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Distribution of Greenland halibut (*Reinhardtius hippoglossoides* Walbaum) in the Northwest Atlantic Depending on Bottom Temperatures

by

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SPECIAL SESSION ON ENVIRONMENTAL CONDITIONS

Introduction

Compared to other species of commercial fishes of the Northwest Atlantic Greenland halibut(Reinhardtius hippoglossoides) stock occupies the largest area, extended from arctic regions in the Baffin Sea to the Nova Scotia shelf in the south (Leim & Scott,1969; Templeman,1973; Atkinson et al.,1982) and appears to be an important object for fishery in the fjords of West Greenland(Smidt,1969), in coastal waters of Eastern Newfoundland (Bowering,1977,1978,1979,1980,1987; Bowering & Brodie,1981,1986) and also on the Baffin Island and Labrador continental slopes (the main fishery area of GDR and USSR).

According to Tompson(1937), the main areas of distribution of Greenland halibut are located within the boundaries of arctic zones of convergence and according to Milinsky (1944) they are limited by bottom temperatures from 3 to 8°C.

Investigations carried out in the Barents Sea have revealed that mature halibut are concentrated for spawning only at great depths of continental slope at water temperatures not below 5°C (Rass, 1934).

Some explorers (Novikov, 1961, 1974; Nizovtsev, Troyanovsky,1970; Fedorov,1971; Smidt,1969) indicate that during the prespawning period mature halibut prefer waters with temperatures from 2 to 4°C,avoiding surface waters with sharp variations and deep waters with obvious lack of oxygen. Halibut are likely to form dense commercial consentrations in deeps shelf hollows and on continental slope when water temperatures are from -0.5 to 4°C (Bayar, 1964; Konstantinov, 1968; Burmakin, 1971; Lear,Pitt,1971; Templeman,1973).

USSR and GDR investigations (Konstantinov,1968; Chumakov, 1969; Burmakin,1971; Ernst,1974) conducted in April-July 1967-1971 on the continental slope of Iceland have revealed the dependence of halibut concentrations upon bottom temperatures and biological conditions.During the postspawning period Greenland halibut (April- May) occurred in catches from warm waters of temperature gradient; the densest concentrations were recorded at temperature from 2 to 2.5°C. During the feeding period (May-July) halibut concentrations were distributed over the cold waters (from -0.6 to 0.2°C).

According to Canadian researches data(Bowering,1984) the optimum temperatures range for getting large catches of halibut was 3-5°C. However,Templeman (1973) assumed Greenland halibut to occur in great numbers, besides spawning grounds, at bottom temperatures from -0.5 to 3°C. Lear and Pitt (1971) also reported all the largest catches of halibut in bays of the Newfoundland eastern coast at temperature below 3°C.

Temperature is known to be an important ecological factor influencing on the vital activity of hydrobios. Due to temperature effect organism of fish undergoes some serious physiological changes causing changes fish behaviour,which are exhibited in seasonal feeding cycles,all sorts of migrations and a number of other behaviour acts. Fishes are also known to orient themselves well under thermogradient conditions and choose quite determined temperature zones. All these facts make it possible to consider thermogradient conditions as one of the factors which determines either forming or disintegration of concentrations and a purposeful (attracting or scaring away) movement over the gradient in space.

The paper objectives are: to analyze seasonal and age dynamics of temperatures chosen; to reveal some general patterns of halibut distribution depending on bottom temperatures on the basis of summarized primary data from GDR,Canada and USSR obtained during trawl surveys and observations made on board some fishing vessels.

Materials and methods

Data used in order to describe the dependence of halibut disrtribution on temperatures were collected during trawl surveys carried out by Canada and USSR research vessels in 1977-1987. The list of surveys as well as the data on number of control trawlings for each survey and NAFO Division are presented in table I. Soviet and Canadian trawl surveys data have been processed according to the common methods.All trawlings had a standard period of 30 min. but in order to join the data from GDR they were recalculated for 1 hour. Data from 3288 commercial trawlings (halibut catches,kg/hour trawling) and measurements of bottom temperatures,conducted by GDR fishing vessels,were also used in the paper.

Analysis of juvenile halibut distribution in Subareas 0+I,2,3 depending on temperature and depth of fishing is based upon the USSR trawl surveys in 1983-1988. This analysis only used the data on catches with information on bottom temperature.

Results and disscussion

Analysis on joint data on GDR,Canada and USSR catches (Fig.1) testifies to the fact that during the active feeding period in July-September halibut occur in relatively shallow areas (200-600 m) within a wide range of bottom temperatures from -1.5 up to 5.9°C. The largest mean catches of halibut were recorded on the shelf at depths 400-500m at temperatures from 1 - 2.9°C. In the upper areas of continental slope concentrations of feeding halibut during this period occurred at temperatures from 2 to 4.9°C.Several large catches of halibut (up to 600 kg /hour trawling) were recorded at temperatures from 4.5 to 5.9°C. As for the whole feeding period (May - September) halibut catches beyond 100 kg per hour trawling were observed at temperatures from -0.5 to 4.9°C. Temperatures being lower or higher, there happens an abrupt decline in halibut catches.(Fig.2,1 and 2 lines; table 2).

