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Some Indicators of the Greenland Halibut Local Groups in the North Atlantic

by

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ABSTRACT

The wide area of distribution of Greenland halibut in the North Atlantic with the prolonged pelagic drift of juveniles create the necessary prerequisites for forming and existence of groups with different degree of diversity. The system of constant currents in the North Atlantic is the determinant of their locations.

Analysis of biological peculiarities of Greenland halibut local groups is presented in this paper.

Biological, physiologic, biochemical and other characteristics of Greenland halibut groups of the North Atlantic area are investigated. Malic enzyme (ME), sorbitol dehydrogenase (SDH) and esterases (EST) of Greenland halibut muscular tissue are used as biochemical markers. Polymorphizm is detected for all the systems.

Geographically isolated large groups and small regional ones are shown to be characterized by certain features the dependence of which on environmental conditions determines the heterogeneity of the analysed material regarding both ecologic-physiological and biochemical aspects. The level of heterogeneity and its reasons are discussed.

INTRODUCTION

The range of Greenland halibut in the North Atlantic covers an extensive area - from the Novaya Zemlya in the East to the Canadian coast in the West, from the North Spitsbergen to the latitude of Bergen in the Norwegian Sea and along the American coast from 76°N to nearly 42°N (Milinsky, 1944; Boyar, 1964). Here we can

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mark out three main areas where Greenland halibut form dense concentrations which are important for fishery: in the eastern Norwegian Sea, in the western Barents Sea, in the insular slope of Iceland and in the Northwest Atlantic areas (Fig.1).

It is suggested that in these areas three large local populations of Greenland halibut are distributed: Norwegian-Barents Sea, population Icelandic and Greenland-Canadian ones. They are rather isolated geographically but their isolation is not absolute (Chumakov, 1969, 1975; Nizovtsev, 1974).

The goal of the paper is to analyze some features characterizing Greenland halibut (Reinhardtius hippoglossoides Walb.) concentrations dwelling in the eastern and western parts of the area. Their studying is necessary for determination of the isolation degree of the stocks in these North Atlantic areas. While determining the isolation of stocks, i.e. studying intraspecific structure, it is necessary to identify its every component in a way allowing to control the identification by research methods, and the results should comply with theoretical ideas about the species. The most important point is detection of reproductive isolation between populations which can be conducted by any biological characteristic (meristic, morphological, karyological etc.).

Biological markers detected by electrophoresis with further hystochemical staining are the most expressed features for determination of differences between groups. Distribution of frequencies of markers occurancy should answer a hypothesis about heredity of differences. According to the Hardy-Weinberg law the correspondence of actual data to the calculated ones proves the genetic unity of the investigated total gene diversity.

MATERIALS AND METHODS

Halibut samples collected by bottom trawls in 1984-86 were analysed. Materials were taken in Divs. 0,2G, 2H, 2J, 3K off the North American coast (the ICNAF areas) and in the ICES areas I, IIa, IIb of the Northeast Atlantic.

Length, weight, sex, maturation and age of all fishes were determined by otoliths. The data obtained formed the grounds for mean statistical characteristics calculation. Data on biological markers

were obtained by the electrophoresis method in a polyacrylamide gel with the subsequent gystochemical staining (Maurer, 1971; Korochkin et al., 1974).

Halibut tissue taken from the anterior part of the dorsal muscle was the material for biochemical analysis . Proteins were divided by the electrophoresis on the monostratum carrier in the vertical blocks of a chamber constructed in the Moscow State University (Truveller and Nefedov, 1974). Electrophoresis is a buffer of tris-EDTA-borate with pH 8.3 and potential 220 V was carried out for 1 hr. 40 min.

Electrophoresis was carried out by the generally known methods (Salmenkova and Malinina, 1976; Korochkin et al., 1977). Statistical processing of genetic data, checking the correspondence between the actual data and calculated ones were conducted in accordance with recommendations of L.A.Zhivotovsky (1979, 1983). 1110 specimens of Greenland halibut caught in the western North Atlantic and 463 specimens from the eastern part were investigated (Table 1).

RESULTS

Some polymorphic fermental systems used in intraspecific group investigations are observed in Greenland halibut tissue (Mork and Haug, 1983; Grant et al., 1984). Under conditions of electrophoresis polymorphism was detected in Malic enzyme (ME, E.C. I.I.I.40), sorbitol dehydrogenase (SDH, E.C. I.I.I.14) and non-specific esterases (EST). Analysis of distribution of phenotypes, genotypes and genic frequencies are adduced only for esterases. Alpha naphtyl acetate was the substrate for their marking out. Three zones of enzyme activity were determined. The most polymorphic was the third (beta globulin) zone. Five fractions of esterases was noted there. They were lettered by A,B,C,D and E in accordance with reduction of their electrophoretic mobility. The fastest was the A fraction, the slowest one - the E fraction. It was noted that fraction electrophoretic mobility of Greenland halibut specimens in the eastern North Atlantic was identical to that in its western part. That is why the nomenclature of fractions is the same for all samples.

Analysis of distribution of esterase phenotypes proves that Greenland halibut samples both from eastern and western parts of the

area are principally in equilibrium (Table 2). It is noted that the distribution equilibrium of fenotypes with B and C alleles is broken in two (No. 3, No. 10) of eleven investigated samples (Tables 1,2).

Correspondence of actual phenotype distribution to the theoretically calculated one proves that temporal and spatial equilibrium is maintained throughout the area (Table 3). That is why it can be supposed that any local stock of Greenland halibut is in equilibrium and in relatively isolation in every part of the area.

However, sample analysis data obtained from the eastern and western North Atlantic do not prove this supposition (Table 1). Exceeding of the chi-square value (9.49 at 0.05) was noted both in the eastern and western parts of the area (Table 2). The comparison of indices by pairs showed that a degree of difference calculated by the identity criterion (Zhivotovsky, 1979, 1983) is very high (69.265) with index of similarity 0.9735. Because of it we carried out an analysis of phenotype distribution in every regional group. With this purpose the comparison of sample pairs was made (Table 4).

It turned out that if samples from the Northwest Atlantic are different then index of similarity proves that they are relatively homogeneous. In the eastern part of the area index of similarity is lower (0.9200) in most cases (Zhivotovsky, 1979, TINRO Recommendations, 1980), that proves the heterogeneity of the samples investigated (Table 4). To a certain extent it could be a result of non-equivalent number of investigated samples. However, a tendency of differentiation in gene diversity is doubtless. Thus, the different stocks of the eastern and western North Atlantic have different degree of heterogeneity.

Analysis of frequencies of allele occurancy, degree of heterogeneity, efficient number of alleles and portion of rare alleles showed the similar distribution of these markers for every gene diversity in every area (Tables 5, 6). Non-equilibrium of diversity in investigated samples is noted by the B and C alleles (Table 5) in the eastern North Atlantic and by the A and D alleles in the western North Atlantic (Table 6). Estimations of heterogeneity of total gene diversities was carried out according to the recommendations of L.A.Zhivotovsky (1983) and Snedecore - Irvine (Workmann, Niswander, 1970) and the results were identical (Tables

5, 6).

