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Changes in Species Composition of Trawl Catches by Depth on the Continental Slope from Baffin Island to Northeastern Newfoundland, 1970-85

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Abstract

Considerable cooling of the water masses in the northern subareas of the Northwest Atlantic occurred during 1973-85, and this influenced the redistribution of beaked redfish, Greenland halibut and roundnose grenadier, which moved to greater depths. The change in hydrological conditions was evidently one of the reasons for the great reduction in nominal catches of roundnose grenadier after 1978. The analysis of bottom-trawl catches by USSR research vessels along the continental slope from Baffin Island to northeastern Newfoundland during autumn investigations in 1970-85 showed that the mean length of roundnose grenadier decreased during the most recent 5-6 years, with the largest decrease in the northernmost area (Baffin Island) where hydrological conditions could affect the fish populations to a greater extent than in the more southerly areas.

Introduction

Roundnose grenadier (*Coryphaenoides rupestris*), Greenland halibut (*Reinhardtius hippoglossoides*) and beaked redfish (*Sebastes mentella*) have been the major components of deepwater trawl fisheries along the continental slope off the Atlantic coast of Canada from Baffin Island to Newfoundland (NAFO Subareas 0, 2 and 3) (Fig. 1). The fisheries for beaked redfish, Greenland halibut and roundnose grenadier were generally conducted in 300-600, 300-1,000 and 600-1,300 m respectively. Catches of the latter two species were usually mixed due to considerable overlap of the depth ranges. The proportions of roundnose grenadier and Greenland halibut in commercial and research catches have changed recently. An analysis of bottom-trawl catches by research vessels in Subareas 0, 2 and 3 indicated that Greenland halibut averaged 34% by weight of the total catch in 1970-76 and 72% in 1977-83 (Chumakov and Savvatimsky, MS 1984). The trawl surveys in 1970-83 demonstrated the relative stability of the beaked redfish and Greenland halibut stocks, but the catches of roundnose grenadier changed considerably (Chumakov, 1982; Chumakov *et al.*, MS 1984, MS 1985).

Annual catches of roundnose grenadier in the Northwest Atlantic ranged from 15,500 to 83,800 (metric) tons during the early period of the fishery in 1967-78 (Table 1), the average being 32,400 tons per year. In the recent period (1979-84), roundnose grenadier catches ranged from 3,600 to 14,700 tons, with an average of 6,300 tons per year. The sharp decrease in catches of roundnose grenadier was recorded first in Subarea 0 (1977) and later in Subareas 1, 2 and 3 (1979-80).

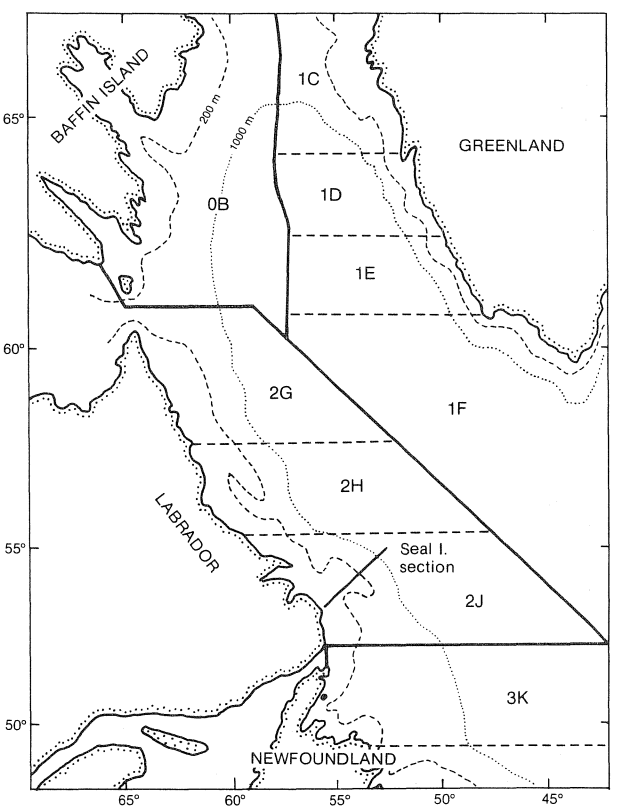

Fig. 1. The northern part of the Northwest Atlantic region with place names and NAFO subareas and divisions mentioned in the text.

Various reasons have been suggested for the decline in grenadier catches. Atkinson (MS 1982, MS 1983, MS 1984) noted that the catch rate decreased from 1.4 tons/hr in 1970 to 0.5 tons/hr in 1983 and

TABLE 1. Nominal catches of roundnose grenadier by all countries in the Northwest Atlantic by subarea (SA) in 1967-84, and total allowable catches (TAC) by management area, 1975-84.

