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The Distribution and Relative Abundance of Greenland Halibut (*Reinhardtius hippoglossoides*) in the Canadian Northwest Atlantic from Davis Strait to the Northern Grand Bank

by

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INTRODUCTION

a) General Distribution

Greenland halibut are found in both the North Atlantic and North Pacific Oceans but absent from intervening Arctic waters (Hubbs and Wilimovsky 1964, Atkinson et al. 1981). Based on meristic and morphometric characters, Hubbs and Wilimovsky (1964) concluded that there is one species found in both oceans, not two as previously thought (Andriyashev 1954).

In the Northwest Atlantic, Greenland halibut are widely distributed along the West Greenland Coast and in the Davis Strait and are reported as far north as Smith Sound (78° latitude) by Smidt (1969) (Fig. 1). In the Canadian far north they are found in abundance in the Baffin Island area (Templeman 1973; Bowering 1978c, 1979a) and extend in the Hudson Strait to Ungava Bay (Dunbar and Hildebrand 1952). They are most prevalent from northern Labrador to the northern Grand Bank (Templeman 1973; Bowering 1977, 1978d, 1979b, 1980b; Bowering and Brodie 1981) with small numbers recorded in the vicinity of the Flemish Cap (Bowering and Baird 1980). Greenland halibut are found incidentally on St. Pierre Bank with a small localized concentration located in Fortune Bay (Bowering 1978b). Earlier investigations by Templeman (1973) indicated that Greenland halibut were found in the northern Gulf of St. Lawrence in relatively small numbers. More recent investigations (Bowering 1979d, 1980a, 1981a) have shown that Greenland halibut have become commercially abundant in this area with very little occurrence on the Scotian Shelf. The most southerly occurrence in Canadian waters was reported by Barrett (1969) in March 1968 in the Bay of Fundy where he caught two Greenland halibut 27 and 42 cm in length. Subsequent to this Templeman (1973) reported catches as far south as the southern tip of the Scotian Shelf.

In the Northwest Atlantic, spawning is believed to take place in spring in the Davis Strait area. It occurs in deep warm water to the south of the Greenland-Canadian cascade located between Greenland and Baffin Island at about 67°N latitude (depths down to 675m) (Smidt 1969). The eggs and small larvae are found in depths of 600-1000m. However, the larvae later rise to the surface waters where they are taken by currents to and along the west coast of Greenland to the northern part of Davis Strait. Here the current turns and larvae are likely transported southward to the banks of Baffin Island (Atkinson et al. 1981). Templeman (1973) hypothesized that larvae caught in the current off Baffin Island drift to the south and colonize the banks off Labrador and eastern Newfoundland. Chumakov (1975) suggested that as Greenland halibut in the Labrador, eastern Newfoundland and the northern Grand Bank region approach maturity, they migrate north from the banks and slopes into deeper water for spawning. This would suggest that most Greenland halibut in the Northwest Atlantic form one continuous stock (Zilanov 1976; Bowering 1977). Lear (1970) and Templeman (1970) suggested that the Greenland halibut in the Gulf of St. Lawrence may be a separate stock; however, Bowering (1980a, 1981a) suggested that while the Gulf of St. Lawrence may support a separate stock of Greenland halibut there appears to be mixing of stocks in this area. This could result from immigration from the Labrador region through the Strait of Belle Isle.

b) Stock Identification Studies

The Greenland halibut resource in the Northwest Atlantic is now managed as three separate stocks; 1) The Gulf of St. Lawrence stock (NAFO Div. 4RST), 2) the Labrador-Eastern Newfoundland stock (NAFO Subarea 2 and Div. 3KL), and 3) the Baffin Island-West Greenland stock (NAFO Subareas 0 and 1) (Fig. 1).

The implications of a management strategy by three separate components with regard to the accuracy of international fish stock assessment of this species in these areas during the last years became an important issue. This is the result of hypotheses that the stock complex from Davis Strait to the northern Grand Bank (Chumakov 1975; Bowering 1977) is a single population not two, as well as the evidence for two populations in the Gulf of St. Lawrence (Bowering 1979d, 1980b, 1981a) not one as previously thought. The management bodies of NAFO (Northwest Atlantic Fisheries Organization) and CAFSAC (Canadian Atlantic Scientific Advisory Committee) therefore recommended considerable research effort be placed into the accurate delineation of Greenland halibut stocks in Canada's far north, to provide for effective biological management of this very valuable resource.

The first investigation into stock identification of Greenland halibut in the Northwest Atlantic was published by Templeman (1970). He analysed meristic characters of Greenland halibut from samples collected from West Greenland to the southern Grand Bank and the northern Gulf of St. Lawrence. A statistical analysis of vertebral numbers averages revealed no significant differences throughout the range under investigation with the exception of the Gulf of St. Lawrence. This area was significantly different from all other areas. He concluded that vertebral averages were not particularly useful in separating Greenland halibut stocks of the Northwest Atlantic apart from the possible separation of the Gulf of St. Lawrence population. Laboratory experiments on the formation of meristic characters by Gabriel (1944), Heuts (1949) and Taning (1944, 1952), however, suggested that while the numbers of vertebrae and fin rays in teleostean fishes may be genotypically selected, the individual phenotype may be influenced by external environmental factors such as temperature and salinity. The phenocritical period during which the final numbers of vertebrae and fin rays are determined in teleostean fishes has consequently been the subject of much discussion and scientific investigations. These investigations have produced varied results for different species (summarized in Templeman and Pitt 1961).

Khan et al. (1981) studied stock delineation of Greenland halibut in the Northwest Atlantic by analysing the prevalence of trypanosome and piroplasm infections as biological tags. Results from the study suggested that Greenland halibut from the Davis Strait, northern Labrador and the northern Grand Bank form a single stock. The southern Labarador data were different from the other areas and might represent an isolated population, but the authors concluded it was part of a cline in the prevalence data. The Gulf of St. Lawrence data were distinct from that of all other areas north and east of Newfoundland and was considered as evidence of a separate stock there. These results were similar to those of Misra and Bowering (1984) who performed a multivariate analysis of meristic characters on Greenland halibut for the same area.

Fairbairn (1981) investigated allele and genotype frequencies at 16 electrophoretically detectable protein loci, from tissue samples of Greenland halibut throughout the range from Davis Strait to the northern Grand Bank. Her analysis suggested that Greenland halibut from the Northwest Atlantic area form a single genetically homogenous stock. She concluded that Greenland halibut in the Gulf of St. Lawrence form a separate stock from the eastern Newfoundland area although this stock was not completely isolated since it showed similarities to the Labrador areas.

Bowering (1981b) studying biological characteristics such as age and growth and sexual maturity also concluded that the Greenland halibut from Davis Strait to the northern Grand Bank formed a single stock.

Given that most studies have reached this conclusion, this paper will describe in detail the seasonal distribution and relative abundance (summer versus fall-winter) of Greenland halibut in the Canadian Northwest Atlantic from Davis Strait to the northern Grand Bank according to geographic area, depth and bottom temperature.

MATERIALS AND METHODS

The data used to describe the distribution were collected during research vessel surveys conducted by both Canada and the USSR from 1977 to 1987. A list of the research vessel surveys and the respective numbers of fishing stations by survey and NAFO Division is presented in Table 1. The Canada and USSR data were treated equally in that no adjustments were made for differences in vessels and fishing gears although all sets were standardized to 30 minutes duration and both gears contained small mesh liners in the codend to avoid escapement of small fish. Sets in which the fishing gear was badly damaged or other reasons considered to interfere with the normal retention of the catch were not used in any of the calculations.

RESULTS

a) Geographic distribution and relative abundance

The geographic distribution and relative abundance is presented as mean numbers caught per 30-minute set per ½° latitude and 1° longitude rectangles. The numbers of fishing sets used in the distributions are shown in figures 2 and 3 for the summer surveys and fall-winter surveys respectively.

Results of the Canadian summer surveys (Fig. 4) indicate that Greenland halibut were abundant throughout the range of the investigations with no apparent break in the continuity of the distribution. In the Davis Strait area they were most abundant in the area south of Disko Island between 68°N and 69°N with good catches in the slope areas off both Baffin Island and West Greenland. In the Labrador areas the high abundance occurred just south of Hudson Strait at the slope area of Div. 2G and in the Hopedale, Cartwright and Hawke Channels of mid to southern Labrador (Div. 2H and 2J). Levels of abundance at the slope areas were less than in the channels towards the coast (Fig. 4). To the south, the highest levels of abundance occurred in an area off northeastern Newfoundland on the inner slopes of the Funk Island Bank area between 49°30'N and 52°N and between 52°W and 55°W. Further south the catch rates diminished to zero on top of the Grand Bank.

The continuity of the distribution of Greenland halibut during the fall-winter surveys of Canada and the USSR is similar to that shown by the Canadian summer surveys (Fig. 5), however, these surveys do not extend quite as far north. In the Davis Strait region Greenland halibut were more abundant at the slope area and were overall more abundant than during the summer (Fig. 5). This is particularly evident in Hudson Strait and just to the north of Hudson Strait. In the northern Labrador area, they were highly concentrated at the slope of Div. 2G but were still more abundant in the channels of mid to southern Labrador. While Greenland halibut were still plentiful off northeastern Newfoundland they appeared to be much more dispersed throughout this area than that experienced during the summer surveys.

b) Distribution and abundance with depth (m)

The distribution with depth is expressed as mean numbers per 30-minute set according to various depth intervals (m) and is shown in Fig. 6. During the Fall-Winter surveys in Div. 2GH the research catch rate increases systematically to peak at a depth of 751-1000 m beyond which the catch rate decreases (Fig. 6)

During Summer surveys in Divisions 2GH a similar trend occurs however, the peak is at a depth of 501-750m. For Div. 2J and 3K only Fall-Winter survey data are presented showing an increasing trend up to a depth of 401-500m beyond which the trend is difficult to evaluate except that very few fish are caught beyond a depth of 1000m. For the Davis Strait area (Subareas 0 + 1) the summer survey catch rate reaches a peak at a depth of 751-1000m then declines sharply with no apparent trend prior to the peak. On the other hand, for the fall-winter surveys in Subarea 0 there is a continuous increasing trend up to a depth of greater than 1000m.

c) Distribution and abundance with bottom temperatures (°C)