Thus, there are Greenland halibut total gene diversities in the eastern and western parts of the area differing in the character esterase distribution.

DISCUSSION

The data obtained allow to suppose a selective character of distribution of specimens with definite genotype in the North Atlantic Greenland halibut local groups. Apparantly, the differential distribution of specimens with definite genotypes is caused by the environmental differences in every part of the area. The main factor determining the difference between local groups is the system stable currents of the North Atlantic (Fig. 2). Difference in character of water movement in the eastern part (from the South to the North) and in the western part (from the North to the South) probably determines what alleles these groups are different in. Different selective values of alleles in many enzyme systems in differing environmental conditions are shown on a great number of samples (Kirpichnikov, 1979). Functional differences of alleles expressed by enzyme activity under the definite environmental conditions usually influence upon morphological peculiarities of specimens (Kirpichnikov, 1987). Using extreme conditions (temperature, oxygen etc.) it was noted that frequency of any allele changes because of different viability of specimens bearing these genotypes. That is why we studied length-age characteristics of specimens with A,B,C,D alleles in both parts of the North Atlantic .

Generally known that Greenland halibut males and females are larger in the northern part of the Northwest Atlantic (Chumakov, 1975; Chumakov, Serebryakov, 1982). Comparison of mature and immature specimens length composition shows that immature specimens are distributed mainly in the southern parts. Mature specimens are distributed chiefly in the northern part of the west area - over the continental slope of the Baffin Island and over Greenland - Canadian Threshold. Older specimens dominate in the northern and central areas. Average weight and length fluctuations of fishes of the same age in different areas are substantial but their amplitude is somewhat lower in the western North Atlan-

tic. This difference can be explained by geostrophic peculiarities of currents in the eastern and western North Atlantic (Fig.2), by spawning grounds locations in the zone of stable currents and by different directions of drift of Greenland halibut at their early stages. Prolonged period of passive drift of Greenland halibut eggs and larvae in pelagic waters promotes wide distribution of this species in the Atlantic coastal areas of the North America and Greenland and in the Barents Sea areas.

Greenland halibut at early stages migrate mainly to the South along the West Greenland, Baffin Island (Canadian) and Labrador Currents from the spawning grounds situated in the south of the Greenland-Canadian Threshold and partly over the Labrador continental slope (Fig. 3).

It is known that moving to the north a branch of the West Greenland Current flow to the left joining the Baffin-Island (Canadian) and Labrador Currents. Thus, prerequisits necessary for drift of Greenland halibut larvae and juveniles from the West Greenland spawning grounds to the shelves of Labrador, Newfoundland (NAFO Subareas 2+3), West Greenland and Baffin Island (NAFO Subareas 0+1) are formed.

In the Northeast Atlantic Greenland halibut at pelagic stages migrate from the spawning grounds located over the continental slope between 71°N and 72°N (Sorokin, 1967) to the northeastern and eastern areas of the Barents Sea where they grow and develop.

Stable currents together with water circulation and eddies retard the drift and make larvae to stay in definite areas of dwelling which influences upon the distribution and abundance of Greenland halibut. Peculiarities of living conditions are the reasons for multiformity of Greenland halibut morphophysiological markers in different parts of the North Atlantic. According to our data the mean length-weight characteristics of specimens in age groups are similar to each other in both parts of the North Atlantic (Tables 7,8,9,10).

Peculiarity of distribution of length-age groups in the eastern and western parts of the North Atlantic determines the heterogeneity degree of a regional group. Apparently, biochemical markers are connected with length-weight characteristics by physiologic

processes and remote genetic connections between functional peculiarities of isozymes and gene blocks which determine the morphological markers.

Thus, Greenland halibut specimens with different markers are distributed in the eastern and western North Atlantic. Geographical remoteness promotes their isolation, and genetic characteristic proves their peculiar variability in spite of their biochemical idenity in every part of the area. Investigations testify to a complex structure of halibut populations, biological peculiarities in various Atlantic areas which formed in the course of evolutionary adaptation to the environmental factors.

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Table 1 Dates and sampling positions

No. of sample	Date	Area	Position		Vessel
			Northeast Atlantic		
I	I5.II.85	II	73°20'	I4°I0'	MG-1356 "Kokshaisk"
2	I0.II.84	II	76°27'	I4°I9'	MG-1362 "Vilnius"
3	2I.II.84	II	74°3I'	II°05'	MG-1362 "Vilnius"
4	06.I0.84	II	72°27'	I5°I3'	MG-1362 "Vilnius"
			Northwest Atlantic		
5	22.I2.84	2	55°02'	53°58'	MB-0023 "N.Kuropatkin
6	06.I2.84	2	59°30'	60°22'	MB-0023 "N.Kuropatkin"
7	I2.I2.84	2	57°02'	58°52'	MB-0023 "N.Kuropatkin"
8	0I.0I.86	2	55°22'	55°50'	MB-0422 "N.Kononov"
9	30.II.84	0	62°I8'	60°26'	MB-0023 "N.Kuropatkin"
I0	I5.II.85	0	62°46'	60°55'	MB-0422 "N.Kononov"
II	28.06.84	3	50°I4'	52°53'	MB-2645 "Suloi"

Table 2 Distribution of chi-square values of Greenland halibut esterases by phenotypes in samples 1,2,3 etc. in the North Atlantic

Phenotype	Northeast Atlantic					Northwest Atlantic							
	I	2	3	4	by area	5	6	7	8	9	IO	II	by area
AA	0,009	0,00I	0,03I	0,06I	0,049	0,047	0,I73	0,0I4	0,I24	0,339	0,7I3	0,005	0,746
BB	0,854	0,I5I	7,I07	0,63I	2,749	0,290	0,788	0,532	0,658	0,083	I,043	0,025	3,039
CC	I,345	0,792	0,I09	0,857	3,0I0	0,662	I,2I3	I,974	I,229	0,534	I,429	0,333	8,434
DD	0,949	0,37I	0,I07	0,265	I,753	0,I97	0,376	0,283	I,498	0,387	0,889	0,2I8	4,II5
EE	0,066	0,000	0,0I0	0,0I7	0,076	0,565	0,057	0,044	0,34I	0,II8	0,26I	0,007	0,506
AB	0,005	0,005	0,026	0,095	0,I22	0,052	0,200	0,020	0,2I3	0,088	0,308	0,027	0,73I
AC	0,000	0,000	0,064	0,0I2	0,002	0,00I	0,0I3	0,0I5	0,032	0,2I7	0,465	0,II4	0,I24
AD	0,008	0,004	0,000	0,000	0,0II	0,004	0,0I9	0,003	0,07I	0,060	0,334	0,000	0,I46
AE	0,003	0,053	0,005	0,003	0,003	0,0I5	0,008	0,025	0,030	0,035	0,047	0,007	0,056
BC	0,834	0,506	0,332	0,602	0,859	0,50I	0,882	I,646	0,454	0,005	0,789	0,055	4,072
BD	0,550	0,068	0,292	0,077	I,I46	0,032	0,065	0,004	0,454	0,003	0,247	0,033	0,I54
BE	0,0I5	0,006	0,083	0,0II	0,330	0,0I5	0,003	0,046	0,0I0	0,027	0,24I	0,006	0,0I4
CD	0,960	0,656	0,036	0,38I	I,874	0,280	0,490	0,629	0,935	0,46I	0,7I9	0,662	4,324
CE	0,I02	0,000	0,000	0,0II	6,III	0,007	0,093	0,066	0,I85	0,0I8	0,086	0,003	0,204
DE	0,0I0	0,028	0,000	0,0I3	0,0I7	0,I06	0,028	0,I07	0,546	0,069	0,2I3	0,048	0,572
Total x^2	5,7I	2,634	8,202	3,036	I2,II2	2,774	4,408	5,408	6,342	2,444	7,436	I,543	27,237
No.of spec.	200	I00	67	96	463	II0	I94	224	I98	I02	I94	88	IIIO

