International Commission for the Northwest Atlantic Fisheries

RESTRICTED

Serial No. 3932
(D.c.3)

ICNAF Res. Doc. 76/VI/109

ANNUAL MEETING - JUNE 1976

THE RESULTS OF THE STUDY OF COMMERCIAL RESERVE OF GREENLAND HALIBUT (REINHARDTIUS HIPPOGLOSSOIDES) AT THE CONTINENTAL SLOPE IN THE NORTH- WESTERN ATLANTIC

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Introduction

Modern trawl fishery is mainly performed on the shelf. Actually it is only in recent years that the reserves of the continental slope have begun to be involved in the sphere of the fishing fleet's activity. Greenland halibut is one of the objects of the fishery in the area of the continental slope in the North-Western Atlantic. The catchings of Greenland halibut by all countries nearly doubled in the period 1967 - 1974 (Table 1). The biggest increase of annual catchings was obtained in Subareas 0, 1, 2 due to exploitation of those areas of the continental slope which had been rarely used before. In the same Subareas the Soviet research vessels made 50 special cruises in 1967-1975 with Greenland halibut listed among other objects of the study. The depths of 500 - 1400 m were studied within the limits of which control trawlings were performed. Standard bottom trawls were used with mesh size prescribed by the Convention. The catchings of Greenland halibut were classified according to the usual method.

In 1975 an attempt was made to determine the reserves of Greenland halibut by area method. The results of the new Soviet research on Greenland halibut in the North-Western Atlantic are mentioned in the present work.

Fish distribution

The area inhabited by Greenland halibut in the North-Western Atlantic stretches from the Georges Bank to the Arctic parts of the Davis Sound. Commercial concentrations are found from the area of the Big Bank to the island of Disco. It is considered that the above mentioned expanse is inhabited by single Greenland halibut population (Chumakov, 1975).

The spawning of Greenland halibut takes place in winter to the South off the Greenland-Canadian cascade and in the Labrador Sea (Templeman, 1973). Fingerlings and larvae are drawn by currents to the near shore bank slopes, into troughs and deep bays. They are widely distributed northwards by the West-Greenland current and southwards by the Labrador current. These parts of the shelf are the main area inhabited by immature halibut. Having reached its maturity, halibut migrates for spawning to the continental slope zone while during the growing period it distributes both along the slope and in deep water troughs (canyons) on the shelf together with immature fish (Pechenik, Troyanovsky, 1970).

Special attention was devoted to the study of halibut taking into account the fact that in recent years the halibut fishery has been developing mainly in the continental slope area. With this purpose the vast expanse of the North Newfoundland Bank slope, up to 69°N

has been studied during the ice free period (June - December - beginning of January).

Table 1. The catchings of Greenland halibut by all countries in 1967 - 1974

Area	1967	1968	1969	1970	1971	1972	1973	1974
0+1								
2G								
2H								
2I								
3K								
3L								
Total catching	27971	35309	38832	38296	28990	43719	38502	41381

The results of the study showed that during the growing period (June - September) halibut disperses practically all over the studied area at quite a wide range of depths with the near bottom temperatures of water varying from 0,5° to 4,5°C). During the prespawning period (October - December) active migration of fish towards warmer waters (4° - 4,5°C) is observed, with further concentration in relatively limited spawning areas. Concentrations of prespawning halibut were discovered along the Central and Northern Labrador drop-off, in the southern part of Baffin Land and South-Eastern part of the Greenland-Canadian cascade.

The analyses of the regularity of concentrations' drifts based on the results of the commercial fishery in the area of the Greenland-Canadian cascade in October-December 1974 - 1975 allowed to make a scheme of pre-spawning migration of halibut (picture 2). As it can be seen in picture 1, fish from the vast expanse to the North and North-West concentrates in spawning areas in December.

The prespawning migrations of halibut at Baffin Land and Labrador slopes are difficult to determine by the results of commercial fishery as in some areas there is no harvesting because of the difficult bottom conditions. The geographical tendency is likely to be determined by age, judging by the northward increase in the dimension composition of the catchings, i.e. with growing age halibut gradually migrates to the North.

This fenomenon does not deny the possibility of migration of the biggest fishes from the area of Northern Labrador and Baffin Land to the Greenland-Canadian cascade.

The spawning areas of halibut were not studied as in January all of them are usually covered with ice. According to the preliminary data obtained at the Greenland-Canadian cascade in January, 1976 halibut migrates for spawning to the depth of more than 1000m.

Calculation of reserves

The habit of halibut inhabiting the continental slope to concentrate in limited areas during the

prespawning period was taken into account in order to determine the commercial reserves by method of trawl survey (other methods are scarcely usable because halibut cannot be fixed by sweeping apparatuses).

