Northwest Atlantic Fisheries Organization

Serial No. N1397

NAFO SCR Doc. 87/93

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1987

Distribution of Greenland Halibut and Roundnose Grenadier in the Northwest Atlantic in Relation to Hydrographic Conditions in 1968-1986

by

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SPECIAL SESSION ON DEEPWATER FISHES

ABSTRACT

Since the second half of the 60's the peculiarities and conditions of life cycles of Greenland halibut (*Reinhardtius hippoglossoides*) and roundnose grenadier (*Coryphaenoides rupestris*) attracted the attention of many scientists, and these species has become the important objects of the deepwater trawl fishery during the development of the research and scouting investigations of the biological resources conducted by the USSR and some European countries especially by GDR and Poland on the continental slope.

The directed fishery of these species on the continental slope of the Northwest Atlantic has begun in 1967 though episodic catches of roundnose grenadier and Greenland halibut were taken yet in 1962-63 (Vogs, Draffehn, 1963; Savvatimsky, 1969).

Mixed concentrations of roundnose grenadier found by the Soviet vessels along the continental slope north of 50°N has stimulated the development of the deepwater trawl fishery.

The commercial ships were fishing initially during the summer period only. They were fishing on a limited area because of poor knowledge of the grounds and the continental slope relief as well as the conditions of Greenland halibut and roundnose grenadier life cycles. But the fishing activity was extended significantly during investigations of commercial objects biology and the area of their distribution. The commercial concentrations of grenadier and halibut depending upon seasonal and hydrographic conditions in different areas and in different depths over the con-

tinental slope were fished out periodically in all accessible to trawl fishery areas from 50°N to 67°N. The biggest catch of roundnose grenadier was registered in Div.3K, in the Northern and Central Labrador area (2GH) and that of Greenland halibut - in Subareas of the Baffin Island (OB) and in the Northern and Central Labrador area.

In the period from the beginning of trawl fishery to the establishment of 200-mile zones the total yield of roundnose grenadier in the Northwest Atlantic fluctuated from 15.5 to 83.7 thou. t, the average value - 36.1 thou.t; that of Greenland halibut ranged from 29 to 53.6 thou.t, the average value - 39.9 thou.t (Tables 1,2). In 1968-76 the mean annual Soviet catches of roundnose grenadier and Greenland halibut were 33.6 and 15.4 thou.t, respectively, i.e. 93.0% and 38.1% of the USSR total yield.

During the period 1978-84 the total catch of roundnose grenadier reduced from 26.5 thou.t to 3.9 thou.t and this reduction was marked in all NAFO Divisions.

After establishing of 200-mile zones Canada and Greenland increased significantly Greenland halibut catches in their coastal waters, however, the total yield decreased from 53.2 thou. t in 1979 to 32.2 thou.t in 1984 (Table 2) and never exceeded the TAC.

There were many explanations of the roundnose grenadier total catch decrease and the reduction of the catch per unit effort (Atkinson, 1982, 1984; Chumakov, Savvatimsky, 1983, 1984; Bowering, 1984; Bowering and Brodie, 1984; Ernst, 1984; Kulka, 1985). Various oceanographic conditions were the reasons for the grenadier concentrations shift to deeper layers and loss of their accessibility to fishery; that is why many authors argued the expedience of the lifting of Greenland halibut by-catch limitation (up to 10%) during the direct fishery for grenadier.

In 1986 because of the increase of the halibut allowable by-catch from 10% to 30% during the direct fishery for grenadier the ships which were fishing on the continental slope got a possibility to use the more productive areas, that improved the realization of the grenadier national quota in Subarea 2+3K.

Significant changes in Greenland halibut distribution and decrease of density of concentrations at various depths over the continental slope in Div. OB were observed in recent years (Chumakov, Borovkov, 1986), which influenced negatively the Soviet fishery efficiency in Div. OB. The fishery in that area was practically not conducted in 1984-86 as catches were very small.

This paper is devoted to the investigations on distribution of Greenland halibut and roundnose grenadier in relation to hydrographic conditions, also to the factors effecting formation and stability of commercial concentrations of these species in the Northwest Atlantic during autumn/winter.

MATERIALS AND METHODS

Soviet trawl surveys data on Greenland halibut stock assessment and also those obtained during research and exploratory cruises in 1968-86 in Subareas 0,1,2 and in Div. 3K are used in the paper.

The official NAFO statistics was used during catch analyses. Besides, the data on the Soviet catches taken in Subareas 0 and 2 were divided into three periods (1969-71, 1972-80, 1981-86) for studying the grenadier and halibut correlation dynamics in the bottom trawl catches. The catches were ranged by 100 m layers. Only the catches with more than 5 kg of grenadier per trawling hour were taken in account. Data sampling and processing of ichthyological material were conducted in accordance with the PINRO methods and NAFO standards.

To study the hydrographic condition dynamics in the South Labrador area we have chosen a standard Section 8-A carried out annually in early November. The location of the Section was published before (Burmakin, 1972). Water temperatures were measured at standard layers. The results of water temperature measurements obtained in 1964-86 were averaged by ten stations in the sector ABC (0-200 m layer) and by three stations in the sector C, these stations being located close to the continental slope (in 0-200 m, 200-500m, 500-1000m layers). The average water temperature values were obtained for every year.

To calculate the frequencies of the temperature fluctuations the method of Shickedan and Bowen was used (Shickedan, Bowen,1977).

The water temperature (Y_i) in the definite layer and year was calculated by the equation*:

$$Y_i = A_o + \sum_{k=1}^{r} A_k \cdot \sin (W_k \cdot i) + B_k \cdot \cos (W_k \cdot i)$$

where

r - quantity of frequencies obtained

W_k - frequencies

A_o - absolute term

A_k, B_k - coefficients of sin. and cos;

(A_o, A_k, B_k - are calculated on the basis of the known frequencies by the least squares method);

i - year;

k - No. of frequency.

The following parameters of the water temperature fluctuations in the chosen sectors and layers of the hydrographic section were obtained:

W - frequency of fluctuations;

T - period, years;

R^2 - spectral density;

S^2 - mean-root-square error (for all obtained frequencies);

R - coefficient of the correlation between input series of water temperature and series restored for all obtained frequencies.

The near-bottom temperatures which were measured after each trawl station also were used in the paper. Near-bottom isotherms were shown in the maps and compared with isobaths location and halibut catches. The ice edge location during the trawl survey and the mean monthly location of the ice in the area of the Baffin Island in September, October and November of 1982-85 calculated by the Murmansk Meteorological Centre data are also represented.

RESULTS

After establishment of 200-mile zones the USSR fished for Greenland halibut mainly in the area of the Baffin Island (OB) and to a lesser degree in Subarea 2 and in Div.3K where halibut

*The method of calculation was worked out by V.G.Korytov in the Laboratory of the short-term prediction (PINRO) were allowed to be caught as a by-catch during the direct fishery for grenadier.

It is known that the Soviet trawl fishery in the Baffin Island area was started in 1968 after the detection of the mixed concentrations of roundnose grenadier and Greenland halibut. At that period catches consisted mainly of roundnose grenadier with a 20-30% of Greenland halibut by-catch. During the subsequent years the composition and size of catches changed because of the shift of the grenadier and halibut concentrations to greater depths.

In the early period (1969-71) in Subarea 0 hauls were conducted at the depths to 1000 m, the mean catches of grenadier at the depths of 600-1000 m being more than 1000 kg per hour trawling (Table 3). The largest catches in 1972-80 were taken at the depths of 800-1200 m. In recent years the catches were significantly less than previously and increased with depth.

In 1969-71 in Subarea 2 the largest catches (above 2000 kg) were observed at the depths of 800-1000 m and in 1972-80 - at the depths of 900-1100 m. In recent years the catches were low but increased at the depths of 1200-1300 m (Tables 4,5,6).

In 1969-86 grenadier catches reduced, their concentrations moved to greater depths (Fig. 1).

The analysis of the research catches shows that in the 1968-1971 period Greenland halibut were distributed in the Davis Strait (Subarea 0+1) without forming dense concentrations. Then the largest halibut catches were registered at 450-600 m depths. Halibut catches more than 1.5 t per trawling hour were taken occasionally at those depths in 1969 and the near-bottom temperature was about 3°C (Fig. 2). In subsequent years the halibut catches from that area increased greatly and those of grenadier were on a gradual decline (Fig. 1,3,4,5).

It was noted that the correlation of these species in the catch changes in connection with the thermal conditions of the sea, since halibut are more resistant to low temperatures than grenadier (Burmakin, Svetlov, Chumakov, 1977). Proceeding from this relationship V.V.Burmakin (1978) suggested the equation which allows to predict the Greenland halibut by-catch in per cent in September:

$$Q = -34.02\ t + 153.9$$

where Q - Greenland halibut percentage in trawl catches in September (per cent of the total catch);

t - water temperature on the hydrographic Section 7-A in May (in the 200-500 m layer).

In the period of 1968-74 the correlation coefficient between the compared values was equal to -0.962 ± 0.018.

To our regret, the absence of the oceanographic observations on this section does not allow us to analyse this equation on larger number of examples.

According to the data of annual trawl surveys conducted in that area since 1979 the correlation between grenadier and halibut in the catches changed greatly in comparison with the initial period of the fishery. Thus, in 1981-83 Greenland halibut were the main species in the trawl catches from all surveyed areas, low grenadier catches were reported only from the southern part of the area at depths below 800 m. At the same time the by-catch of northern wolffish (Anarchichas latifrons) and roughhead grenadier (Macrourus berglax) increased significantly. In 1984-86 roundnose grenadier catches (to 500 kg per hour trawling) were usually taken at the 800-1300 m depths.

Year-to-year changes in grenadier/halibut ratio in Subareas 0+1 in 1968-84 can be detected by summing up the statistical data on the total catches taken by the ships of the USSR, GDR and FRG. The analysis of the curves of grenadier/halibut ratio shown in Fig. 6 allows to mark out three periods (1968-71, 1972-80, 1981-86) with different types of the spatial distribution of Greenland halibut and roundnose grenadier in Subareas 0 and 1. Till 1971 roundnose grenadier were the dominating species in catches (75-80%); from 1972 to 1980 the portion of grenadier averaged 50 % and since 1981 it approached 20%. These changes are connected with the year-to-year vertical displacements of fish concentrations.

