Nordeuropa. Annalen der Hydrographie und Maritimen Meteorologie, 64. Jahrg., p. 96. Berlin, 1936.—Idem, l.c. 1937, p. 263.

at Spitzbergen must be counted among the greatest known climatic changes!" comments SCHERHAG (l. c. 1937, p. 265).

At Franz Joseph Land the mean temperature of the air, as determined by the observations of the Meteorological Station established there in 1929, has been 3.6° C., for the three winter months even 7° C., higher than the temperatures measured on various earlier expeditions, according to Prof. WIESE[1].

With regard to the ice conditions, basing his conclusions on the publications of the Danish Meteorological Institute dealing with the ice conditions in the Arctic seas 1898—1934, Dr. SCHERHAG[2] has calculated, that in the period 1909—1918 the late-summer ice-limit in the waters east of Spitzbergen lay south of the average position in the period 1898—1922, whereas since then the ice-limit in 1919-1934 has not at all advanced beyond the average position in a southerly direction. How the position of the ice-limit is most closely connected with the air temperature at Spitzbergen, appears clearly from a comparison of both values for the separate years, as represented in SCHERHAG's publication of 1936[3].

The Russians also report, that it has been observed on their numerous expeditions in the Polar Sea, that the ice-edge has withdrawn far to the north in the course of the last 15 years. As a striking example of the retreat of the polar ice we are given the following facts. In 1935 the ice-breaker "Sadko" was able to cover the distance from Cape Jelanija (north point of Novaya Zemlya) to the northern end of Ssevernaya Zemlya (Northern Land) and farther north in open water up to 82° 41′,—the northernmost point ever reached by

[1] V. J. WIESE: Cause of the rise of temperature in the Arctic. Sovjetic Arctica, January 1937, p. 59 (in Russian).

[2] l. c. 1937, pp. 266—267.

[3] l. c. 1936, Tafel 12, Fig. 1.

a ship in the Arctic Ocean (i. e. under its own power; other ships reached farther north drifting with the ice). Alongside this voyage for comparison we have the information, that the powerful icebreaker "Jermak" sought in vain to reach Cape Jelanija in 1901[1]. Further, we are reminded, that in the summer 1932 the ship "Knipowitsch" was able for the first time in the whole history of Arctic voyaging to sail round Franz Joseph Land[2].

In connection with these interesting observations we may also remember, that the waters east of North-East Land were perfectly free of ice in the summer of 1930, and a Norwegian scientific expedition—with the sealing vessel "Bratvaag" and under the direction of the geologist Dr. Gunner Horn—was able to land on the dazzling white Giles Land (White Island, Kvitøya of the Norwegians), covered with ice and snow, on the way to Franz Joseph Land, and there found the remains of the ill-fated Andrée Expedition, previously searched for in vain, with the bodies of the three members of the Expedition who in October 1897, 33 years before, had succumbed to exhaustion and the cold[3]. The discovery of their last camp in the summer of 1930 was due on the one hand just to the unusual ice-conditions permitting a landing on Giles' White Island, which as a rule is surrounded by drift-ice and is considered to be one of the most inaccessible spots in the whole Svalbard Archipelago (l. c. p. 187), and on the other to the favourable climatic conditions, as the snow and ice melting seem to have been greater than for many years (l. c. p. 212).

[1] Wiese l. c. p. 60.

[2] N. N. Zubov: The Circumnavigation of Franz Josef Land. The Geographical Review, Vol. XXIII, p. 394. New York, 1933.

[3] Andrées Polarfærd 1897, af S. A. Andrée, Nils Strindberg og Knut Frænkel. Published by Svenska Sällskapet för Antropologi och Geografi. København, 1930.

On variations in the temperature of the Gulf Stream and its offshoots.

Various cases have been noted in the foregoing of temperature variations in widely separated areas of the ocean. And the view has been put forward, that the rise of temperature is due to the influence of the branch of the Atlantic Current (Gulf Stream), which penetrates into the respective areas.

What do we find now in the case of the Gulf Stream itself? Can we detect corresponding fluctuations in its temperature and volume, before it reaches the Arctic?

Dr. SCHERHAG[1] states in this connection, that according to a comparative study made by G. SLOCUM of an extensive material the surface temperature was on an average 0.42° C. warmer during the period 1926 to 1933 than in the period 1912 to 1918 in all the areas where the Gulf Stream takes its origin (Yucatan Channel, east, north-west, north and south-west parts of the Gulf of Mexico, Caribbean Sea and Florida Channel). A rise of the water temperature by 0.4° C. within a period of 15 years and over such an extended area must be regarded as very considerable, Dr. SCHERHAG explains.