Table 3 Distribution of esterase phenotypes of Greenland halibut in the North Atlantic

	Northwest Atlantic								Northeast Atlantic							
	Number		Portion, %		arc sin. p		x^2 (by Fisher)	x^2 (by Student)	Number		Portion, %		arc sin. p		x^2 (by Fisher)	x^2 (by Student)
	Actual	Calculated	Act.	Calcul.	Act.	Calc.			Act.	calcul.	Act.	Calc.	Act.	Calc.		
AA	67	22,35	6,04	2,02	0,495	0,284	0,746	3,534	II	3,902	2,38	0,84	0,3II	0,I84	0,049	0,222
BB	I37	49,56	I2,34	4,46	0,7I7	0,428	3,039	I0,5I5	89	38,777	I9,22	8,38	0,907	0,588	2,749	8,553
CC	239	I04,I4	2I,53	9,38	0,964	0,623	8,434	24,728	94	42,032	20,30	9,08	0,935	0,6I3	3,0I0	9,347
DD	I55	54,706	I3,96	4,94	0,767	0,448	4,II5	I2,899	70	29,309	I5,I2	6,33	0,798	0,507	I,753	6,0I0
EE	53	I5,588	4,78	I,40	0,442	0,237	0,506	2,47I	I3	2,0II	2,8I	0,43	0,336	0,I3I	0,076	0,373
AB	2I	66,564	I,89	5,99	0,277	0,49I	0,73I	3,4I7	I4	24,6	3,02	5,32	0,348	0,465	0,I22	I,044
AC	8I	96,49	7,29	8,69	0,546	0,599	0,I24	2,334	27	25,6I3	5,83	5,53	0,486	0,473	0,002	0,I7I
AD	52	69,934	4,68	6,28	0,437	0,507	0,I46	2,088	I8	2I,388	3,89	4,62	0,398	0,432	0,0II	0,332
AE	27	37,329	2,44	3,37	0,3II	0,07I	0,056	0,939	4	5,602	0,86	I,2I	0,I86	0,220	0,003	0,079
BC	37	I43,68	3,33	I2,94	0,363	0,735	4,072	I0,946	28	80,745	6,05	I7,44	0,495	0,86I	0,859	6,987
BD	87	I04,I38	7,84	9,39	0,566	0,623	0,I54	2,699	36	67,425	7,77	I4,56	0,566	0,787	I,I46	5,944
BE	50	55,586	4,50	5,00	0,428	0,45I	0,0I4	0,605	I2	I7,66	2,59	3,8I	0,324	0,392	0,330	0,486
CD	24	I50,957	2,I6	I3,59	0,298	0,755	4,324	9,464	28	70,I97	6,05	I5,I6	0,495	0,80I	I,874	6,I25
CE	60	80,578	5,42	7,27	0,469	0,546	0,204	2,648	8	I8,386	I,73	3,97	0,262	0,403	6,III	0,786
DE	20	58,40	I,80	5,26	0,269	0,465	0,572	2,9I9	II	I5,353	2,38	3,32	0,3II	0,363	0,0I7	0,334
	III0		I00				27,236	92,206	463		I00				I2,II2	46,793

r_r=0,9735 I_I=69,265

A=0,820 B=I,I93 C=0,008 D=0,286 E=0,904

Table 4 Similarity index and identity criterion of Greenland halibut samples in the North Atlantic

No. of sample	I0	9	6	7	8	5	II
			Northwest Atlantic				
I0	-	0,9504	0,9678	0,9233	0,957I	0,9523	0,9254
9	22,52[X]	-	0,9509	0,9056	0,9367	0,9468	0,9304
6	22,97[X]	2I,45	-	0,9620	0,9570	0,98I0	0,9578
7	48,49[X]	45,02[X]	25,20[X]	-	0,93I7	0,9569	0,9324
8	3I,67[X]	32,74[X]	33,7I[X]	53,I4[X]	-	0,9552	0,9454
5	25,49[X]	I9,69	I0,67	22,72[X]	25,34[X]	-	0,9475
II	34,73[X]	20,94	20,44	32,2I[X]	25,7I[X]	20,53	-

No. of sample	I	4	2	3
		Northeast Atlantic		
I	-	0,9439	0,9352	0,9200
4	2I,95	-	0,88I4	0,8902
2	23,20[X]	28,64[X]	-	0,8647
3	32,I2[X]	29,96[X]	36,24[X]	-

[X] Difference is statistically significant

Table 5 Genotype markers of Greenland halibut samples in the Northeast Atlantic

No. of sample	Spec.	Gene frequency A	B	C	D	E	X^2	X^2	Heterozygosis	Number of alleles	Number of phenotypes	Rare alleles + dispersion	Portion of rare alleles
I	200	0,065	0,2475	0,3025	0,300	0,085	6,840	5,7I0	0,400	3,4967	I2,2269	4,5869±0,047	0,08262
2	I00	0,085	0,295	0,380	0,225	0,0I5	3,928	2,634	0,450	3,I395	9,8565	4,I94I±0,I69	0,I6II8
3	67	0,0896	0,4925	0,I642	0,I567	0,097	3,425	8,202	0,388I	3,4I08	II,6336	4,4674±0,I78	0,I0652
4	96	0,I563	0,2292	0,3I25	0,2447	0,0573	4,325	3,036	0,3646	3,367I	II,3374	4,6966±0,074	0,06068
	463	0,09I8	0,2894	0,30I3	0,25I6	0,0659	I2,II2	46,793	0,40I7	3,5224	I2,4073	4,6I459±0,0I9	0,077I
Heterogeneity by Zhivotovsky (1983)		I3,I56	33,752	I7,949	I2,I89	3,869	-	-	-	-	-	-	-
by Workman, Niswander (1970)		I3,I6I	39,285	I7,598	I2,4I7	4,409	-	-	-	-	-	-	-