The range of preferable (optimum) temperatures is contracting with depth (Fig.1), this results in increase of concentrations density and consequently of CPUE (hour trawling) (Fig.2 3 line).

After the feeding period is over (September- October- transitional period) halibut migrate into the open-sea areas and form in November - December dense wintering concentrations and prespawning ones in deep shelf hollows and in deepwaters of continental slope. These concentrations are the base of deepwater trawl fishery of GDR and USSR vessels in Subarea 0 and Div.2GH. The range of optimum temperatures for halibut within the prespawning period contracts to that for spawning.(3.2 - 3.5°C),(Smidt, 1969; Chumakov, Serebryakov,1982).

At the end of the feeding period (September, depth down to 600m) temperatures of halibut occurrence range from 2 to 4.5°C with the optimum 2.5 - 3.5°C,as for wintering and prespawning concentrations they occur within a more narrow temperatures range (3-4°C).

Data from trawl surveys conducted annually by Canada and USSR research vessels in the Newfoundland shallow areas indicate only insignificant or scattered halibut concentrations (Bowering, 1984). Waters with temperatures -1°C and colder occupy a considerable part of the area where scattered halibut concentrations occur.This temperature range indicates the lower limit of halibut distribution during the feeding period (Ernst,1974,1987).

A certain interest is caused by the observations on juvenile halibut distribution depending on temperatures in various Atlantic areas that is extremely important for detection of migration routes and feeding grounds. According to Soviet trawl surveys data juvenile halibut commence to occur in bottom trawl catches when 7-8cm long. At this length juvenile halibut are likely to be caught badly due to insufficient reaction to the straining canvas of a trawl net or other reasons, and they are registered in great numbers in catch composition only when 10-14cm long (Fig.3).

As seen from the Fig. 4-7 juvenile halibut were recorded at relatively small depths (200-400m) of the continental shelf practically all along the Baffin Island coast (OB),Labrador peninsula (Subarea 2) and off the continental slope of the Grand Newfoundland Bank.

In Subarea 0 in September-December 1984-1987 the largest mean catches of juvenile halibut (about 100 spec. per hour trawl.) were taken from depths 350-450m at bottom temperatures from -1 to 1.9°C.

The greatest numbers of juvenile halibut in trawl catches occurred on the shelf in Div. 3K. A powerful cyclonic eddy that causes retaining and accumulation of passively drifting larvae and juveniles was described by Buzdalin & Elizarov (1962) just in this area.

In Div. 2J+3K trawl surveys were carried out twice- in June-July and November-December 1978 that made it possible to analyze seasonal distribution of juveniles in these areas. Fig. 8 and 9 show that in June-July the main proportion of juvenile halibut was distributed over shelf deeps at depths beyond 300m. The greatest catch (903 fish per tow) occurred in the south-west of the Funk Island bank in 320 m depth at bottom temperature of 2.7°C. In shallow waters of the Belle Isle, Funk Island and Hamilton banks the number of young Greenland halibut was found to be 10-15 times lower, and they were observed in even smaller numbers on the continental slope. Some amount of juveniles was found also near the boundary of coastal fishing zone (Fig. 8).

In November-December 1978 the number of juveniles in the surveyed area was found to be 2-4 times lower than in June-July, and they were almost totally absent on the Funk Island and Belle Isle banks. In deeps and outer parts of the shelf near the continental slope juveniles were found to be much less numerous than in June-July, while they were more plentiful at the very boundary of the fishing zone in November-December, which was an indirect indication of the presence of young halibut in inshore areas in this period (Fig. 9).

Fig. 3 shows unequivocally that in November-December 1978 the size of fish from Div. 2J+3KL increased with the increase of depth. In June-July 1978 (Fig. 3), no regular increase of fish size with depth was observed, because of prevalence of the young in 300-500 m depth. Different bathymetric distribution of the young and adults, dwelling together, in different seasons is, in our opinion, due to weaker mobility of the young. In spring-summer with the warming of inshore waters the majority of Greenland halibut, dwelling on the shelf, is known to migrate coastwards for feeding. Prevalence of young halibut in 501-550 m in June-July and their almost totoal absence in November-December may be associated with a slower migration of fish to the coast, and prevalence of the young in shallow waters of the inshore area in November-December with their later migration off the coast to wintering grounds.

A certain amount of juveniles, apparently, a greater portion, continued to keep off the bottom, which was indicated by their occurrence in mid-water trawl tows. For example, young Greenland halibut 6 to 20 cm in length, with the mode of 7-8 cm, were found in mid-water trawl catches in the north of the Greenland-Canadian Threshold (Div. OB). The trawl was towed in 240-290 m, at temperature -1.1°C at 30-40 m off the bottom.

Quite considerable quantities of juvenile halibut are recorded at negative water temperatures in November annually by the acoustic capelin survey near the boundary of coastal fishing zone of Newfoundalnd and Labrador (2J+3K).