It is known that the route of mature halibut migration to spawning grounds situated in the southern part of the Greenland-Canadian Threshold (Subarea 1) lies through this area. That's why it is interesting to analyse year-to-year fluctuations of halibut length composition basing on trawl survey data.

As is seen from Fig. 7 halibut length composition in Div.OB in 1979-86 was not stable. In 1979-83 males and females above 56-65 cm long dominated in trawl catches, while in 1984-86 their relative quantity sharply reduced and the number of fish 44-45 cm long increased.

It is naturally that such sharp and significant changes in the length composition, in the trawl fishery productivity and in the reduction of the halibut biomass from 355.3 ± 102.4 thou.t in 1982 to 158.6 ± 33.8 thou.t in 1986 (Table 7) cannot be explained by the fishery influence because according to the Statistical Bulletin NAFO data, the fishery in that area was minimum and in 1984 it was stopped at all. To our mind, the above changes were caused by the redistribution of the older age groups in Subareas 0 and 1.

The largest catches (more than 2000 kg per trawling hour) were registered at the 800-1100 m depths in Subarea 2 in 1969-71 and at the 900-1100 m depths in 1972-80. In the last years the catches were small and increased at the depth below 1200 m.

The reasons of these changes in the vertical and horizontal distribution and also in the halibut and grenadier concentration density can be explained, first of all, by changes of water thermal regime.

The sharp fall of water temperature in the Northwest Atlantic registered in early 70's led to the descent of roundnose grenadier stock to greater depths and reduced the accessibility of concentrations to the bottom trawl fishery thus being one of the reasons of the total grenadier catch decline in those years. The same conclusion was drawn by R.Ernst (1984), while explaining the reduction of grenadier catches on the continental slope in Subarea 2.

It should also be noted that the trawl fishery for grenadier at great depths over the continental slope is hampered by the bottom relief and a higher number of accident hauls. Besides, gears should have special rigging for deepwater fishery.

The changes in the hydrographic regime promoted the increase in density of halibut concentrations in Div.0B and Subarea 2 (Tables 8,9; Fig. /3,4).

Migration of Greenland halibut to deeper waters can be proved by comparison of the mean catch data for 1983-84 with those in 1969 (Table 8; Fig. 2,4). In 1969 the maximum halibut catches were taken in the 450-600 m layer and in 1983 - in the layers below 1000 m (Fig. 8).

Immature specimens of Greenland halibut are distributed mainly in the southern part of the area on the shelf and continental slope within a relatively wide temperature range (from - 0.9°C to + 4.5°C). The relative quantity of mature males and females and the mean fish length increase towards the north (Chumakov, 1975). In Subarea 0 halibut are distributed within the narrower temperature range than in the southern areas (Fig. 8).

As it was noted before (Savvatimsky, 1986; Ernst, 1984; Kulka, 1985), the gradual shift of the concentrations of Greenland halibut, roundnose grenadier and redfish into deep waters was caused supposedly by the changes of the hydrographic conditions and the ratio of these species in the research and commercial catches has changed in recent years.

According to our data, the Greenland halibut distribution is strongly connected with the hydrographic regime in the dwelling area, thus affecting the trawl survey and fishery results.

It is known that in the years with low water temperatures in the main branch of the Labrador Current conditions for the Greenland halibut dense concentrations and their effective fishery are formed. With the temperature rise the roundnose grenadier catches increase and mixed concentrations of roundnose grenadier and Greenland halibut are observed then nearby the continental slope (Konstantinov, Noskov, 1977; Burmakin, 1978). The water temperature in the main branch of the Labrador Current has fallen notably since 1973 and that in the 200-500 m and in the 500-1000m layers of the continental slope of Labrador (Section 8-A, sector C) is lower than the long-term mean level (Savvatimsky, 1986, 1987). In 1986 the water temperature in the 200-500 m layer was 3.64°C (the mean temperature was 3.91°C in 1964-86) and in the 500-1000 m layer - 3.45°C (the mean value was 3.76°C) (Table 10).

In order to study the year-to-year fluctuations in the hydrographic conditions in the area of fish dwelling the results of the long-term observations on Section 8-A were analysed and the periodicity of water temperature fluctuations in the upper layers of the shelf and slope as well as in deep layers nearby the slope was revealed.

Three periods of water temperature fluctuations with rather high (and important) correlation coefficients (11.4; 2.1 and 3.8 years) were determined in the 0-200 m layer of Sector ABC (Table 11). Two periods (11.5 and 2.1 years) were revealed in the 0-200 m layer of Sector C. Two periods (30.2 and 6.3 years) were determined in the 200-500 m layer of the same sector as well as in the 500-1000 m layer (35.3 and 4.4 years). It is noteworthy that the long-term fluctuations in the 200-500 and 500-1000 m layers are characterized by a high correlation coefficient (R is more than 0. 7).

Prognostic values of water temperature for 1987-91 in the chosen layers were obtained taking in account all the determined periods of water temperature fluctuations with correlation coefficients always exceeding 0.8.

The sharp water cooling in the upper layers (0-200 m) in the area of the shelf and nearby the continental slope of the Southern Labrador started in 1982 (Fig. 9). Cooling was maximum in 1984, and by 1985-86 water temperature was about the long-term mean (1964-86). The rise in temperature in the upper layers is expected in the subsequent years with the maximum in 1989-90.

The water cooling in the 200-500 m and 500-1000 m layers nearby the continental slope started much earlier than in the upper layers and lasted for a long time from 1974 to 1986. The water temperature in these layers can reach the long-term mean by 1988 and exceed it by 1991 (Fig. 9).

Though water cooling in 1984-86 seemed to have favoured the halibut fishery, no dense halibut concentrations in the Baffin Island area in those years were observed (Table 8; Fig. 5) and, consequently, the fishery was not successful. The hydrographic conditions in 1984 were similar to those in 1985. The water temperature on 1 November 1984 was lower than the 1964-86 mean level (Table 10).

During the trawl surveys in the area of the Baffin Island and Labrador in cold 1984 and 1985 years mean halibut catches per hour trawling were significantly less than previously when the temperature of the main branch of the Labrador Current waters was low. The trawl fishery conditions and the accessibility of the fish concentrations were worse than in previous years because of wider fish distribution over the shelf and continental slope that was probably connected with the hydrographic conditions on the shelf.

The insufficient results do not allow to analyse properly the year-to-year anomalies of the oceanographic conditions, nevertheless, it is possible to state that the area of Arctic waters on the shelf reduced slightly from the autumn of 1984 to the end of 1985, i.e. the area of waters with negative temperatures decreased. The near-bottom 0° isotherm in Subarea 2G was very far from the continental slope in December 1985 whereas it was close to the slope, for example, in December 1982 (Fig. 10). Thus, in 1982 practically the whole shelf was occupied by waters with negative temperatures in the bottom layers. The water cooling in the shelf area of the Baffin Island in 1982 was, probably, greater than in the area of Labrador which is proved by the location of the ice edge along the 1000 m isobath in November 1982 (Fig. 11). The ice edge was very far from the slope. It was farther to the west in November 1983 than in 1982 and the mean monthly location of the ice edge in November 1984 was similar to that in 1985 (Fig. 12), i.e. the year-to-year gradual movement of the ice edge from the slope towards the shelf was observed. This indicates the rise in temperature in the upper layers over the shelf and the continental slope. The rise in temperature depends not only on the radiational heating but also on the interaction of the cold Baffin Island Current and the warm branch of the West Greenland Current, and if the latter becomes stronger warm waters penetrate farther to the west than usually and occupy the part of the shelf. In such years halibut are scattered over a wide area, do not form dense concentrations and the fishery productivity is not usually high. On the contrary, when cold waters force the fish out of the shelf they form dense concentrations in the narrow areas of the slope under the so-called "core" of the branch of the West Greenland Current. Thus, the trawl survey in the area of the Baffin Island was conducted in September of relatively warm 1984 (according to the location of the ice edge and near-bottom isotherm on the shelf) when the autumn/winter migration of halibut into great depths had not yet started.

The significant part of the shelf was occupied by relatively warm waters and on 29 November 1984 the ice edge was located 20-25 miles west of the 500 m isobath. The near-bottom 0°C isotherm was located between 200 m and 500 m isobaths. There was no usual increase of the mean length of fish with depth when the halibut migration from coastal to offshore waters comes to an end (Chumakov, 1982). In September 1984 during the trawl survey the fish were scattered over a wide area (Fig. 13), and catches were low (up to 700 kg per trawling hour). In fact the halibut fishery was not conducted in that area. The greatest catches were taken from shallow depths (Table 8).

The similar hydrographic situation was in the Baffin Island area in November 1985. The near-bottom 1°C isotherm was between 200 m and 500 m isobaths, the 2°C isotherm corresponded approximately to the 500 m isobath and the 3°C isotherm was between the 500 m and 1000 m isobaths (Fig. 5). In November the ice edge was far from the slope and was located over the shallow waters (Fig. 11). Halibut were scattered in a wide area without forming dense concentrations and their catches were small.

In November of anomally cold 1983 the hydrographic situation was different. On 15 November the ice edge was located between 500 m and 1000 m isobaths. The halibut catches were higher than in the corresponding period of 1984 and 1985 (Fig. 4) especially in the layers deeper than 1000 m (Table 8). The maximum catches exceeded 3000 kg per trawling hour. In November 1982 the ice edge was located slightly easterly than in 1983 and halibut catches were also higher. The mean catch per trawling hour was 1101 kg in 1982 and 715 kg in 1983 (Table 8). The USSR halibut catches taken from the Baffin Island area were 3.5 thou.t in 1982 and 3.7 thou.t in 1983 (Stat. Bull. NAFO, vol. 32, 1984; vol. 33,1985), i.e. 91.1% and 83.2%, respectively, of the total catch. In 1984 the Soviet catch in that area was only 109t and in 1985 - 179 t (Chumakov, Borovkov, 1986).