Bottom temperature data were only available for the Canadian surveys. Comparisons were made between summer and fall surveys for Div. 2GH and for Div. 2J3K respectively. The results are presented as mean numbers and weights per 30 minute set for various bottom temperature intervals and are shown in Fig. 7. For the summer surveys in Div. 2GH Greenland halibut were caught in temperatures of less than 0.0°C to greater than 6.0°C. The peak abundance occurred at 5.1-6.0° however, this was based upon only 3 sets. The second peak was at a temperature range of 3.1-4.0°C based upon 131 sets, the highest sample size for this series of surveys. For the fall surveys, Greenland halibut were relatively abundant from a temperature range of less than 0.0°C up to about 5.0°C. The highest catch rate, however, was at temperatures of less than 0.0°C based upon quite large sample sizes (338 sets less than 0.0°C).

d) Length frequency distribution by depth interval (m)

Length frequency distributions by various depth intervals(m) are presented for summer and fall-winter surveys for NAFO Subarea 0 and Div. 2G and 2H and for fall-winter surveys for Div. 2J and 3K. The results are shown in Fig. 8-11 inclusive, respectively. An overall length frequency distribution by Division regardless of depth and season is shown in Fig. 12. The mean lengths with standard errors from the length frequencies presented in Figures 8-11 inclusive is shown in Fig. 13 while the mean lengths and standard errors regardless of depth zone are shown in Fig. 14.

i) Subarea 0 and 1

During the summer survey (Fig. 8) there were proportionately higher numbers of fish less than 40 cm caught in depths up to 400 m with few fish caught less than 40 cm beyond 500 m in depth. The depth range 401-500 m appeared to show nearly the same proportion of fish on either side of 40 cm. The trend over depth was similar during the winter surveys (Fig. 8) except that overall, catches of larger fish were proportionately higher than in the summer.

ii) Division 2G

In this division during summer surveys (Fig. 9) the change in size composition was more abrupt with most of the catch being less than 40 cm up to 300 m in depth beyond which practically no fish were caught less than 40 cm in length. The distributions from 301-1000 m were about the same. During the fall-winter surveys (Fig. 9) the size distribution with depth shifted systematically to the right with much larger fish predominating the deeper water.

iii) Division 2H

For the summer surveys (Fig. 10) the length distributions were similar for depth up to 300 m with most fish less than 40 cm. For the depth range 301-750 m about equal numbers of fish greater than and less than 40 cm were represented. Beyond 750 m in depth few fish were represented in the catch less than 50 cm in length. In the winter surveys (Fig. 10) the size composition was less segregated by size over depth compared to the summer surveys. In fact, the modal length was probably greatest at depths of 301-500 m unlike those already reported.

iv) Divisions 2J and 3K

The length distributions from fall-winter surveys in Div. 2J (Fig. 11) and 3K (Fig. 11) are very similar except that the large mode at 10cm shown for Div. 3K (Fig. 11) was not apparent in Div. 2J (Fig. 11) at less than 200 m in depth. The major change in size composition for both divisions occurred at about 500 m in depth and a length of about 40 cm appeared to be the point at which change occurred. See Fig. 13 for a summary of mean size by depth.

A comparison of overall length compositions by division, all depths and seasons combined (Fig. 12) would suggest a systematic shift in the proportion of larger fish going from south (Div. 3K) to north (Subarea 0). See Fig. 4 for summary of mean size by division.

e) Age distribution

For comparison, age compositions were presented for Div. 2G, 2H, 2J, 3K and 3L for the years 1978, 1979 and 1981 and are shown in Fig. 15. The distributions are not all that different by year within division except for some possible differences in year class strengths. However, it would appear that few fish beyond 10 years old are caught in either division. It is clear, on the other hand, that fish greater than 6 years old predominate Div. 2G whereas fish less than 6 years old predominate in Div. 2H, 2J and 3K. In Div. 3L there does not appear to be many older or very young fish with most of the catch in this division dependent mainly on a couple of age groups.

The age compositions from the commercial fishery data presented in Fig. 16 would also indicate that commercial exploitation is also dependent on very few age groups with about 80% (on average) of the commercial catch comprised of 3 age groups usually ages 6-8 or 7-9 years old.

DISCUSSION

Greenland halibut are widely distributed throughout Davis Strait 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.

According to Bowering (1977, 1981, 1983), Chumakov (1975) and Zílanov 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, older fish in the length and age 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 Div. 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 the coast of Baffin Island and in Davis Strait. This was also considered as evidence of a deep water northward 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. In more recent years, in fact, these same year classes have predominated the fishery in some fjords of northwest Greenland.

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 1970) and areas of high abundance may be associated with the large concentrations of capelin in these areas as reported by Pinhorn (1976). All these areas are coincidental with the areas of highest abundance presented here. 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 Polar and Labrador currents, 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 although from the present study it is difficult to determine the optimum temperature range for Greenland halibut. 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 500 m depth zone.

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Table 1 . List of research vessel surveys by Canada and the USSR and the respective numbers of fishing stations per survey and NAFO Divison used in the analyses.

SUMMER SURVEYS

SETS FISHED

NAFO DIVISION

COUNTRY	SHIP	YEAR	0A	0B	1A	1B	1C	1D	2G	2H	2J	3K	3L
CANADA	GADUS ATLANTICA	1978							53	51	63	91	
		1979							59	75			
		1981							52	83			
		1986	26	114	14	29	39	13					
		1987											110
	WILFRED TEMPLEMAN	1984											209

FALL & WINTER SURVEYS

SETS FINISHED

DIVISIONS

COUNTRY	SHIP	YEAR	0A	0B	2G	2H	2J	3K	3L
USSR	SULOY	1979		100	35	75			
	NIKOLAI KONONOV	1980-81		39	21	17	49	35	
	PERSEY	1981-82		13	16	47	23		
	SULOY	1982-83		53	19	29	36	67	
	SULOY	1883-84		71	27	35	13	32	
	SULOY	1984		32	15	1			
	KUROPATKIN	1984		25	27	25	19		
	N. KONONOV	1985-86	1	177	16	18			
	KLINTSY	1986		66	9	19	15		
CANADA	GADUS ATLANTICA	1977					119	8	
		1978					55	70	
		1979					99	128	
		1980					104	144	
		1981					104	121	
		1982					157	146	
		1983					129	126	
		1984					108	165	
		1985					131	196	
	WILFRED TEMPLEMAN	1983						126	
		1985						232	

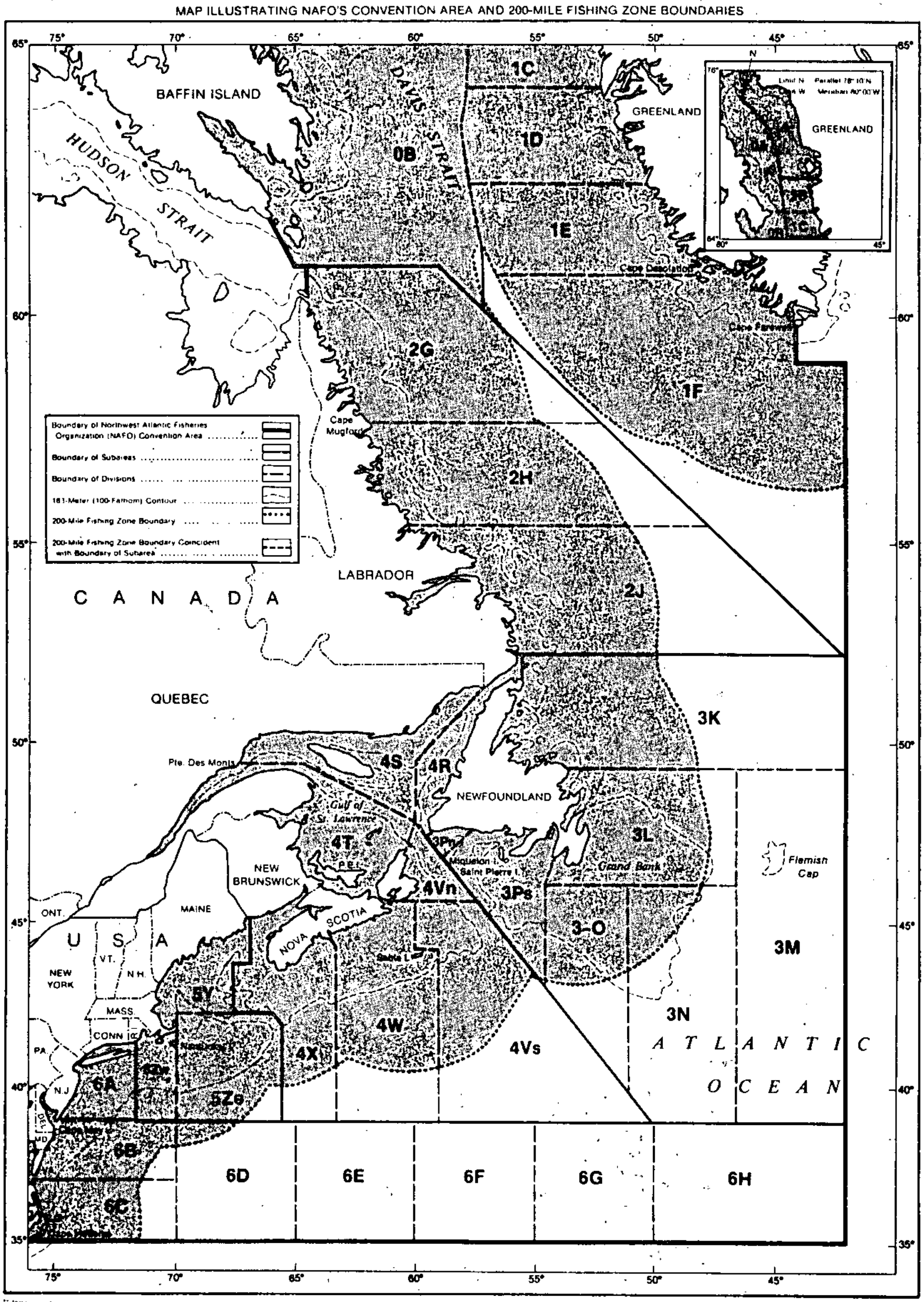


Fig. 1. Map of NAFO Convention area including the study area.