The occurrence of juveniles at negative temperatures is explained by a number of researchers by their higher eurythermity, compared to adult fish. However, by now this problem has not been studied yet. Simulataneously, as reported by Stroganov (1956), who carried out experiments with mosquitofish, juveniles adapt much worse to low temperatures, than adult fish. The occurrence of juvenile halibut at extreme water temperatures (below -0.5°C) is indicative of the fact, that up to certain age the young are not capable of leaving the area with unfavourable conditions, because of poor energetic resources, rather than of their higher eurythermity compared to adult fish.

This is consistent with the findings of Templeman (1965), who reported massive death of halibut in the Trinity Bay (southeast Newfoundland) during pelagic capelin fishery (Mallotus villosus Müller). According to this author feeding halibut in their chase of capelin enter the mid-water layers, where temperatures are below -1°C.

Available in the literature summarized data on bottom temperatures, at which Greenland halibut catches were obtained, show a wide range from -1.5°C (Templeman, 1965; Shuntov, 1965; Bowering, 1984) to 8°C (Milinsky, 1944; Shuntov, 1965), indicating extreme boundaries of halibut distribution as species. In the Northwest Atlantic Greenland halibut occurred in catches at bottom temperatures from -1.5° to 6.4°C (Table 2).

According to the data previously published (Templeman, 1973 Chumakov, 1975; Bowering, 1977, 1983; 1984a; Chumakov, Serebryakov, 1982; Zilanov et al., 1976; Bowering and Chumakov, 1987; Ernst, 1987a) the Greenland halibut inhabiting shelf Labrador and Newfoundland as well as deepwater bays of East Newfoundland are in the bulk immature. The majority of mature fish is distributed farther north and in deeper waters. For this reason, larger fish from older age groups are distributed in northern deepwater areas, to which they migrate to complete maturation and to spawn. The above researchers did not observe any spawning concentrations or mature fish in southern areas, therefore, they assumed, that Greenland halibut did not reproduce in those areas, but, apparently, migrated northwards into the Davis Strait, where massive spawning occurred.

Separate residency of juveniles and adults in different areas of the Atlantic as well as plentiful initial data collected by the GDR, Canada and the USSR together make it possible to specify both extreme boundaries of Greenland halibut occurrence for separate areas (Newfoundland, Labrador, Baffin Land) and optimum temperatures, first reported by Ernst (1987), at which greatest catch can be obtained in accord with fish biological state.

Thus, in the southern part of the distribution area on the Newfoundland shelf (Div. 3K), inhabited mainly by immature fish, in the spring-summer period feeding halibut were distributed in waters with bottom temperatures from -1.5° to 5.9°C. Densest concentrations were observed at temperatures from -0.5° to 4.9°C. In autumn-winter extreme and optimum temperatures for feeding halibut dwelling in the same area were -1 to 5° and 1 to 3°C, respectively. Feeding halibut, distributing on the continental slope in the autumn-winter period, aggregated at higher positive temperatures, than those on the shelf, inhabited primarily by small fish. (Fig. 2, Table 2).

Observations show, that by the end of a year, when the halibut aggregate in wintering and pre-spawning concentrations, an optimum temperature range becomes much narrower.

In October-December, occasionally in late September, Greenland halibut with reproductive products on the verge of releasing occurred in 700-1200 m at water temperatures from 2.5 to 5°C. Greatest catches were obtained at temperatures from 3 to 4°C)Table 2). These data are in good conformity with observations by Ernst (1987) previously reported.

By December wintering concentrations of halibut on the continental slope are normally formed. In this period densest concentrations were found deeper 700 m at temperatures from 3 to 4.5°C. Catches obtained at the same temperatures contained males and females with running gonads, i.e. spawning fish. Greatest catches of halibut with running gonads were found earlier in January-February in the south of the Greenland-Canadian Threshold at bottom temperatures from 3.2 to 3.4°C(Chumakov, Serebryakov, 1982).

The relationship between density and bottom temperature and biological state of fish as well as interactions among these parameters surely produce effect on the distribution of halibut and, hence, on fishery yield. For example, because of anomalous changes in the thermal regime of waters observed by a number of researchers (Chumakov, Savvatimsky, 1983, 1984, 1987; Ernst, 1984, 1987; Savvatimsky, 1986) halibut were found to migrate from relatively shallow waters (600-800 m) in 1968-1971 to deeper ones (800-1500 m) in 1975-1983, and the density of aggregations was observed to grow due to distribution of fish in a thin depth range and over a smaller area.

The heat content of the Baffin Land waters is observed to increase since 1984, which has resulted in a decrease of halibut density on the continental slope and, hence, in a reduction of fisheries production (Chumakov, Borovkov, 1986; Chumakov et al., 1987; Chumakov, Savvatimsky, 1987; Chumakov, Bowering, 1988).

Thus, the present study allows to gain insight into general mechanisms governing the distribution of Greenland halibut depending on bottom temperatures, specifies and complements our knowledge of seasonal dynamics of extreme and optimum (preferred) temperatures by age. Results obtained can be used for practical purposes in forcasting the production level of the halibut fisheries in the Northwest Atlantic.

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Table 1. List of surveys and number of control trawlings carried out by USSR and Canada research vessels in Div. 3K and 2GH in 1978-87.

