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Distribution and Relative Abundance of the Labrador-Eastern Newfoundland and Stock Complex of Greenland Halibut (*Reinhardtius hippoglossoides*)

by

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INTRODUCTION

The Greenland Halibut (Reinhardtius hippoglossoides) is one of the major groundfish resources off the Canadian east coast. The largest stock area of Greenland halibut (NAFO Div. 2G, 2H, 2J, 3K and 3L) extends from 61°N latitude at the northern tip of Labrador southward to 46°N latitude to include the northern half of the Newfoundland Grand Bank (Fig. 1). In this area the total allowable catch is presently set at a level of 75,000 MT annually and according to Bowering and Brodie (1983), the minimum trawlable biomass of Greenland halibut in this area is probably well in excess of 300,000 MT.

The distribution of Greenland halibut in this area was first described by Lear and Pitt (1971), however, the surveys from which the data were collected using mostly gillnets and longlines, were limited to the deepwater bays off the Newfoundland east coast. Templeman (1973) described the distribution of Greenland halibut throughout the Northwest Atlantic from data collected from research vessel surveys using mainly otter trawl. The information for the northern Labrador area (NAFO Div. 2G and 2H) and for depths beyond 550 m however, were based on a very limited database (see Templeman 1973; Fig. 2, Table 1).

This paper will describe the distribution and relative abundance of the Labrador-eastern Newfoundland stock complex of Greenland halibut as it relates to geographical position, depth, and bottom temperature. The analysis is based on extensive survey data collected by Canada, the Soviet Union, the German Democratic Republic, and the Federal Republic of Germany performing groundfish surveys in general or Greenland halibut surveys in particular.

MATERIALS AND METHODS

Data from all countries were collected by stern trawling research vessels using various types of bottom otter trawls. All trawls used, however, were equipped with small mesh (<30mm) liners placed in the codend to prevent the escapement of small fish. For the purpose of this study, the catchability of all ships and gears was considered to be the same. Most sets were of 30 minutes duration at a towing speed of 3.5 knots, however, if towing time was different than 30 minutes, the catch by weight and number was adjusted proportionately to estimate a catch as if it were a 30 minute set. Sets in which the fishing gear was badly damaged or for other reasons retention of the catch was interferred with were not used in any of the calculations. During all trips, fishing was conducted on a 24 hour per day basis. A summary of trips from which data are presented is shown in Table 1 by country, ship, year, NAFO Division, and cruise dates.

Except for the Soviet Union survey in all NAFO Divisions and Canadian surveys in NAFO Div. 2G and 2H, surveying was conducted according to stratified-random survey design based upon depth (Doubleday 1982). The Soviet Union survey and Canadian surveys in NAFO Div. 2G and 2H were performed according to fixed station design in which the fishing stations were also selected acording to depth. The maximum depth fished was in excess of 1000 m for all NAFO Divisions except NAFO Div. 3L where the maximum depth fished was less than 800 m.

For each fishing set the catch of Greenland halibut was weighed and counted on board the vessel. The total catch (or some portion of it) was then measured in 2 cm length groups and the length frequency adjusted up to total catch if only a portion were measured. Only length frequency data for the Federal Republic of Germany and Canadian surveys, however, are available for presentation. At the end of each set a bottom temperature (˚C) was taken where possible.

The geographic distribution and relative abundance of Greenland halibut are presented by indicating in ½˚ latitude and 1˚ longitude rectangles, average weights (kg) of fish caught per 30 minute set per rectangle. The numbers of fishing sets used to plot the distribution are presented in Fig. 2. To determine if size distribution varied throughout the stock area, length frequency distributions were combined for all trips where data were available and then presented by each NAFO Division separately. A similar exercise was carried out to examine for changes in size distribution with depth. In this case, all areas and trips were combined, with length frequency distributions presented individually for 9 depth intervals: <300 m, 301-400 m, 401-500 m, 501-600 m, 601-700 m, 701-800 m, 801-900 m, 901-1000 m, and >1000 m. The average weight (kg) per set for the same depth intervals were then plotted for determining distribution of catch rates over depth.

The average weight (kg) per set was also presented by bottom temperature in ½˚C intervals from 1.5˚ to 6.5˚C inclusive to examine for changes in catch rate as it relates to bottom temperatuare. Since depth and bottom temperature are generally related, the catch rates (average weight (kg) per set) were also presented in a single figure by depth and temperature to determine optimum levels of catch for both parameters.

RESULTS

GEOGRAPHICAL DISTRIBUTION AND RELATIVE ABUNDANCE

Results of research vessel surveys throughout the entire stock area indicate that Greenland halibut are found in high abundance from about the latitude of Cape Chidley (the most northerly tip of the Labrador Coast) to the deeper waters on the northern slope of the Grand Bank (Fig. 3) with no apparent break in the continuity of the distribution. In NAFO Div. 2G high catches were experienced in the southernmost portion of Hudson Strait with catches ranging from 123-357 kg per set. High catches (>100 kg/set) were located along the continental slope east of Saglek Bank where the largest average catch was 512 kg per set (based on 1 set). Catches were much lower on the shallower waters of the bank. Large catches were also experienced throughout NAFO Div. 2H with the exception of the shallow water directly on top of Nain Bank. Large average catches in excess of 200 kg per set were associated with the deep eastern slope of Nain Bank and to the south of Nain Bank in the Hopedale Channel area. The largest average catch throughout the entire stock area was from NAFO Div. 2H at unit area L11 (Fig. 3) at a level of 616 kg per set based upon 5 sets. Average catches were also high at the southern limits of NAFO Div. 2H, particularly in the northern Cartwright Channel area eastward to the continental slope.