Year	Nominal catches (tons)[a] SA 0	SA 1	Total	TAC SA 0+1	Nominal catches (tons)[a] SA 2	SA 3	Total	TAC SA 2+3
1967	1,129	6	1,135	—	1,085	16,219	17,304	—
1968	5,907	284	6,191	—	7,104	24,159	31,263	—
1969	2,642	68	2,710	—	990	11,789	12,779	—
1970	545	5,980	6,525	—	1,904	22,524	24,428	—
1971	4,172	4,132	8,304	—	56,998	18,447	75,445	—
1972	5,783	2,311	8,094	—	3,109	21,277	24,386	—
1973	1,054	3,830	4,884	—	6,744	10,820	17,564	—
1974	2,661	9,657	12,318	—	5,660	22,856	28,516	—
1975	204	4,749	4,953	10,000	11,779	15,646	27,425	32,000
1976	2,610	5,893	8,803	14,000	6,682	13,911	20,593	35,000
1977	721	2,214	2,935	8,000	3,328	12,058	15,386	35,000
1978	—	5,839	5,839	8,000	5,437	15,265	20,702	35,000
1979	106	6,815	6,921	8,000	4,563	3,218	7,781	35,000
1980	32	1,721	1,753	8,000	1,498	555	2,053	30,000
1981	87	392	479	8,000	3,123	3,962	7,085	27,000
1982	43	48	91	8,000	1,635	2,709	4,344	27,000
1983	46	22	68	8,000	1,566	2,003	3,569	11,000
1984	25	25	50	8,000	399	3,474	3,873	11,000

[a] Data from ICNAF and NAFO Statistical Bulletins.

assumed that the decline was caused by intensive fishing activity. Because the roundnose grenadier stock inhabits a broad range of depths along the slope from 300 to more than 2,000 m (Wheeler, 1969; Atkinson *et al.*, 1982), it is not possible to obtain reliable estimates of abundance and biomass from the results of trawl surveys. Although virtual population analysis (VPA) of commercial catch-at-age data was considered to provide a rather crude assessment of the stock, the results indicated that the fishery during 1967-80 did not adversely affect population abundance (Atkinson, MS 1981; Savvatimsky and Shafran, MS 1981). Moreover, the total catches in the northern (Subareas 0 and 1) and southern (Subareas 2 and 3) parts of the region (Table 1) were consistently less than the recommended total allowable catches (TACs). It should also be emphahized that length and age compositions of grenadier catches during the period of most intensive fishing activity (1967-79) were stable except for short-term (1967-71) variation in Subarea 3 (Savvatimsky and Shafran, MS 1981).

One of the reasons for the decreased catches of roundnose grenadier, after extension of fishery jurisdiction by Canada to 200 miles in 1977, was the limitation of Greenland halibut by-catch to 10% of the total catch in the directed fishery for roundnose grenadier (Atkinson, MS 1982, MS 1984; Bowering, MS 1983; Chumakov and Savvatimsky, MS 1983, MS 1984). The recent increase in abundance of Greenland halibut in the depth zones where roundnose grenadier have traditionally been fished has resulted in the trawlers being forced to fish for that species in areas of marginal abundance and at great depths. This redistribution of fishing effort by depth and area was believed to account for fluctuations in by-catches of Greenland halibut and beaked redfish in the directed fishery for roundnose grenadier and for the decline in roundnose grenadier catches (Kulka, MS 1985).

It has also been suggested that the decrease in roundnose grenadier catches and the change in proportions of Greenland halibut and roundnose grenadier in the catches from various depths have resulted, to some extent, from cooling of the water masses in recent years (Chumakov and Savvatimsky, MS 1984; Ernst, MS 1984).

The aim of this paper was to examine the recent changes in catches and abundance of deepwater fishes along the continental slope in Subareas 0, 2 and 3 and to elucidate the reasons for these changes in availability of commercial species to the bottom-trawl fishery of the region.

Materials and Methods

Data on the distribution and abundance of Greenland halibut, roundnose grenadier and beaked redfish along the continental slope off Baffin Island (Subarea 0), Labrador (Subarea 2), and northeastern Newfoundland (Div. 3K) were obtained by USSR research vessels mostly during bottom-trawl surveys in 1970-85. The surveys were carried out yearly in the autumn-early winter period, with trawling in a wide range of depths on the continental shelf and slope. The research trawl had a small-mesh liner in the codend. The data from these surveys allowed an analysis of variation in catch composition with time and depth of fishing.

The data of Canadian observers from the directed fishery for roundnose grenadier by fishing vessels from the USSR and German Democratic Republic in

Subarea 2 and Div. 3K during 1978-83 were also used in this paper. The data series, involving the proportions of roundnose grenadier, Greenland halibut, beaked redfish and other species in the catches, were compiled from the report by Kulka (MS 1985).

In cases where smoothing of data is noted in the Tables and Figures, this was accomplished by the formula, B = (a+2b+c)/4, where a, b and c are three consecutive values of the series and B is the computed term. In cases where data were analyzed by depth intervals, mean catch per year was computed by summing the catch rates for the various depth intervals and dividing by the number of intervals.

Mean water temperatures in the 200-500 m and 500-1,000 m depth zones were from hydrological observations on the seaward end of USSR oceanographic section 8-A off southern Labrador during 1964-76 and the seaward stations on the standardized Seal Island section in approximately the same area during 1977-84. These observations were made in early November of each year and were assumed to be characteristic of variations in water temperature along the continental slope, the upper part of which is under the influence of the main branch of the Labrador Current. Water temperatures were averaged for three stations in 1964-76 and two stations in 1977-84 (Table 2).