Table 6 Genotype markers of Greenland halibut samples in the Northwest Atlantic

No. of sample	Number spec	Gene frequency A	B	C	D	E	X^2	X^2	Heterozygosis	Number of alleles	Number of phenotypes	Rare alleles+ dispersion	Portion of rare alleles
I0	I94	0,I856	0,20I0	0,3I70	0,20I0	0,0954	7,766	7,476	0,304I	3,3692	II,35I5	4,8372±0020	0,03256
9	I02	0,2009	0,I6I8	0,2696	0,2059	0,I6I8	2,444	4,45I	0,4II8	3,5745	I2,777I	4,9536±00II	0,00930
6	I94	0,I4I8	0,2500	0,29I2	0,I933	0,I237	4,408	6,48	0,438I	3,65I3	I3,332	4,87332±00I6	0,2534
7	224	0,I429	0,2478	0,3660	0,I563	0,0870	5,408	6,067	0,4688	3,4643	I2,00I4	4,4I37±0058	0,II726
8	I98	0,I086	0,I59I	0,2702	0,3358	0,I263	6,342	6,85	0,3535	3,4369	II,8I23	4,76593±0028	0,4682
5	II0	0,0955	0,2500	0,2864	0,I909	0,I772	2,774	4,726	0,4455	3,5608	I2,6793	4,84907±0033	0,03020
II	88	0,I079	0,I8I8	0,3I25	0,30I2	0,0966	I,543	3,28	0,5568	3,6086	I3,022	4,724I±0074	0,05520
	IIIO	0,I4I9	0,2II3	0,3063	0,2220	0,II85	27,236	92,206	0,4I35	3,62I9	I3,II82	4,86295±0003	0,02750
Heterogeneity by Zhivotovsky (1983)	2I,I399	I9,47I	I2,207	52,079	I7,825		-	-	-	-	-	-	-
by Workman, Niswander (1970)	2I,I22	I9,479	I2,204	52,075	I7,830		-	-	-	-	-	-	-

Table 7 Mean length (L) and variation coefficient (C) of Greenland halibut in the Northeast Atlantic

Age	Sex	Sample 1		Sample 2		Sample 3		Sample 4	
		L, cm	C	L, cm	C	L, cm	C	L, cm	C
4	Σ	–	–	–	–	–	–	–	–
	♂	–	–	34,0±0	0	–	–	–	–
	♀	36,0±0	0	–	–	–	–	–	–
5	Σ	–	–	4I,I±I,I	7,34	38,6±0,8	4,34	44,2±I,4	I2,29
	♂	43,8±I,3	8,95	40,9±I,2	7,26	38,0±2,8	7,44	45,4±I,7	II,84
	♀	–	–	42,0±4,2	I0,I0	39,0±0,7	2,56	4I,6±2,6	I2,33
6	Σ	49,4±0,4	6,I9	44,3±0,5	7,65	48,0±0,5	7,33	49,I±0,4	6,04
	♂	49,4±0,4	6,23	44,0±0,5	7,I0	48,4±0,5	7,I9	49,I±0,4	6,I0
	♀	49,0±0	0	46,I±I,7	9,66	45,8±I,I	6,58	46,9±I,4	5,93
7	Σ	–	–	48,2±0,6	8,5I	50,9±0,3	5,50	52,I±0,3	6,47
	♂	52,9±0,3	5,I8	47,6±0,6	7,47	5I,I±0,3	5,09	52,2±0,3	6,I5
	♀	–	–	50,3±I,7	I0,83	49,8±0,8	6,94	5I,5±I,3	8,57

Table 7 Continuation

Age	Sex	Sample 1		Sample 2		Sample 3		sample 4	
		L, cm	C	L, cm	C	L, cm	C	L, cm	C
8	Σ	57,7±0,6	6,94	53,9±0,8	9,00	53,4±0,3	5,75	55,6±0,4	5,97
	♂	56,5±0,6	6,02	52,6±0,9	7,95	5I,5±0,3	5,5I	55,7±0,4	5,4I
	♀	6I,8±I,0	4,90	55,6±I,2	9,39	53,4±I,2	7,93	54,7±2,2	9,77
9	Σ	65,8±I,0	6,I4	62,6±0,9	8,II	60,0±0,9	6,62	6I,6±0,6	4,30
	♂	60,6±I,4	4,46	57,8±I,4	6,69	57,4±0,9	4,82	60,5±0,6	3,6I
	♀	67,8±0,7	3,36	64,3±0,9	6,7I	62,6±I,0	5,22	64,0±0,9	3,I3
I0	Σ	-	-	67,3±0,9	7,78	64,3±I,0	5,44	65,6±I,4	8,2I
	♂	-	-	67,9±I,3	8,34	60,0±2,8	4,7I	60,8±5,I	I4,44
	♀	70,5±0,9	4,97	66,5±I,2	7,0	65,2±I,0	4,62	67,4±0,7	3,20
II	Σ	-	-	7I,4±I,0	7,25	-	-	7I,8±2,4	7,34
	♂	-	-	62,0±0	0	-	-	68,5±3,5	5,I6
	♀	75,7±I,8	3,33	7I,8±I,0	6,88	67,8±I,3	5,6I	73,5±3,2	7,58
I2	Σ	-	-	-	-	-	-	-	-
	♂	-	-	-	-	-	-	-	-
	♀	79,0±0	0	75,2±I,5	8,25	70,5±0,7	I,00	70,0±0	0
Total spec.		252		28I		294		292	

Table 8 Mean length and variation coefficients (C) by Greenland halibut age groups in the Northwest Atlantic

Age	Sex	Sample 5		Sample 6		Sample 7		Sample 8	
		L, cm	C	L, cm	C	L, cm	C	L, cm	C
4	Σ	-	-	35,9±0,5	7.59	35,0±0.9	6.I7	34.0±I.4	5.88
	♂	-	-	35.3±0.6	7.52	35.0±0	0	36.0±0	0
	♀	-	-	36.5±0.7	7.47	35.0±I.3	7.56	33.0±I.4	4.26
5	Σ	4I.I±0.6	5.83	4I.0±0.6	8.95	38.0±0.4	6.05	37.9±0.4	4.08
	♂	40.I±0.8	6.06	4I.7±0.8	9.27	37.9±0.6	7.30	36.7±0.6	4.79
	♀	4I.6±0.8	5.66	39.2±0.8	6.23	38.I±0.4	4.5I	38.I±0.5	3.I9
6	Σ	44.5±0.4	6.95	46.I±0.4	6.44	43.I±0.3	6.35	42.3±0.3	6.93
	♂	44.5±0.6	7.I7	46.I±0.6	6.6I	43.2±0.4	6.56	4I.7±0.4	6.24
	♀	44.5±0.5	6.85	46.I±0.7	6.36	42.9±0.4	6.I0	42.8±0.5	7.28
7	Σ	49.2±0.4	6.65	5I.7±0.4	6.37	49.I±0.3	5.07	47.0±0.3	5.5I
	♂	49.2±0.5	5.25	5I.I±0.5	5.89	48.9±0.3	5.28	46.5±0.5	6.I2
	♀	49.I±0.6	6.I4	53.I±0.8	6.6I	49.4±0.4	4.7I	47.6±0.4	4.29