Greenland halibut were abundant on both the inner and outer slopes of Hamilton Bank in NAFO Div. 2J. However, the area of highest average catches (up to 185 kg per set) was Hawke Channel, a trough of deep water up to 600 m in depth extending between the south end of Hamilton Bank and the north slope of Belle Isle Bank. Average catches in general were not as high as those of NAFO Div. 2G and 2H.

Areas of high abundance in NAFO Div. 3K were generally connected with channels of deep water around Funk Island Bank and south of Belle Isle Bank with average cathes up to 110 kg per set. Relatively high concentrations were found in Notre Dame Channel which extends into Notre Dame Bay. In this area average catches were just over 100 kg per set. The highest average catch in NAFO Div. 3K was 152 kg per set (based on 16 sets) taken at the continental slope (unit area T23; Fig. 3). In the southern portion of NAFO Div. 3K the abundance of Greenland halibut began to diminish with the possible exception of the very deep water at the continental slope. Average catches in NAFO Div. 3L were similar to those of southern NAFO Div. 3K and were mainly confined to the northern and northeastern slopes of the Newfoundland Grand Bank. Substantial portions of NAFO Div. 3L yielded negligible catch, particularly on the shallow top of the Newfoundland Grand Bank. The highest average catch in this Division was 56 kg per set (unit area T25) based upon 6 sets.

SIZE DISTRIBUTION BY AREA AND DEPTH

Length frequency distributions by NAFO Division presented in Fig. 4 indicate a decreasing trend in the proportion of larger fish (>50 cm) going from north to south. In NAFO Div. 2G more than half the fish caught were more than 50 cm in length while in all other divisions the reverse occurred. The highest proportion of smaller fish (<30 cm) occurred in NAFO Div. 2H followed closely by NAFO Div. 2J and 3K, however, the trend decreased moving southward. With the exception of NAFO Div. 2G and 2H (the most northernly areas) the intermediate sizes of 36-56 cm were predominent in the three southerly NAFO Divisions.

Length frequency distribution by depth interval (Fig. 5) indicates that fish >50 cm become proportionately more abundant as depth becomes progressively greater. Fish <40 cm are relatively high in abundance up to depths of 700 m, however, beyond 700 m an abrupt change in distribution occurs where fish <40 cm are practically non-existent in the catches (Fig. 5).

AVERAGE CATCH (KG) BY DEPTH AND TEMPERATURE

Average catch (kg) per 30 min set by depth interval indicates an almost linear increase with increased depth (Fig. 6, Table 2) up to 900 m. An abrupt increase occurs in average catch at 901-1000 m, however, it stabilizes again at depths beyond 1000 m. The value at 901-1000 m is a result of high variability as shown by the 95% confidence limits in Table 2. While confidence limits in the deeper zones overlap to some degree the increasing trend in catch rate is clearly evident (Table 2).

Catches of Greenland halibut occurred in all bottom temperatures ranging from -1.5°C to 6.4°C (Fig. 7). Catches beyond this level fell to negligible levels, however, these values were only based upon two and one set(s) respectively. Statistical analyses of these data (Table 3) give trends in the 95% confidence limits which suggests that the trends in the data are probably real at least up to the 4.0 to 4.4°C interval. Confidence limits are not meaningful beyond this.

Given that depth and bottom temperature are generally related, mean catch for both variables combined are shown in Fig. 8. It would appear from this relationship that the optimum combined ranges for catching Greenland halibut are about at temperatures of 3.0 to 5.0°C in depths of 400-1000 m.

DISCUSSION

Greenland halibut are widely distributed along the Labrador and eastern Newfoundland coasts to the northern slopes of the Newfoundland Grand Bank. The areas of highest abundance are generally associated with the deeper waters along the continental slope as well as the deep channels running between the fishing banks. The more dense concentrations appear in the northern Labrador area along the deep continental slope as well as in the deep Hopedale and Cartwright Channels south of Nain Bank.

According to Bowering (1977, 1983), Chumakov (1975) and Zilanov et al. (1976), Greenland halibut inhabiting the continental shelf of Labrador and eastern Newfoundland and the deep bays of eastern Newfoundland are mostly immature. Most mature fish are found further to the north and in deeper water. This would explain why the larger fish in the frequency distributions presented here are found in deeper water and to the north since the larger fish are obviously more likely to be maturing. Spawning concentrations or fully mature fish have not been observed in these southern areas and it has been suggested by these authors that since Greenland halibut inhabiting this portion of the range do not reproduce here, it may be assumed that these fish migrate for spawning probably to the Davis Strait area when they approach maturity. Bowering (1983) in fact found that of the large fish examined for maturity condition throughout the range, the proportion of mature fish increased significantly as the samples examined were taken progressively northward to NAFO Division 2G. Bowering (1984) while examining migrations of Greenland halibut from tagging studies indicated that tagging operations in the eastern Newfoundland area yielded many tag returns from the deep slopes (>500 m) of northern Labrador to as far north as Baffin Island and Davis Strait. This was also considered as evidence of a deep water northward spawning migration of maturing fish.

In assessing the Greenland halibut stock complex in this area, Bowering and Brodie (1983) indicated that the commercial catches of Greenland halibut in the late 1970's and 1980's were mainly comprised of the 1971-74 year-classes inclusive and were considered to be much stronger than average. The commercial fishery was mostly concentrated in the Northeast Newfoundland region by gillnetters in the late 1970's with considerably high catches. These catches subsequently declined during the early 1980's while the catches of otter trawlers during this time increased substantially in the deeper waters of NAFO Div. 2H comprised mainly of these same year-classes. This was also related to the movement of larger fish into deep water and to the north as shown by the data presented here.