BMRT type vessels (scientific research vessels 'Zarnitsa', 'Suloy' and 16 fishing vessels) took part in the survey made in December 1975, all of them using the same type of trawl. According to the results of the trawlings made by them the charts of halibut distribution were made and integration of the catchings by area made it possible to avaluate the commercial stock in relative units. Trawl parameters and its capacity were introduced into calculations to discribe the stock in weight units,

The general solution is as followes:

$$W' = \int_0^{S_b} s^{ds} \qquad (1)$$

where W' is the stock described in fish density units, tons per hour of trawling.

b_s - current density.

S - area of subpopulation

Stock value in weight units $W = \frac{W'}{g \cdot S_{hour}}$ (2)

where S_{hour} is the area which is being trawled in one hour.

g - trawl's capacity.

After figure integration the first formula (1) reads as follows:

$$W' = S_e \sum_{i=1}^{N} \bar{b}_i n_i \qquad (3)$$

S_e - the surface of one elementariness of rectangle, km2

$\bar{b}_i = \frac{b_j + b_{j+1}}{2}$ - the fixed average density of fish (between two isolines - j and j+1), tons per hour of trawling.

n_i - the number of elementary rectangles of the area with the average fish density.

$N = \sum n$ - concentration area.

The most exact data was obtained for the prespawning part of the population which had concentrated in the South-Eastern part of the Greenland-Canadian cascade (picture 2). The survey of the places of the maximum density was made by 16 BMRT type vessels which completed 59 trawlings of 170 hours each within one day (December 12 - 13, 1975). Particularly in this period there was no meridional migration (southwards along fathom lines) and zone migration (across fathom lines) was reduced to minimum. The peripheral survey of subpopulation was made from December 2 till December 21, 1975 (42 trawlings, 59 hours long each.)

The following equipment parameters and logical functions were considered in calculations:

1. Trawl capacity (g) is constant and is equal to 0,1.
2. Horizontal opening of the trawl is 18m.
3. The average speed of trawling is 3,4 knots.
4. Halibut is concentrated in the 4m near bottom layer which is being trawled.

From points 2 and 3 it can be concluded that the following area is trawled in one hour:

$S_{hour} = 0,114\ km^2$

The station is divided into a number of elementary rectangles, in this case the criterion is 1/30 of the trapezium 5 miles long latitudewise and 6,55 miles longitudewise. Its surface is:

$$S_e = 3,75\ km^2$$

The calculations are made according to the working formula:

$$W = \frac{S_e}{e \cdot S_{hour}} \sum_{i=1}^{N} \bar{b}_i n_i = 32,9 \sum_{i=1}^{N} \bar{b}_i n_i \ m \qquad (4)$$

Its usage showed that the commercial stock of the prespawning part of the population (picture 2) is $2\widehat{\ }66.10^3$ ton

In Subareas 0 + 2G and 2H the commercial stock was calculated in the following way.

To analyse the data given by fishing vessels which operated in December 1975, the continental slope within the limits of 500 - 1100 m was divided into 11 sections (picture 3) (chart making similar to the Greenland-Canadian cascade was subject to substantial predicaments because of the difficult bottom conditions unsuitable for trawling).

For every section average daily catchings per hour were calculated. Halibut stock in relative units for one section K is equal to

$$W' = \frac{b_k \cdot S_k}{S_{hour}} \qquad (5)$$

where b_k is the average halibut density in section K, S_k - the surface of section K.

In Subarea 2H the average density of halibut concentration within the limits of 500 - 1100 m varied from0,1 to0,9 tons per hour of trawling , which makes

in average 0,4 tons per hour of trawling. In Subareas 0 and 26 it was 0,5 tons per hour varying from 0,2 to 1,3 tons per hour. Their surfaces were 3890 and 6100 sq. km respectively. The stock in weight units all over the area is

$$W = \frac{1}{g \cdot S_{hour}} \sum_{K\ 1}^{m} \bar{b}_k \cdot S_K = 87{,}8 \sum_{K=1}^{m} \bar{b}_K \cdot S_K \quad (6)$$

3here m (=11) is the number of sections (picture 3). The calculations according to the a.m. formula (5) gave the following results:

commercial stock in Subareas 0 2g - 272 . 10^3t

in Subarea 2H - 140 . 10^3t

Thus, the commercial halibut stock in the North-Western Atlantic by the data of three Subareas (1,0+2g, 2H)- is 678 . 10^3t.

It should be mentioned that the a.m. value is the lower limit of the stock since vast areas outside the depth limits of 500 - 1100 m were not taken into account, and the area southwards off 54°N where halibut was also observed in December 1975 was not considered either.

Eventual commercial removal of the halibut stock

For the discussion we have used the Greenland-Canadian cascade data concerning haibut. In our opinion, this subarea gave the most reliable information of the dimension composition as well as the age one.