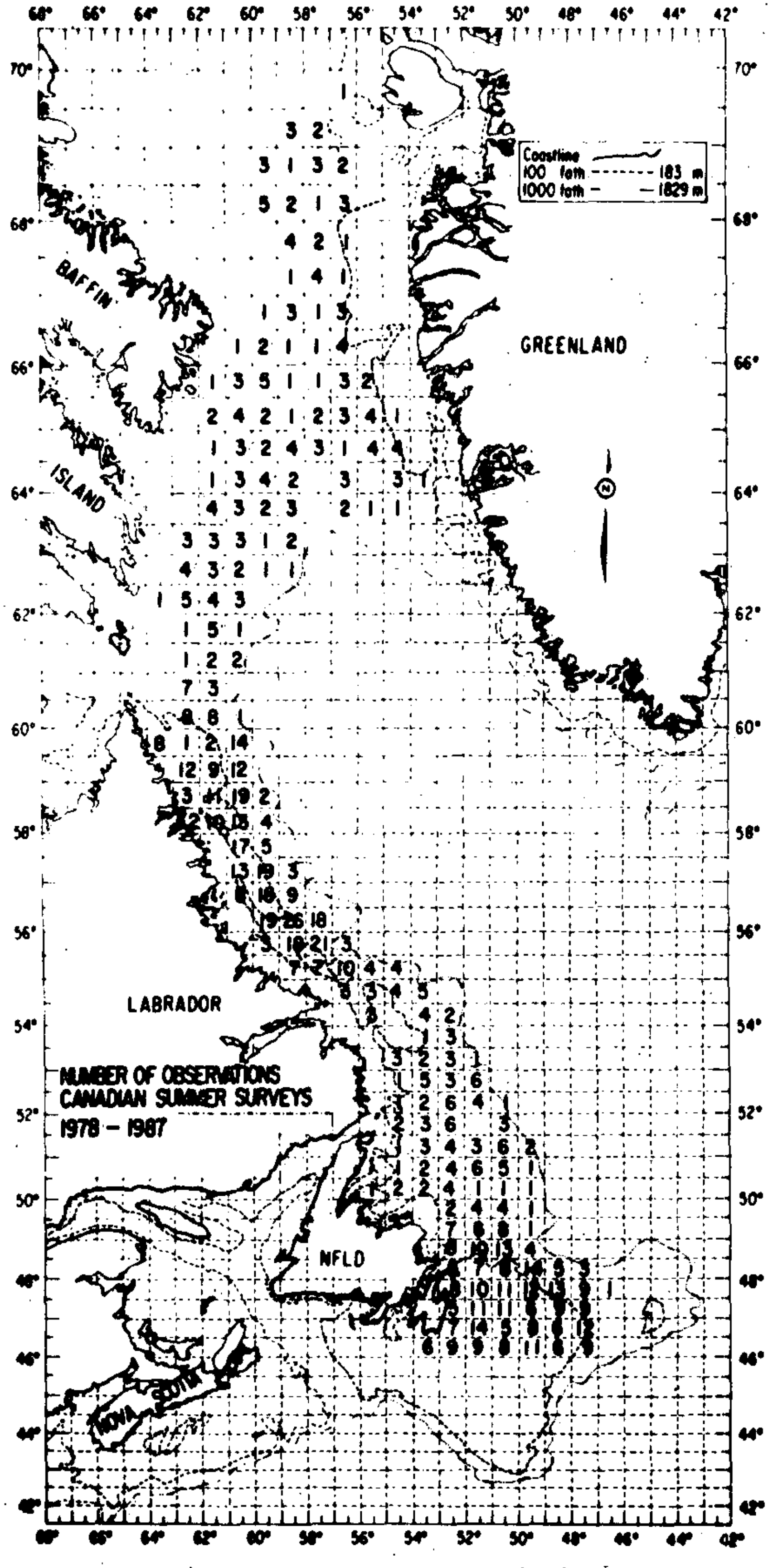


Fig. 2. Map showing numbers of successful fishing sets during the Canadian summer surveys, 1978-87.

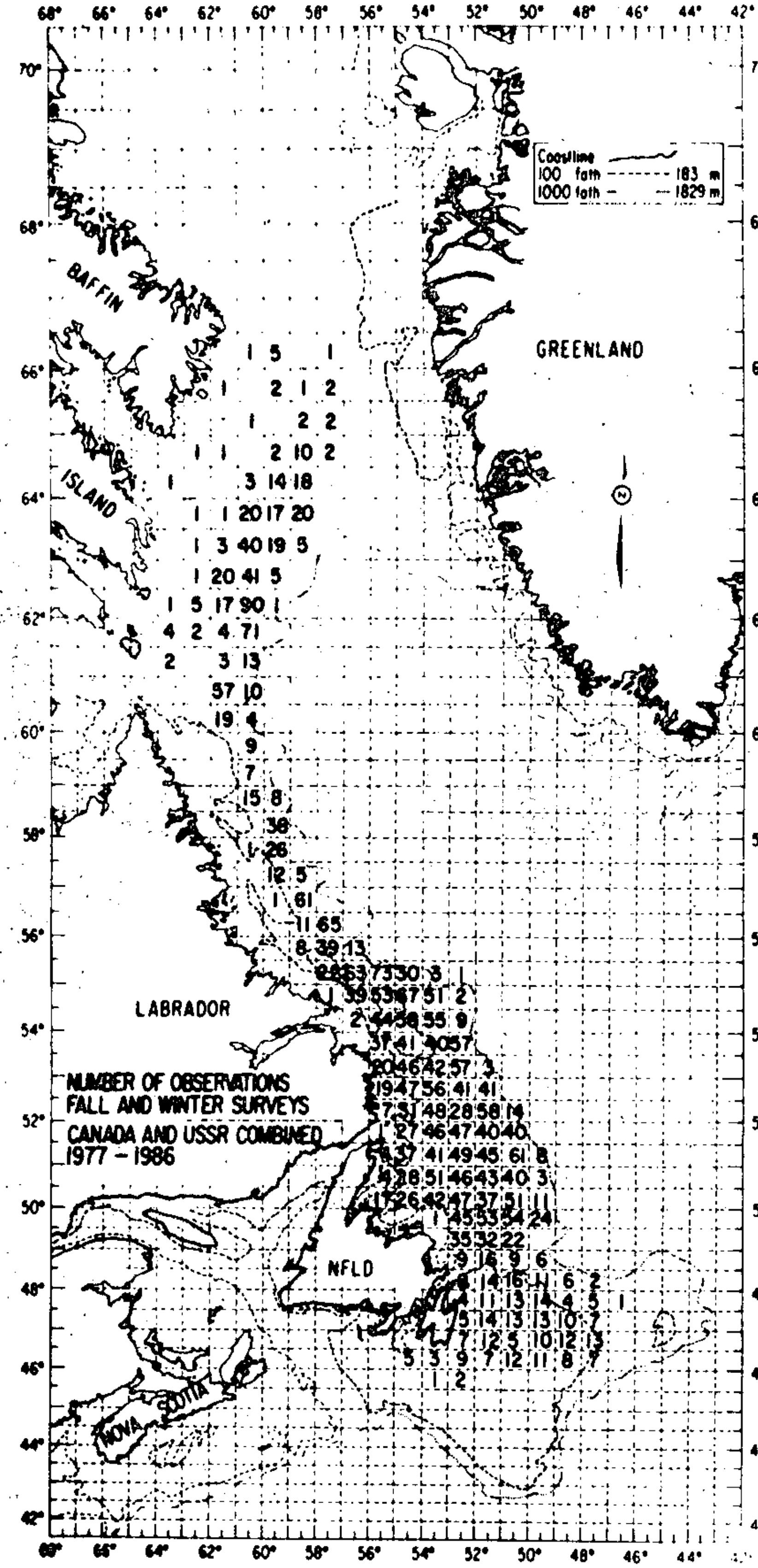


Fig. 3. Map showing number of successful fishing sets per unit area during fall-winter surveys of Canada and the USSR, 1977-86.