Results and Discussion

Several fishery researchers have noted the recent cooling of water masses in the northern part of the Northwest Atlantic (Chumakov *et al.*, MS 1984; Ernst, MS 1984; Borovkov and Burmakin, MS 1985;). Analysis of hydrological observations at stations on the continental slope seaward of Hamilton Bank off southern Labrador indicated that considerable cooling of the water began in the early 1970's (Fig. 2), with temperatures since 1973 being consistently lower than the long-term (1964-84) average. Such a change must have affected the distribution of bottom fishes which inhabit the continental slope, particularly Greenland halibut, roundnose grenadier and beaked redfish. Savvatimsky (1982) noted that the ratio of male and female grenadier was subject to seasonal and year-to-year variations due to temperature fluctuations. It is also known that the distributions of fishes are heavily influenced by year-to-year variations in hydrological conditions, and that, despite the stability of fish stocks, the productivity of a fishery (catch rates) may change greatly (Burmakin *et al.*, 1984). Greenland halibut was the dominant species in catches off Baffin Island (Subarea 0) when water temperatures were lower than the long-term mean, whereas roundnose grenadier prevailed when the temperature was higher than the long-term mean (Konstantinov and Noskov, MS 1977; Burmakin, 1978).

In connection with the effects of changing environmental conditions on the distribution of fish along the continental slope, the compositions of bottom-trawl catches by research vessels in relatively warm (1970-71) and cold (1983-84) years were examined. In 1970-71, when autumn water temperatures in the 200-500 and 500-1,000 m depth zones on the continental shelf and slope off Labrador were higher than 4° C (Fig. 2), the combined catch of roundnose grenadier and Greenland halibut increased with depth and was highest at 901-1,000 m, with roundnose grenadier con-

TABLE 2. Positions of hydrographic stations near or on the Seal Island Section off Labrador (Fig. 1) for which data were summarized to give the trends in Fig. 2.

Period	Depth (m)	Station positions	
		Lat.	Long.
1964-76	1,550	54°55'N	53°22'W
	2,150	55°00'N	53°12'W
	2,925	55°13'N	52°52'W
1977-84	1,306	54°47'N	53°00'W
	2,636	55°04'N	52°30'W

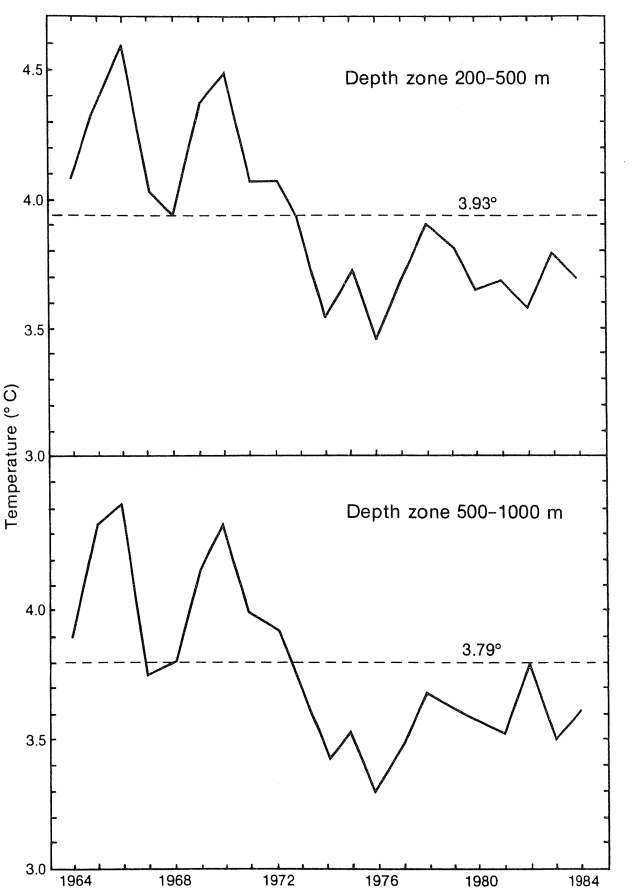

Fig. 2. Trends in mean water temperature of the 200-500 and 500-1,000 m layers on the continental slope off southern Labrador (see Table 2) in early November, 1964-84. (Dashed lines indicate long-term means.)

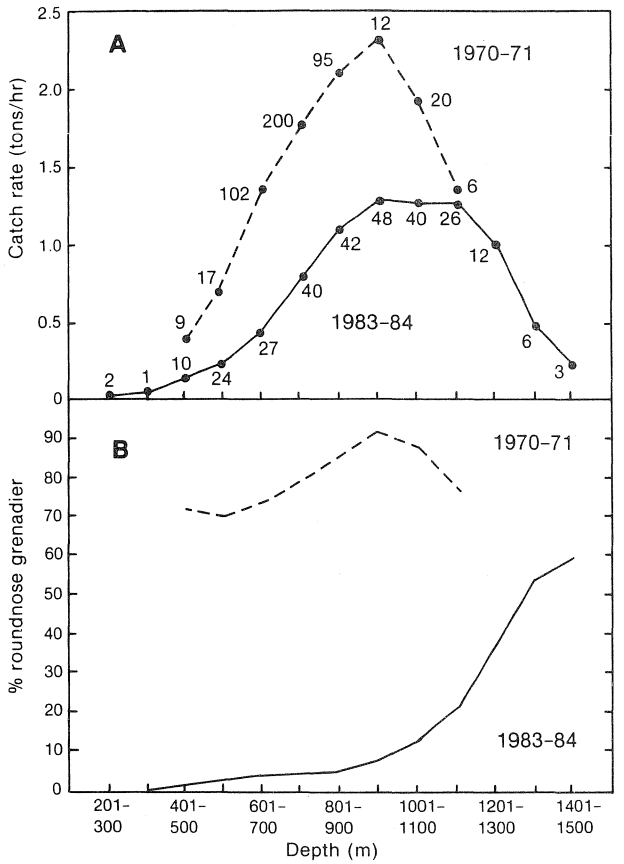

Fig. 3. Comparison of results of 1970-71 and 1983-84 autumn surveys in Subareas 0 and 2 by depth zone: (**A**) mean catch-per-hour trawling of roundnose grenadier and Greenland halibut combined, and (**B**) corresponding percentage of roundnose grenadier by weight. (Numbers of tows are given in the upper section.)