Bowering, Parsons, and Lilly (1983) indicated that the high abundance of Greenland halibut in Hopedale and Cartwright channels (where depths go to >600 m) is associated with the main fishing grounds of the pink shrimp (Pandalus borealis) on which these fish were feeding heavily. Jensen (1935) and Smidt (1969) also found this to be the case for the west Greenland area where the pink shrimp is the most important food item in the diet of Greenland halibut. They found that high abundance of Greenland halibut was always associated with high abundance of pink shrimp. The Greenland halibut is also prevalent in the Hawke Channel area of southern Labrador which is also the locality of a commercial concentration of pink shrimp (Parsons et al. 1981) although to a lesser extent than the more northerly areas. The highest abundance in the more southerly area occurred in White Bay and Notre Dame Bay (about 400-500 m). In this area the main food item in the diet of Greenland halibut is the capelin (Mallotus villosus) (Lear MS 1970) and areas of high abundance may be associated with the large concentrations of capelin in these areas as reported by Pinhorn (1976). Greenland halibut abundance diminishes very quickly near the Grand Bank area particularly in the shallow waters (<100 m) at the top of the bank where bottom temperatures are often less than - 1˚C. Templeman (1965, 1973) reported that large numbers of Greenland halibut were killed in Trinity Bay in 1964 and suggested that they probably died while pursuing capelin into waters of intermediate depths where temperatures were below -1˚C. If this is the case, it is unlikely Greenland halibut would inhabit the Grand Bank at such low temperatures.

It has been hypothesized by Templeman (1973), Chumakov (1975) and Atkinson et al. (1981) that because of the southward movement of the Labrador Current, the young Greenland halibut from the north are led into the deep bays along the east coast of Newfoundland and along the continental shelf and slope. The wide continental shelf in the southern Labrador and eastern Newfoundland area which contains many deep channels and these deep east coast Newfoundland bays would be suitable areas for these fish. Bottom temperatures in these areas would be lower than similar depths along the continental slope due to projections of the cold current. However, it is likely that most maturing fish would migrate from these colder areas northward to the deep warmer waters on the continental slope (Templeman 1973) where temperatures are more suitable for spawning (Jensen 1935; Smidt 1969). Considering the evidence presented here, this is likely to be the case.

From the present study it appears that the optimum temperature range for the largest catches of Greenland halibut is about 3.0 to 5.0˚C. Templeman (1973), however, suggested that apart from spawning concentrations Greenland halibut were most abundant where bottom temperatures ranged from -0.5˚ to 3.0˚C in deep water over large areas. Lear and Pitt (1971) also found that the largest catches of Greenland halibut in the east coast of Newfoundland bays all occurred at temperatures less than 3.0˚C. Ernst (1974) reported that Greenland halibut in the Icelandic area was most abundant just after spawning in bottom temperatures of 2.0 to 2.5˚C whereas during foraging they were most abundant at temperatures of -0.2 to 0.2˚C. It should be noted, however, that previous reports were based upon very little data beyond the 500m depth zone. The present study, on the other hand, is based on results of almost 2,600 fishing sets of which almost 400 are deeper than 500 m in areas where spawning concentrations are not believed to occur.

ACKNOWLEDGEMENTS

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Table 1. Summary of data sources used in the analyses.

Country	Ship	Year	Sets Fished Divisions 2G	2H	2J	3K	3L	Cruise Dates
Federal Republic of Germany	Anton Dohrn	1975			48	22		Nov.-Dec.
	Walter Herwig	1976			57	25		Oct.-Nov.
German Democratic Republic	Ernst Haeckel	1978	15	12	32	34		Sept.-Oct.
	Walther Barth	1979	20	15	40			Nov.-Dec.
Soviet Union	Suloy	1982	19	29	22			Nov.-Dec.
		1983			14	67		Jan.
Canada	Gadus Atlantica	1978			57	82	43	July-Aug
			52	51				Sept.-Oct.
					53	70		Nov.
		1979					81	May-June
			56	72				Aug.
							54	Aug.-Sept.
					43	56		Sept.-Oct.
					50	67		Nov.-Dec.
		1980					53	May
					48	56		Oct.
					53	78		Nov.-Dec.
		1981					61	Sept.
			47	74	1			Oct.-Nov.
					99	20		Nov.
						97		Dec.
		1982			154	14		Oct.-Nov.
						127		Nov.-Dec
		1983			89			Oct.-Nov.
					28	53		Nov.
					2	69		Nov.-Dec.

Table 2. Mean catch in weight by depth.

Depth (m)	No. of Sets	Mean catch (kg)	STD Error of Mean	CV	95% Confidence Limits Lower	Upper
<300	1,260	26.50	1.84	246.06	22.89	30.11
301-400	655	58.30	3.90	171.29	50.66	65.94
401-500	276	113.96	8.50	123.91	97.30	130.62
501-600	166	142.06	13.60	123.33	115.40	168.72
601-700	71	195.40	37.19	160.36	121.02	269.78
701-800	44	244.81	69.68	188.81	104.06	385.56
801-900	54	227.63	36.71	118.51	154.21	301.05
901-1000	20	635.86	196.21	138.00	223.82	1,047.90
>1,000	35	208.90	52.73	149.33	101.33	316.47

Table 3. Mean catch in weight by temperature.