According to the data of Murmansk Meteorological Centre, in October 1986 in the Baffin Island area south of 65°N no ice was detected (it was only in the bays), while the ice edge 40 miles wide was observed to the north. According to the data of MG-1330 "Klintsy" which conducted the trawl survey of halibut stock in that area, there were positive anomalies of water temperatures in the 50-200 m layer of the shelf. That indicates the intensified influence of the West Greenland Current warm branch on the heat content of shelf waters. Halibut were scattered in a wide area that is why catches taken by MG-1330 "Klintsy" were small.

So, the halibut distribution is connected with the oceanographic conditions on the shelf and continental slope in the areas of the Baffin Island and Labrador, which allows to determine the fishery conditions in those areas in advance. It is possible to predict ice conditions for November/December (the most favourable period for the halibut fishery) analysing the changes in the location of the ice edge in the area of the Baffin Island from September to October. So, in September/October 1984 and 1985, when the shelf was occupied by relatively warm waters, the ice off the Baffin Island was not found, and in September/October 1982 and 1983 it was detected as the coastal ice field (Fig. 14) and at the end of October it was 40-50 miles wide.

DISCUSSION

It is known that the hydrographic conditions of the definite year or season are the main factors influencing the distribution of commercial species and determining the results of trawl surveys for their abundance assessment. For example, it was noted that the reduction in abundance and biomass of cod, American plaice, witch flounder and Greenland halibut, according to the Canadian trawl surveys data for 1985 in Divs. 2J and 3KL, was connected with the fish distribution in near-bottom waters where temperatures were lower than in previous years (Baird and Bishop, 1986). The Soviet catches taken during trawl surveys for Greenland halibut stock assessment in the Northwest Atlantic vary by areas from year to year notably. This leads to significant fluctuations in the calculated values of fish abundance and biomass and make difficulties while estimating the stock and predicting the fishery and total yield. It is possible that in connection with the variable hydrographic conditions the mature halibut migrations to the spawning grounds situated in the Greenland-Canadian Threshold area and partly in the 200-mile zone of Greenland take place annually in different periods and with different intensity, which can also influence the results of the trawl survey for stock assessment.

The hydrographic regime influences the behaviour and distribution of demersal fish and determines to a great extent the fishery conditions. The cooling of water masses in the Northwest Atlantic in early 70's led to displacement of roundnose grenadier and Greenland halibut into deep waters and reduced their accessibility to the bottom trawl fishery. The changes of the hydrographic conditions reduced the grenadier total yield and increased the halibut concentration density and stability as well as the efficiency of fishery. The cooling in the upper layers of the Labrador Current in the area of the shelf and slope started in 1982 and in the 200-500 m and in the 500-1000 m layers nearby the slope - in 1974. In 1985-86 the water temperature was similar to the long-term mean. The rise in temperature in the upper layers is expected in the subsequent years with the maximum in 1989-90. The water temperature in the 200-500 m and in 500-1000 m layers nearby the continental slope can reach the long-term mean by 1988 and will exceed it by 1991. These changes can influence the vertical fish distribution and the fishery conditions. .

The fishery conditions in the area of the Baffin Island and Labrador, the halibut accessibility to the gear during trawl surveys for stock assessment are determined by the fish distribution in the shelf and continental slope area. The most favourable period for trawl surveys is in November/January when the halibut migration from the coastal zone to the offshore waters comes to an end and fish form dense wintering concentrations on the continental slope (Chumakov, 1982). The halibut accessibility to the research bottom trawl is determined by a general dislocation of concentrations in deep waters (as a result of year-to-year water temperature changes) and by specific hydrographic conditions during the survey. Time of concentration formation, their density and stability are connected also with the hydrographic conditions arising in the shelf area from the interaction of the cold Baffin-Island Current and the warm branch of the West Greenland Current. In those years when the whole shelf is occupied with waters having negative bottom temperatures halibut are concentrated over the continental slope. If relatively warm waters of the West Greenland Current branch penetrate far to the west than usually and occupy the part of the shelf, then halibut are scattered in a wide area and do not form stable concentrations. The hydrographic front arising from the interaction of the above currents nearby the 1000 m isobath is the main factor affecting the formation of halibut concentrations. The largest halibut catches are taken in the area of the continental slope where the 1-3°C isotherms are located close to each other.

Halibut concentrations in the area of the continental slope of the Baffin Island occur, probably, nearby the ice edge. The stable halibut concentrations favouring effective fishery are formed when the ice edge is between the 500 m and 1000 m isobaths, i.e. along the boundary between the shelf and the continental slope. However, it is not clear if the ice cover and the ice edge location affect the formation of halibut concentrations, though the connection between the commercial fish distribution and the ice edge location is generally known. The experience of successful fishery near the ice for fish concentrations in the upper layers (capelin) and in deep waters (redfish, cod) prove the fact that the ice edge is one of the factors affecting the formation and density of commercial concentrations.

In this paper the ice edge location in the period of the halibut concentrating nearby the continental slope is considered to be the index of the thermal state of shelf waters but it can be, possibly, used to predict the halibut fishery conditions in the area of the Baffin Island in November/December as well as the conditions of the research trawl survey 1-2 months in advance.

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Table 1 Roundnose grenadier catches (t) in Subareas 0+1 and 2+3KL in 1968-84 according to NAFO data

Year	Canada	Green-land	GDR	Poland	FRG	USSR	Other count-ries	Total yield
1968	-	-	4735	-	-	32719	-	37454
1969	-	-	446	-	-	15043	-	15489
1970	-	-	1564	-	-	29389	-	30953
1971	-	-	1185	105	-	82459	-	83749
1972	-	-	445	270	-	31765	-	32480
1973	-	11	2519	294	-	19624	-	22448
1974	-	5	4580	181	199	35779	-	40734
1975	-	6	2890	1499	33	27949	-	32378
1976	16	1	678	101	148	28152	-	29096
1977	15	10	674	-	693	16922	7	18321
1978	9	32	1801	51	6780	17760	108	26541
1979	4	21	480	96	6794	7307	-	14702
1980	-	-	898	36	1753	1119	-	3806
1981	-	39	1407	18	353	5747	-	7564
1982	-	37	1640	15	11	2732	-	4435
1983	-	22	2586	50	-	979	-	3637
1984	-	35	3650	51	23	172	2	3933

Table 2 Greenland halibut catches (t) in Subareas 0+1 and 2+3KL in 1968-84 according to NAFO data

Year	Canada	Green-land	GDR	Poland	FRG	USSR	Other count-ries	Total yield
1968	13322	1568	4259	5806	137	10217	-	35309
1969	11553	1477	10022	5406	270	10204	98	39030
1970	10706	1212	9158	8266	26	8047	875	38286
1971	9408	1159	1021	5234	16	10937	1215	28990
1972	8952	2950	965	7121	214	19825	3692	43719
1973	6840	4567	2435	9060	772	12783	2045	38502
1974	5745	4058	3302	7105	517	19201	1492	41380
1975	7807	3724	2081	8447	646	29669	1255	53629
1976	9306	3546	1672	5942	1020	17733	1168	40387
1977	17965	6110	2428	5998	1345	8664	1978	44590
1978	24692	5985	1636	5215	5987	5632	1038	50185
1979	29940	5273	178	1813	12893	2948	212	53257
1980	31774	5356	316	203	1229	1784	252	40914
1981	24125	5755	1350	1806	10	6951	246	40243
1982	19248	5397	2487	1111	66	5009	2177	35495
1983	17113	4136	2587	5258	16	4709	2707	36526
1984	17181	6949	2498	943	24	549	4037	32181

Table 3 Mean catch of roundnose grenadier per trawling hour (kg) (numerator) and number of catches (denominator) in the Baffin Island area in 1969–86

Layer, m	1969–71			1972–80					1981–86				
	August	September	August/ September	August	September	October	November	August/ November	September	October	November	December	Sep./ Decem.
501–600	600/I	240/2	353/3	93/4	I57/5	544/5	–	277/I4	–	–	–	–	–
601–700	I47I/66	I296/46	I399/II2	464/I3I	2I7/55	842/4	I625/2	4I3/I92	–	–	40/6	–	40/6
701–800	II8I/74	I249/53	I209/I27	35I/I94	452/26	323/I0	289/3	360/233	–	–	33/8	35/I	34/9
801–900	II2I/4	I597/26	I534/30	684/II0	737/32	783/I5	294/9	682/I66	III/4	5/I	32/I2	–	5I/I7
901–I000		I000/I	I000/I	573/I0	568/9	64I/5	–	585/24	I89/4	50/2	57/I4	8I0/2	I49/22
I00I–II00	–	–	–	283/2	–	327/2	–	305/4	2I9/5	7/I	83/I6	–	III/22
II0I–I200	–	–	–	77I/4	–	I687/2	–	I077/6	I24/2	–	207/I4	–	I96/I6
I20I–I300	–	–	–	–	–	–	–	–	–	–	259/II	–	259/II

Table 4 Mean catch of roundnose grenadier per trawling hour (kg) (numerator) and number of catches (denominator) in Subarea 2 in 1969-71

Layer, m	June	July	September	October	November	December	June/ December
40I-500	–	608/3	III2/I9	9I6/9	804/33	47I/6	865/70
50I-600	–	598/7	996/24	I444/2I	893/42	528/37	88I/I3I
60I-700	I745/3	226I/5	–	25I6/5	IIII/2I	342/II	I249/45
70I-800	255I/26	2660/28	3983/4	900/I	970/5	5II/I4	2I75/78
80I-900	2I26/24	2945/I0	2960/4	–	II64/4	500/I	2267/43
90I-I000	3388/2	205I/I0	998/4	–	–	–	I955/I6
I00I-II00	–	I998/I3	2823/I	–	–	–	2057/I4
II0I-I200	–	526/4	800/I	–	–	–	58I/5