stituting about 90% of the total catch by weight (Fig. 3). Duirng this early period, roundnose grenadier persisted as the dominant species (70-90%) in the catches from all depth zones between 401-500 and 1,101-1,200 m. In 1983-84, when the autumn water temperatures were below the long-term means, the combined catches of roundnose grenadier and Greenland halibut increased to maximal values in the 901-1,200 m depth intervals (Fig. 3). The most conspicuous change in catch composition between the two periods was the dominance of Greenland halibut in 1983-84, with the proportion of roundnose grenadier being less than 10% in depths to 901-1,000 m and increasing to only 30% at 1,201-1,300 m. At greater depths (to 1,500 m) where catches were lower, the proportions of roundnose grenadier increased to 50-60%, which were still below the minimal percentages in the 1970-71 surveys.

Relative to the combined catches of roundnose grenadier and Greenland halibut in Subareas 0 and 2 during the autumn surveys in the two periods (Table 3), roundnose grenadier accounted, on the average, for 79-84% of the catches from 501-1,000 m in 1970-71 in

TABLE 3. Roundnose grenadier percentages of combined catches of Greenland halibut and roundnose grenadier from research vessel trawl surveys in autumns of 1970-71 and 1983-84.

Depth (m)	Percent of catch by weight (number of tows)			
	1970	1971	1983	1984
501-600	70 (1)	65 (16)	0.4 (11)	6.2 (13)
601-700	74 (18)	75 (84)	1.8 (11)	10.6 (16)
701-800	82 (77)	79 (123)	2.1 (19)	5.2 (21)
801-900	93 (26)	81 (69)	1.8 (19)	13.3 (23)
901-1000	100 (1)	95 (11)	5.9 (30)	10.2 (18)
Overall	84 (123)	79 (303)	3.8 (90)	9.5 (91)

contrast to only 3.8-9.5% in 1983-84. Clearly, the changes in catch composition of the two main species occurred in all depth intervals between 501-600 and 901-1,000 m. In addition, the by-catch of other species in 501-1,000 m increased from 3.7% in 1970-71 to 14.0% in 1983-84. This increase was due mainly to the by-catches of beaked redfish in 501-600 m during the 1983-84 surveys, whereas that species was not found in quantity deeper than 500 m in 1970-71. These changes in catch composition were apparently due to the migration of roundnose grenadier and Greenland halibut, as well as beaked redfish, to greater depths as cooling of the water masses occurred along the continental slope after about 1973.

Variations in the species composition of catches by commercial fishing vessels (USSR and German Democratic Republic) in the Northwest Atlantic during directed fishing for roundnose grenadier in 1978 and 1983 is well illustrated by the data of Canadian observers (Kulka, MS 1985), as presented in Fig. 4. In both years, the proportions of roundnose grenadier did not exceed 50% in catches from depths less than 700 m. However, this species accounted for more than 90% of the catches from depths greater than 850 m (to 1,600 m) in 1978, in contrast to 50-75% of the catches from the same depths (to 1,450 m) in 1983. Beaked redfish, which accounted for only 10% of the total catch at 500 m and were not caught deeper than 900 m in 1978, constituted more than 50% of the total catch at 500 m in 1983 and were caught at depths to 1,250 m (Fig. 4). In 1978, most of the Greenland halibut were caught in 450-800 m, the proportion being less than 10% in depths exceeding 800 m. In 1983, the proportion of Greenland halibut was highest in catches at 701-1,000 m and decreased to about 10% at 1,300 m.

There was a gradual change in the relative catches of Greenland halibut (as by-catch) in the directed fishery for roundnose grenadier from 1978 to 1983 (Fig. 5). The proportions were maximal (40-52%) in depths less than 500 m during 1978-80 and exhibited a declining trend to about 5% at 1,201-1,300 m. A change occurred during 1981-83 whereby the proportions of Greenland halibut increased with depth to maxima