We may also refer to Professor HELLAND-HANSEN, whose exact measurements of the physical conditions of the Gulf Stream, in a section from the entrance to the Sogne Fjord towards the north-west, has shown that abnormal quantities of warm Atlantic water may sometimes flow into the Norwegian Sea[2].

In May of the years 1901—1905 temperatures above 8° C. were only rarely found at a depth of 50 m. or more, and

[1] R. SCHERHAG l. c. 1937, p. 268.

[2] BJØRN HELLAND-HANSEN: The Sognefjord Section. James Johnstone Memorial Volume, p. 257. Liverpool, 1934.

none as high as 9°C.; the investigations of later years demonstrate the presence of considerable quantities of water of more than 8°C.; in May 1929, temperatures even higher than 9°C. were observed below 50 m. in many places. In May of the years 1901—1905, 1925 and 1927 the salinity was 35.30—35.35 ‰ at depths of 50 m. and deeper, but in 1929 the salinity was >35.4 the maximum being 35.45, that is to say, water of a more distinctive Atlantic character than usual in the month of May had entered the Norwegian Sea; in August the maximum salinity was 35.43 ‰ in 1928, 35.40 ‰ in 1932 against 35.37 ‰ in the earlier years. From these data Helland-Hansen draws the following conclusion: "It might seem probable that comparatively "strong" Atlantic water flowed into the Norwegian Sea in the summer of 1928 and continued so to flow for many months or even years afterwards". Further, Helland-Hansen found that quite considerable variations occurred in the volume of Atlantic water flowing northwards through the Norwegian Sea; according to his calculations the volume was about 20 per cent. greater in May 1929 than in 1927. At the same time the average temperature of this water was much higher in 1929 than in 1927 and, consequently, the quantity of heat, brought from the Atlantic to the Norwegian Sea much greater.

In a paper just published[1] Professor H. Ahlmann writes, that Helland-Hansen has informed him, that new investigations in the Sogne Fjord section were undertaken in May—June 1935 and 1936. The observations indicate, that at the entrance to the Norwegian Sea the temperature of the Atlantic Current was invariably higher in these years than it was at the beginning of the century.

[1] The Geographical Review, Vol. XXVIII, p. 436. New York, 1938.

Further, Professor SVERDRUP[1] has called attention to the fact, that great variations are found in the character of the Atlantic intermediate layer to the north of Spitzbergen[2]. He shows this by comparing the mean values of temperature and salinity at 200, 300 and 400 m., as observed by Norwegian expeditions at three neighbouring stations in August for the years 1912, 1922 and 1931:

	1912	1922	1931
Mean temperature 200—400 m. . .	1.7°	3.70°	3.18° C.
Mean salinity 200—400 m.	34.90‰	35.05‰	35.10‰

In this connection also a paper by Dr. JAKHELLN deserves close attention.

Dr. JAKHELLN, who has worked up the hydrographical material from the Norwegian expeditions to North-East Greenland (ca. 72° – 75° N. L.) in the summers of 1930, 1931 and 1932[3], has found that in the years 1931 and 1932 the Atlantic water off East Greenland was of an exceptional character. The salinity in the core of the Atlantic water was up to 35‰, and the temperature above 2.10° C.. The maximum temperatures previously found (the "Belgica" Expedition in 1905 and the "Danmark" Expedition of 1906—1908) are all under 1.5° C.. and the maximum salinity under 34.95‰—with two exceptions (34.96 and 34.97). And Dr. JAKHELLN places this phenomenon in connection with Professor HELLAND-HANSEN's evidence of the fluctuation in

[1] H. U. SVERDRUP: Oceanography. Scientific Results of the "Nautilus" Expedition, 1931, II, p. 37. Papers in physical Oceanography and Meteorology, Vol. II, No. 1, Cambridge, Mass., 1933.

[2] Cf. also the statement of Prof. AHLMANN quoted p. 53 in the present paper on the result of the Swedish-Norwegian investigations in 1931.

[3] ANTON JAKHELLN: Oceanographic Investigations in East Greenland Waters in the Summers of 1930—1932. Norges Svalbard- og Ishavs-Undersøgelser, Nr. 67. Oslo, 1936.

the Norwegian Atlantic Current. "These extraordinary conditions are obviously the same as those first pointed out by Helland-Hansen off the Norwegian coast in the autumn of 1928, and also found by H. Mosby in August 1931 in the Atlantic water in the Polar Sea north-east of Spitzbergen, as mentioned by Helland-Hansen. It looks as if this extraordinary water appeared for the first time in 1931 off East Greenland, and that the water had a still more extraordinary character in the late part of the summer of 1932".