Table 8 Continuation

Age	Sex	Sample 9		Sample 10		Sample 11	
		L, cm	C	L, cm	C	L, cm	C
4	Σ	35,4±I,0	9,2I	30,2±0,4	7,78	32,7±0,5	6,86
	♂	35,6±I,I	9,53	29,3±0,3	4,96	33,3±0,8	7,49
	♀	34,0±0	0	3I,7±0,7	8,50	32,2±0,6	6,07
5	Σ	4I,3±0,5	7,I6	36,8±0,5	9,28	36,0±0,3	5,30
	♂	4I,4±0,5	6,59	36,8±0,7	9,26	36,2±0,5	4,93
	♀	40,7±3,9	I3,54	36,8±0,7	9,47	35,9±0,4	5,56
6	Σ	45,4±0,3	6,25	42,9±0,3	6,37	4I,3±0,4	8,08
	♂	45,9±0,4	5,9I	42,4±0,4	6,I4	4I,I±0,6	7,53
	♀	43,5±0,6	5,69	43,3±0,4	6,57	4I,5±0,6	8,56
7	Σ	50,0±0,4	6,42	48,4±0,3	5,68	46,I±0,5	6,24
	♂	50,9±0,4	5,46	48,3±0,4	6,04	45,6±0,8	5,49
	♀	48,4±0,7	6,82	48,6±0,4	5,23	46,4±0,7	6,69
8	Σ	54,2±0,6	5,96	53,9±0,2	5,0	52,4±0,8	4,85
	♂	55,7±0,6	4,05	53,2±0,3	4,37	50,0±0	0
	♀	53,0±0,8	6,54	54,9±0,4	5,27	52,6±0,9	4,84

Table 8 Continuation

Age	Sex	Sample 5		Sample 6		Sample 7		Sample 8	
		L, cm	C	L, cm	C	L, cm	C	L, cm	C
8	Σ	53.8±0.4	5.44	55.4±0.6	6.25	53.4±0.4	4.33	53.1±0.8	7.16
	♂	53.4±0.4	5.61	55.4±0.7	6.34	52.8±0.4	3.60	50.1±1.0	6.03
	♀	54.7±0.6	4.75	55.3±1.5	6.41	55.2±0.9	4.86	55.0±1.0	5.96
9	Σ	57.9±0.4	3.59	-	-	57.6±0.8	4.27	57.9±0.7	4.03
	♂	57.1±0.5	3.06	-	-	57.3±1.2	4.91	56.5±1.8	5.50
	♀	59.3±0.7	3.26	59.2±1.5	4.5	58.3±1.1	2.62	58.5±0.6	3.15
10	Σ	63.1±0.7	3.10	62.2±1.2	3.27	60.7±1.8	4.15	61.3±0.5	5.08
	♂	64.5±0.7	1.10	61.3±1.1	2.42	58.0±0	0	59.0±0.5	3.22
	♀	62.7±0.9	3.30	64.0±3.2	4.58	62.0±1.4	2.28	62.8±0,6	4.49
11	Σ	-	-	-	-	72.3±3.3	6.39	65.6±0.7	4.81
	♂	-	-	-	-	67.0±0	0	63.8±0.9	4.42
	♀	68.9±2.4	8.40	69.0±0	0	75.0±0	0	67.6±0.7	3.29
12	Σ	-	-	-	-	-	-	-	-
	♂	-	-	-	-	-	-	-	-
	♀	75.4±1.2	3.74	75.2±6.4	6.36	-	-	71.9±0.9	4.15
Total		263		232		294		277	

Table 8 Continuation

Age	Sex	Sample 9		Sample 10		Sample 11	
		L, cm	C	L, cm	C	L, cm	C
9	Σ	57,4±0,6	3,94	58,I±0,3	5,68	57,3±2,7	6,60
	♂	57,3±2,7	6,60	57,4±0,3	5,24	53,0±0	0
	♀	57,4±0,6	3,53	59,7±0,6	5,64	59,5±0,7	I,I9
I0	Σ	60,I±I,5	7,29	63,8±0,4	5,94	6I,3±I,4	4,08
	♂	54,0±0	0	62,5±0,4	4,59	65,0±0	0
	♀	60,8±I,4	6,67	66,2±0,8	6,26	60,0±0	0
II	Σ	-	-	67,7±0,6	4,9I	-	-
	♂	-	-	65,2±0,8	4,34	-	-
	♀	67,5±4,0	I0,30	69,3±0,6	3,72	-	-
I2	Σ	-	-	73,8±0,8	5,20	-	-
	♂	-	-	68,8±I,4	3,64	-	-
	♀	7I,0±2,8	3,98	74,9±0,7	4,30	-	-
Total, spec.		250		684		I93	

Table 9 Mean weight (M) and variation coefficients (C) by Greenland halibut age groups in the Northwest Atlantic

Age	Sex	Sample 5		Sample 6		Sample 7	
		M, gr	C	M, gr	C	M, gr	C
4	Σ	–	–	395,4±17,3	25,87	365,7±24,6	16,47
	♂	–	–	369,2±22,0	24,57	375,0±21,2	5,66
	♀	–	–	421,7±26,4	25,83	362,0±36,3	20,05
5	Σ	602,6±49,1	34,58	611,6±29,5	28,11	503,6±16,2	20,09
	♂	519,0±36,2	20,92	642,8±36,4	27,73	513,8±26,8	23,33
	♀	695,6±90,8	36,93	533,5±44,0	24,75	492,4±18,2	15,67
6	Σ	782,9±21,5	21,94	833,5±24,2	20,48	712,7±14,1	18,66
	♂	788,4±35,2	24,44	838,3±31,9	20,50	714,8±19,8	19,82
	♀	777,9±26,6	19,67	826,7±38,7	20,94	709,7±20,0	17,18
7	Σ	1037,2±39,1	28,18	1254,6±33,5	20,68	1043,7±17,5	16,88
	♂	986,2±42,3	22,72	1190,2±32,9	17,46	1016,5±21,5	16,90
	♀	1090,0±66,5	31,70	1386,5±70,5	22,15	1091,4±29,3	16,11