Table 5 Mean catch of roundnose grenadier per trawling hour (kg) (numerator) and number of catches (denominator) in Subarea 2 in 1972-80

Layer, m	June	July	August	September	October	November	December	June/ December
30I-400	–	–	–	–	552/3	–	7/5	2II/8
40I-500	–	–	356/4	I042/5	877/32	I0/I	40/I	808/43
50I-600	–	68/4	8I8/8	2672/8	I082/29	7I/I0	202/4	970/63
60I-700	480/I	434/I0	627/6	I892/I4	730/I7	829/I6	234/6	888/70
70I-800	–	273/7	27I/5	I897/I8	I489/I0	925/4	5II/I5	I079/59
80I-900	2002/2I	I676/34	I99/4	I470/I0	I384/I3	486/7	382/I9	I326/I08
90I-I000	4470/4	366I/37	2235/5	I623/6	I400/I9	632/4	790/8	2526/83
I00I-II00	3568/I6	2956/45	3500/I	2I47/I7	2I22/I2	I736/5	2700/2	275I/98
II0I-I200	–	I647/8	68/I	–	I000/I	–	5/I	I295/II

Table 6 Mean catch of roundnose grenadier per trawling hour (kg) (numerator) and number of catches (denominator) in Subarea 2 in 1981-86

Layer, m	July	September	October	November	December	July/ December
50I-600	-	-	I7I/I	300/I	I7/I	I63/3
60I-700	-	200/I	25/I	II00/I	I2/4	I96/7
70I-800	300/I	I64/I	-	I5/I	I68/I2	I66/I5
80I-900	I00/I	I75/3	5/I	II40/I	2I6/20	235/26
90I-I000	200/I	3I4/I	67/4	775/4	508/3I	498/4I
I00I-II00	-	I82/I	I36/3	600/I	3I9/I9	296/24
II0I-I200	-	-	-	940/I	255/I7	294/I8
I20I-I300	-	-	-	-	698/3	698/3

Table 7 Results of trawl survey for Greenland halibut in Div. OB in 1979–86

Index	1979 September/ November	1980 November/ December	1981 December	1982 November	1983 November	1984 September	1985 November/ December	1986 October/ November
Abundance, mill. ind.	I09,I	I6I,3	64,5	I9I,0	I79,0	72,6	I22,7	I38,5
± error, mill. ind.	±I4,7	±26,5	±I9,6	±49,5	±43,0	±I6,9	±37,8	±32,9
Biomass, thou.t	200,9	240,0	I05,I	355,3	304,I	II9,I	II0,2	I58,6
± error, thou.t	±27,9	±48,9	±38,7	±I02,4	±80,5	±23,0	±27,0	±33,8
Number of hauls	98	39	I3	53	7I	33	77	66
Depth range	40I-I250	30I-I250	50I-I250	40I-I500	40I-I500	50I-I250	20I-I500	200-I250
Percentage of area surveyed	44,I	56,7	23,8	40,7	48,2	35,4	77,5	95,5

Table 8 Greenland halibut catches from different depths of the continental slope in DIV.OB in 1979–86 (kg per trawling hour). (The number of hauls is given in brackets).

Depth range, m	Year, month							
	1979 September/ November	1980 November/ December	1981 December	1982 November	1983 November	1984 September	1985 November/ December	1986 November
50I–600	455 (I2)	45 (4)	I30 (I)	I70 (4)	907 (2)	–	I0I (2)	II6 (5)
60I–700	52I (I3)	7I (4)	–	336 (7)	242 (7)	3I7 (5)	292 (3)	–
70I–800	482 (I5)	I30 (2)	–	783 (6)	247 (9)	635 (9)	277 (7)	346 (8)
80I–900	488 (8)	9I8 (4)	220 (3)	986 (II)	400 (9)	490 (7)	466 (I5)	534 (I9)
90I–I000	398 (5)	I379 (II)	6I8 (6)	934 (9)	6I5 (I2)	369 (3)	497 (II)	34I (8)
I00I–II00	455 (2)	I3I6 (6)	76I (3)	2I30 (I3)	865 (8)	280 (5)	224 (4)	242 (4)
II0I–I200	–	–	–	I68I (I)	I482 (II)	I09 (3)	2I5 (3)	–
I20I–I300	–	–	–	–	I024 (5)	–	2I2 (4)	–
50I–I300	478 (55)	886 (3I)	522 (I3)	II0I (5I)	7I5 (63)	425 (32)	360 (49)	39I (44)

Table 9 Greenland halibut catches (average) taken from different depths of the continental slope of the Northern and Central Labrador in 1979–86 (kg per trawling hour). (The number of hauls is given in brackets).

Depth range, m	Year, month							
	1979 October/ November	1980 November/ December	1981 December 1982 January	1982 Nov./Dec. 1983 January	1983 Nov./Dec. 1984 January	1984 December 1985 January	1985 December	1986 October/ November
30I-400	426 (I6)	34 (4)	33 (I3)	-	-	-	7 (2)	-
40I-500	295 (I6)	I6 (2)	II3 (3)	I97 (4)	22 (3)	44 (5)	4 (3)	244 (I)
50I-600	288 (20)	2I8 (2)	264 (5)	439 (4)	29I (4)	49 (5)	25 (6)	I22 (2)
60I-700	344 (II)	427 (4)	427 (4)	I379 (3)	473 (3)	II5 (5)	25 (3)	39 (2)
70I-800	384 (I5)	I737 (3)	506 (6)	I862 (6)	I446 (5)	3I9 (6)	I8 (2)	45 (I)
80I-900	697 (6)	2783 (6)	2865 (6)	I732 (7)	29I4 (8)	763 (6)	II0 (8)	28I (I)
90I-I000	440 (3)	2762 (I0)	I753 (9)	3520 (5)	2686 (I6)	I088 (7)	2I0 (5)	537 (4)
I00I-II00	938 (4)	I83I (6)	I504 (I)	II39 (7)	I492 (I0)	I220 (4)	374 (6)	534 (2)
II0I-I200	-	II46 (I)	-	623 (I)	2749 (5)	439 (4)	I36 (5)	866 (2)
I20I-I300	-	-	-	-	454 (I)	265 (3)	-	-
I30I-I500	-	-	-	-	-	I0I (7)	-	-
30I-I500	397 (9I)	I699 (34)	879 (47)	I5I8 (37)	I9I4 (55)	448 (52)	I47 (34)	390 (I5)

Table 10 The mean water temperature in the 200-500 m and 500-1000 m layers of the main branch of the Labrador Current in 1964-86 (Section 8-A, sector C)

Layer, m	Year			
	1964-86	1984	1985	1986
200-500	3.91	3.70	3.84	3.64
500-1000	3.76	3.62	3.50	3.45

Table 11 Calculated frequencies of water temperature fluctuations in the 0-200m, 200-500m, 500-1000m layers of the ABC and C sectors on standard hydrographic section 8-A in 1964-86

Sector, layer	Frequency, W	Period, years, T	Spectral density, R^2	Mean-root-square error, S^2	Coefficient of correlation, R
ABC 0-200	0,549	II,437	0,448	0,439	0,669
	2,996	2,097	0,I99	0,35I	0,804
	I,629	3,856	0,I85	0,242	0,9I2
C 0-200	0,547	II,494	0,420	0,598	0,648
	2,969	2,II6	0,245	0,455	0,8I5
C 200-500	0,208	30,223	0,628	0,I9I	0,792
	0,997	6,305	0,I07	0,I7I	0,837
C 500-I000	0,I78	35,276	0,562	0,2I0	0,750
	I,426	4,407	0,I35	0,I83	0,8I8

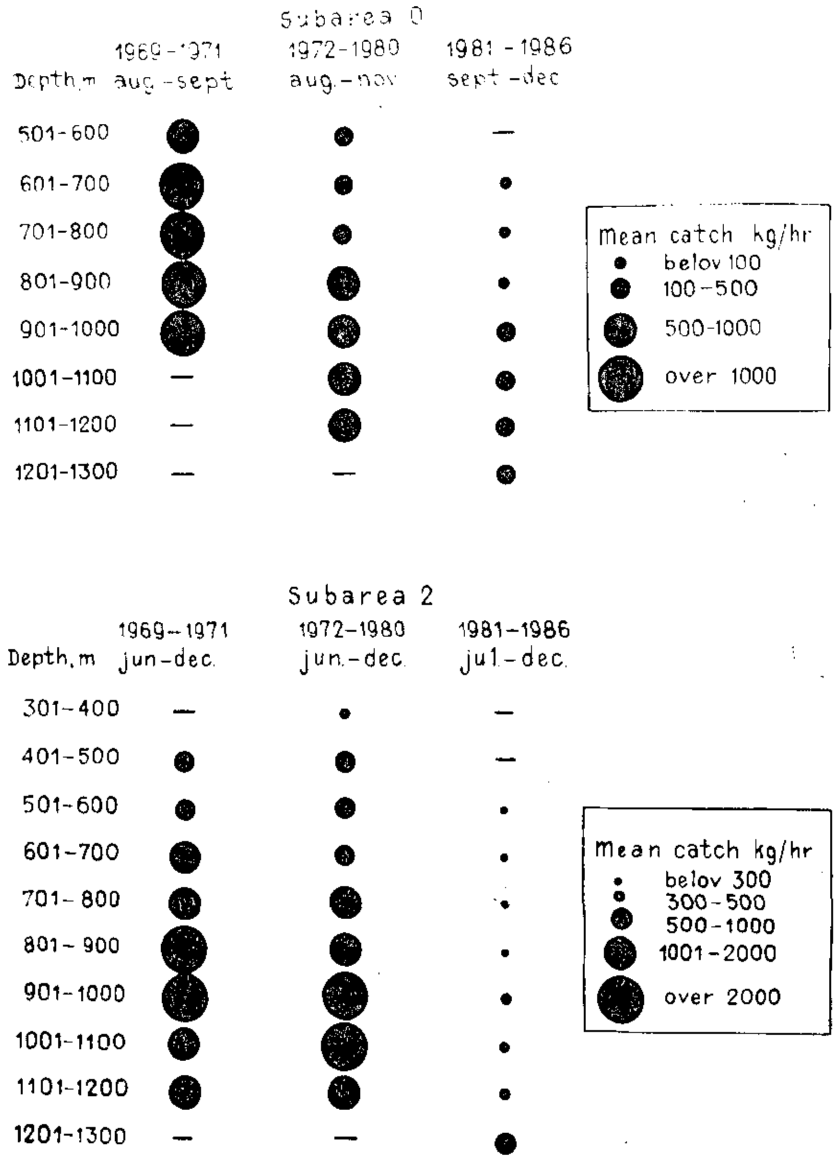

Fig. 1 Mean catches of roundnose grenadier taken by the bottom trawl at different depths in Subareas 0 and 2 in 1969-86