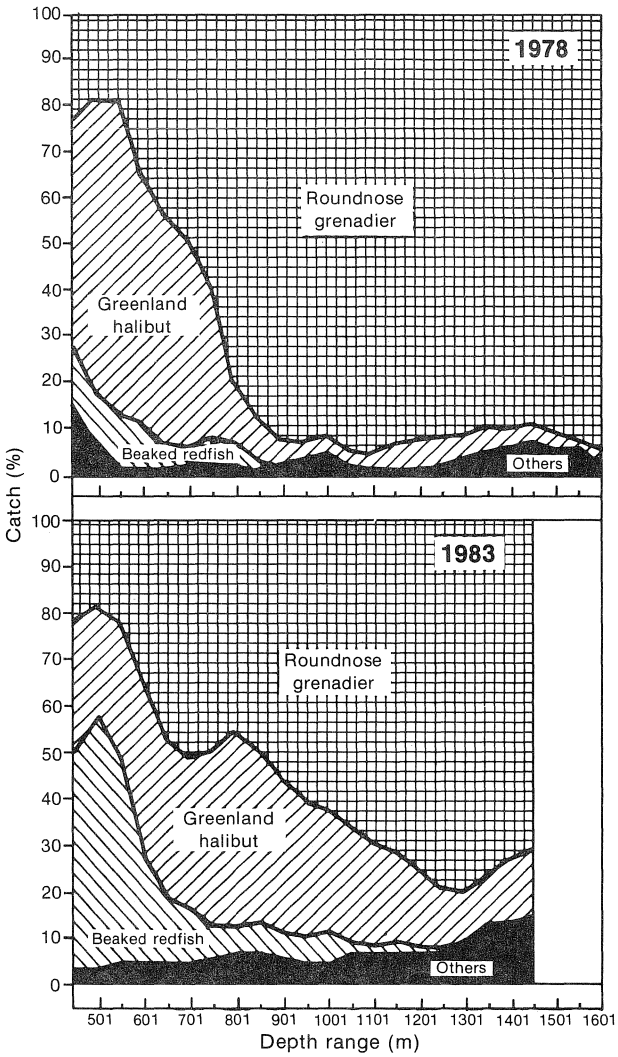

Fig. 4. Composition of catches of USSR and German Democratic Republic trawlers during the directed fishery for roundnose grenadier in Subarea 2 and Div. 3K by depth in 1978 and 1983, based on the data of Canadian observers (Kulka, MS 1985).

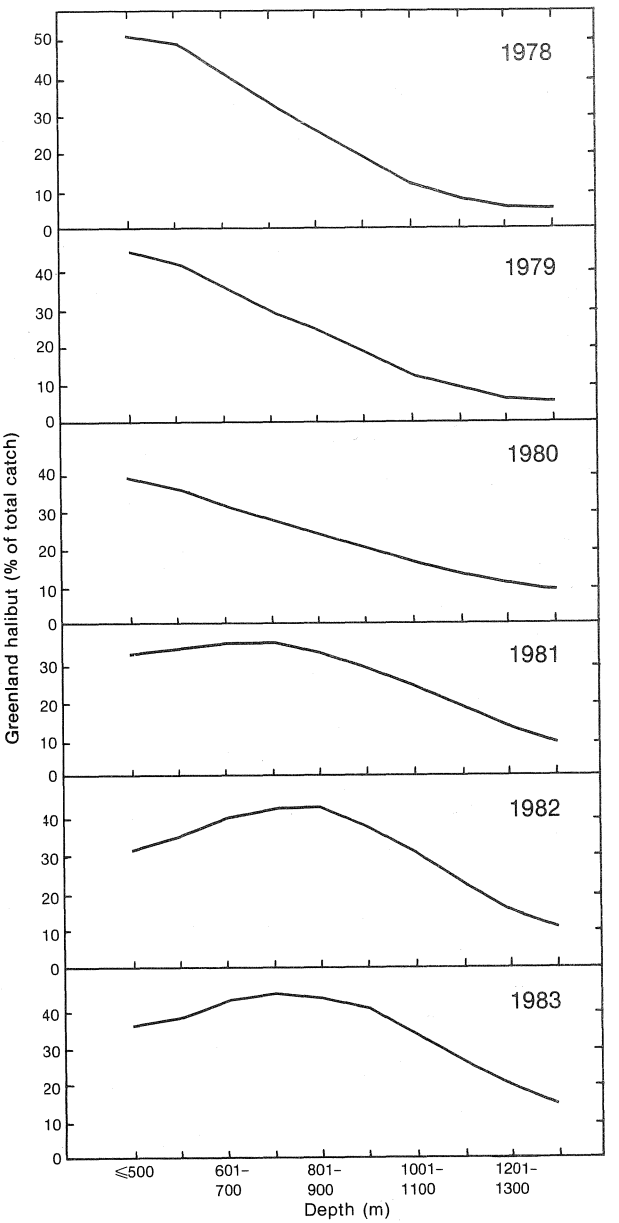

Fig. 5. Variation in relative quantities (% by weight) of Greenland halibut by depth in total catches from Subarea 2 and Div. 3K in 1978-83. (Data from Kulka, MS 1985; percentages are smoothed as defined in the text.)

(40-45%) at 801-900 and 701-800 m in 1982 and 1983 respectively, in constrast to 25-30% at these depths in 1978-79. Trends in relative catches with time for the various depth intervals in 1978-83 (Fig. 6) indicate decreasing proportions of Greenland halibut in depths less than 600 m from maximal values in 1978, approximately equal proportions at 601-700 m in 1978 and 1983, and increasing proportions to maximal values in 1983 for the remaining depth intervals to 1,301-1,400 m. The largest increase (18% in 1978 to 40% in 1983) was noted for the 901-1,000 m depth interval.

Data from the USSR trawl surveys in Subarea 0 and Div. 2GH since 1979 support the conclusion regarding the migration of Greenland halibut to greater depths (Table 4). Mean catches were small (<250 kg/hr) at depths less than 500 m but they decreased during the 1979-83 period, whereas catches from depths greater than 600 m increased during the period. It is noteworthy that the average catch for all depth intervals increased nearly two-fold from 599 kg/hr in 1978 to 1,036 kg/hr in 1983, implying a recent substantial increase in abundance and biomass of the Greenland halibut stock.