Table 9 Continuation

Age	Sex	Sample 8		Sample 9		Sample 10		Sample 11	
		M, gr	C	M, gr	C	M, gr	C	M, gr	C
4	Σ	3I6,7±3I,9	I4,24	392,I±30,0	25,36	22I,7±I0,8	30,86	306,7±I6,I	25,I2
	♂	360,0± 0	0	395,9±32,7	26,II	200,5±7,4	I7,75	300,0±23,4	24,68
	♀	295,0±35,4	II,98	350,0± 0	0	25I,7±22,7	36,09	3I2,3±23,7	26,28
5	Σ	436,8+I7,8	I5,74	6I3,I±42,I	37,6	478,5±I9,9	29,64	434,7±I2,0	I8,26
	♂	42I,I±30,3	20,34	6I9,3±44,9	37,7	485,6±27,4	27,07	420,0 ±20,4	I9,42
	♀	457,I±I4,0	7,52	555,3±I69,7	43,22	472,4±29,3	32,24	443,6±I5,0	I7,62
6	Σ	6I3,9±I2,6	I8,97	924,6±37,8	34,45	704,0±I4,3	I9,33	654,7±2I,2	27,70
	♂	582,5±I5,7	I6,85	970,4±45,I	34,46	670,I±I9,7	I9,45	64I,8±26,4	23,29
	♀	640,6±I8,4	I9,50	764,4±48,3	24,48	736,5±20,I	I8,50	665,I±32,4	30,78
7	Σ	867,3±20,6	I8,54	I260,2±43,7	28,82	I030,I±I7,8	I8,48	908,I±29,2	I7,89
	♂	84I,6±30,8	22,0	I345,2±57,8	28,I6	989,6±22,3	I8,44	870,0±46,4	I7,70
	♀	905,2±22,3	I2,05	III6,4±57,6	25,80	I088,7±28,0	I7,45	93I,0±38,3	I7,93
8	Σ	I275,0±6I,2	22,0I	I562,4±79,2	28,68	I387,5±22,0	I8,22	I372,7±74,I	I7,07
	♂	III8,0±86,6	23,25	I782,7±97,2	20,40	I287,5±22,9	I5,69	I340,0± 0	0
	♀	I405,8±70,I	I6,53	I378,9±I05,9	3I,66	I533,8±34,6	I6,44	I376,0±82,2	I7,93

Table 9 Continuation

Age	Sex	Sample 5		Sample 6		Sample 7	
8	Σ	I387,3±34,9	2I,34	I503,3±5I,2	I9,27	I347,2±30,9	I4,I5
	♂	I390,2±46,I	23,70	I497,7±57,I	I9,07	I298,7±29,3	I2,I3
	♀	I380,0±44,0	I4,24	I524,3±I33,5	2I,45	I508,9±74,5	I3,97
9	Σ	I862,8±77,7	20,43	-	-	I7I4,0±64,7	II,32)
	♂	I758,8±90,6	I9,94	-	-	I7I8,6±94,6	I3,48
	♀	2047,8±I34,I	I8,52	I729,0±7I,9	I2,47	I703,3±64,2	5,33
I0	Σ	2256,3±I2I,9	I4,30	2II5,6±I76,7	23,62	2060,0±I96,9	I3,5I
	♂	2435,0±I34,4	5,52	I960,0±73,I	8,34	I8I0,0± 0	0
	♀	2I96,7±I58,I	I6,I0	2426,7±597,5	34,82	2I85,0±247,5	II,33
II	Σ	-	-	-	-	3700,0±389,3	I4,88
	♂	-	-	-	-	3200,0± 0	0
	♀	3302,9±468,I	34,7I	2830,0± 0	0	3950,0±480,8	I2,I7
I2	Σ	-	-	-	-	-	-
	♂	-	-	-	-	-	-
	♀	377I,4±270,I	I7,55	32I5,0±I350,6	42,0I	-	-
Total spec.		263		232		294	

Table 9 Continuation

Age	Sex	Sample 8		Sample 9		Sample 10		Sample 11	
		M, gr	C	M, gr	C	M, gr	C	M, gr	C
9	Σ	I765,0±74,0	I5,I2	I900,0±II2,3	23,63	I798,6±30,8	I8,84	I760,0±208,7	I6,77
	♂	I627,5±I93,6	20,6I	I833,3±2II,2	I6,29	I702,2±28,8	I5,40	I420,0± 0	0
	♀	I820,0±77,2	I2,72	I9I4,3±I33,9	25,22	20II,7±64,4	I9,47	I930,0±28,3	I,47
I0	Σ	2044,2±56,7	I7,3I	235I,0±I36,9	I7,47	24I3,2±59,2	20,97	2282,5±I59,0	I2,06
	♂	I763,7±6I,0	I3,40	I840,0± 0	0	2I96,0±49,3	I5,24	2680,0± 0	0
	♀	223I,3±60,7	I3,04	2407,8±I38,5	I6,27	279I,3±I06,9	I9,53	2I50,0±64,8	4,26
II	Σ	2507,I±93,6	I6,69	–	–	29I8,9±I04,7	20,29	–	–
	♂	2302,7±I03,9	I4,26	–	–	2355,4±68,6	I0,09	–	–
	♀	2732,0±I34,2	I4,74	27I5,0±379,3	24,I9	3285,2±I0I,6	I3,49	–	–
I2	Σ	–	–	–	–	3978,7±I6I,2	I9,43	–	–
	♂	–	–	–	–	2772,5±I80,I	II,25	–	–
	♀	3402,7±83,2	7,73	36I0,0±I074,8	29,77	4220,0±I33,9	I3,83	–	–
Total spec.		277		250		684		I93	

Table 10 Mean weight (M) and variation coefficients (C) by Greenland halibut age groups in the Northeast Atlantic

Age	Sex	Sample 1		Sample 2		Sample 3		Sample 4	
		M, gr	C	M, gr	C	M, gr	C	M, gr	C
	Σ	-	-	-	-	-	-	-	-
4	♂	-	-	390,0±0	0	-	-	-	-
	♀	410,0±44,2	15,23	-	-	-	-	-	-
	Σ	-	-	637,8±76,7	34,03	430,0±45,1	20,99	715,6±49,1	26,58
5	♂	762,3±64,6	29,37	601,4±79,0	32,18	395,0±120,2	30,43	752,7±58,0	24,39
	♀	-	-	765,0±332,3	43,44	453,3±59,3	18,50	634,0±99,2	31,28
	Σ	1087,8±21,2	17,18	813,3±34,1	30,82	1065,2±42,8	30,34	1112,5±38,0	28,58
6	♂	1086,9±21,4	17,28	777,9±27,0	23,56	1099,2±46,6	29,70	1087,3±34,0	24,62
	♀	1160,0±0	0	1021,2±171,6	44,45	852,5±79,6	24,70	1311,2±215,5	43,48
	Σ	-	-	1034,1±42,5	29,90	1222,6±22,8	18,72	1314,5±34,5	26,49
7	♂	1270,7±23,4	15,61	985,8±42,7	28,06	1237,1±21,5	15,85	1307,2±31,7	22,88
	♀	-	-	1222,7±116,7	30,19	1155,0±83,2	29,69	1365,4±174,1	44,18