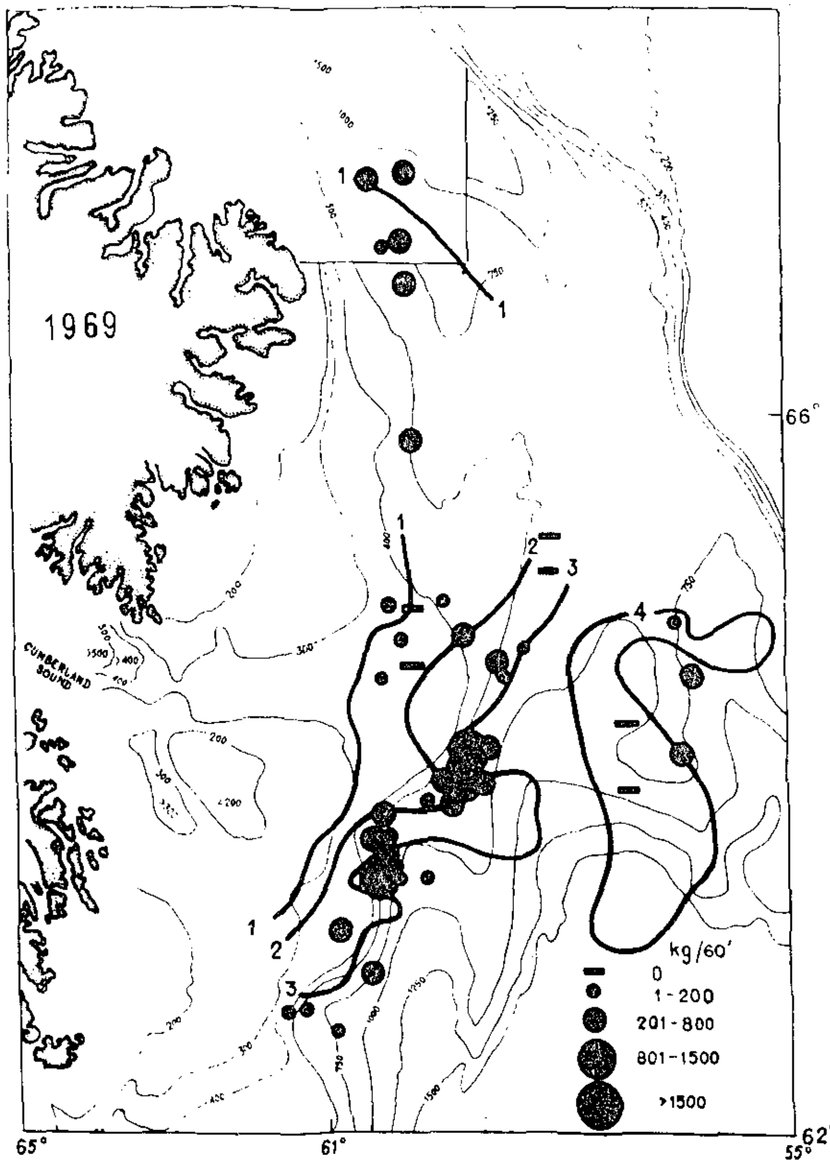

Fig. 2 Distribution of Greenland halibut catches and near-bottom isotherms location in August/September 1969 in Subareas 0+1 according to the data of exploratory vessels

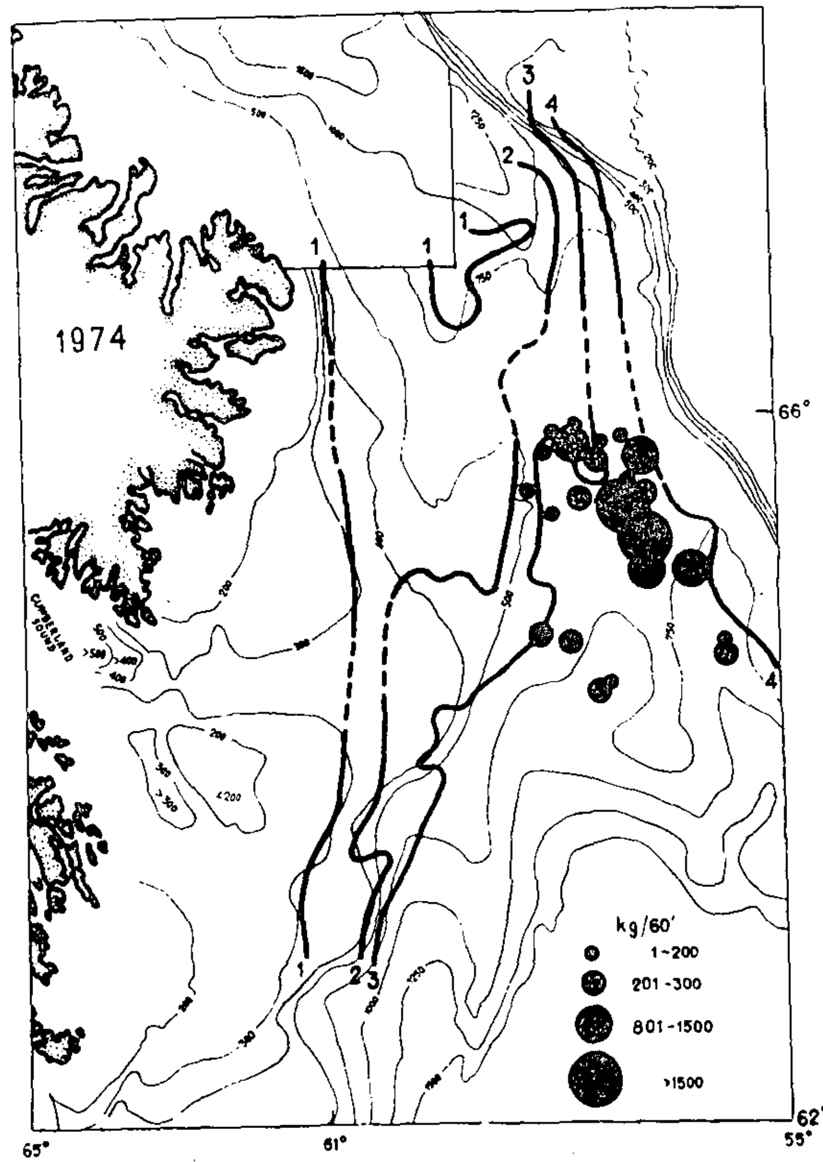

Fig. 3 Distribution of Greenland halibut catches and near-bottom isotherms location in Subareas 0+1 in November 1974 according to the data of exploratory vessels

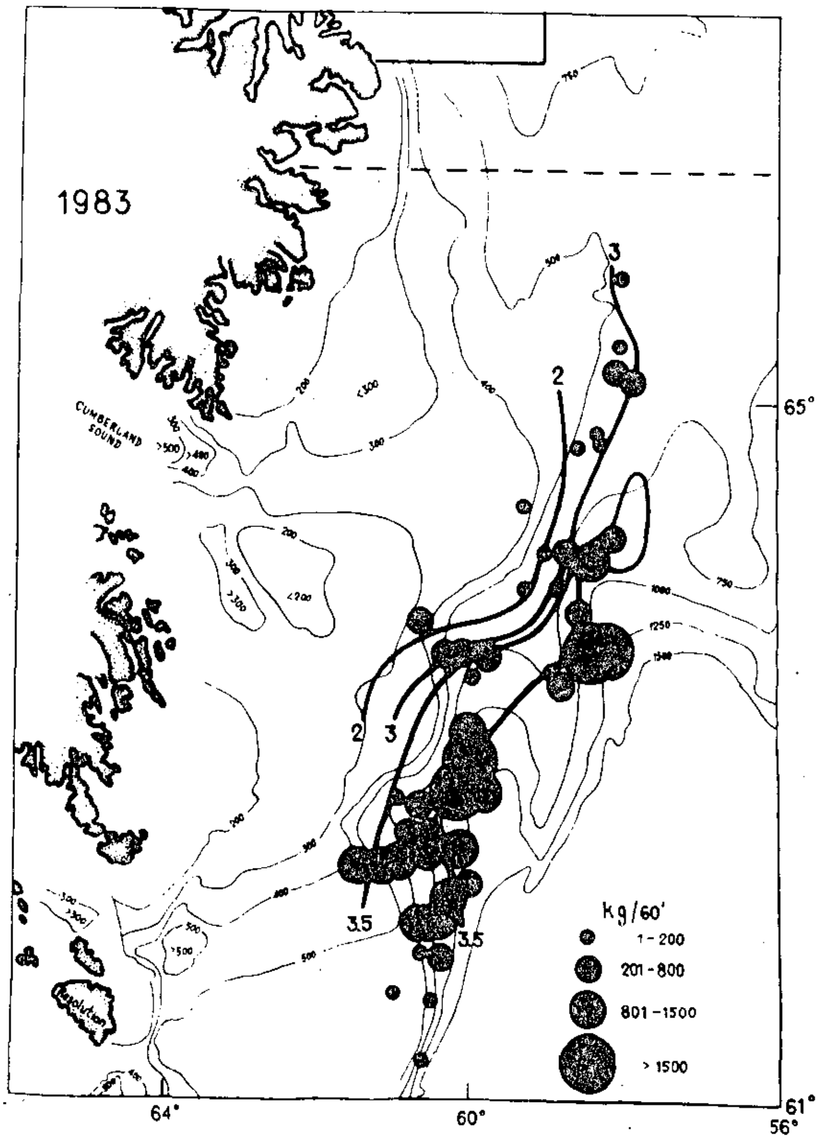

Fig. 4 Distribution of Greenland halibut catches and near-bottom isotherms location in Div. OB in November 1983 according to the trawl survey data