Temp. (°C)	No. of Sets	Mean Catch (kg)	STD Error of Mean	CV	95% Confidence Limits Lower	Upper
-1.5 to -0.9	7	7.75	2.97	101.57	0.12	15.38
-1.0 to 0.6	75	16.67	2.78	144.30	11.14	22.20
-0.5 to -0.1	113	35.01	5.68	172.49	23.71	46.31
0.0 to 0.4	206	26.60	3.58	193.12	19.58	33.62
0.5 to 0.9	162	52.47	8.27	200.70	36.26	68.68
1.0 to 1.4	157	41.77	9.01	270.24	24.11	59.43
1.5 to 1.9	179	39.33	5.45	185.25	28.65	50.01
2.0 to 2.4	162	30.07	4.73	200.02	20.80	39.34
2.5 to 2.9	433	50.95	4.10	167.36	42.91	58.99
3.0 to 3.4	436	65.15	5.85	187.43	53.68	76.62
3.5 to 3.9	299	98.05	9.05	159.58	80.31	115.79
4.0 to 4.4	64	119.28	22.19	148.84	75.34	163.22
4.5 to 4.9	7	122.28	59.94	129.69	-31.77	276.33
5.0 to 5.4	7	141.99	108.95	203.00	-138.01	421.99
5.5 to 5.9	2	4.45	2.05	65.15	-	-
6.0 to 6.4	1	3.63	-	-	-	-

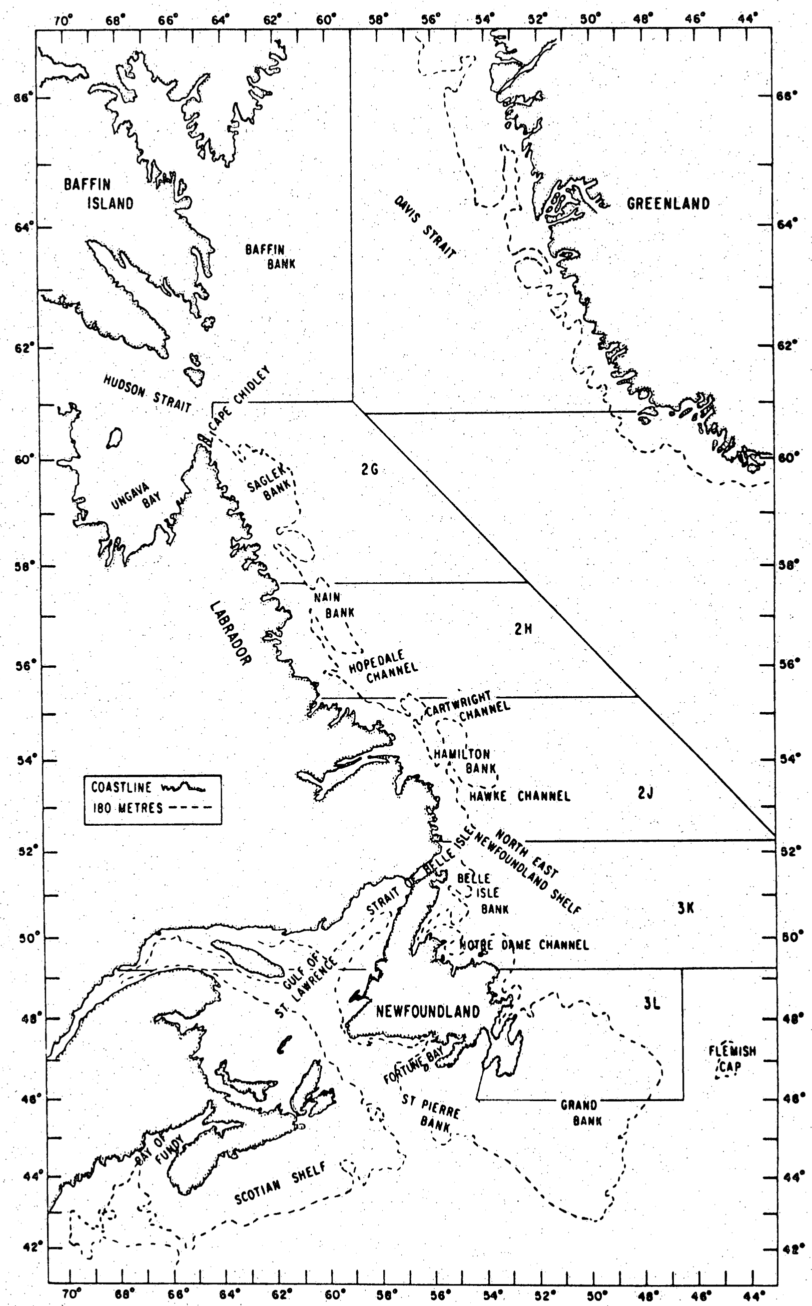

Fig. 1. Major locations and NAFO divisions mentioned in the text.