It appears from this last sentence, however, that Dr. Jakhelln has overlooked the observations of Commander Riis-Carstensen, who found on the "Godthaab" Expedition to East Greenland in 1930 a maximum temperature in the warm current of 2.15° C. with an accompanying salinity of 34.98 ‰[1].

Reduction in thickness of the layer of Polar water in the Arctic Sea north of Eurasia.

To throw further light on the changes in the hydrographical condition of the Arctic Sea north of Eurasia, we may refer to a paper by Professor Schokalsky[2]. This is so much the more worthy of attention in that it gives us some impression of the intensive work carried out by Russian scientists in their investigation of these arctic waters. For example, during the last 12 years the Moscow Oceanographical Institute has sent out over a hundred expeditions, each lasting about two months, to study the physical and

[1] Bulletin Hydrographique pour l'Année 1930, p. 97. Copenhague, 1931.

[2] Jules Schokalsky: Recent Russian researches in the Arctic Sea and in the mountains of Central Asia. The Scottish Geographical Magazine, Vol. 52, No. 2. Edinburgh, 1936.

biological oceanography of the Barents Sea and even of the Greenland Sea.

With regard to the present subject, Professor SCHOKALSKY takes as starting point the memorable voyage of the "Fram" (1893—1896), when NANSEN discovered that the upper layer of the Arctic Ocean from 200 to 250 metres in thickness was less saline than the deeper water, and that it had a temperature of $-1.0°$ to $-1.9°$ C., while the deeper layer, from 600 to 700 metres thick, was of oceanic salinity (over 35.00‰) and had a temperature of 1.2° C..—Five years later (1901) S. O. MAKAZOV on the ice-breaker "Ermak" found, between Franz Joseph Land and Novaya Zemlya, that the zero temperature occurred at a depth of about 200 metres and that, below this, the temperature rose to 1.1° C.. This confirmed NANSEN's observations.

But, during the oceanographical investigations carried out by numerous scientific expeditions (Russian with the vessels "Elding", "Krassin", "Sedov", "Persée", "Lomohasov", "Knipowitsch" and "Sadko", and an American with the "Nautilus") during recent years (1927, 1928, 1929, 1931, 1932, 1934 and 1935) in the waters between Novaya Zemlya and Franz Joseph Land, north of Spitzbergen, between Franz Joseph Land and the Northern Land Archipelago, and a little north-west of Northern Land right up to 82° 42′ N., —in all these waters it has been found, that the cold and less saline surface layer was only ca. 70—125 metres thick, and that beneath this lay a thick saline layer of Atlantic water with a temperature of 0.6° to 2.6° C.. In 1929 the "Sedov" and the "Persée", at almost the same place as MAKAZOV chose for his observations in 1901, found the isotherm of zero at the depth of 125 metres instead of

200 metres. Again, in 1931, the "Persée" found this isotherm at 75 metres in the same vicinity.

"These records"—writes Prof. Schokalsky—"and others not cited here, together provide incontestable evidence of a progressive warming of the Arctic Ocean. The branch of the North Atlantic Current which enters it by way of the edge of the continental shelf round Spitzbergen has evidently been increasing in volume, and has introduced a body of warm water so great, that the surface layer of cold water, which was 200 metres thick in Nansen's time, has now been reduced to less than 100 metres in thickness".

Changes in glaciers and tundras.

The amelioration of the climate in arctic and subarctic regions which has occurred in recent years, has also affected the land-ice, both glaciers and ground-ice.

Among the scientists who have been engaged in late years with the study of glaciological conditions we must mention H. Ahlmann[1], Professor of Geography at the Stockholm Högskola, who has contributed greatly to our knowledge of the nature and life of glaciers. After studying a glacier in Jotunheim in Norway for 5 years Professor Ahlmann in 1931 investigated the glaciers on North-East Land, an island in the group embraced under the name of Svalbard. Wherever he went on this North-East Land he was able to detect, that the glaciers were much declining; to a

[1] Hans W: Son Ahlmann: Scientific Results of the Swedish-Norwegian Arctic Expedition in the Summer of 1931. VIII, Glaciology (especially pp. 180—186). Geografiska Annaler, Bd. XV. Stockholm, 1933.—Idem: Investigations into the Life of Glaciers. Arctica, Vol. III, p. 33. Leningrad, 1935.—Idem: The Fourteenth of July Glacier. Geografiska Annaler, Bd. 17. Stockholm, 1935.—Idem: Tre Nordiska Forskningsexpeditioner. Nordisk Tidsskrift, pp. 121—138. Stockholm, 1936.

great extent he would characterize them as dying. And he explains later, that the English Oxford Expedition, which continued his investigations in 1935—36, found the glaciers of North-East Land in even worse condition than he had calculated.