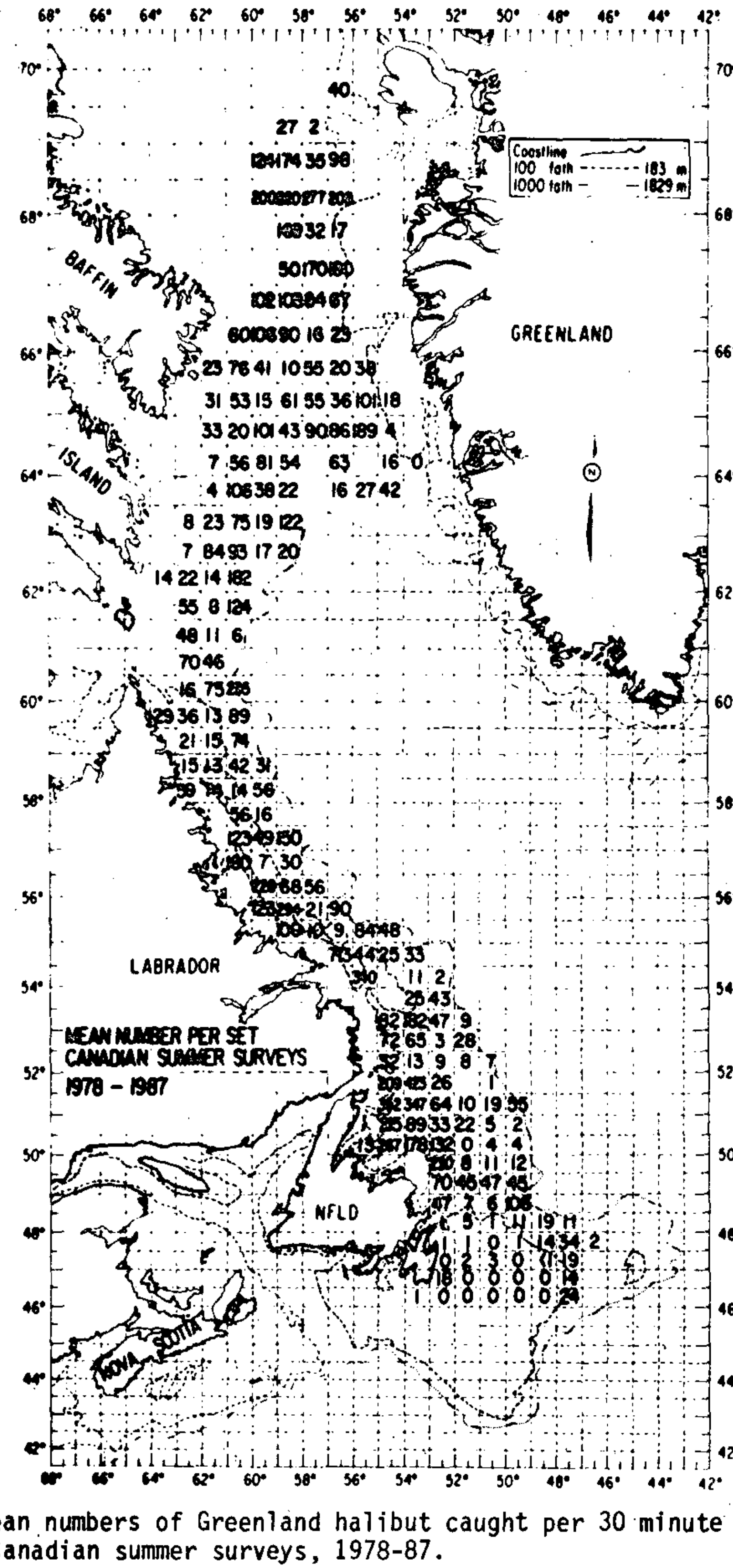


Fig. 4. Mean numbers of Greenland halibut caught per 30 minute set per unit area from Canadian summer surveys, 1978-87.

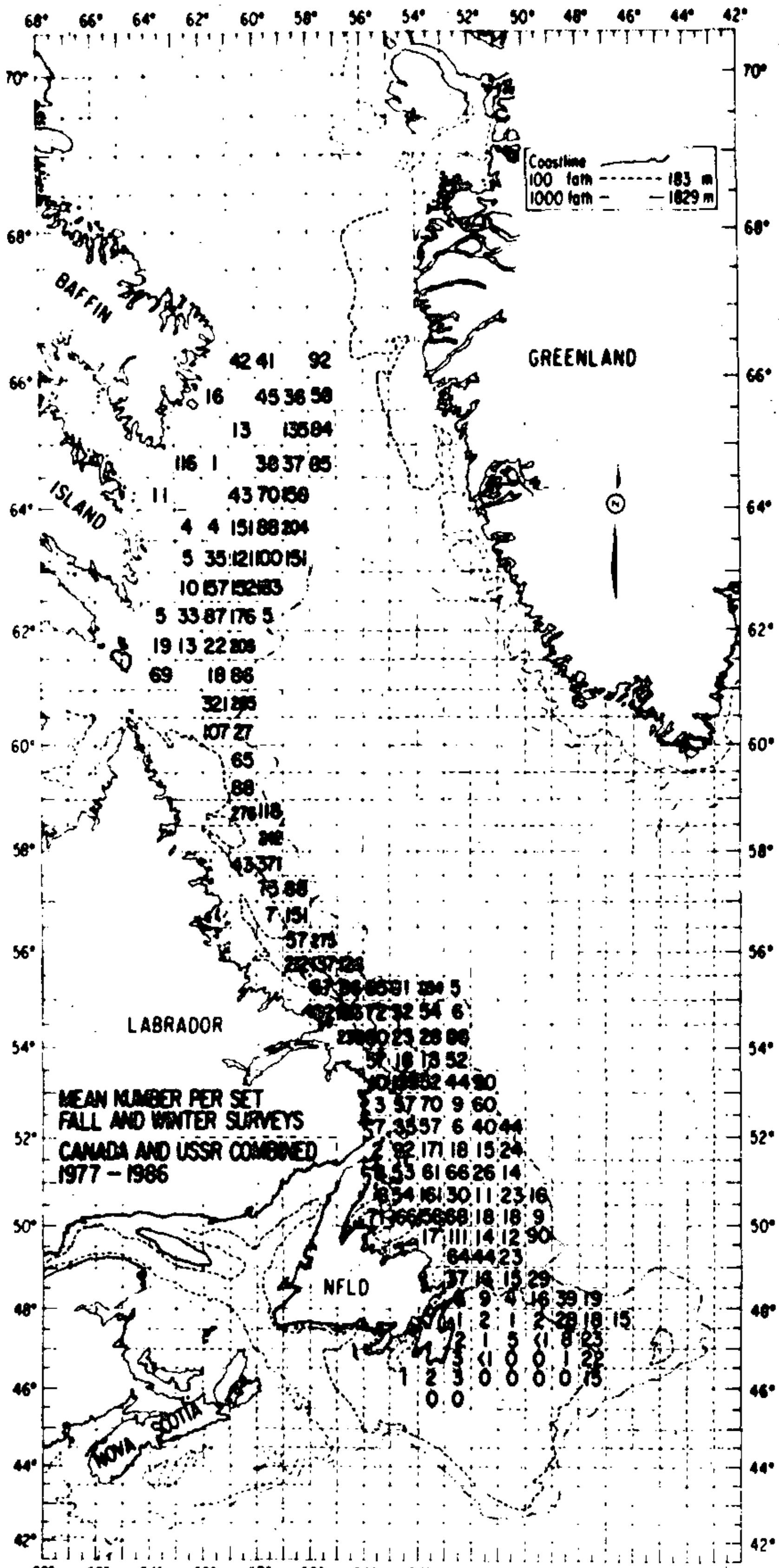


Fig. 5. Mean number of Greenland halibut caught per 30 minute set per unit area from Canadian and USSR fall-winter surveys, 1977-86.

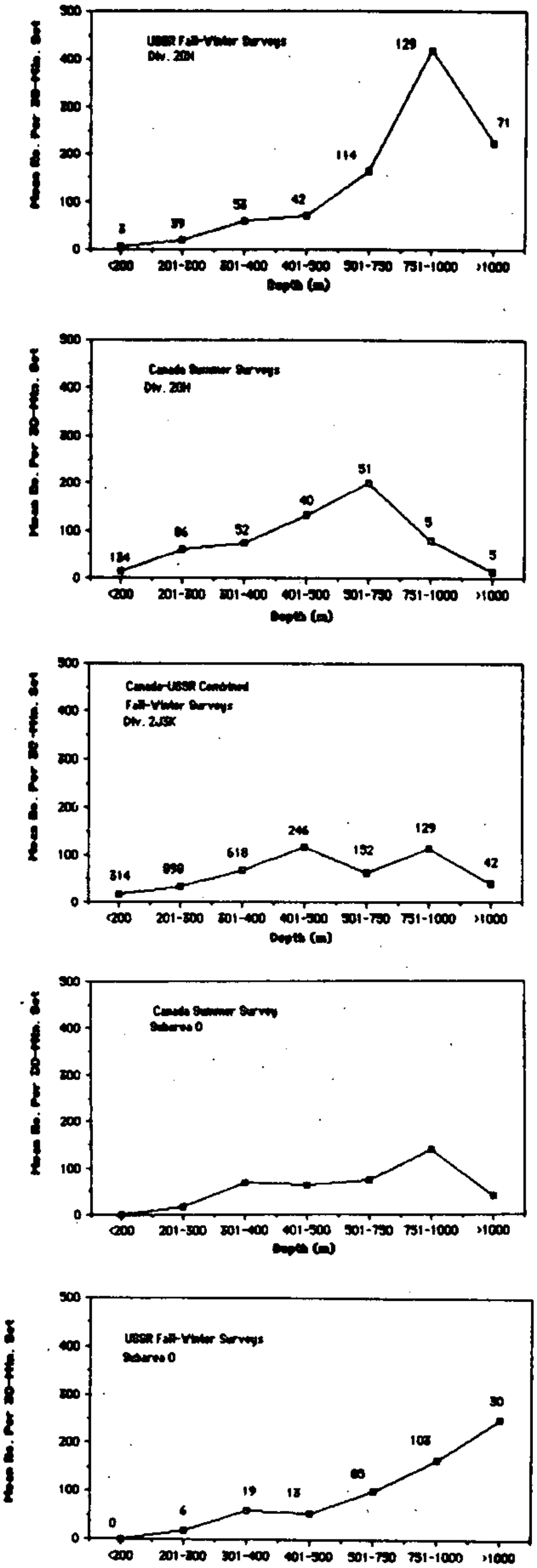


Fig. 6. Mean numbers of Greenland halibut caught per 30 minute set at various depth intervals from research vessel surveys. (Numbers on figures are numbers of sets)