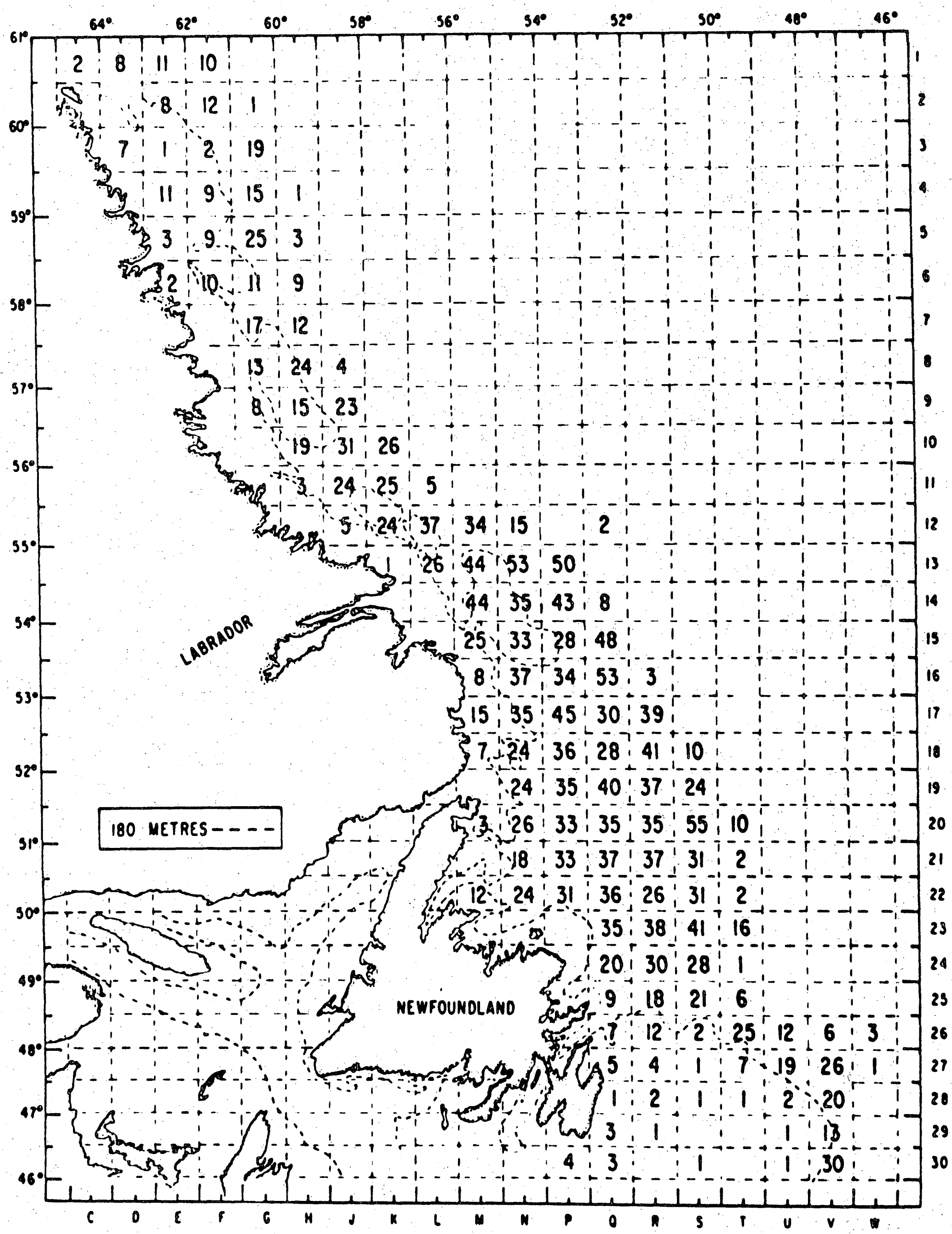

Fig. 2. Number of sets in each unit area used to calculate the mean weight (kg) of Greenland halibut per standard 30-minute set per unit area.