In 1934 Professor AHLMANN examined the 14th of July Glacier on West Spitzbergen. The study of the increase or decrease of glaciers was brought by him into new and rational lines; above all he sought by exact methods (digging, boring, measuring etc.) to throw light on the aspect of the glaciers' condition, which he calls their economy: how much snow is added yearly as income to the glacier and how much water it is deprived of yearly as expense. He found, that the income of the 14th of July glacier during the winter of 1933—34, in the form of snow converted into water, amounted to 78 million cubic metres, whilst the loss during the summer of 1934 by melting and evaporation was equal to 113 million cubic metres of water. The "negative balance in the budget" is so great, that it would bring about a catastrophe to the glacier if such conditions prevailed for a number of years. The result of this investigation was thus a confirmation of the conditions discovered during the previous expedition, namely, that the glaciers on Spitzbergen are now in a period of degeneration.

As a result of his own and other observers' investigations of the condition of the Spitzbergen glaciers Professor AHLMANN states, that for the last couple of decades so great a majority of the glaciers have been in a recessive stage, that we might speak of a present, general retrogression of glaciation in Spitzbergen.

In 1936 Professor AHLMANN undertook an expedition to Iceland to study the Vatnajøkull; from his combined

methods of investigation he found, that this like the Spitzbergen glaciers was in recession for the time being.

This great recession of the glaciers in recent years is due, according to Professor Ahlmann, to the transfer of heat from milder areas, probably from the warm areas of the sea.

On East Greenland also it has been found that the glaciers are receding. On the 7th Thule Expedition, under the leadership of Dr. Knud Rasmussen, glaciological investigations were carried out by the geologist Mag. sci. Keld Milthers. These investigations have not yet been published, but Milthers permits me to refer to his preliminary report to the second-in-command of the expedition, Captain C. C. A. Gabel-Jørgensen, who forwarded it to the Committee of the Expedition, of which I am a member and thus came to be acquainted with its contents.

Immediately on his arrival at Angmagssalik (13. 7. 1933) Milthers made a journey of reconnaissance round the district and selected 11 glaciers in all for his investigations. On this journey he found not a single glacier showing forward progress; a proposed comparison between ice-edges of glaciers advancing and those retreating could therefore not be made. Chief importance was then attached to the photogrammetric registration of the changes at the edge of the glaciers and for this purpose a phototheodolite was used.

The success was attained of registering 4 suitable glaciers in this way and a chart of the present state of 5 glaciers in all can be made, whilst photographs were taken of altogether 11 so-called "dead" glaciers.

All the glaciers bore evidence of a retrograde movement of the edge during a long series of years and it was typical of them all, that a vacated terminal moraine lay in front of the edge for a distance of about 100 m.

In connection with this we may also draw attention to the statement of Prof. AHLMANN: It is generally known that the Greenland glaciers are diminishing[1].

In the east also, on the island group of Franz Joseph Land in the Siberian Arctic Sea, the glaciers are in retreat. The results of the Russian investigations here have been summed up as follows: "The glaciation of the archipelago is at present in a regressive phase of its development, to which point the existence of glacier remnants and the border-remains, at some distance from the border of the glacier"[2].

Lastly, we have reports, that the boundary of the ground-ice in the northern districts of the Sovjet Union is moving northwards[3].

In 1837 A. SCHRENK visited the town of Mesen (65° 50′ N.) whilst on an expedition through the north-eastern part of European Russia and he reported, on the base of his own observations and statements of the inhabitants, that the ground remains permanently frozen from a depth of 2 m.

In 1933 a Commission appointed by the Russian Scientific Academy sent out a special expedition to investigate the limits of the ever-frozen soil. This expedition found, that ground-ice no longer persists at Mesen and its immediate neighbourhood; the ground-ice was first met with 40 km. north of the town, at the village of Sjomsha on the west coast of the Kanin Peninsula. Nor is there any ground-ice now found in the regions about Cape Bubnov and Cape Olchovsky.

[1] l. c. 1935, p. 206.

[2] T. N. SPIZHARSKY: On the Glaciation of Franz-Joseph Land. Transactions of the Arctic Institute, Vol. XLI, Geology, p. 37. Leningrad, 1936.

[3] cf. among others LEO S. BERG, l. c., pp. 11—12.

The belief is, that the shifting of the edge of the ground-ice northwards is connected with the increasing warmth of recent years in these northern regions.

Importance of air currents on the rise of temperature.

It may be recalled, that Dr. B. Sæmundsson sought for the cause of the high winter temperatures in Iceland and of the great scarcity of ice in these northern waters, in the higher temperature of the sea round Iceland in conjunction with the prevalent southerly winds during this period.