Year	Vessel (cruise number)	Number of trawlings	
		3K	2GH
1978	Persey-III (20)	34	
1978	Persey-III (21)	39	
1978	Gadus Atlantica (15)	69	
1979	Suloy (2)	38	
1979	Gadus Atlantica (27,29)	136	
1979	Suloy (3)		112
1980	N.Kononov (2/80)	61	
1980	Gadus Atlantica (42,44)	146	
1980	N.Kononov (3)		41
1981	N.Kononov (4/81)	48	
1981	Gadus Atlantica (57)		138
1981	Gadus Atlantica (58,59)	133	
1981	Persey-III (26)		63
1982	Suloy (2)	58	
1982	Gadus Atlantica (71,72)	155	
1982	Suloy (26)		48
1983	Suloy (29)		62
1983	Suloy (27)	82	
1983	Gadus Atlantica (87,88)	131	
1984	Suloy (30)	100	
1984	Gadus Atlantica (101,102,103)	183	
1984	N.Kuropatkin (6)		52
1985	Genichensk (2)	49	
1985	Gadus Atlantica (117,118)	214	
1985	N.Kononov (33)		34
1986	N.Kononov (34)	110	
1986	Gadus Atlantica (132,133)	120	
1986	Klintsy (23)		28
1987	Persey-III (37)	102	
1987	Gadus Atlantica (146,147)	171	
1987	K.Shaitanov (8)		93

ıble 2. Extreme and optimum temperature ranges for Greenland halibut in the Northwest Atlantic in relation to the fish physiological condition in different seasons.

	Temperature range, °C		Month	Depth, m	Author
	extreme	optimum			
Total stock	-I.5 to 6.4	-0.5 to 5	Jan–Dec	I00- >I200	Templeman (1965) Bowering (1984)
Feeding aggregations in spring-summer (shelf)	-I.5 to 5.9	-0.5 to 4.9	Apr–Sep	200-600	Templeman (1965), Ernst(1987) Our data
Feeding aggregations in autumn-winter (shelf)	-I to 5	I to 3	Sep–Dec	I00-600	Lear, Pitt (1971) Our data
Feeding aggregation on continental slope	I to 5.5	2 to 4.4	Sep–Nov	600-I500	Our data
Pre-spawning aggregations	2.5 to 5	3 to 4	Sep/Oct–Dec	700-I200	Ernst (1987) Our data
Spawning	3 to 4.5	3.2 to 3.4	Jan–Mar	I000-I500	Chumakov, Serebryakov (1982) Our data
Wintering aggregations (immature and mature fish on continental slope)	3 to 4.5	3.4 to 4	Dec–?	> 700	Ernst (1987) Our data
Young halibut (30 cm)	-I.5 to 6.4	0 to 3.9?	Jan–Dec	I00-I000	Our data

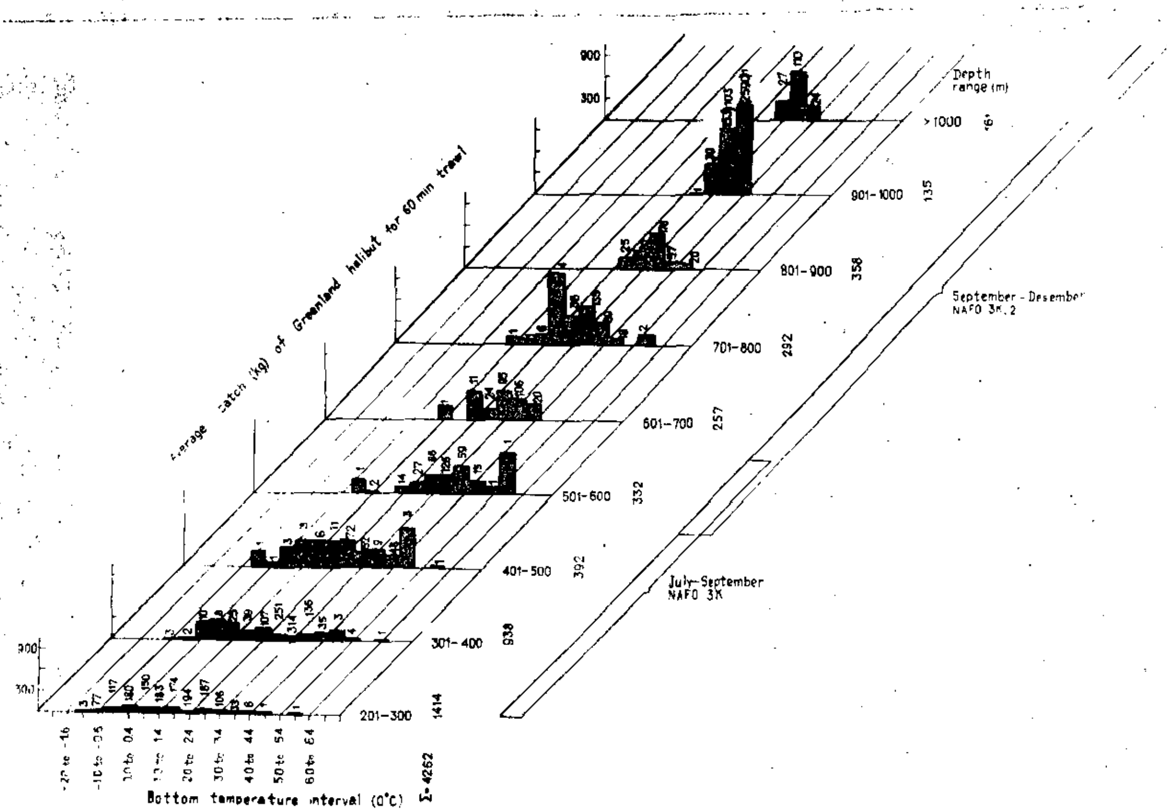

Fig. 1. Mean catches of Greenland halibut by 100 m depth intervals depending on bottom temperature. Summarized catch data by the GDR (1968-83), Canada, USSR (1978-87). Number of sets is indicated above diagram columns.