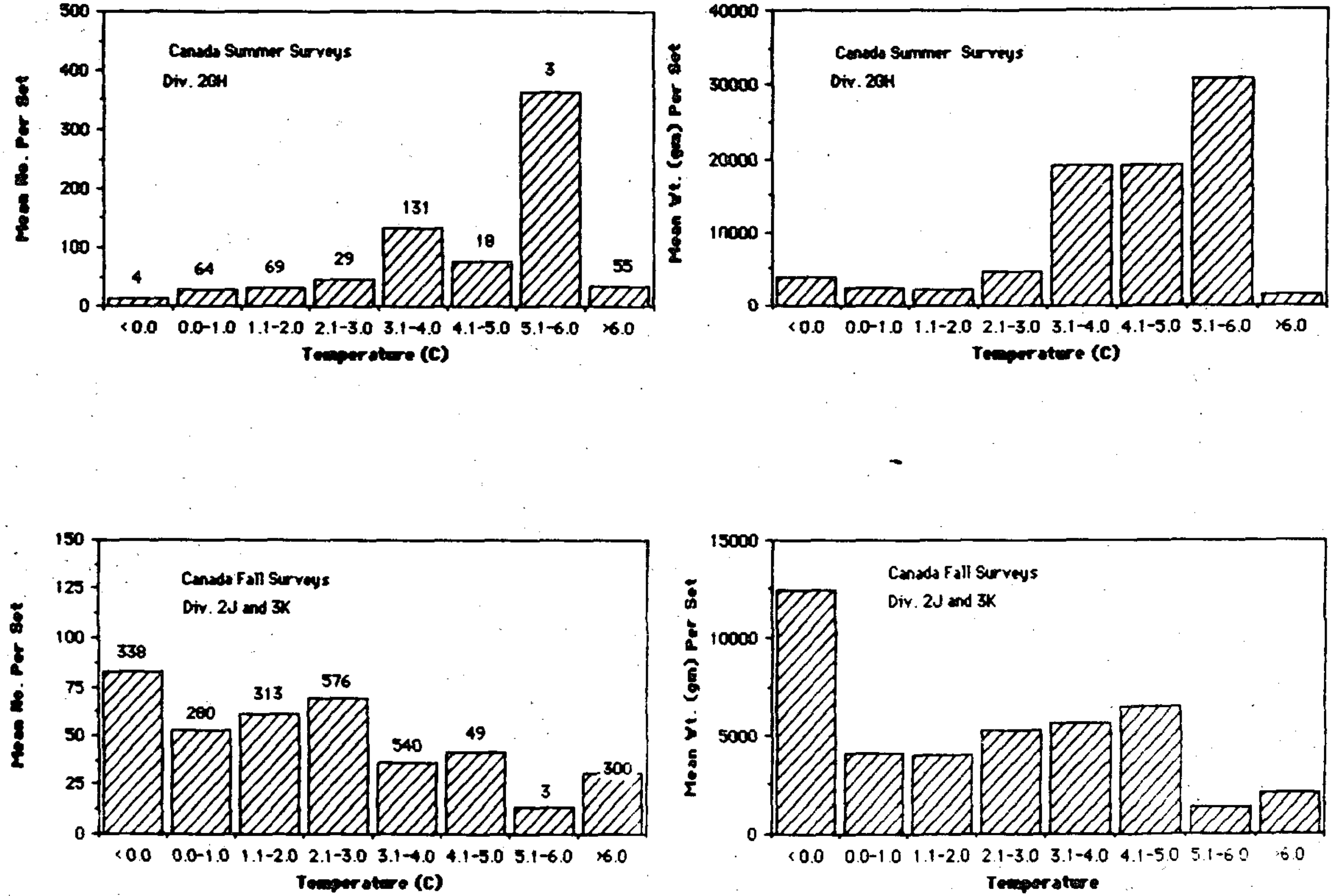


Fig. 7. Mean numbers of Greenland halibut caught per 30 minute set at various temperature intervals research vessel surveys. (Numbers on figures are numbers of sets)

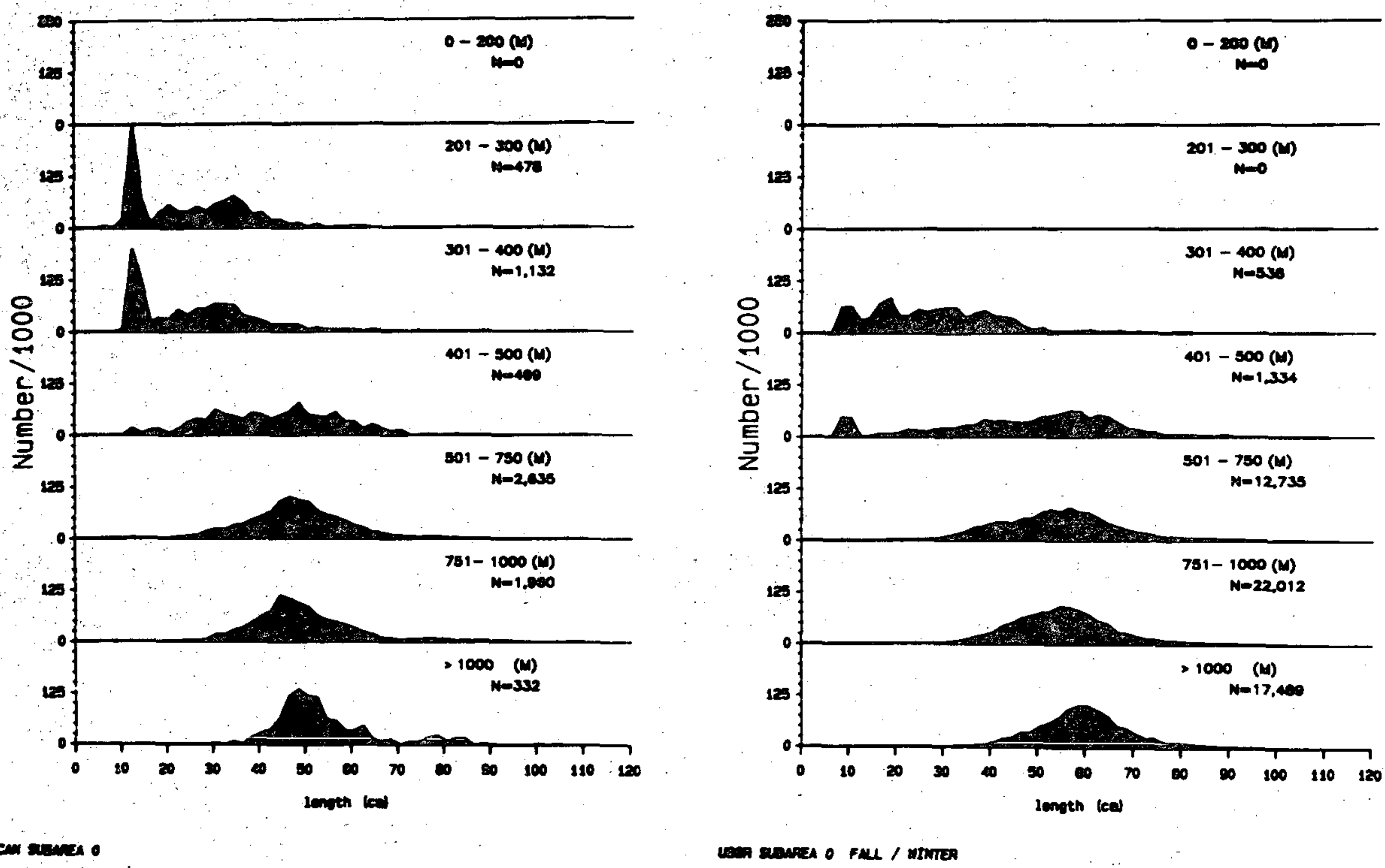
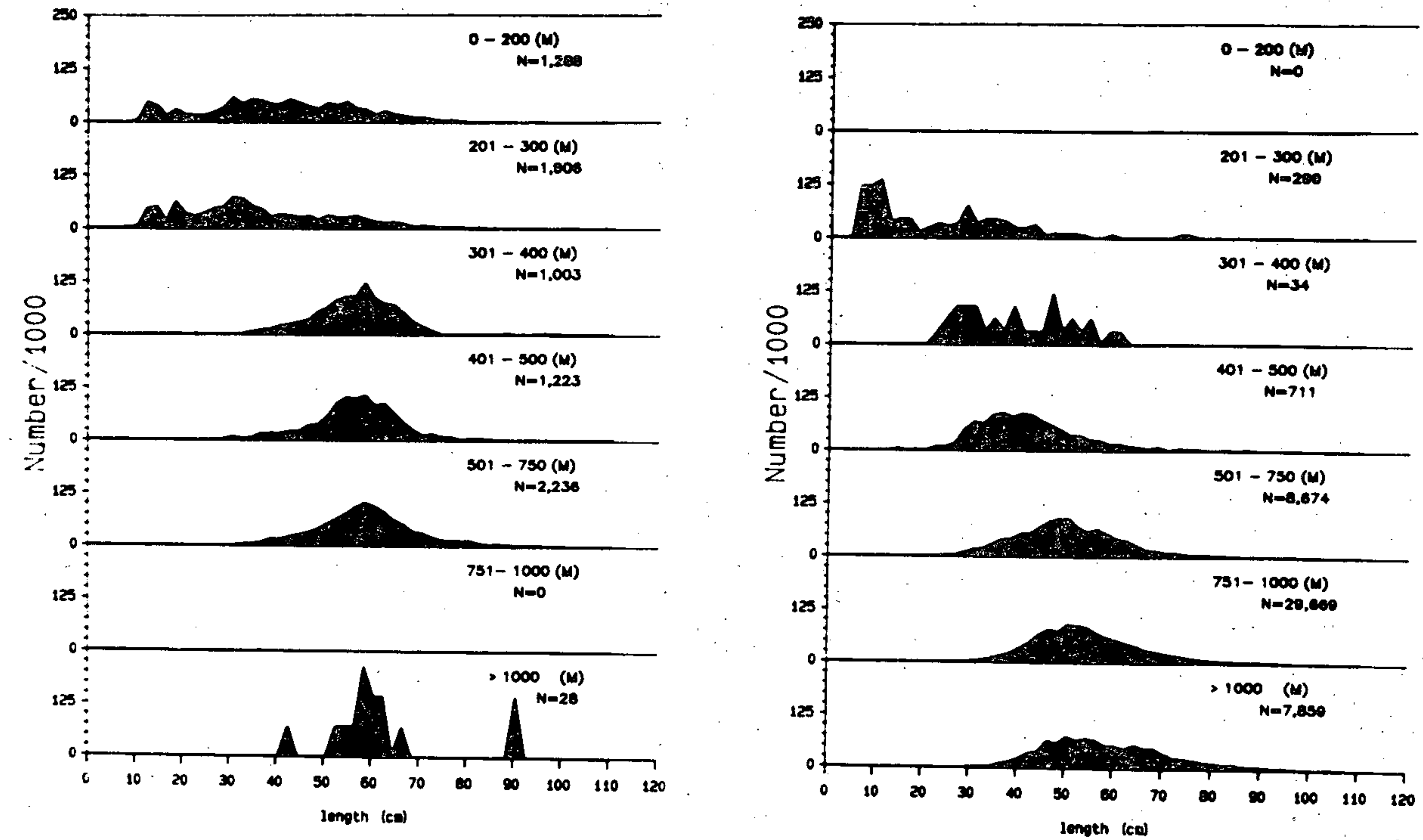


Fig. 8. Length frequency distributions of Greenland halibut at various depth intervals from research vessel surveys in NAFO Subarea 0 during summer and fall-winter.



DIVISION 2G CANADIAN SUMMER SURVEYS.

USSR 2G FALL / WINTER

Fig. 9. Length frequency distributions of Greenland halibut at various depth intervals from research vessel surveys in NAFO Division 2G during summer and fall-winter.