In his glacier studies Professor Ahlmann points out, that there is a connection between glacier recession and atmospheric activity. Regarding Vatnajøkull on Iceland Ahlmann writes, that the melting depends in high degree on the quantities of heat carried in over the glacier by the southerly winds. And regarding the Spitzbergen glaciers he writes, that their great recession in recent years is due to the transfer of heat from milder regions, probably from the warm areas of the sea, which means that an increased exchange or greater work of transport has taken place in the atmosphere. In this connection he brings into consideration Professor Helland-Hansen's investigations into the variations of the heat content of the Gulf Stream (cf. present paper pp. 57—58).

By including the atmospheric circulation in the discussion of these conditions Dr. B. Sæmundsson and Professor Ahlmann have touched upon one side of the problem, which has recently been brought strongly into the foreground by the meteorologists (Scherhag, Wiese). It is emphasized, that the cause of the rise in temperature and recession of the sea-ice in the Arctic must first and foremost be sought for in the great current movements of the air.

In 1929 already A. WAGNER showed, that the atmospheric circulation was greater in the decade 1911—1920 than in 1886—1895. Then SCHERHAG in his paper of 1936 indicated, that this increase had continued on a greater scale in 1921—1930[1]. The cause of this increased circulation is, that during this period a strengthening of the subtropical high-pressure belt has taken place simultaneously with a deepening of the barometric minima on the polar front. This would of necessity lead to the result, that large quantities of warm Atlantic air would stream in over Europe and over the Arctic regions and there effect a climatic change towards more oceanic conditions. It is just since 1920 that such a rise of air temperature has been detected in the Arctic regions, especially in the winter.

Although the cause of the rise of temperature in the higher latitudes must be found first and foremost in the atmospheric circulation, this may agree quite well with the fact, demonstrated by SLOCUM, that a rise of 0.4° C. has occurred in the areas of origin of the Gulf Stream itself, since indeed there is a close connection and interchange between these two influences.

WIESE[2] gives the same explanation as SCHERHAG of the rise in temperature both in the air and sea, maintaining that the common cause must be sought for in an increase of the atmospheric circulation; this leads on the one hand to warm masses of air being brought up into the higher latitudes, eastwards up to the New Siberian Islands at least, and on the other to an increase in the activity of

[1] R. SCHERHAG: Die Zunahme der atmosphärischen Zirkulation in den letzten 25 Jahren. Annalen der Hydrographie und maritimen Meteorologie, 64. Jahrg., pp. 397—407, Tafel 58—63. Berlin, 1936.

[2] V. J. Wiese l. c.—Idem: Ice prognoses. Problems of the Arctic, No. 1, p. 80. Leningrad, 1937.

the marine currents, with consequently a stronger inflow of Atlantic water into the Norwegian Sea and the Polar Sea. Whilst these warm masses of water are certainly able to react on the atmospheric circulation and increase this further by deepening the barometric minima round Iceland and South Greenland, they cannot have any direct influence on the air temperature in the high-arctic regions, since here they are at a depth of 100 to 200 m. below the greatly cooled upper layer. Further, he points out, that the more prevalent south-westerly winds of recent years have forced the southern limit of the ice in the Barents Sea farther north.

Concluding remarks.

It is of course not in every single case, where southern animal forms as described in the foregoing have been discovered in the arctic and subarctic regions during the warm period, that we can see clear evidence of a heat increase in the sea. Naturally enough, since in recent years increasing interest has been shown in northern seas; consequently, far more observations are made than in earlier years, so that possibly one or other animal form now discovered for the first time may wrongly be regarded as a new immigrant.

Nevertheless, in the abundance of the discoveries we are justified in seeing clear signs of the rise of temperature. Further, some of the southern species—especially those of importance economically or commercially—have occurred in northern waters in such quantities, that they could not have been overlooked earlier, if in similar numbers.

That the temperature conditions have great influence on the distribution of the heat-variable (poikilothermic) marine animals—and it is these especially that come into

consideration here—has become manifest from abundant observations in nature and examination of museum materials brought home by expeditions.

Experimentally also endeavours have been made, to throw light on the influence of the temperature. Of these only a few need be mentioned here, which seem to be of special interest for the present investigation.

Dr. RUNNSTRÖM has been able to determine experimentally in the case of a number of invertebrate animals, that the eggs only develop in a normal way within certain limits of temperature; for arctic-boreal species these lie between —1° and 11° C.; in boreal species between 4° and 16° C.; in Mediterranean-boreal species between 8° and 23° C.. On the other hand, the hatched-out larva or the young, as also adults, are much less sensitive to the temperature than the earliest developmental stages[1].—A rise of temperature in northern seas must consequently have the effect, that the lower limit for the normal embryonic development of boreal species can be reached or passed and, consequently, the existence of the species in all stages is assured. Should unfavourable temperature conditions again recur, and the eggs perish just after fertilisation, the continuance of the species in the region is threatened, unless the pelagic larvae, which are remarkable for their greater eurythermy, are conveyed by the currents from the original spawning places in neighbouring boreal regions[2].