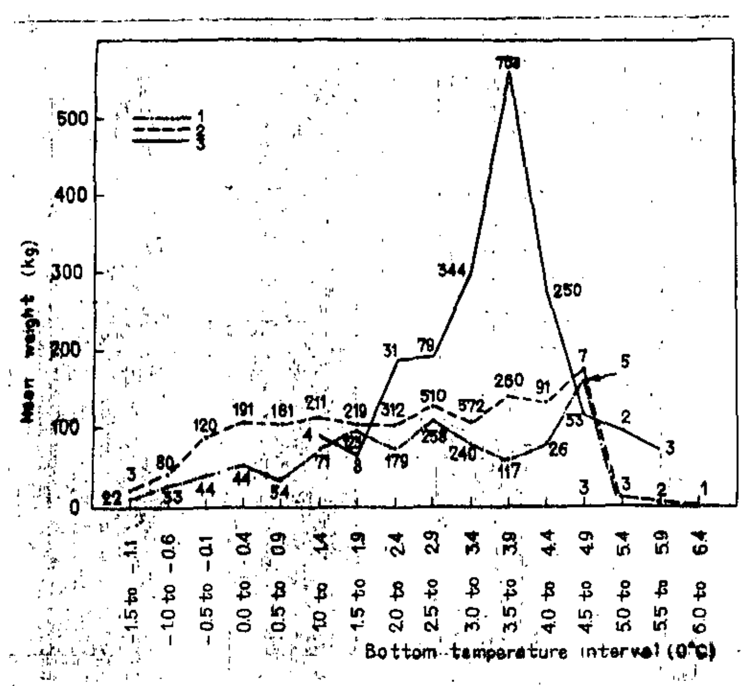

Fig. 2. Mean catches of Greenland halibut depending on bottom temperatures, kg per hour trawling (Legend: 1 - NAFO Div. 3K, October-December 1978-87 Canada trawl surveys data; 2 - NAFO Div. 3K, shelf (100-500 m), May-September 1978-87 data from GDR, Canada, USSR; 3 - NAFO Div. 2GH, continental slope (600-1,500 m), September-December 1978-87 data from GDR, Canada, USSR.

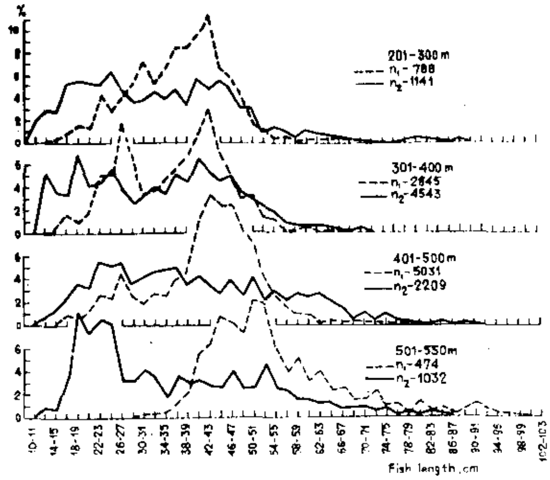

Fig. 3. Size composition of Greenland halibut in different depths on the shelf in November-December (dashed line) and June-July 1978 (solid line).