Table 10 Continuation

Age	Sex	Sample 1		Sample 2		Sample 3		Sample 4	
		M, gr	C	M, gr	C	M, gr	C	M, gr	C
8	Σ	I765,3±62,I	23,84	I508,3±76,7	32,95	I460,7±33,0	20,59	I565,I±42,5	20,86
	♂	I6I0,0±45,7	I6,78	I327,3±70,5	25,47	I456,6±35,3	20,26	I55I,7±39,4	I8,32
	♀	2273,6±I37,3	I9,09	I736,8±I35,7	33,I5	I483,I±98,9	23,09	I666,4±236,0	34,69
9	Σ	2703,9±I58,I	24,I	2548,2±I38,I	3I,I3	2I0I,4±II5,4	25,I6	2I82,6±I37,I	26,65
	♂	I836,0±I0I,2	II,03	I872,2±I50,7	22,76	I720,9±73,6	I3,52	I892,3±I05,3	I9,27
	♀	3037,7±II3,I	I2,9	279I,6±I54,3	27,09	248I,8±I46,5	I8,67	28II,7±202,4	I6,09
I0	Σ	-	-	3207,2±I57,6	29,07	2769,2±I9I,2	22,90	2693,7±I7I,4	23,8I
	♂	-	-	33I6,2±233,4	3I,47	I830,0±2I2,I	II,59	2I02,5±450,4	37,I0
	♀	3495,3±202,9	2I,72	3054,7±202,5	24,8I	2974,0±I52,3	I5,36	2908,6±I42,4	I5,48
II	Σ	-	-	4I36,9±2I3,4	27,29	-	-	4I70,0±566,3	30,37
	♂	-	-	2080,0±0	0	-	-	3225,0±643,5	I9,95
	♀	4706,7±I95,8	5,88	42I0,4±207,2	25,58	3342,2±225,3	I9,06	4642,5±739,7	27,60
I2	Σ	-	-	-	-	-	-	-	-
	♂	-	-	-	-	-	-	-	-
	♀	4750±0	0	4758,9±302,4	26,2	4000,0±I4I,4	3,54	3I70,0±0	0
Total spec.		252		28I		294		292	

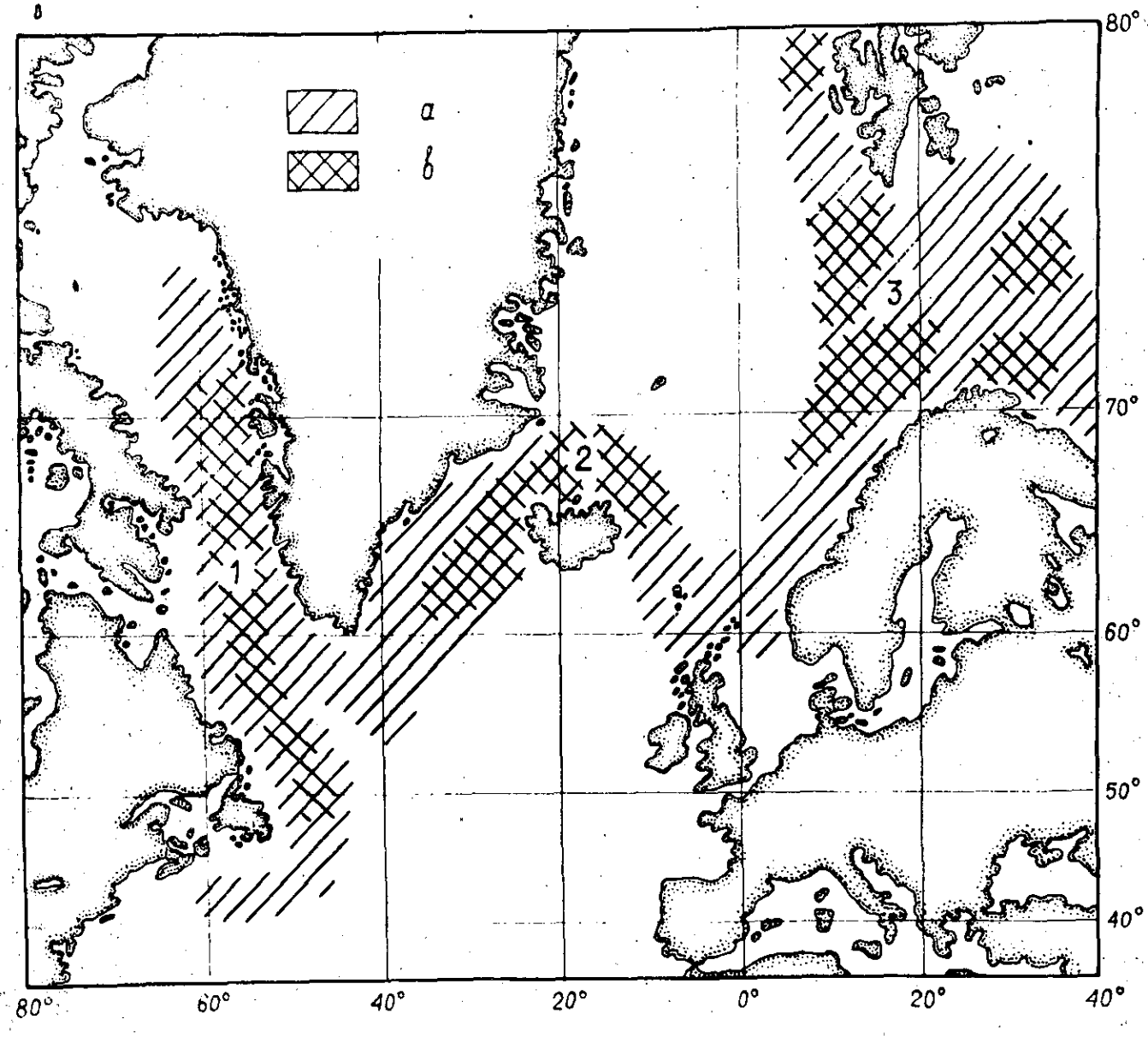

Fig. 1 Area (a) and places (b) of Greenland halibut dense concentrations in the North Atlantic:

1 - Greenland-Canadian populations;

2 - Iceland population;