In Fig. 7 the age composition */ of fishes in the catchings is described. It is reevaluated on the basis of dimension composition. By samples taken in 1975 the age of 349 males and 545 females was determined. It is seen in the picture that the maximum age of the harvested males is 14 years and of females - 16 years. The bulk of commercial catchings consists of males in the age of 6 - 12 years and females in the age of 6 - 13 years, which allowed to refer this species to fast growing fishes with a comparatively short life cycle.

Till the age of 5 years both males and females are growing nearly equally but with entering the maturing period the growth in dimetsions becomes slower (picture 6). Males begin to mature having reached the length of 45 - 57 cm at the age of 5 years and the females - at the length of 48 - 52 cm and the age of 6 - 7 years.

The average weight of males and females and their annual growth are given in Table 2. The annual frowth of biomass calculated by this data equals 16,6% for males and 20,7% for females.

*/ The age was determined by scale with the help of microprojector magnifying by 20. In cases where there were difficulties, ear stones were examined additionally.

The age was determined by ear stones in reflected light under a binocular microscope. The ear stones were grinded and moistened with glycerine - alcohol mixture beforehand. /*

Table 2.

The weight growth of Greenland halibut in the area of the Greenland-Canadian cascade.

Age	Average weight of males g	Average growth of males g	Age composition of males in catchings %	Average weight of females g	Average growth of females g	Age composition of females in the catching %
3	300	-	+	298	-	+
4	480	180	0,3	480	182	0,4
5	667	187	1,6	850	250	4,0
6	892	225	5,2	986	300	8,8
7	1174	282	16,2	1444	414	15,7
8	1490	315	21,4	1902	458	15,1
9	1785	295	18,2	2522	620	16,7
10	2078	293	13,2	3204	682	9,6
11	2395	317	12,0	3949	745	8,9
12	2720	325	7,2	4853	904	7,5
13	3050	330	4,7	5875	1022	6,8
14	-	-	-	6954	1079	4,0
15	-	-	-	8100	1146	2,1
16	-	-	-	9200	1100	0,3
Number of individuals	394	-	2327	545	-	822
$M_{aver.}$	1793,3	297,9 (16,6%)	-	2956,1	614,8 (20,7%)	-

Judging by the evaluation of the stock, eventual commercial removal may be approximately equal to the growth of biomass. Then the halibut harvest in the main

subareas where the stock has been avaluated should make 112 - 140 thousand tons (Table 3).

Table 3.

Eventual annual harvest of Greenland halibut in subareas of the North-Western Atlantic.

Subareas	Commercial stock (thousand tons)	Admissible harvest (thousand t)	
		while removing 16,6% of biomass	while removing 20,7% of biomass
1 (the Greenland - Canadian cascade)	266	44	55
o +2g	272	45	56
2H	140	23	29
Total:	678	112	140

When the figures which characterise the harvest of all countries in the North-Western Atlantic (Table 1) are being compared with those of the admissible harvest (Table3) it becomes vivid that there is an underexploitation of the Greenland halibut commercial stock.

The available data of the halibut harvest should be undoubtedly corrected by way of annual trawl and instrumental (underwater photographing) surveys.

The existing biological materials make it possible to analyse the unfluence of the specialized fishery in recent years on the Greenland halibut stock in the North-Western Atlantic. In pictures 4 - 5 there is the data of annual dimension composition of the Greenland halibut harvest for the areas of the Greenland-Canadian cascade and Baffin Land.

In the right part of the pictures the annual drifts from long-time average figures are shown. The pictures show that there were no substantial regular changes in the dimension composition of the population in the years of fishery in these areas and the dimension composition of halibut registered lately (1974, 1975) is practically similar to that of the first years of fishery.

It is also of interest in this respect to analyse the dynamics of the sex composition of halibut in the main spawning areas.

Table 4 shows that males dominate in all the catchings. The surplus of males during the whole prespawning period and the spawning period itself is characteristic of many fish species (Monastyrsky, 1940. Persov and Sakun, 1962). As to the halibut, it is connected with the fact that males are usually the first to start the spawning migration and they stay longer in the spawning areas too (Chumakov, 1969). It is obvious that sufficiently active harvest of prespawning concentrations may influence considerably the sex composition, since the number of withdrawn males will exeed that of females. The results of the analysis show that sex composition by areas and years remains rather stable.

Smidt (1969) determined a strict dependance between the number of Greenland halibut in Western Greenland and the change of the climat. According to his point of view, the cooling of water mass caused the growth of number and area of halibut in this part of the world.

As far as at present the secular recession of solar activity is being registered with consequent cooling of

water mass (Southward, Butler and Pennycnick, 1975) there is enough evidence to suppose that this phenomenon will further the improvement of survival conditions for halibut and lead to the increase of its populations.