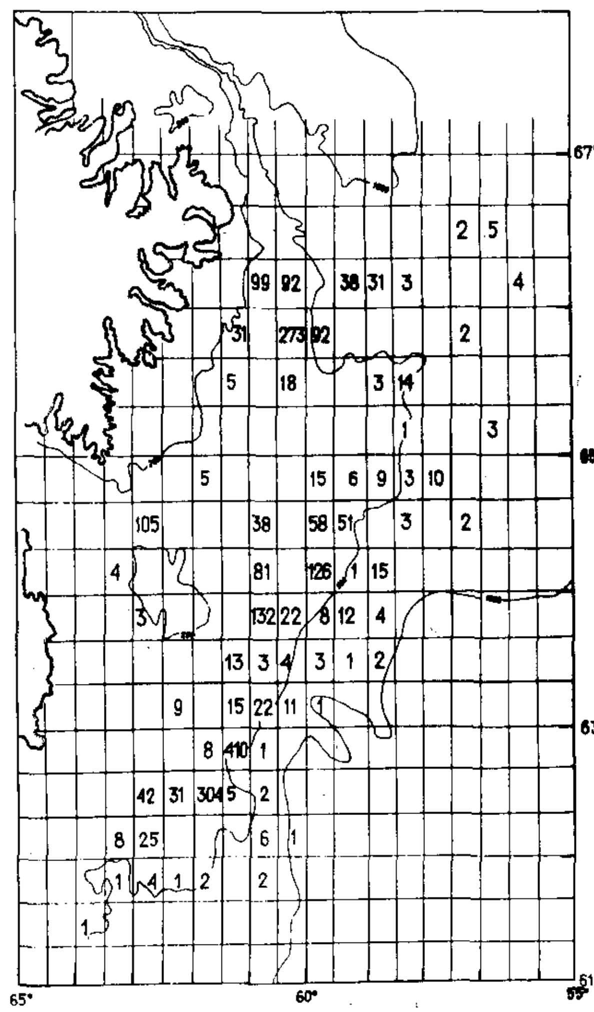

Fig. 4 Distribution of mean catches of young Greenland halibut (≤ 30 cm) in Div. 0B in September-December 1983-1987, fish per hour tow.

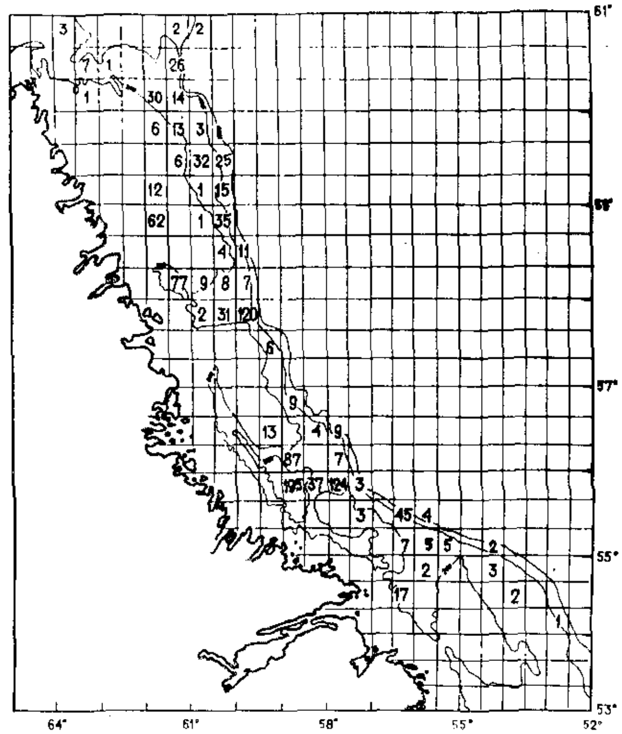

Fig. 5 Distribution of mean catches of young halibut (≤ 30 cm) in Divs. 2GH in October-December 1983-1987, fish per hour tow.

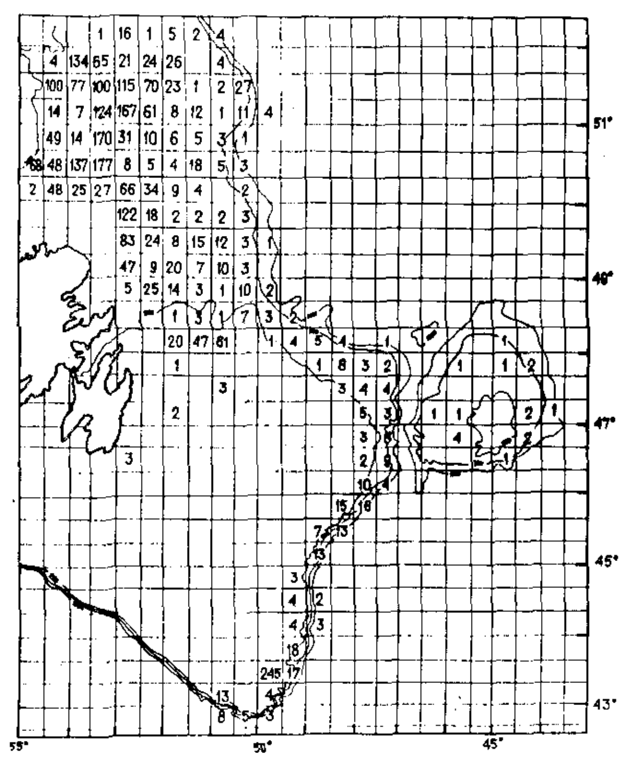

Fig. 6 Distribution of mean catches of young halibut (≤ 30 cm) in SA3 in April-July 1984-1988, fish per hour tow.