Intensive cooling of water masses in the northern part of the Northwest Atlantic region occurred in 1983 and 1984. Hydrological observations during the course

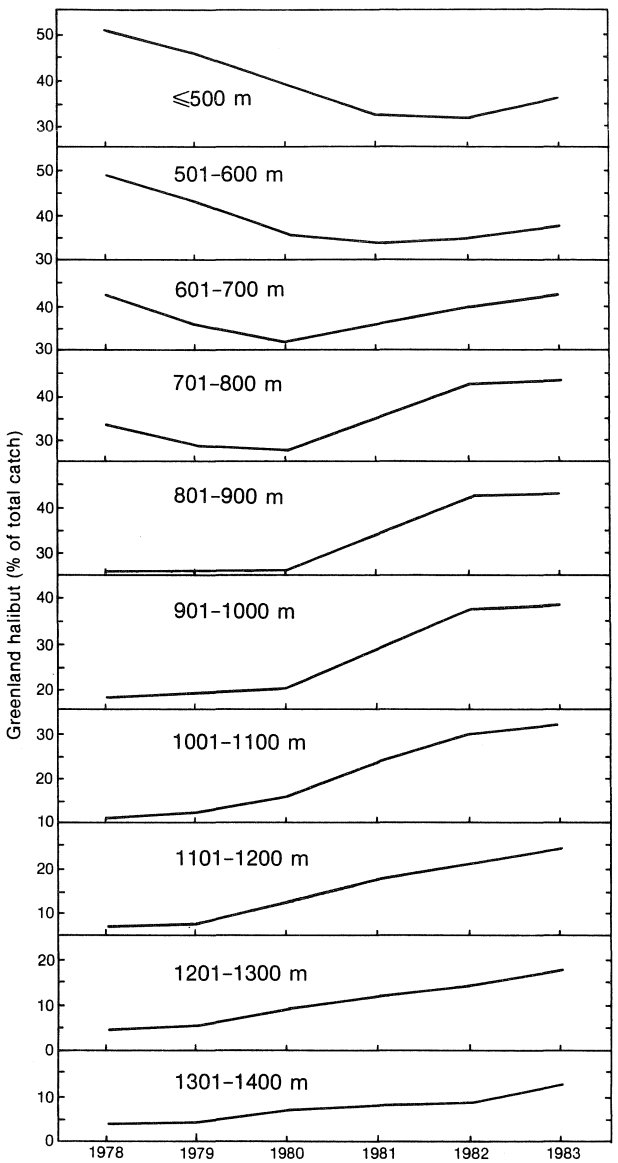

Fig. 6. Variation in relative quantities (% by weight) of Greenland halibut by year in total catches from Subarea 2 and Div. 3K for the different depth intervals. (Data from Kulka, MS 1985; percentages are smoothed as defined in the text.)

of the surveys indicated increased (relative to 1982) spreading of cold Arctic water on both the shelf and slope areas of Subarea 0. In Subarea 2 and the northern part of Subarea 3, there was extreme cooling of water on the slope and seaward part of the shelf and enlargement of the volume of cold Arctic water transported by the Labrador Current in 1983 (Chumakov *et al.*, MS 1984). In 1984, negative temperature anomalies were observed on some standard hydrological sections across the continental shelf and slope in Subareas 0, 2 and 3 (Borovkov and Burmakin, MS 1985).

The species composition of trawl catches by depth in Subareas 0 and 2 (combined) did not differ much during the 1983 and 1984 autumn surveys (Table 5), although the catch rates at depths greater than 600 m were much less in 1984 than in 1983. Greenland halibut constituted the bulk of the catches from 600 to 1,300 m in both years, with the largest catches from 900 to 1,200 m. Relative catches of roundnose grenadier were generally small from depths less than 1,000 m, but they increased to 32% at 1,201–1,300 m in 1983 and to 49% in depths exceeding 1,300 m in 1984. Beaked redfish were taken mainly in depths less than 600 m in 1984. The relative catches of other species were generally negligible at most depth intervals. The results from 17 hauls in Div. 3K in January 1984 showed that beaked redfish constituted 65–85% of the catches in 401–600 m, Greenland halibut predominated in 801–1,100 m, and the proportions of roundnose grenadier reached 35% in 1,101–1,400 m. Thus, in the autumns of the abnormally cold years (1983 and 1984), Greenland halibut, roundnose grenadier and beaked redfish were distributed at much greater depths than in years prior to the cooling of the water masses.

The length and sex compositions of roundnose grenadier catches during the autumn trawl surveys also varied with changes in environmental conditions. In the autumn-early winter survey of 1984–85, there was a consistent increase in average length of both males and females with increasing depths in samples from Div. 2J and 3K (Fig. 7). Catches from the depths

TABLE 4. Mean catches (kg) of Greenland halibut per hour trawling and numbers of hauls (in parentheses) from various depth intervals during autumn-early winter surveys in Subarea 0 and Div. 2GH.

Depth (m)	1979 (Sep-Nov)	1980 (Nov-Dec)	1981/82 (Dec-Jan)	1982/83 (Nov-Jan)	1983/84 (Nov-Jan)
301-400	264 (16)	124 (4)	49 (13)	—	—
401-500	242 (16)	136 (2)	131 (3)	193 (4)	198 (3)
501-600	278 (32)	212 (6)	248 (6)	329 (8)	342 (6)
601-700	418 (24)	416 (8)	489 (4)	578 (10)	570 (10)
701-800	687 (30)	891 (5)	993 (6)	988 (12)	922 (14)
801-900	934 (14)	1,386 (10)	1,530 (9)	1,430 (18)	1,418 (17)
901-1000	1,004 (8)	1,443 (21)	1,595 (15)	1,592 (14)	1,630 (28)
1001-1100	965 (6)	1,221 (12)	1,339 (4)	1,469 (20)	1,565 (18)
1101-1200	—	1,388 (1)	—	1,362 (2)	1,465 (16)
1201-1300	—	—	—	—	1,219 (6)
Average	599	791	797	993	1,036

TABLE 5. Composition of bottom-trawl catches by depth intervals from autumn research surveys in Subareas 0 and 2, 1983 and 1984.