Table 4. The percentage of females of Greenland halibut in trawl catchings by months and years in the North-Western Atlantic.

Year	The Greenland-Canadian cascade	Baffin Land	Northern Labrador	SNB shelf
1969		VIII-IX $\frac{46.5(914)}{610 - 860}$		
1970		IX-X $\frac{47.3(482)}{560 - 1020}$		
1971	VI-X $\frac{38.0(2337)}{600 - 920}$	VIII $\frac{46.1(2556)}{620 - 1020}$	IX-X $\frac{48.6(2246)}{415 - 900}$	VIII $\frac{47.9(521)}{325 - 400}$
1972	VII-IX $\frac{38.2(676)}{440 - 790}$	VIII-IX $\frac{35.6(1142)}{500 - 800}$		VI-VIII $\frac{51.0(1459)}{300 - 400}$
1973	IX-XI $\frac{38.3(2611)}{480 - 750}$			
1974	IX-XII $\frac{39.9(5516)}{520 - 1190}$	VIII-IX $\frac{43.6(1229)}{600 - 875}$	VI $\frac{46.3(674)}{540 - 1140}$	II,VI $\frac{55.1(2064)}{400 - 500}$
1975	VI-XII $\frac{39.9(822)}{560 - 1140}$	VIII-IX $\frac{42.5(1899)}{560 - 840}$	VI-X $\frac{45.8(599)}{570 - 900}$	I-II,VIII $\frac{52.0(1359)}{320 - 450}$
1969-1975	38.9(11962)	43.6(8222)	46.9(3519)	51.5(5403)

N O T E : numerator - percentage of females in the catchings,
parentheses - number of females ,
denominator - depth range of trawling.

Inference

1. The continental slope of the North-Western Atlantic is the area inhabited by mature Greenland halibut. During the prespawning period the fish concentrates in the spawning area within narrow depth limits which allows to count the stock by method of trawl survey.

2. On the basis of the works made in December 1975 from the Soviet scientific research and fishing vessels in Subareas 2H, 2G, o, 1 at the depth 500 - 1100 m the reserve of mature halibut was determined - 678 . 10^3 tons. Taking into consideration wider depth distribution of halibut and its distribution to the South of the studied area, we assume that the a.m. figure represents the lower limit of the stock.

3. The analysis of the biological data, the survey of the reserve show that the present fishery of Greenland halibut is performed on a narrow scale. It can be increased to not less than 112 thousand tons without any danger of damaging the continental slope stock in Subareas 2H, 2G, o and 1.

4. The quotas for halibut fishery which are established on the basis of the harvest obtained in previous years, mainly in the shelf zone, are not grounded enough as they nearly do not consider the possibility of exploitation of mature fish stock inhabiting the continental slope.

List of publications

1. G.N. Monastyrsky - 1940 - The roach stocks in the North Caspian and methods of their calculation. The scientific works of VNIIRO, v.11.

2. G.M.Persov, O.F.Sakun - 1962 - Genital glands' condition of pink selmon in different phases of its life cycle in conjunction with its acclimatization in the White and Barents seas. Scientific records of LGU. No.311, issue 48.

3. L.N.Pechenik, F.M.Troyanovsky - 1970 - The resourse base of trawl fishery at thecontinental slope in the North-Western Atlantic. Murmansk.

4. A.K.Chumakov - 1975 - To the problem of locality of Greenland halibut populations in the North-Western Atlantic. The scientific works of PINRO, issue 35, Murmansk.

5. A.K.Chumakov - 1969 - Fishery and marking the Greenland halibut Reinhardtius hippoglossoides (Walbaum) near Iceland. "Problems of Ichthyology", vol.9, issue 6.

6. Historical catches of TAC species by stock area and country for the period 1965-1974. 1976.Annu. Meet. int. Comm. Northw. Atlant. Fish., Comm. Doc. 76/VI/10, Serial No. 3773.

7. Smidt E.L.B. 1969 The Greenland halibut, Reinhardtius hippoglossoides (Walb.) biology and exploitation in Greenland Waters. Meddelelser fra Danmark Fiskeri-og Havundersogelser, 6, No.4 København.

8. Southward A.I., Butler E.I. & Linda Pennycuick. 1975. Recent cyclic changes in climate and in abundance of marine life. Nature, vol. 253. February 27, pp 714-717.