[1] SVEN RUNNSTRÖM: Über die Thermophatie der Fortpflanzung und Entwicklung mariner Tiere in Beziehung zu ihrer geographischen Verbreitung. Bergens Museums Årbok 1927. Naturvidensk. Række, Nr. 1, 2. Bergen, 1928.—Idem: Weitere Studien über die Temperaturanpassung der Fortpflanzung und Entwicklung mariner Tiere. Ibid. 1929, Nr. 3, 10. Bergen, 1930.

[2] For animals highly able to move about, that is certain fishes, it might perhaps be added: or unless constant immigration of adult individuals on their food wanderings takes place.

Many investigators have studied the influence of the temperature on the development of the eggs of fishes and the results all show, that low temperatures delay the development. In the case of the Cod *(Gadus callarias)* Dannevig obtained the following results[1]:

Temp. in °C.....	—1°	3°	4°	5°	6°	8°	10°	12°	14°
Time of incubation in days (24 hours)	42	23	20½	17½	15½	12¾	10½	9⅔	8½

This is a striking example again of the great influence exercised by the temperature on the development of the eggs.

It is quite evident, that the relatively high temperatures in the water at places in West Greenland have in recent years been favourable to the development of the cod eggs, even as the cod have adapted their spawning to the special conditions and changed their time of spawning to the months of May and June, when the water has reached a temperature suitable for hatching (4° to 6° C. is considered the most favourable temperature). For the sake of comparison it may be mentioned, that the main spawning time on the south coast of Iceland falls in March and April for *Gadus callarias*; the surface temperature is then above 5°

[1] Harald Dannevig: The Influence of Temperature on the Development of the Eggs of Fishes. 13. Ann. Rep. of the Fishery Board for Scotland, being for the year 1894, Part III, p. 149., Edinburgh, 1895.— In some earlier experiments carried out by R. E. Earll the hatching lasted longer at negative temperatures, namely 50 days at —0.6° C. (U. S. Commission of Fish and Fisheries, Part VI, Rep. of the Commissioner for 1878, p. 724. Washington, 1880). A. C. Johansen and A. Krogh found in their experiments, that the lower limit for the full development of the cod eggs lies at about 0° to —1.0° C., but that cod eggs were not hatched at temperatures as high as 12° and 14° C. (Publ. de Circonstance, No. 68, p. 19. Copenhague, 1914).

already, a temperature only reached later in the year at West Greenland[1].

One circumstance would be of great interest to have determined experimentally, namely, whether a fish like the Cod (*Gadus callarias*), which, as we have frequently learnt, has undertaken extensive wanderings during the warm period into the arctic seas lying beyond their usual area of distribution — whether such a fish can really appreciate such small differences of temperature as come in question here.

Such an investigation has recently been undertaken by Dr. BULL at the Dove Marine Laboratory[2]. Through experiments planned on a large scale, with well-thought out technique as well as with great patience he has shown, that fishes are able to appreciate and react to even very small changes in temperature. Dr. BULL summarises the result of his investigations as follows: "By the use of a "conditioned response" technique it has been shown that teleostean fishes respond "purposively" to an increase in temperature of the water surrounding them of between 0.03° and 0.10° C.". The experiments concerned 19 species of marine fishes (Teleosts) including *Gadus callarias*.

At my request Dr. phil. Å VEDEL TÅNING and Mag. scient. A. KIILERICH have kindly read through my manuscript crit-

[1] On 15. June 1925 the following temperatures were measured in Kapisigdlit Fjord, one of the innermost ramifications of the extensive fjord complex known as the Godthaab Fjord: 0 m. . . 9.25° C.; 5 m. . . 7.34° C.; 10 m. . . 6.49° C.; 13 m. . . 5.77° C.; 20 m. . . 4.28° C.; 25 m. . . 2.06° C.. Half an hour's haul with a 2 m. stramine net at the surface yielded 2712 cod eggs in all stages of development. Cf. AD. S. JENSEN l. c. 1926, pp. 87 and 89.

[2] HERBERT O. BULL: Studies on Conditioned Responses in Fishes. Part VII. Temperature Perception in Teleosts. Journal of the Marine Biological Association of the United Kingdom, N. S., Vol. XXI, No. 1, p. 1. Plymouth, 1936.

ically and I am indebted to them for both corrections and supplementary notes; my heartiest thanks are due to them. To Dr. H. M. Kyle, who has undertaken the translation of this work into English, I wish also to express my best thanks.