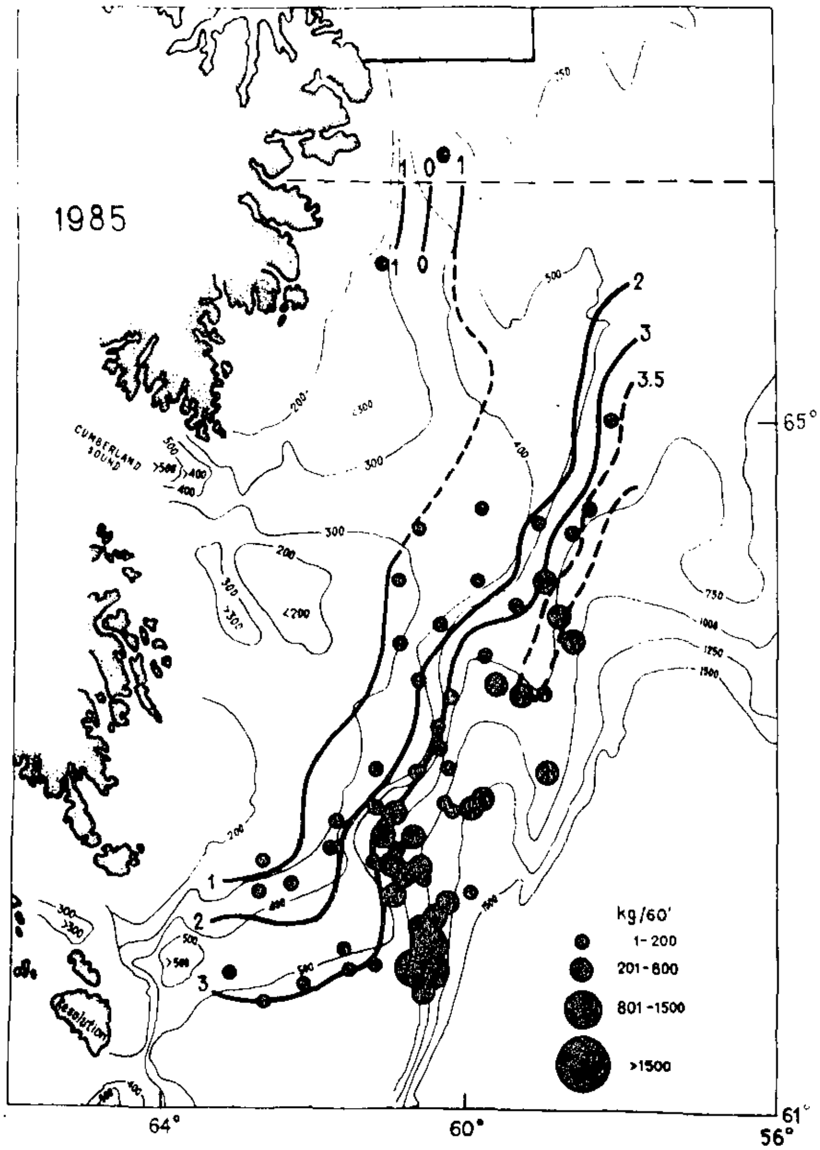

Fig. 5 Distribution of Greenland halibut catches and near-bottom isotherms location in Div. 0B in November 1985 according to trawl survey data

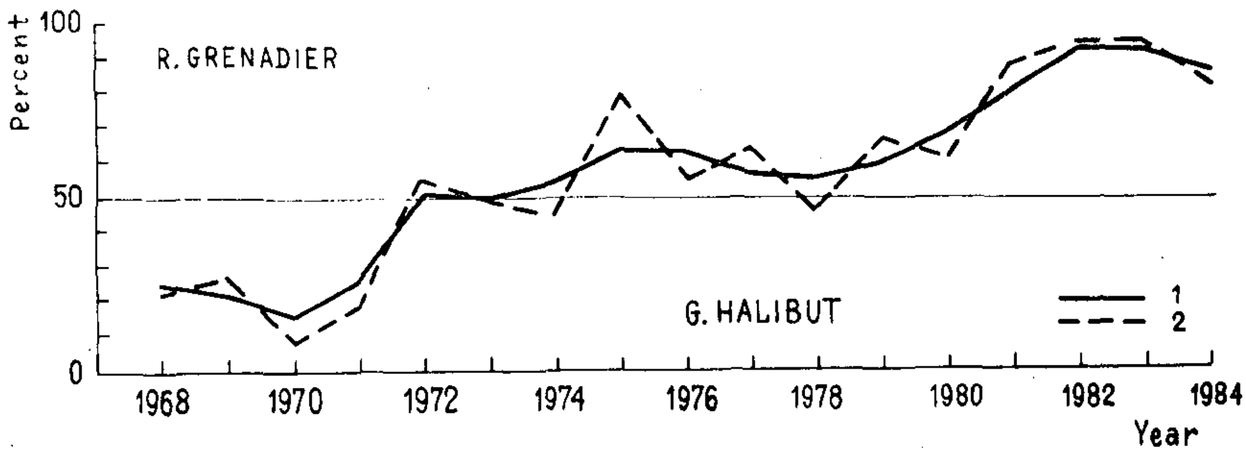

Fig. 6 Roundnose grenadier to Greenland halibut ratio in the total catches taken by the USSR, GDR and FRG in 1968-84 in Subareas 0+1 (1 - smoothed curve; 2 - initial data)

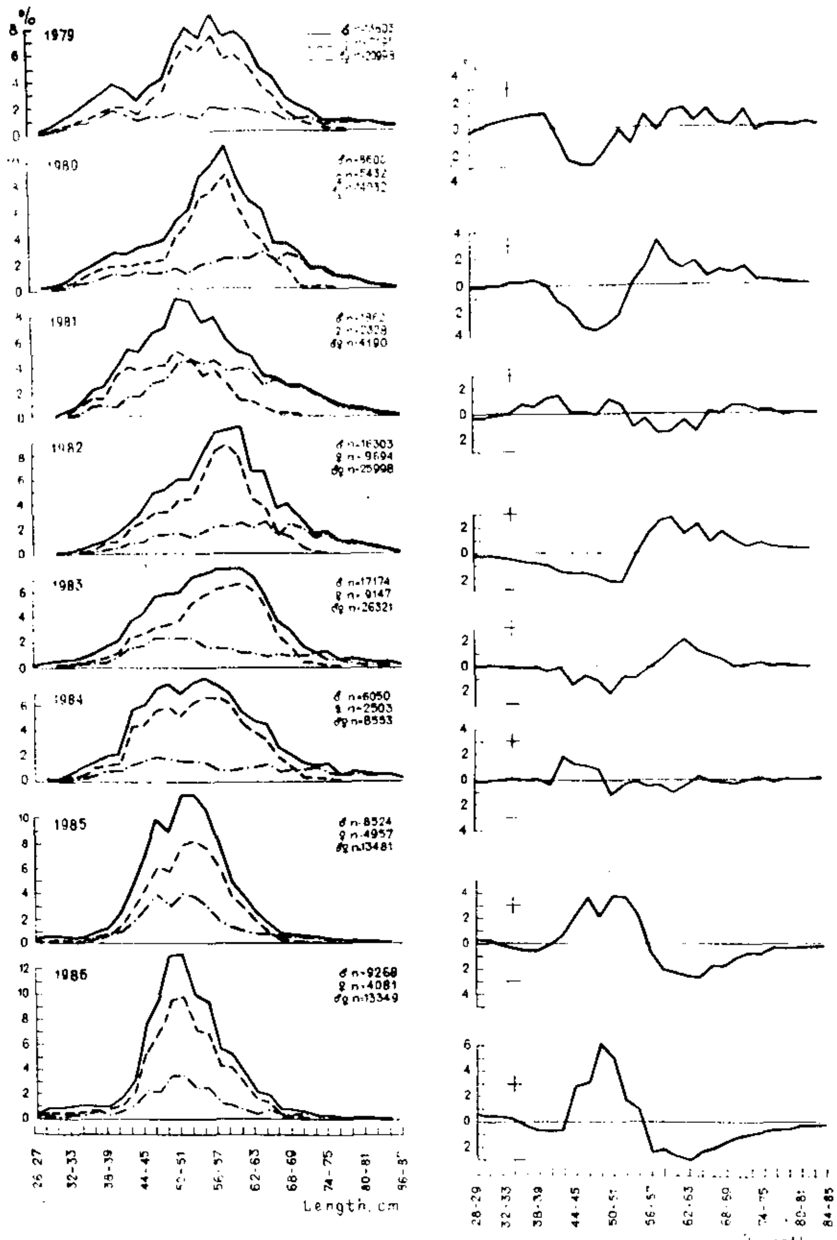

Fig. 7 Length composition of Greenland halibut and mean long-term errors in Div. 0B in 1979-86 according to trawl survey data