9. Templeman W. 1973. Distribution and abundance of Greenland halibut in the Northwest Atlantic. ICNAF. Research Bulletin, No. 10

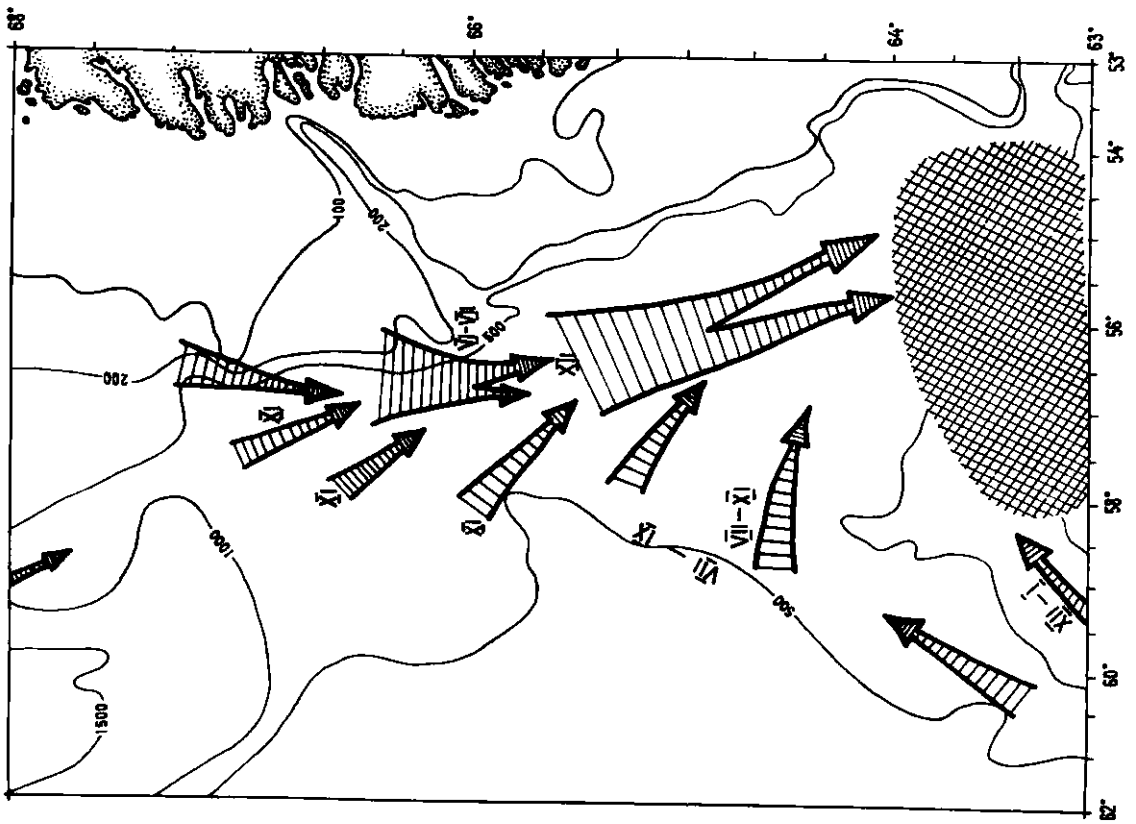

Figure 1 - The scheme of prespawning migration of Greenland halibut in the Greenland-Canadian cascade area.