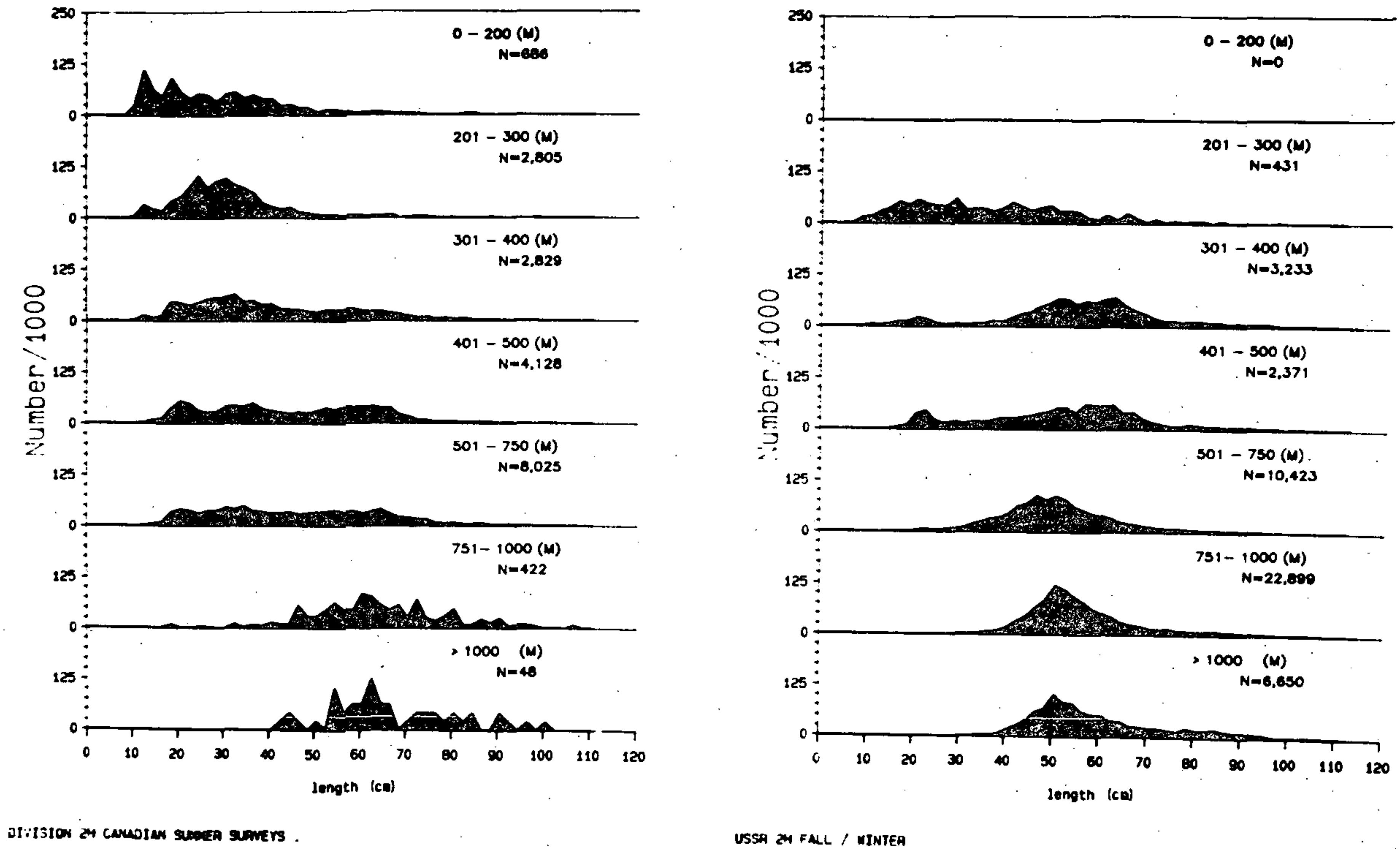


Fig. 10. Length frequency distributions of Greenland halibut at various depth intervals from research vessel surveys in NAFO Division 2 H during summer and fall-winter.

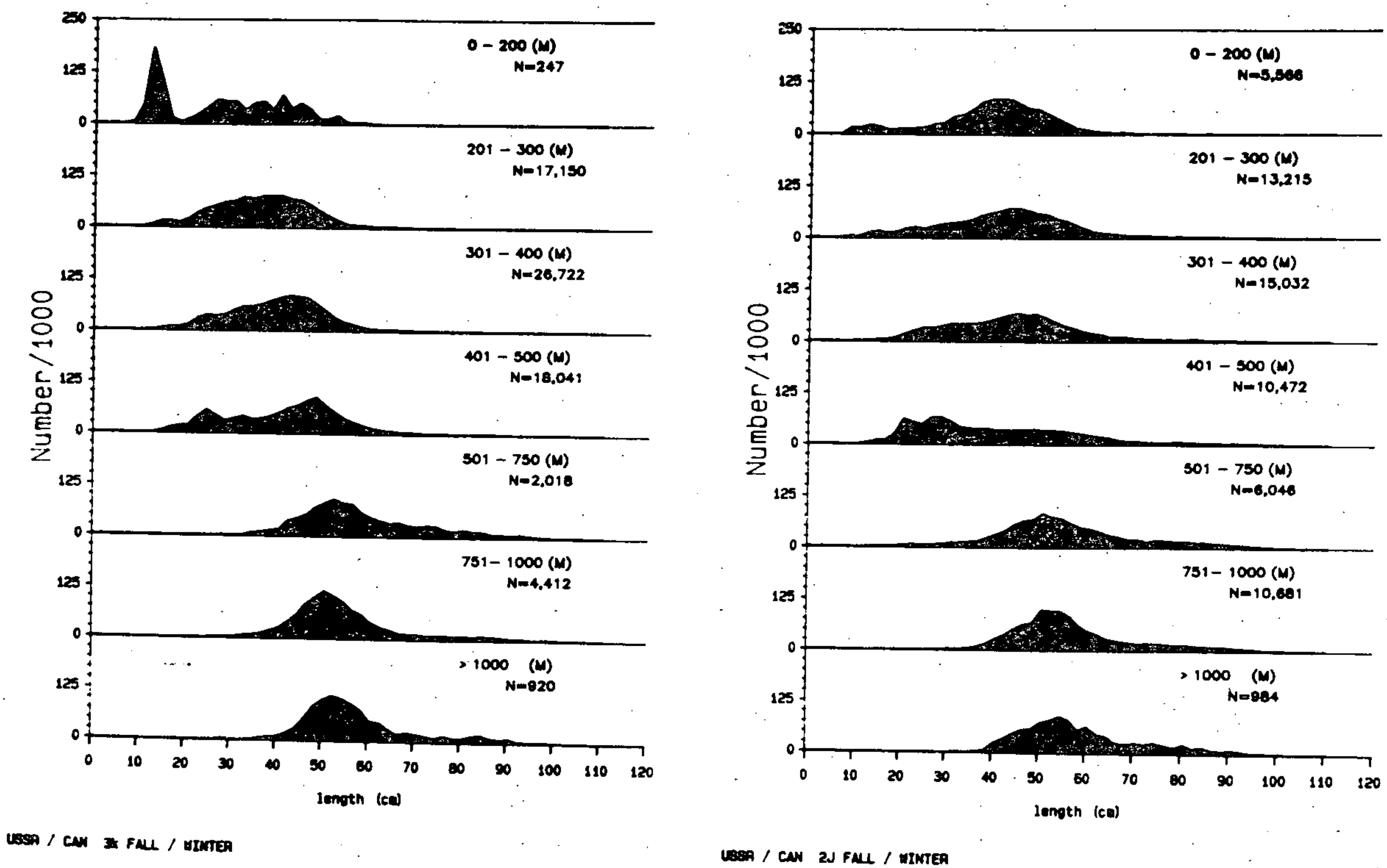
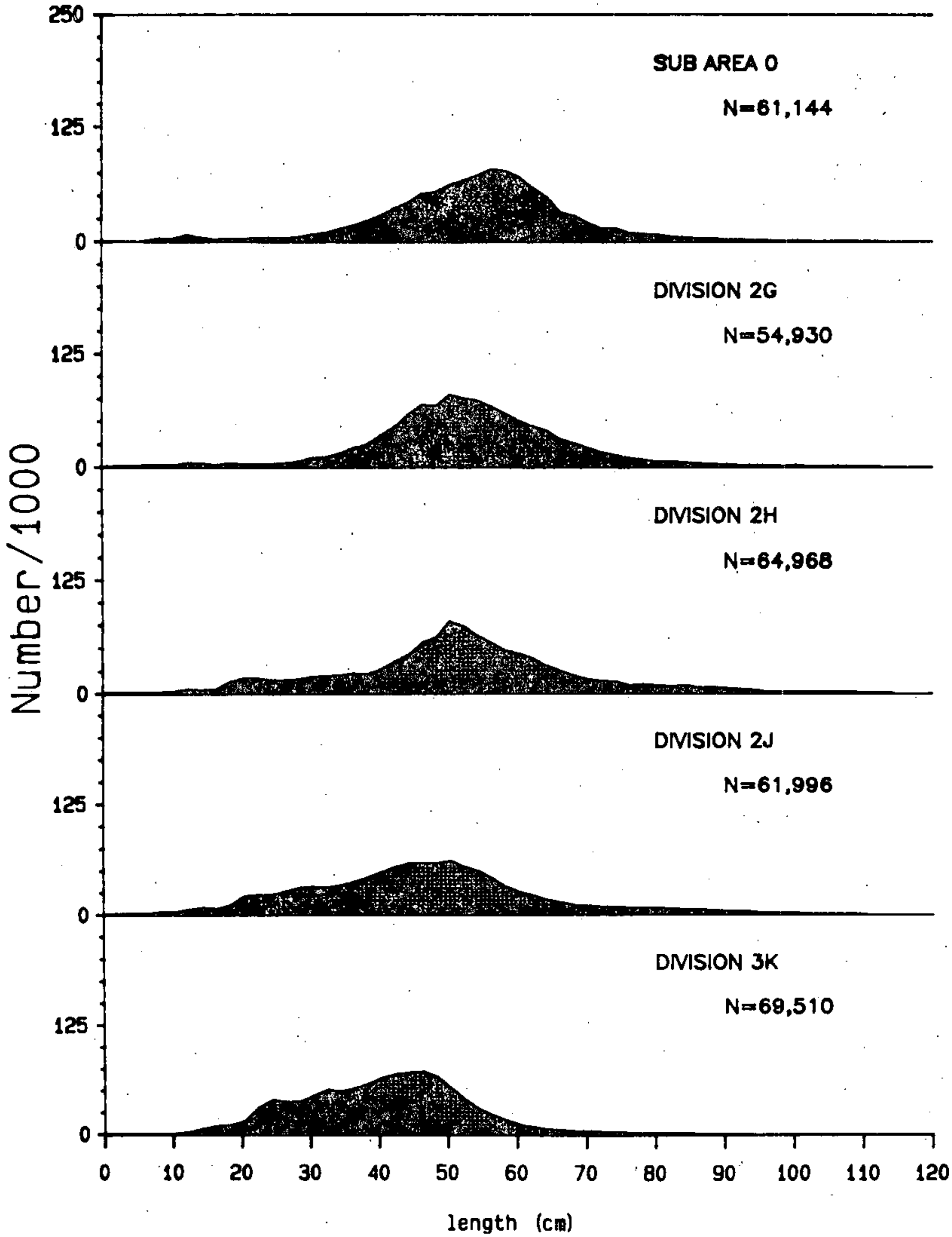
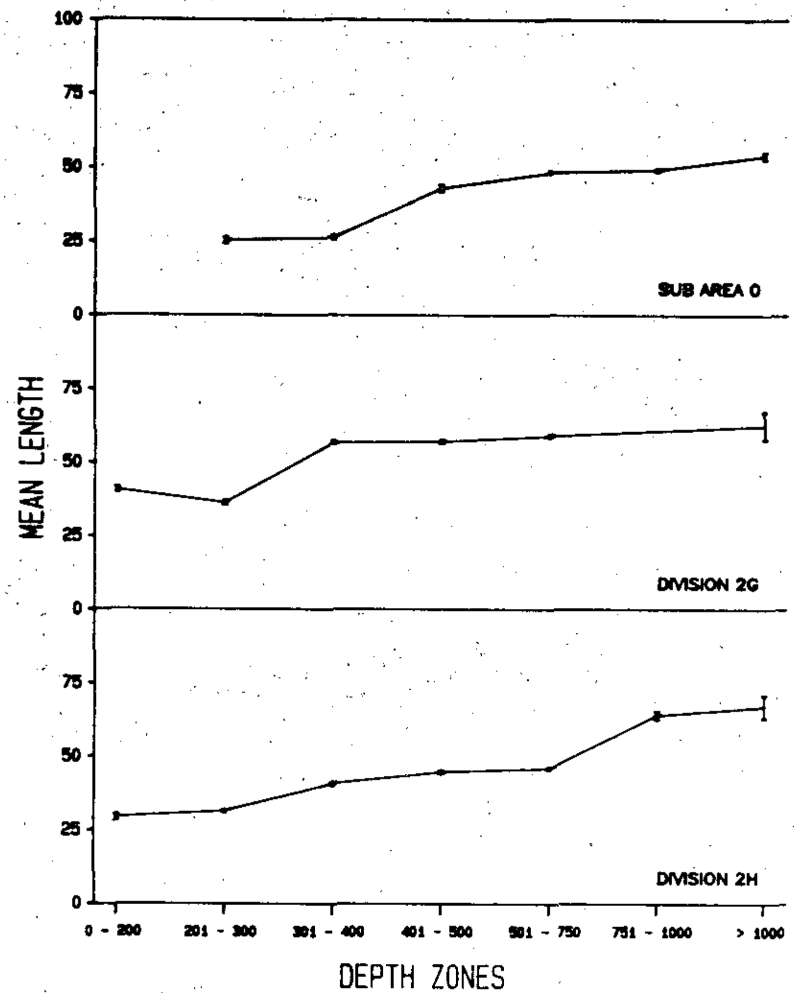