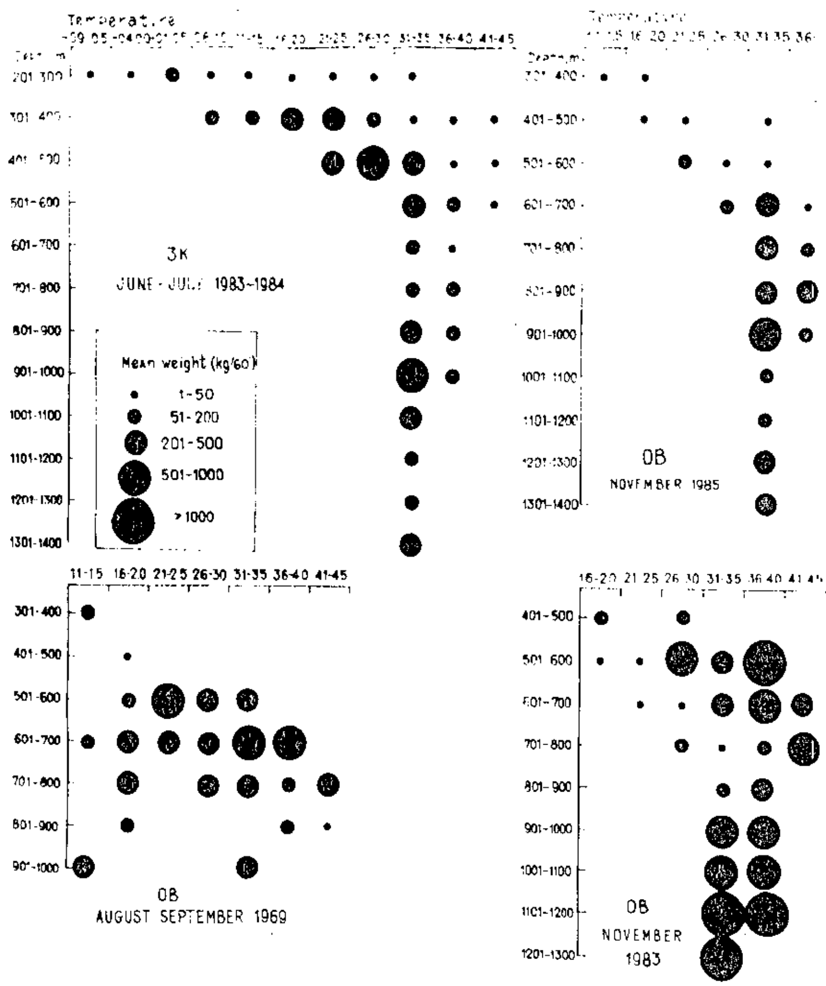

Fig. 8 Distribution of Greenland halibut mean catches within the 100-m ranges in connection with near-bottom temperatures (number of research hauls is designated by figures)

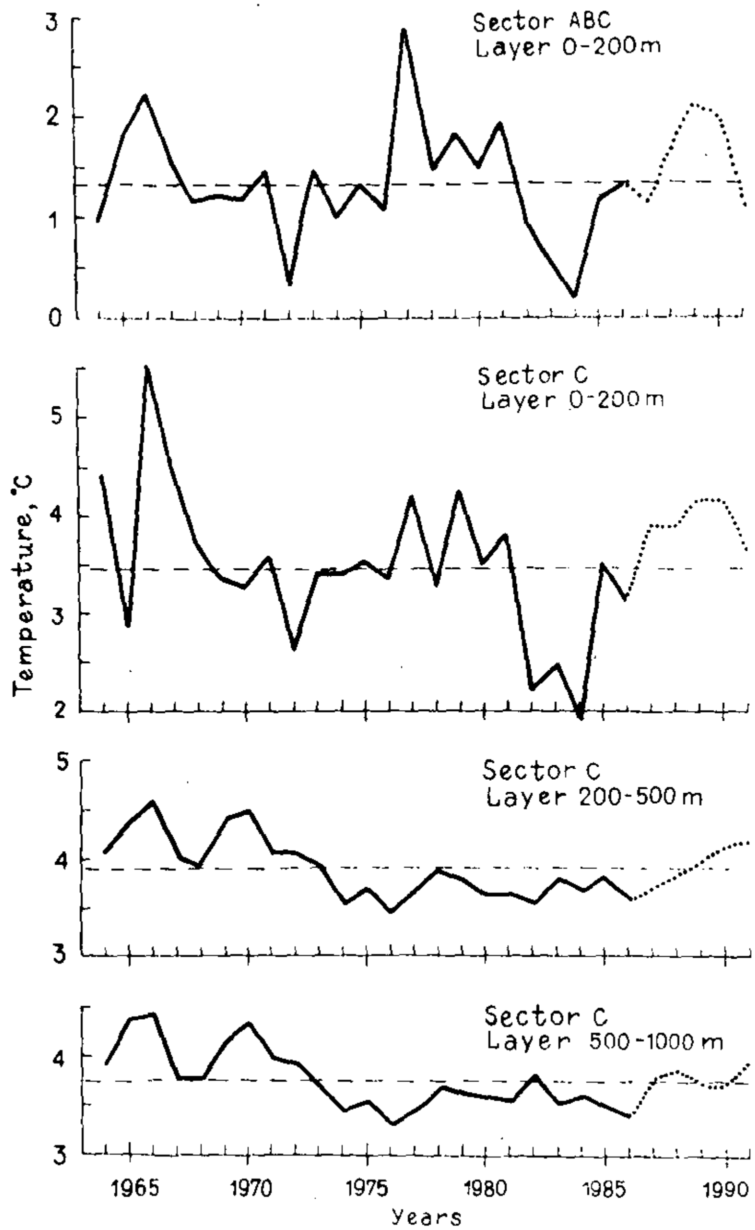

Fig. 9 Mean water temperature in various layers of hydrographic section 8-A in November 1964-86 (solid line), the average for 1987-91 (dotted line) and mean temperature in the layers in 1964-86 (broken line)

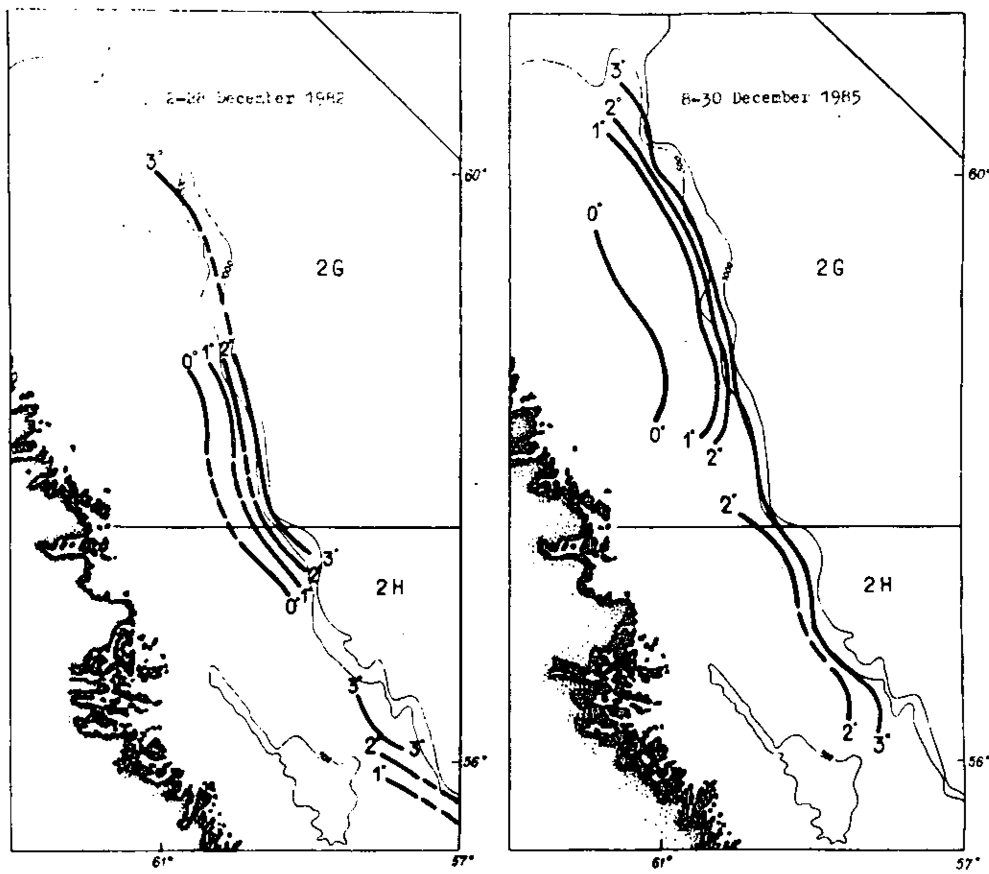

Fig. 10 Near-bottom isotherm location in the area of the shelf and continental slope of Northern and Central Labrador in December 1982 and 1985

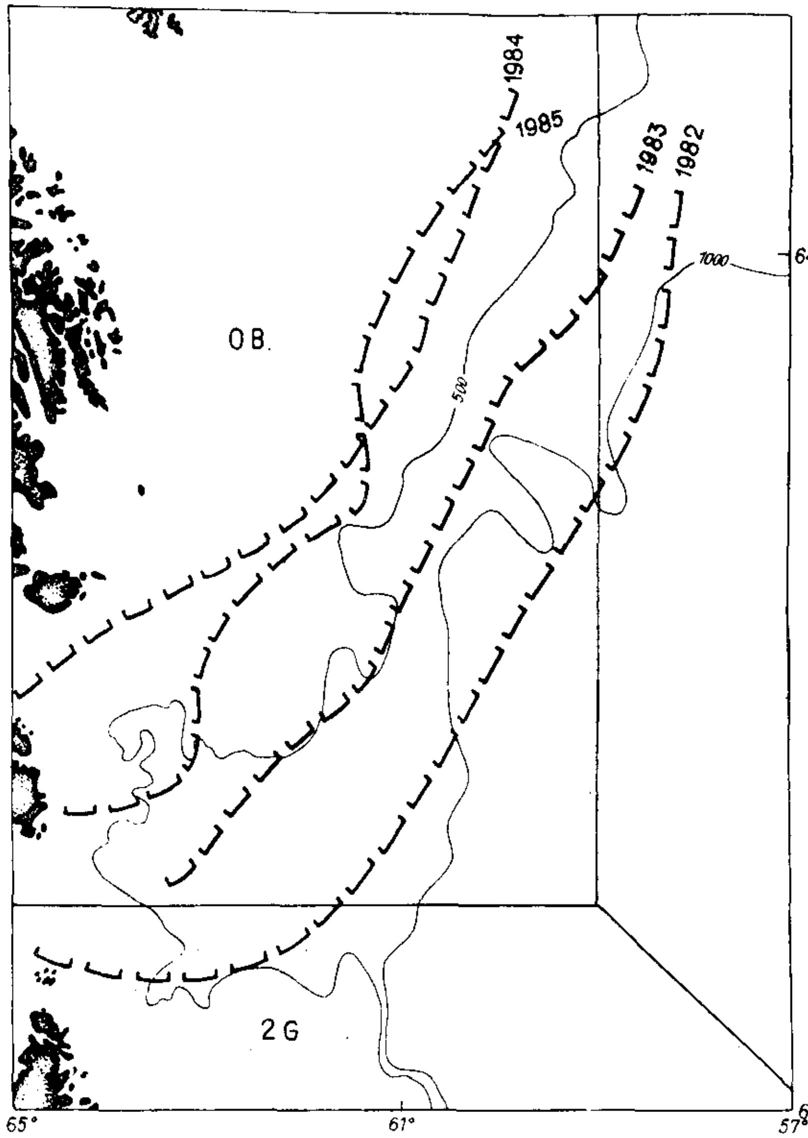

Fig. 11 Ice edge location during the trawl surveys off the Baffin Island in November 1982-85