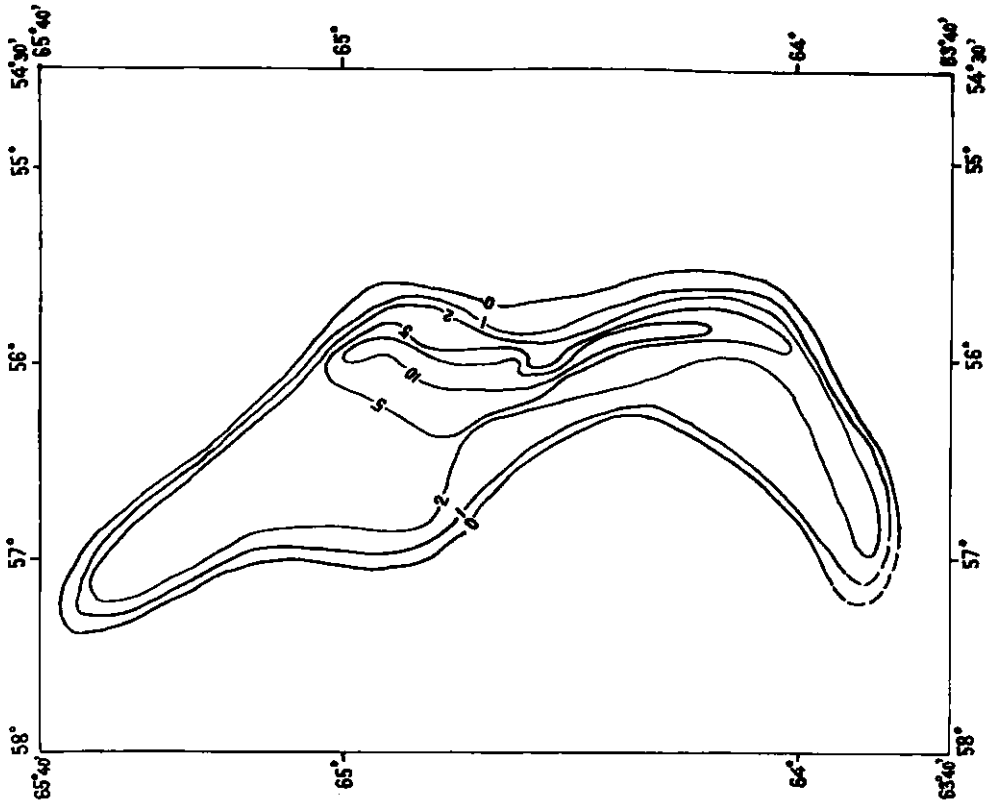

Figure 2 - Distribution of isolines of average catchings (tons/hour of trawling) of Greenland halibut in the Greenland-Canadian cascade area (beyond isoline 0 the catchings of halibut are rare) in the period December 2 - 12, 1975.

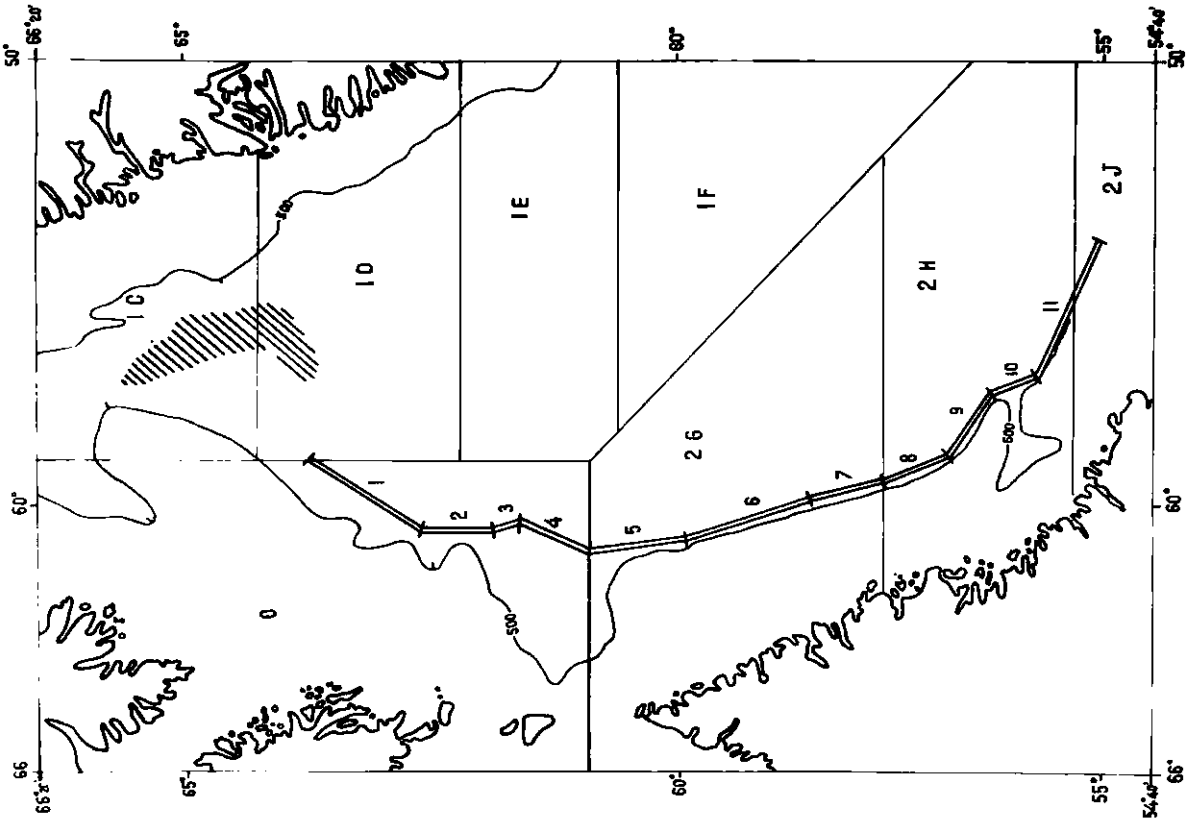

Figure 3 - The situation of the sections of trawl survey in the North-Western Atlantic.