Fig. 11. Length frequency distributions of Greenland halibut at various depth intervals from research vessel surveys in NAFO Divisions 2J and 3K during fall-winter.

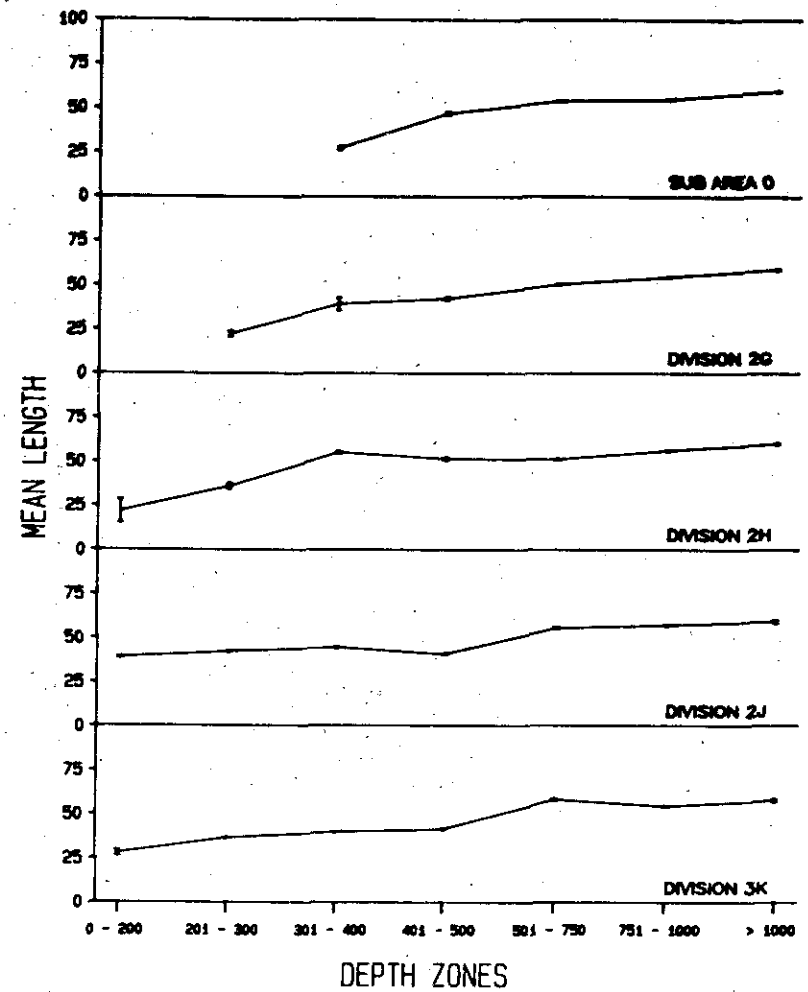


ALL DEPTH ZONES COMBINED.

Fig. 12. Length frequency distributions of Greenland halibut by NAFO Area, all depths and seasons combined from Canadian and USSR research vessel surveys.

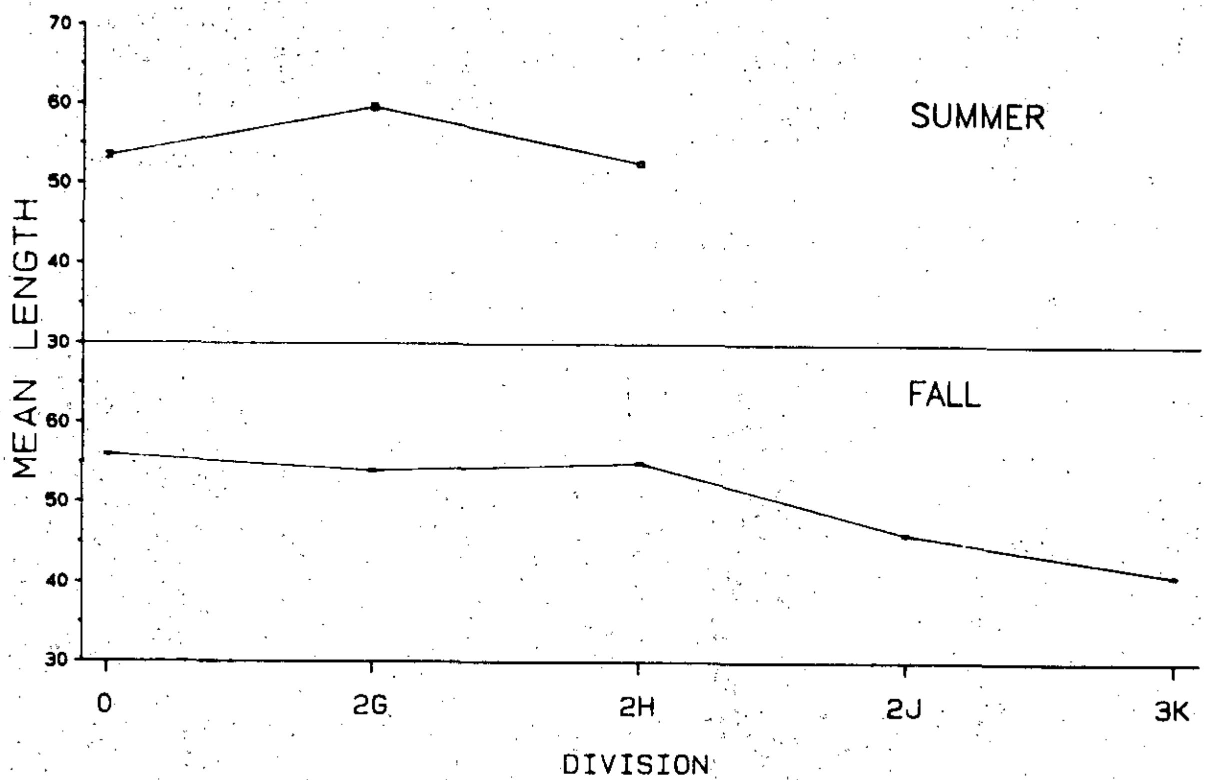


SUMMER SURVEYS



FALL SURVEYS

Fig. 13. Mean lengths (cm)and standard errors of Greenland halibut per depth interval and NAFO area during summer and fall winter research vessel surveys by Canada and the USSR.