3 - Norwegian-Barents Sea population

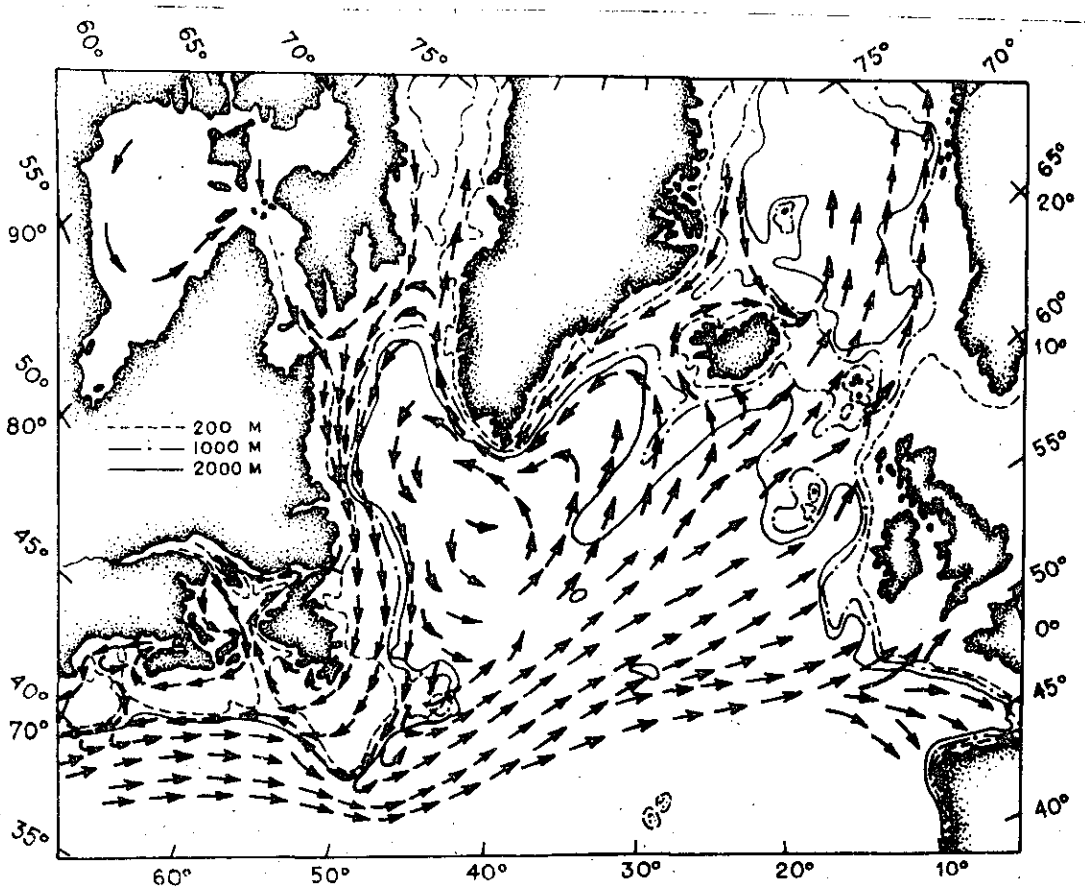

Fig. 2 General sceme of the North Atlantic Currents (Templeman, 1967).

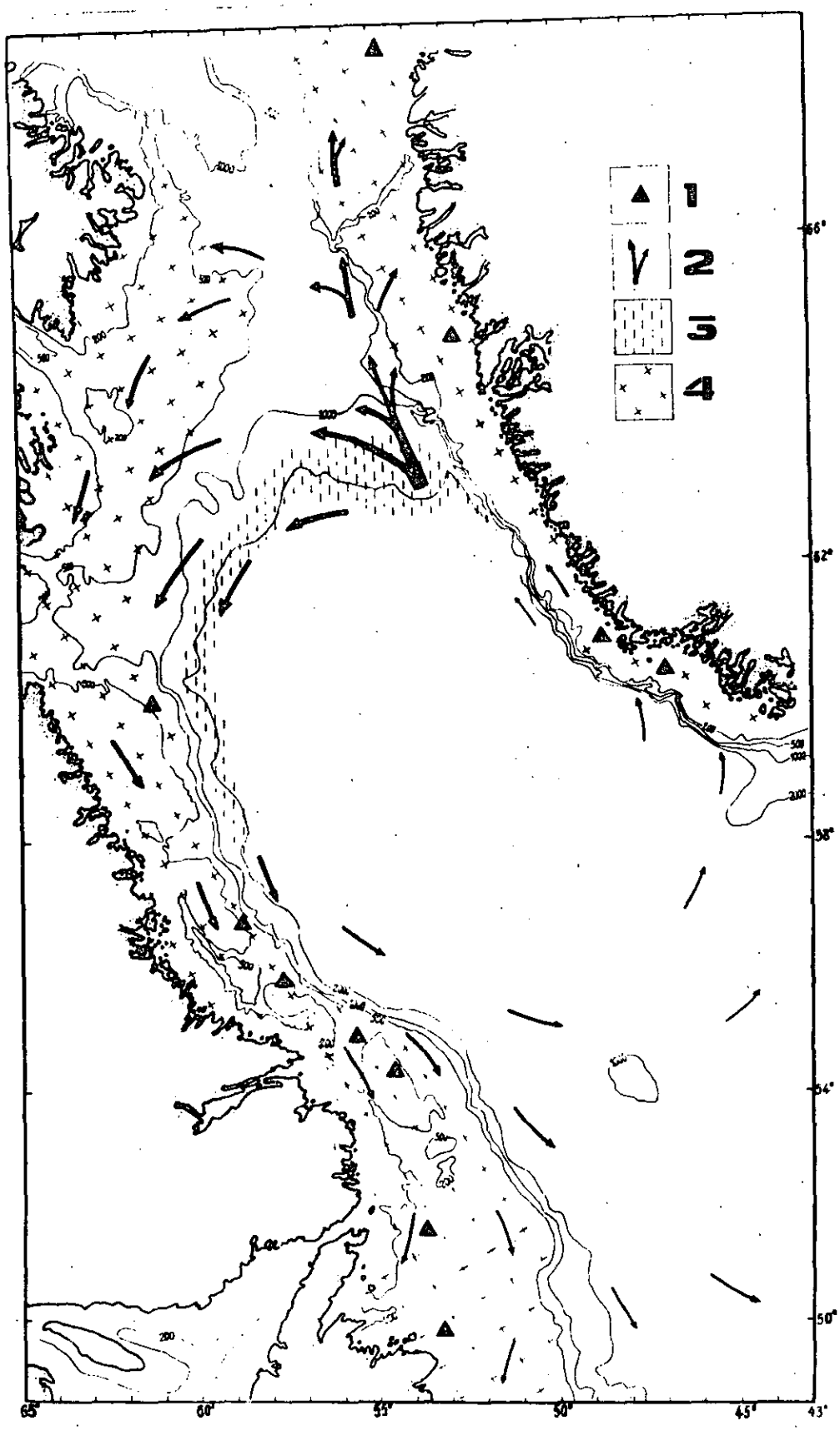

Fig. 3 Location of spawning grounds, distribution and drift of juvenile Greenland halibut in the Northwest Atlantic:
1 - places of detection of larvae and fries of Greenland halibut in cod stomachs;
2 - drift ways;
3 - spawning grounds;
4 - juveniles distribution.