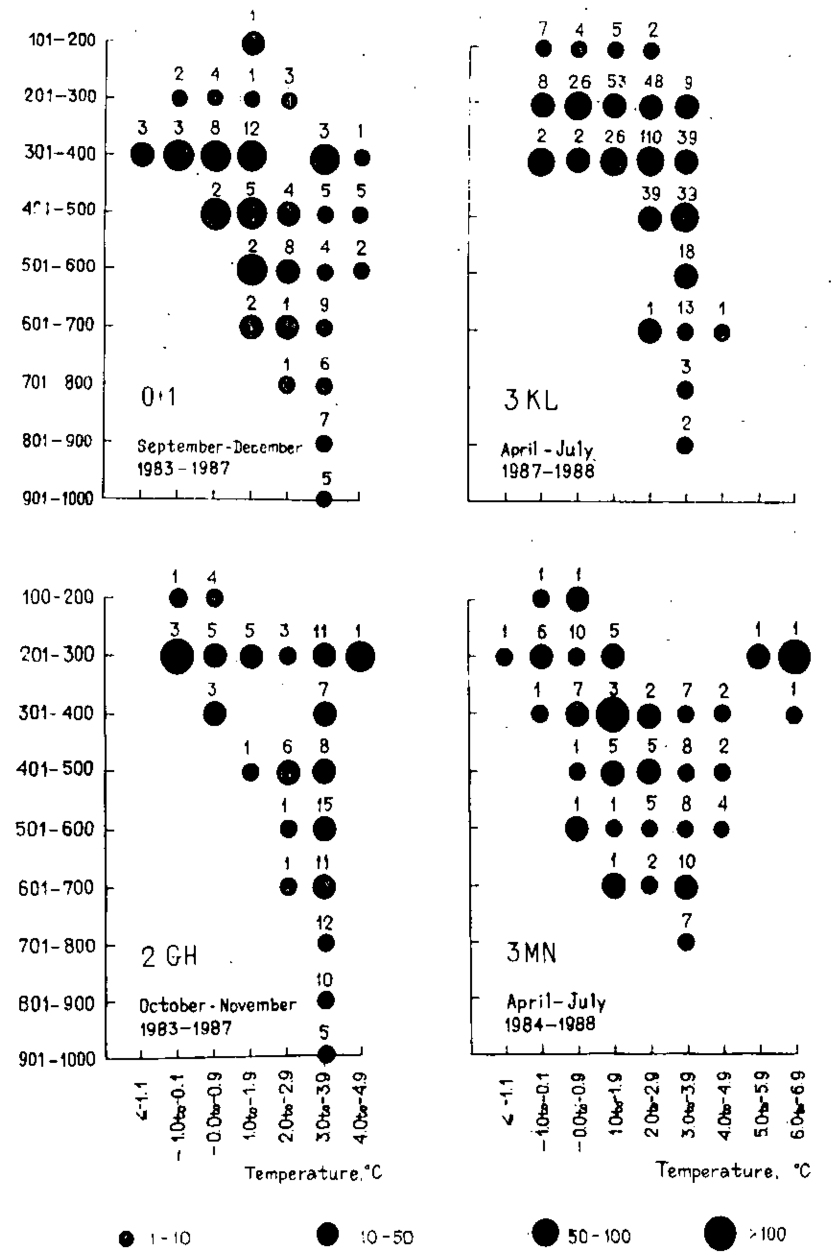

Fig. 7 Mean catch of young Greenland halibut (30 cm) (fish per hour tow) in relation depth and bottom temperature. Number of sets is given above mean catch symbols.