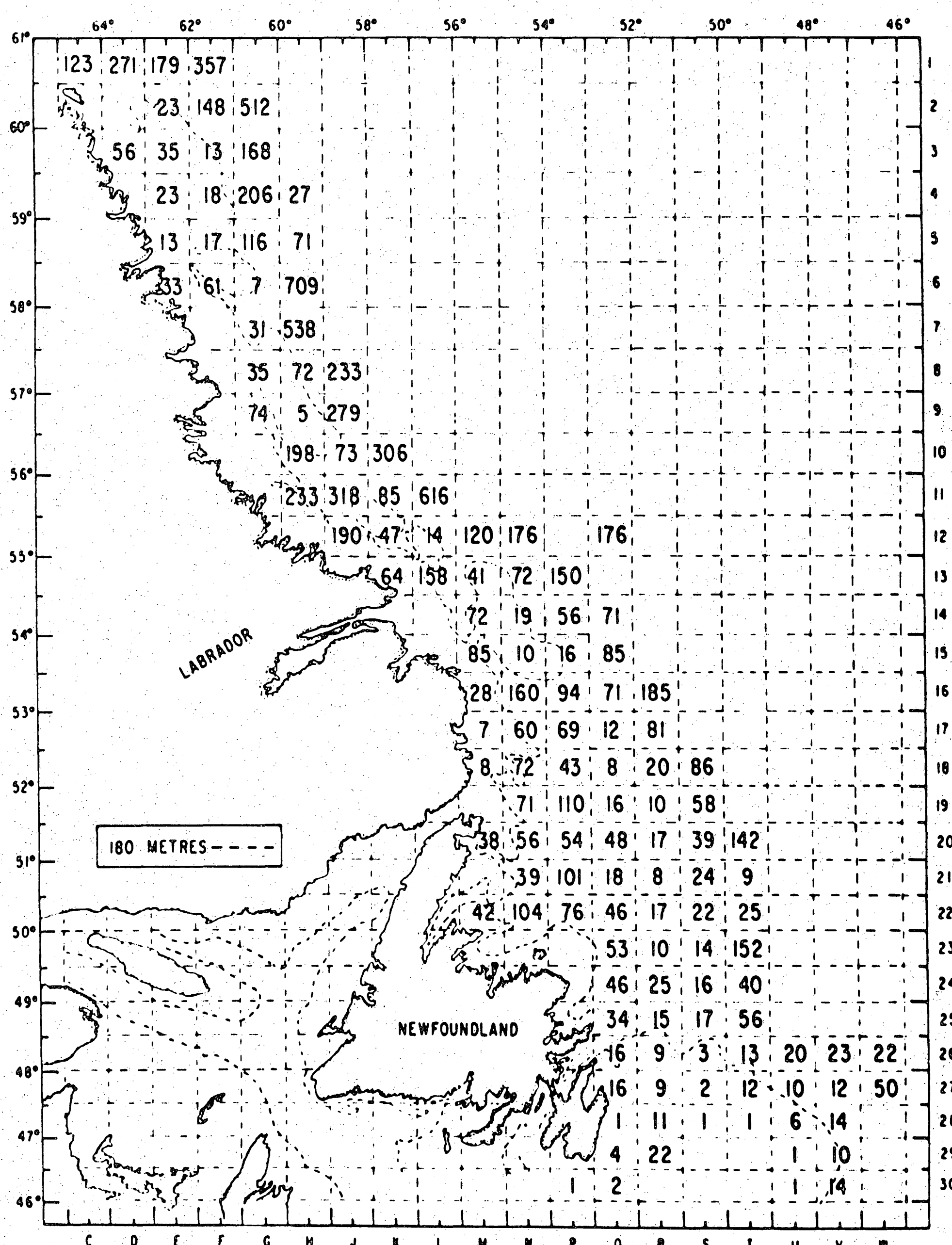

Fig. 3. Mean weight (kg) of Greenland halibut per standard 30-minute set per unit area.

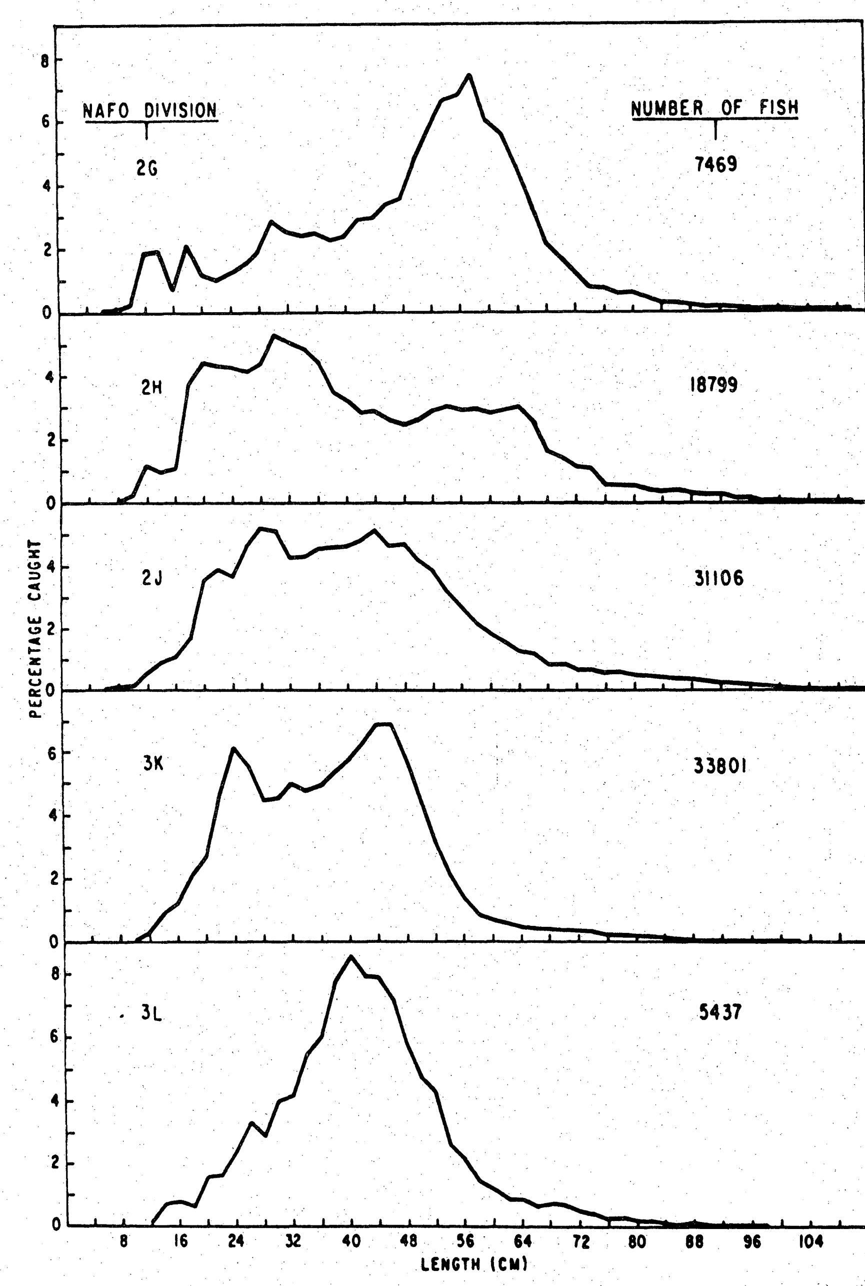

Fig. 4. Length frequency distributions of Greenland halibut by NAFO division from 1975-83 combined where data were available.