Fish species or groups	Percentage catch composition within depth interval (m)									
	≤500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300	>1300
1983 (07 November-31 December)										
Greenland halibut	47.0	81.6	66.8	82.8	90.1	87.2	78.3	75.6	52.9	
Roundnose grenadier	—	0.3	1.3	1.8	1.7	5.5	9.7	16.1	31.5	
Roughhead grenadier	0.4	0.9	5.0	2.5	1.5	1.2	1.3	0.5	0.9	
Beaked redfish	5.0	8.3	3.2	1.5	0.2	0.1	0.2	—	0.1	
Northern wolffish	21.0	8.4	5.3	5.8	2.9	4.1	6.7	4.5	7.9	
Blue antimora	—	—	0.3	0.1	0.3	+	0.3	0.2	0.2	
Alepocephalidae	—	—	—	—	—	—	0.2	0.2	4.6	
Rajiformes	0.5	—	1.2	1.1	0.8	0.8	1.0	0.9	0.8	
Squaliformes	—	—	13.7	3.4	2.1	0.2	1.2	1.3	0.7	
Other fishes	26.0	0.5	3.2	1.0	0.4	0.8	1.2	0.7	0.4	
Mean catch (kg/hr)	112	477	709	1,608	1,738	2,225	1,390	2,493	1,779	
Number of tows	7	11	11	19	19	30	25	16	7	
1984 (14 September-30 December)										
Greenland halibut	9.3	39.6	76.4	90.6	79.7	84.6	75.6	59.6	58.1	31.9
Roundnose grenadier	0.1	2.6	9.0	5.0	12.2	9.6	18.0	15.3	24.8	48.5
Roughhead grenadier	—	0.1	0.3	0.4	1.3	1.0	0.4	0.3	3.7	0.6
Beaked redfish	66.5	42.6	10.6	0.6	0.4	1.0	+	10.7	0.4	0.4
Northern wolffish	1.1	2.1	1.3	1.5	0.8	2.0	2.5	10.3	8.4	0.1
Blue antimora	—	+	0.2	0.3	0.1	0.2	0.2	1.0	0.2	1.5
Alepocephalidae	—	—	—	—	—	+	0.1	0.1	—	2.3
Rajiformes	—	0.4	0.4	0.3	0.7	0.4	1.2	0.7	2.3	0.1
Squaliformes	—	—	0.2	0.4	4.4	0.1	0.9	1.5	1.4	3.4
Other fishes	23.0	12.5	1.6	0.9	0.4	1.0	1.0	0.5	0.7	0.6
Mean catch (kg/hr)	917	481	249	511	511	813	617	380	430	377
Number of tows	6	13	16	21	23	18	15	10	5	9

less than 1,000 m consisted mainly of small fish, on the average, with the larger sizes being found at much greater depths than in previous years. The mean lengths of males and females did not differ much within depth zones. There was a change in the sex ratio in Div. 2J, where the proportion of females increased from 41% at 760-880 m to 61% at 1,400 m, but the relative numbers of females in Div. 3K were about the same (34-36%) at all depths. In 1985, hydrological conditions were about the same as in the two preceding cold years, and the species composition of the trawl catches in Subareas 0 and 2 was approximately the same. As in the 1984 survey, the length and sex compositions of roundnose grenadier changed with increasing depths of tow (Table 6).

The recent variations in vertical distribution of fishes due to environmental conditions led to a general decrease in length composition of the roundnose grenadier catches from Subareas 0, 2 and 3 (actuallly Div. 3K) (Fig. 8). From 1981 to 1985, the mean length of fish in samples from the region as a whole (Subareas 0-3) decreased from about 59 cm in 1981 to 52 cm in 1985, despite an increase in mean depth of trawling from 830 to 1,000 m (Table 7). This decrease was most likely minimal, because the 1981 value does not take account of fish sizes in Subarea 0 where the largest roundnose grenadier are usually found. Nevertheless, there was a substantial, and possibly continued, decline (13 cm) in mean length of fish between 1979 and 1985 in Subarea 0 (Fig. 8A), where hydrological conditions could affect the distribution of roundnose grenadier to a greater extent than in the other areas. In Subarea 2, the mean length of fish decreased by 9.6 cm from 1981 to 1985 (Fig. 8B), but most of this decrease occurred after 1984. In Subarea 3 (Div. 3K), apart from the low value in 1983, the decrease in mean length was 5-6 cm between 1981-82 and 1985 (Fig. 8C).

Although hydrological conditions in the autumn of 1985 were below average, a weakening of the Labrador Current was observed, the November water temperature in the active layer being about 1°C higher than at the same time in 1984. During the trawl survey of Subarea 0 in late 1985, the near-bottom temperatures varied from 1°C on the edge of the continental slope to about 3.5°C at 1,000 m. The 1°C isotherm was at the 300 m isobath, 2°C at 500 m, and 3°C at 600 m. Near-bottom temperatures were, on the average, 0.5° to 1.0°C higher than in 1983 when they were abnormally low. Under these conditions in 1985, Greenland halibut concentrations were scattered, with maximum catches of 300-500 kg/hr in 901-1,000 m in contrast to much larger catches from this depth zone in the preceding