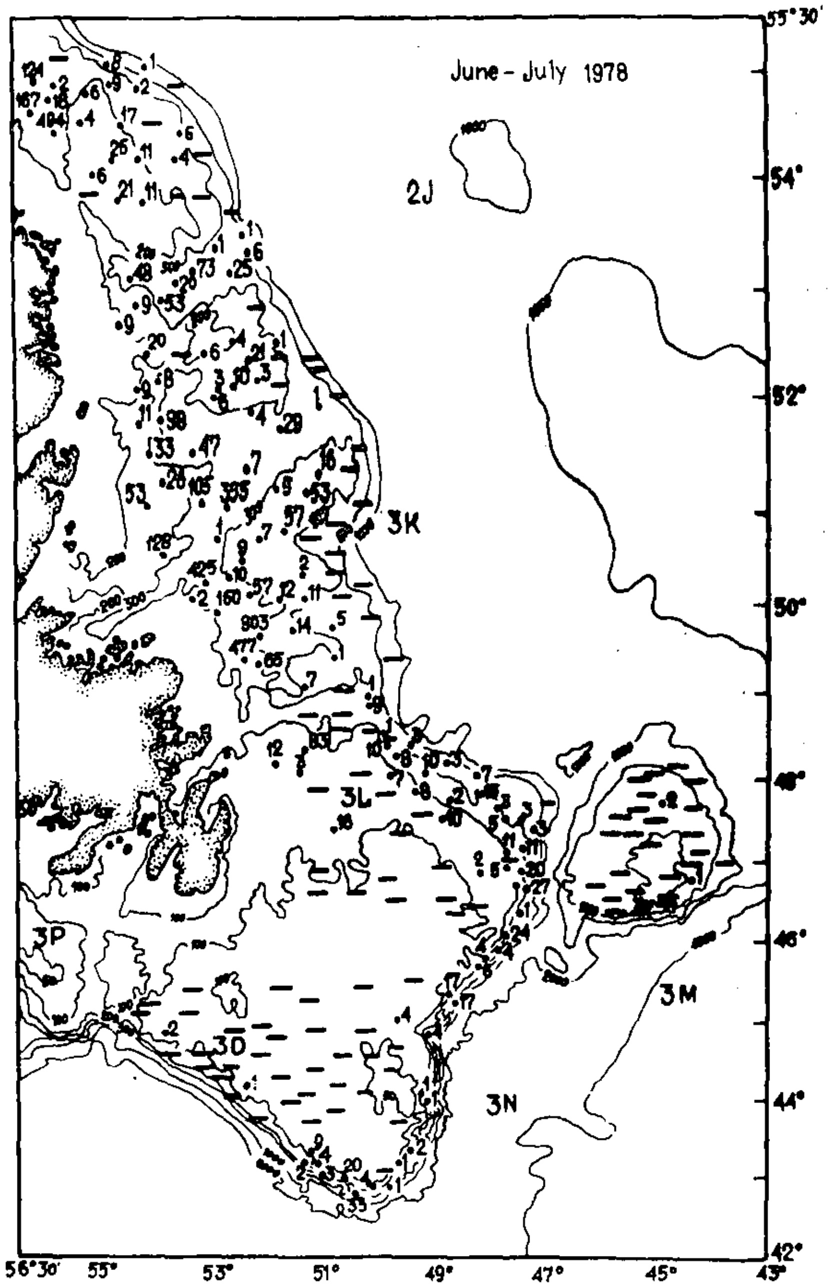

Fig. 8 Distribution of catches of young Greenland halibut (≤ 30 cm) in June-July 1978, fish per hour tow.

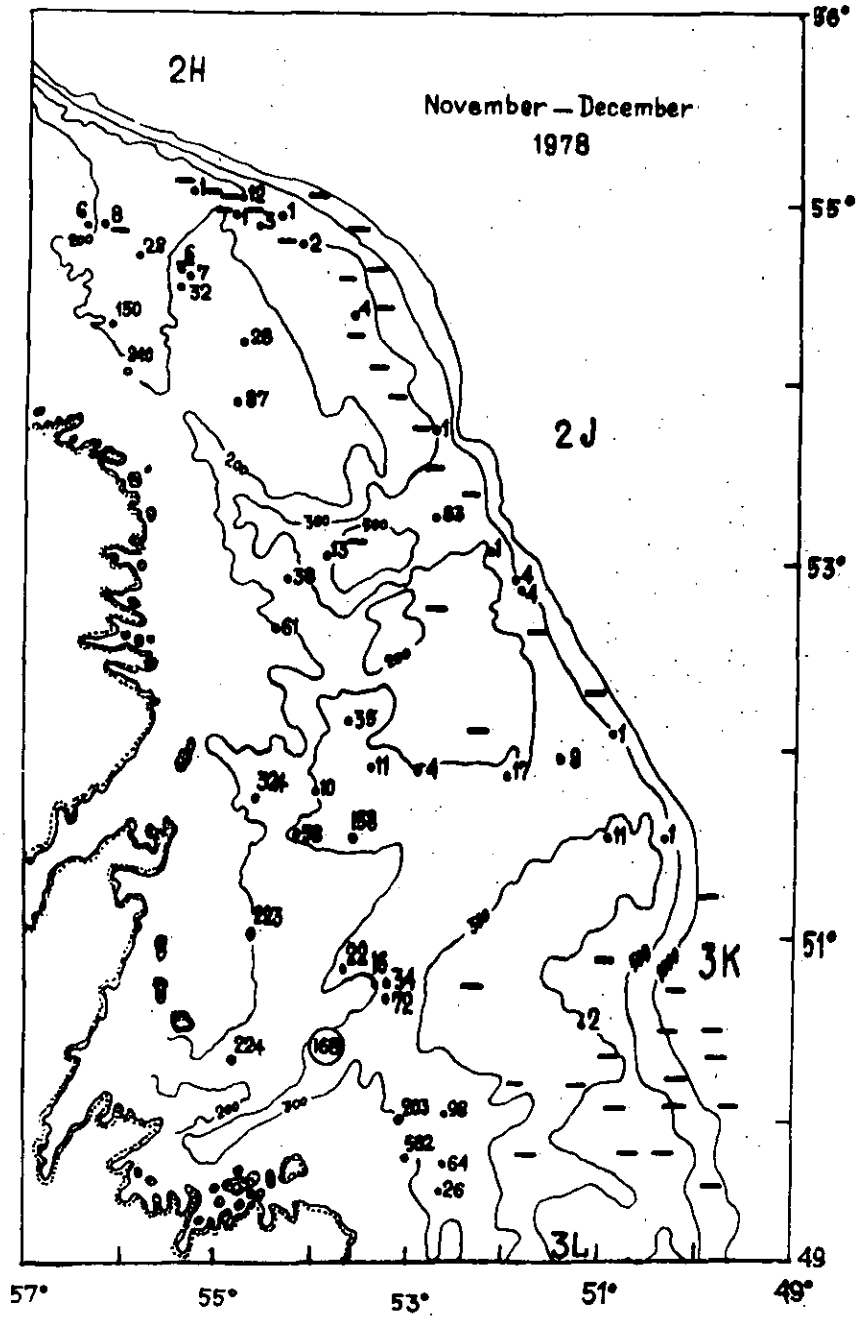

Fig. 9 Distribution of catches of young Greenland halibut (≤ 30 cm) in November-December 1978, indiv. per hour tow.