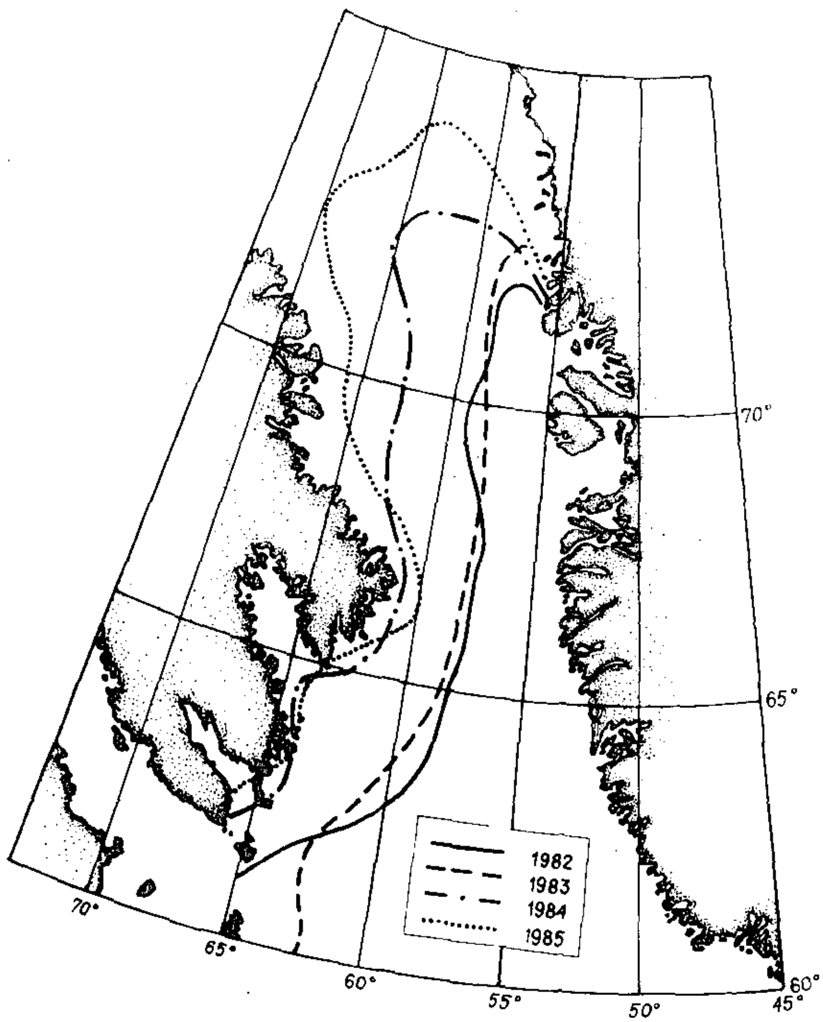

Fig. 12 Mean monthly location of ice edge in November 1982-85 off the Baffin Island according to Murmansk Meteorological Centre data

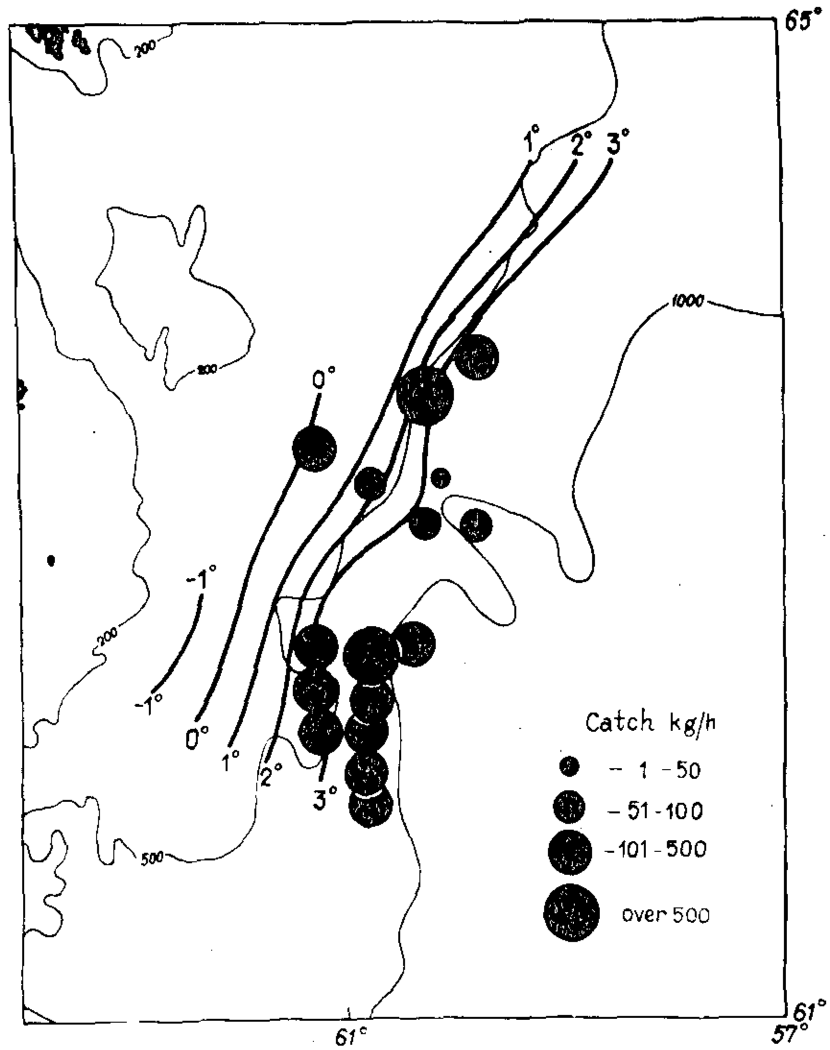

Fig. 13 Mean halibut catches per trawling hour taken during the trawl survey and near-bottom isotherm location on 18-29 September 1984 off the Baffin Island

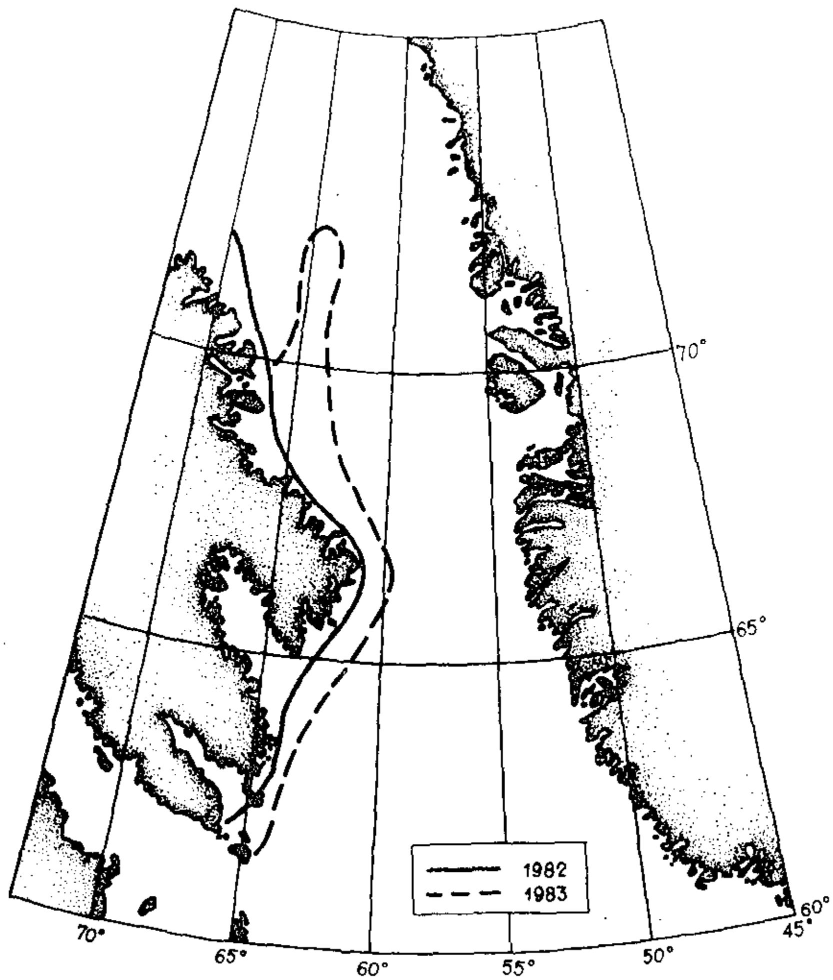

Fig. 14 Mean monthly location of ice edge in October 1982 and 1983 off the Baffin Island according to Murmansk Meteorological Centre data