ALL DEPTH ZONES COMBINED

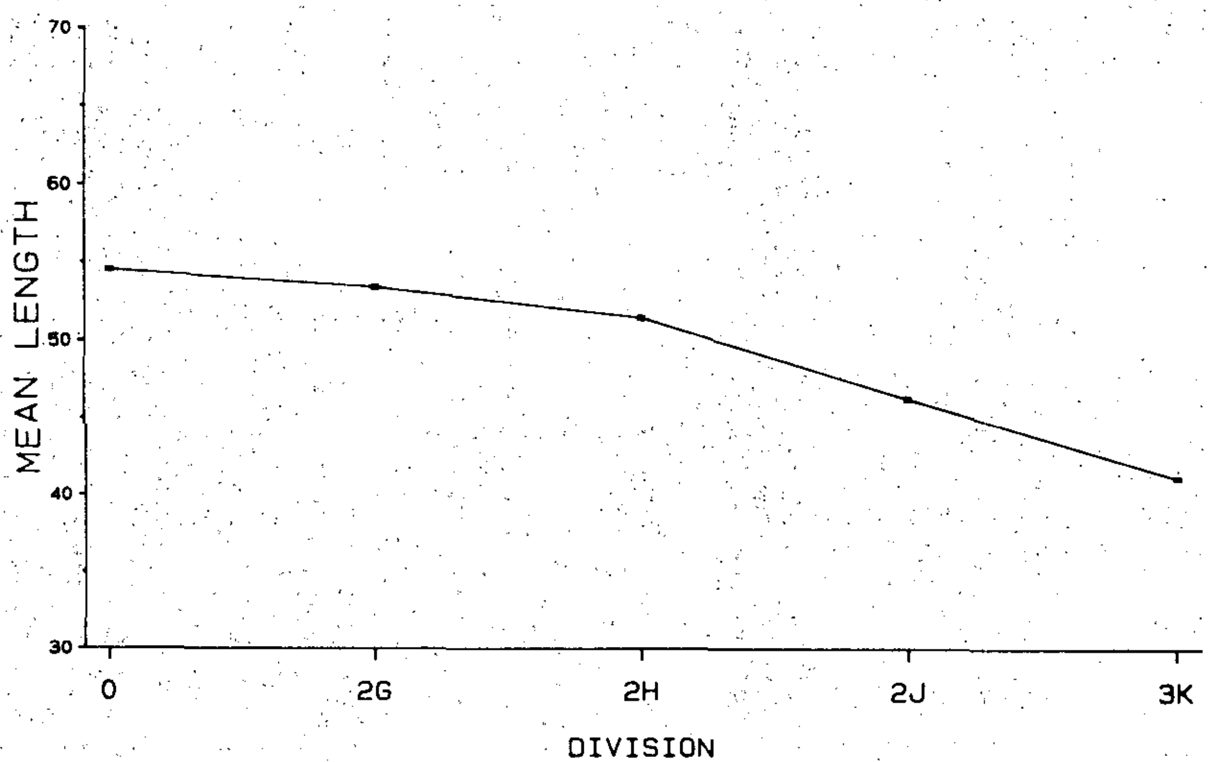


Fig. 14. Mean lengths (cm) and standard errors of Greenland halibut by NAFO area, all depths combined during summer and fall winter research vessel surveys by Canada and the USSR.

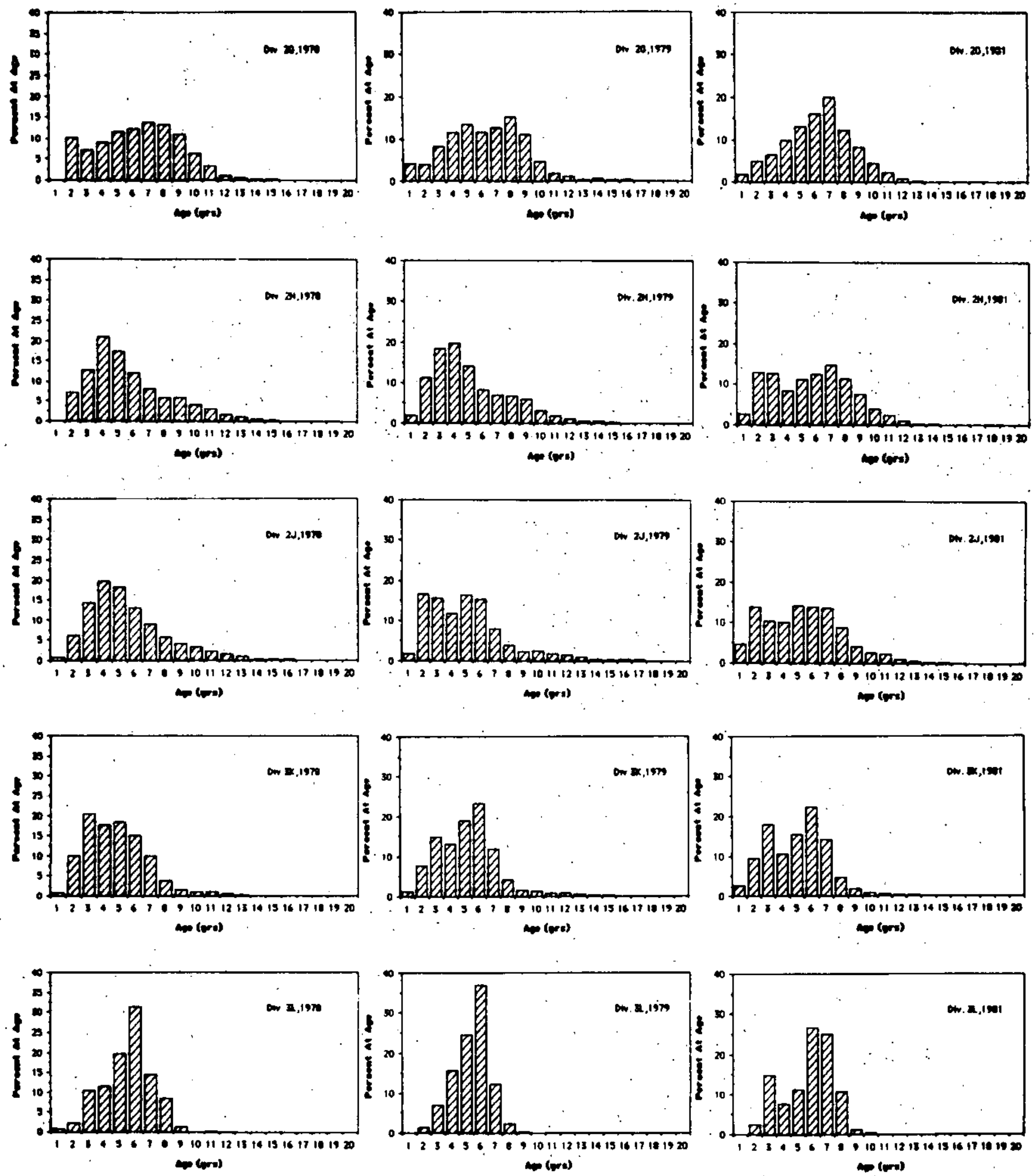


Fig. 15. Age compositions of Greenland halibut from Canadian research vessel surveys in NAFO Division 2G, 2H, 2J, 3K and 3L from 1978, 1979 and 1981.

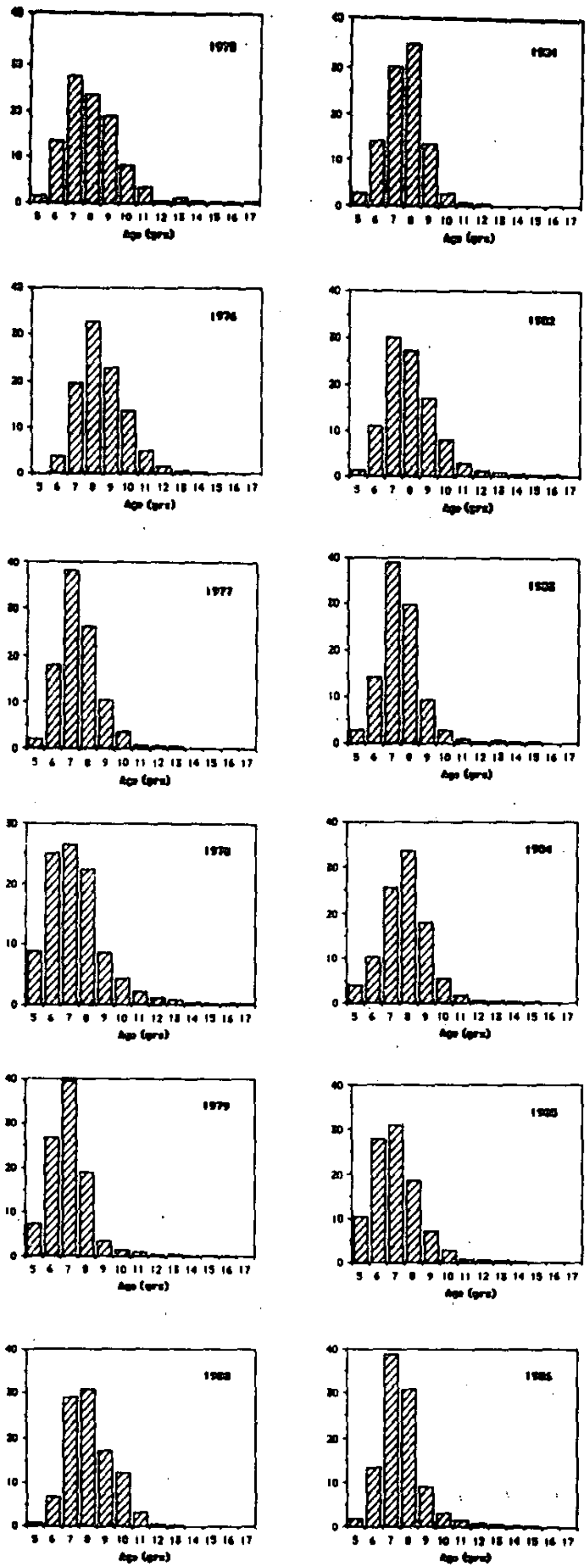


Fig. 16. Age compositions from the commercial fishery for Greenland halibut in NAFO Subarea 2 and Divisions 3K and 3L during 1975-86 inclusive.