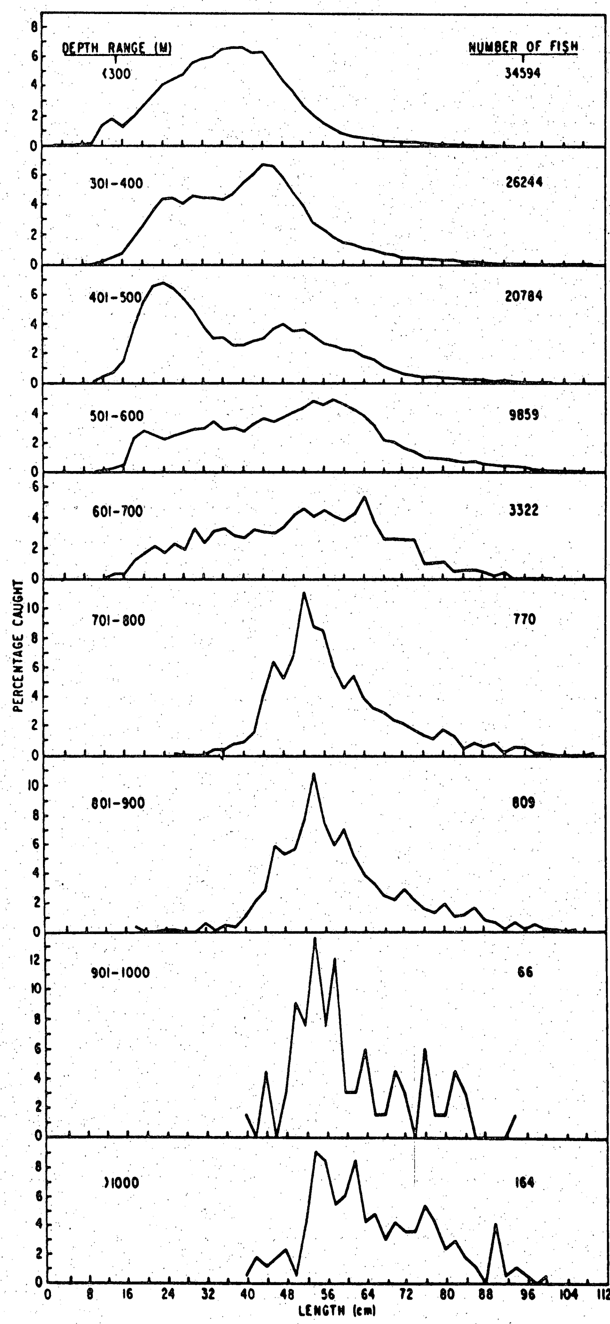

Fig. 5. Length frequency distributions of Greenland halibut by depth interval (m) for NAFO Subarea 2 and Division 3KL for 1975-83 combined where data are available.

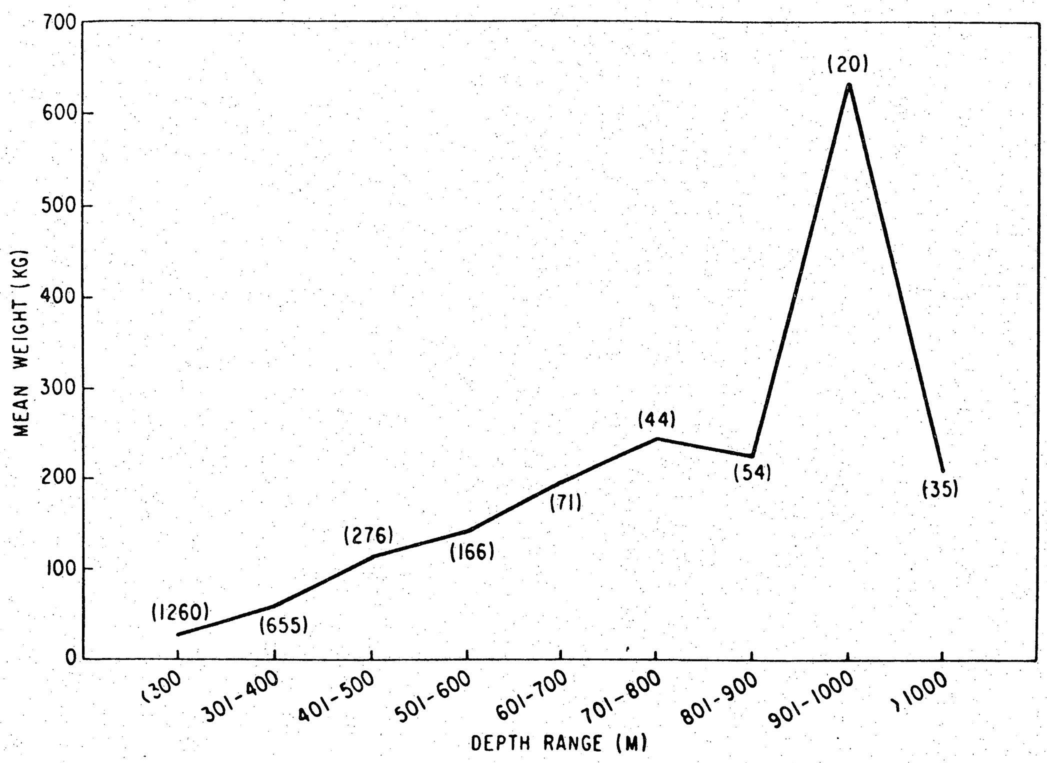

Fig. 6. Mean weight of Greenland haibut (kg) per standard 30-minute set by depth interval (m). Number of sets in brackets.