Summary.

The region dealt with in this paper embraces the arctic and subarctic from Greenland in the west to Eurasia in the east.

From the review undertaken it appears, that many southern (boreal) species of animals, including mammals, birds, fish and invertebrates, have in recent years been able to extend their area of distribution farther north, whilst on the other hand the southern limit for certain northern (arctic) species has retreated northwards. Further, a number of southern (boreal) species, which formerly only occurred here and there and in small numbers, have now become common and occur in large quantities.

The cause of these zoogeographical changes is sought in the fact, which has occurred contemporaneously, that the temperature of the sea and air has risen in the regions in question. Along with this rise of temperature there has also been a retreat of the ice-boundary in arctic seas, whilst on land the glaciers and tundras have diminished and retreated.

Postscript.

Within quite recent years changes have again occurred in the hydrographical conditions at South-west Greenland. In 1937 and especially in 1938 unusually low temperatures have been found everywhere in the waters of the fjords and on the coasts, according to the investigations undertaken

by Cand. mag. PAUL HANSEN for the Greenland Administration.

We could hardly expect this cooling of the water-layers to produce already any outstanding change in the biological conditions after such a relatively short period. Nevertheless, we can note certain changes in the animal life, which may be briefly referred to here.

At South-west Greenland the arctic Fjord Cod (*Gadus ogac*) has again become common. The arctic Deep-sea Halibut (*Reinhardtius hippoglossoides*) again penetrates in increasing numbers to the earlier rich fishing grounds in the Julianehaab district; in the Lichtenau Fjord the stock was on the increase in 1937 and in the summer of 1938 the number of standard-size fish had shown such an increase, that a commercial fishery could be restarted.

From the Sukkertoppen district it is reported, that quantities of Cod (*Gadus callarias*) and other species, such as the Lumpsucker (*Cyclopterus lumpus*), Sea-cat (*Anarrhichas*) and Norway Haddock (*Sebastes marinus*), came up dead to the surface in the winter and spring of 1937—38; it is quite fifty years since such a phenomenon has been known. And from Amerdlok Fjord in the Holsteinsborg district it is stated, that in 1938 from the end of May and through the whole of June a large number of dead or dying large cod came up in the trawl, when fishing for the deep-water prawns, which has never happened before in the years this fishery has been carried on. In both cases it has evidently been the great cold in the water, which has killed or deadened the fish. In Amerdlok Fjord the temperature was negative in the last half of June 1938 at depths of 150—500 m., lying between $-0.26°$ and $-0.93°$ C.; for comparison it may be mentioned, that at the same period in 1936 at corres-

ponding depths the temperatures were about 2° C. higher.

Again it is reported from various fishing stations, that the weight of liver taken from the cod caught in 1938 was less than in the previous year (ca. 40 % less in similar quantities of fish) and the oil contents of the liver were small. This points to a badly nourished condition, presumably owing to the cold in the water affecting the fish, making them less desirous of food. Experiments, recently carried out by R. A. Mc. Kenzie, have shown, that in the matter of feeding the water temperature is a greater controlling factor than anything else: and at low temperatures it has been found that the cod practically cease feeding at 0° C. or lower[1]. How the liver of the cod is affected in circumstances like these, is a question I put to the zoophysiologist, Dr. phil. P. Brandt Rehberg, who has very kindly answered in the following manner: "The liver in fishes may, *inter alia*, be regarded as a storing organ, its weight being influenced to a great extent by the nourishment of the fish and we should expect that failing supply of food will make itself felt in the weight of this organ before in that of any other".

Further, it is reported from Amerdlok Fjord, where as mentioned trawling for the deep-water prawn (*Pandalus borealis*) is carried on for the cannery in Holsteinsborg, that the spawning of this species has been greatly delayed; normally it should begin in the middle of July, but in 1938 the first egg-carrying prawns were not seen before the middle of August, presumably because the sea-water even at the great depths where the prawns live (ca. 200—500 m.), remained ice-cold far on into the summer (cf. above).

[1] Atlantic Biological Station, St. Andrews, New Brunswick, Canada, Note Nr. 47. 1936.

It may be added, that *Halopsis ocellata* (cf. pp. 23—24) an immigrant medusa from warmer seas to West Greenland, was not observed in the summer of 1938, though a sharp look-out was kept for it.

At the present moment we cannot tell, whether these quite recent changes in the temperature of the sea-water in the fjords of South-west Greenland and along its coasts indicate a returning tendency of the "cold" period; or whether it is just a brief fluctuation, which may soon be replaced by a new onslaught of the "warm" period.