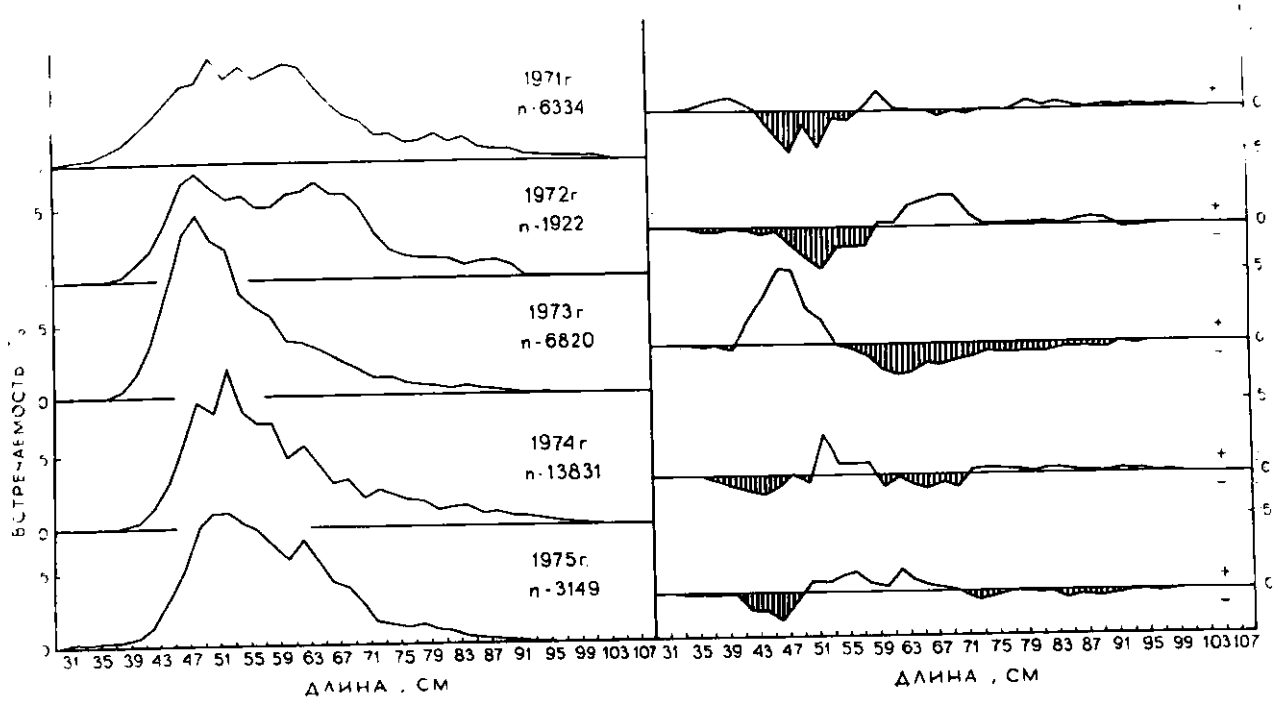

Figure 4 - Dimension composition of Greenland halibut by years for the Greenland-Canadian cascade area.