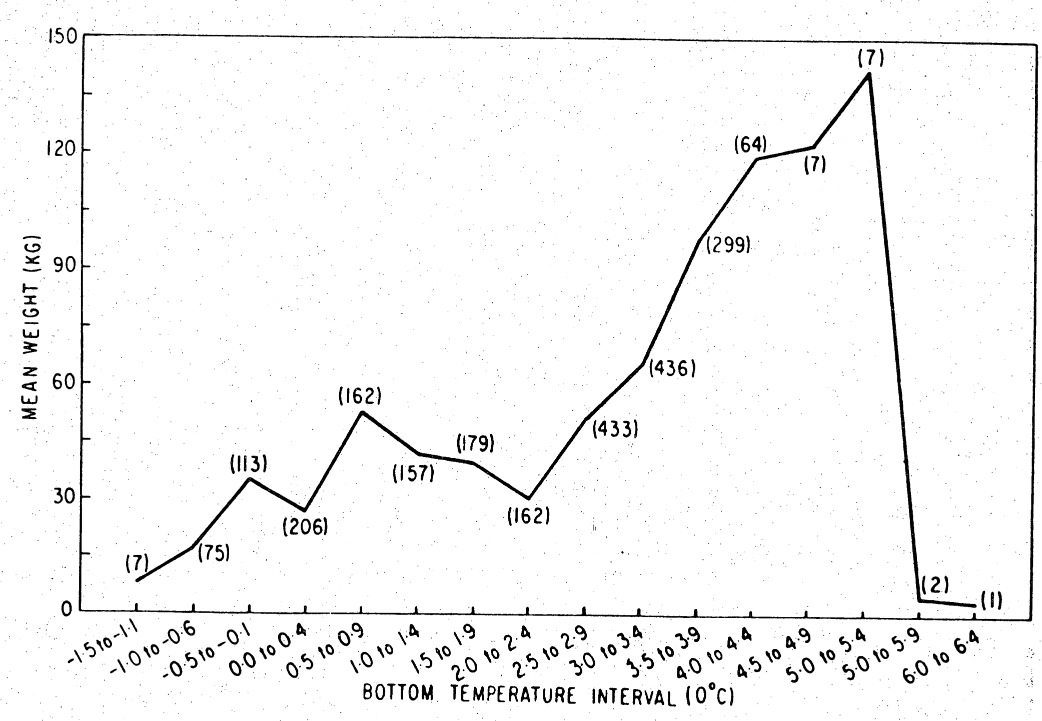

Fig. 7. Mean weight (kg) of Greenland halibut per standard 30-minute set by temperature interval (°C). Number of sets in brackets.

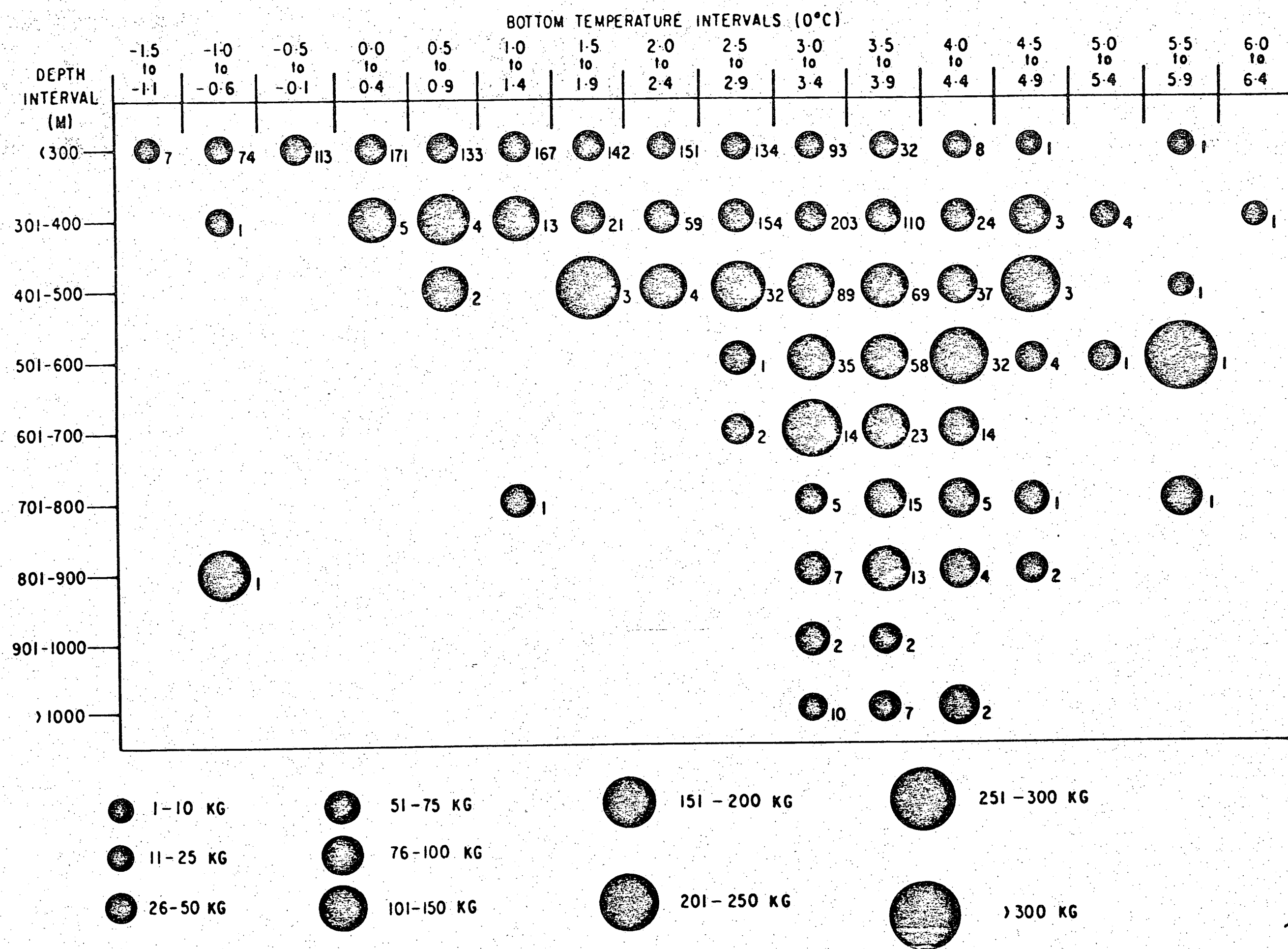

Fig. 8. Mean weight (kg) of Greenland halibut per standard 30-minute set by depth interval (m) and temperature interval (°C). Number of sets at the lower right of the circular symbols.