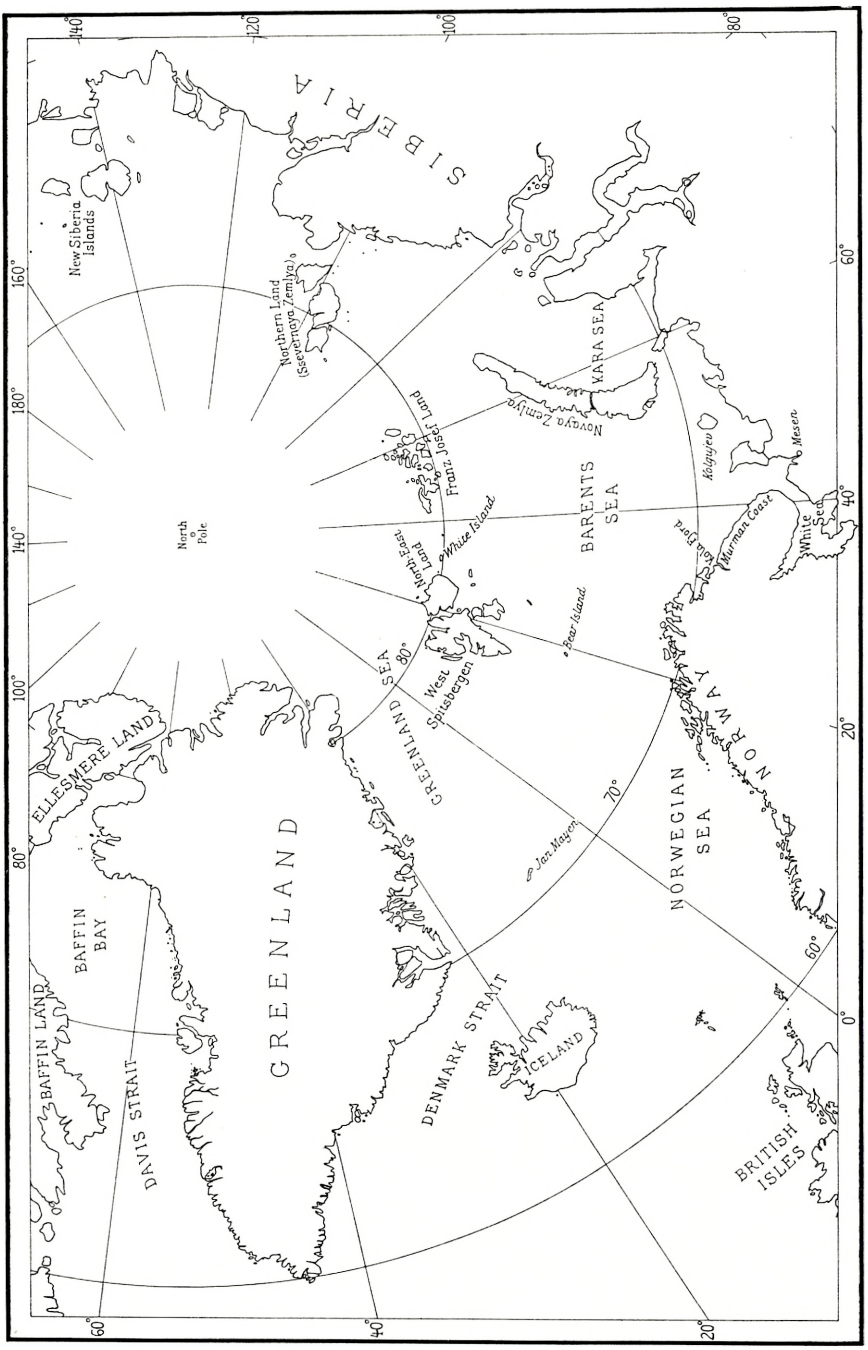
As mentioned on p. 53, Prof. AHLMANN had access to a paper by Dr. MOSBY, then not yet in print, and from it cited some remarks regarding the changes in sea temperatures at Spitzbergen; I have quoted these at the place mentioned. Dr. MOSBY's work has appeared since the present manuscript was sent to be printed and I must content myself therefore, with referring readers to this important work[1] for information regarding the hydrographical conditions in the area of Svalbard.

[1] HÅKON MOSBY: Svalbard Waters. Geofysiske Publikasjoner, Vol. XII, No. 4. Oslo, 1938.

Contents.

Indleveret til Selskabet den 12. Januar 1939.
Færdig fra Trykkeriet den 26. April 1939.

Chart of Greenland, showing position of most of the places mentioned in text. The sign ⊙ indicates settlements after which the districts are named.



Survey Chart of the whole region dealt with.

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