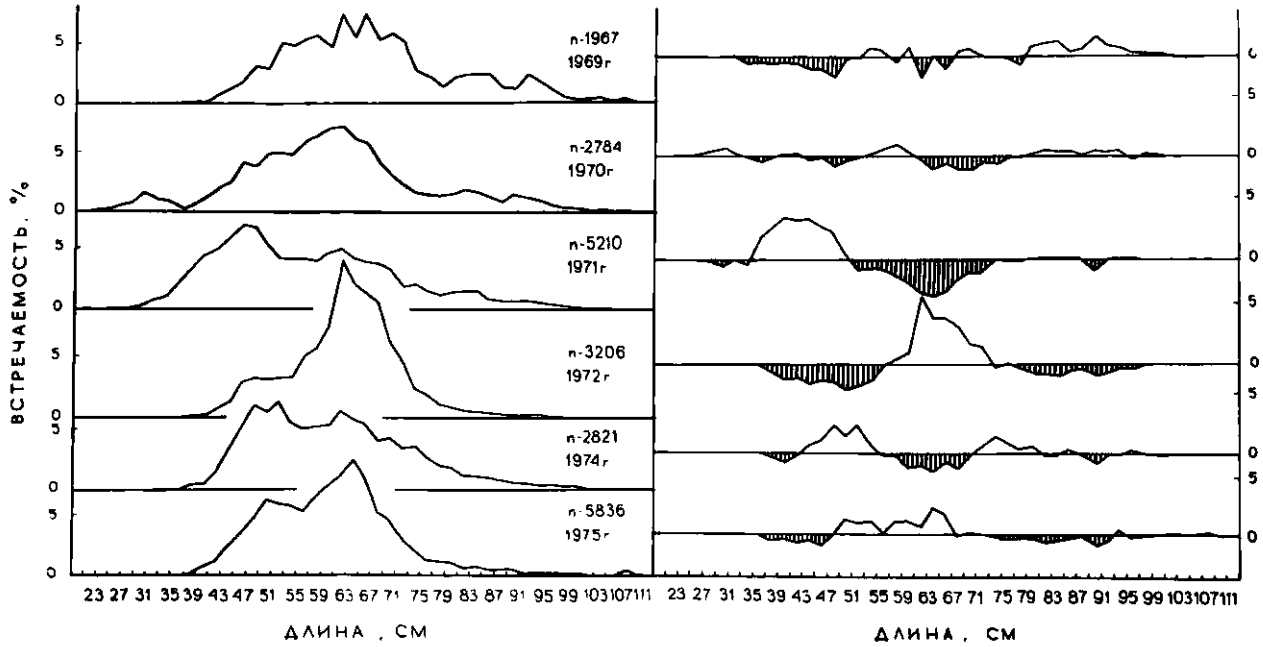

Figure 5 - Dimension composition of Greenland halibut by years in Baffin Land area.

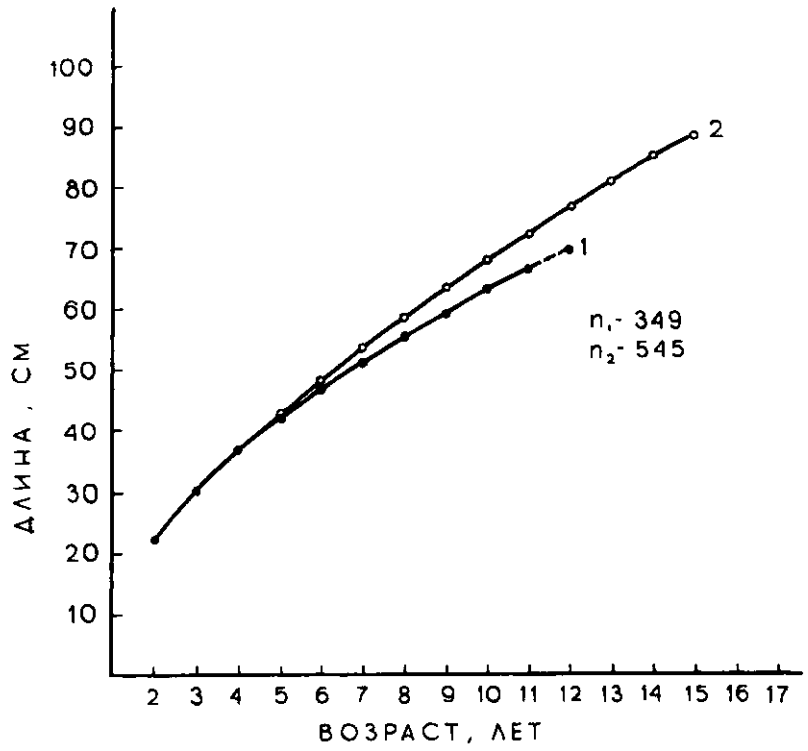

Figure 6 - The length growth of Greenland halibut in the Greenland-Canadian cascade area. 1 - males, 2 - females.

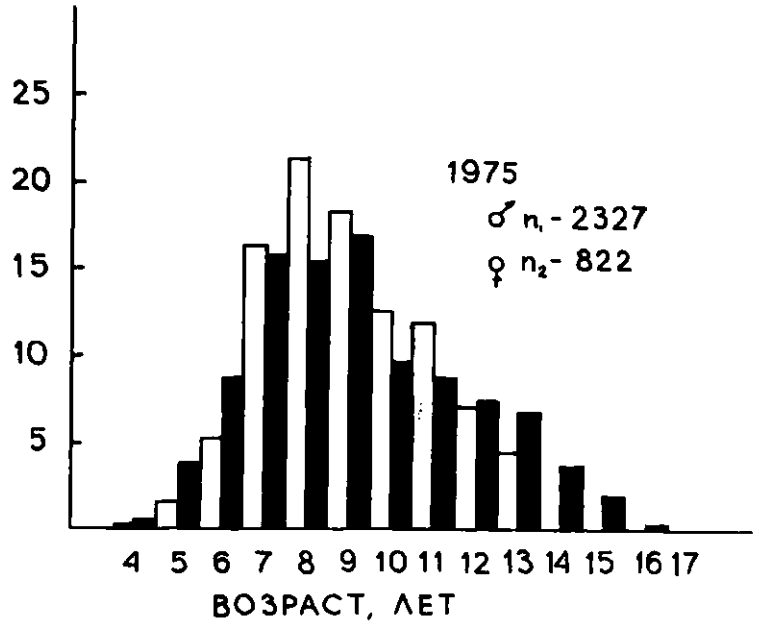

Figure 7 - Age composition of males (white columns) and females (black columns) of halibut in the Greenland-Canadian cascade area. (1975)