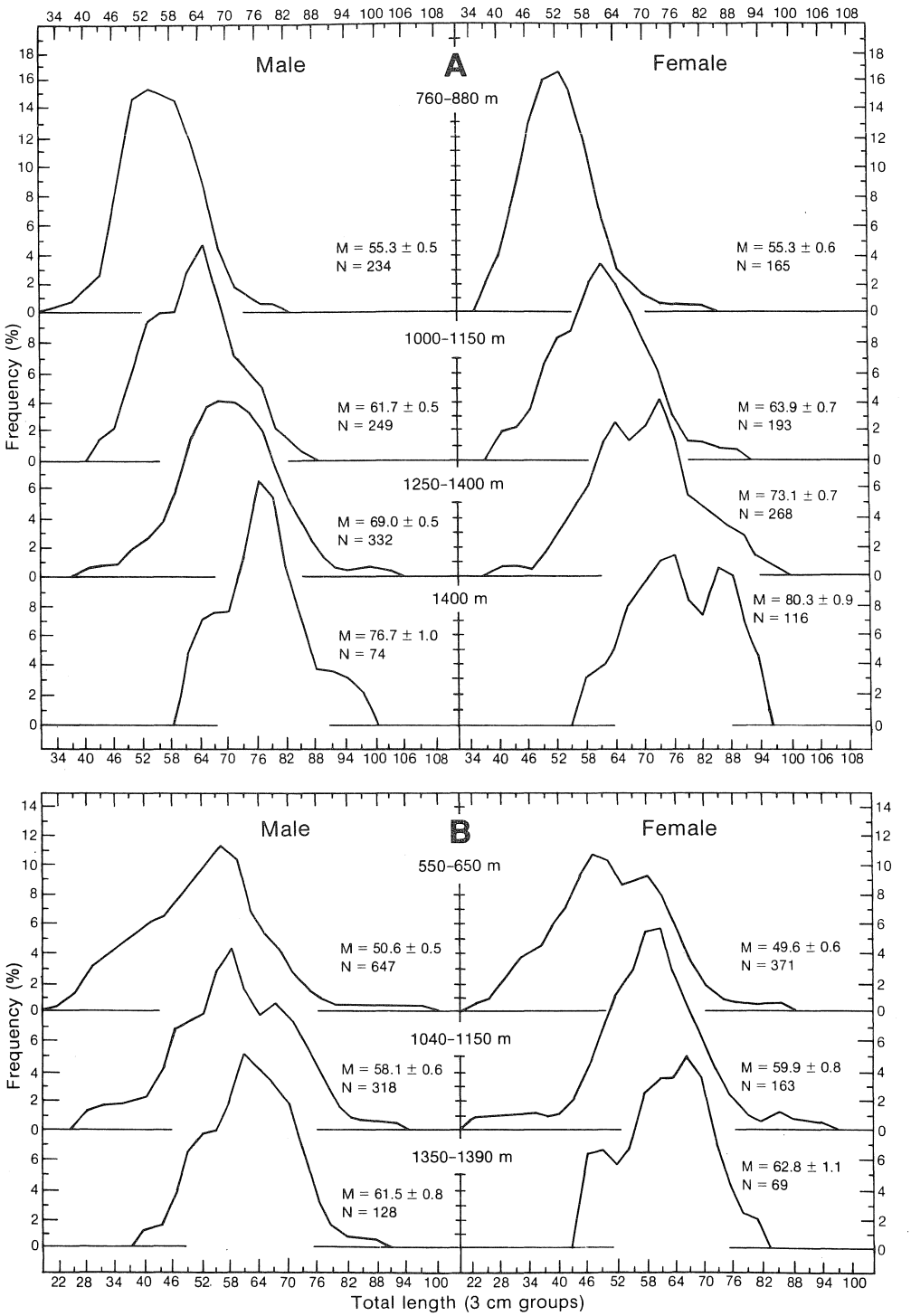

Fig. 7. Length compositions of male and female roundnose grenadier in research vessel catches at different depths from (**A**) Div. 2J on 17-30 December 1984 and (**B**) Div. 3K on 14-17 January 1985. (Data are smoothed as defined in the text; mean lengths (cm) with standard errors, and numbers of fish are given.)

years. Thus, the availability of Greenland halibut was dependent not only on a general migration to and concentration in greater depths because of abnormal year-to-year variations in water temperature, but also on specific hydrological conditions during the survey periods.

TABLE 6. Variation in mean length and sex composition of roundnose grenadier by depth in trawl catches during the autumn survey of Subareas 0-3 in 1985.

Depth (m)	No. of fish	Length (cm) Mean ± SE		Percent female
≤900	385	44.5	0.7	40.5
901–1000	1,086	52.0	0.3	47.1
1001–1100	2,198	51.1	0.2	44.9
1101–1200	1,671	51.9	0.3	45.0
>1200	1,417	57.3	0.3	48.3
All depths	6,757	52.3	0.1	45.8

Conclusions

A considerable cooling of the Northwest Atlantic water masses in recent years has resulted most likely in redistribution of the bottom fishes which inhabit the continental slope from Baffin Island to northeastern Newfoundland. Beaked redfish concentrations moved to greater depths than previously, and sometimes this species constituted about 40% of the bottom-trawl catches at 600 m. Greenland halibut concentrations also migrated to deeper areas along the slope

TABLE 7. Variation in mean length and sex composition of roundnose grenadier by depth in trawl catches during the surveys of Subareas 0, 2 and 3 in 1981–85.

Year	Depth (m) Range	Mean	Average fish length (cm) SA 0	SA 2	SA 3	SA 0-3	Number of fish	Percent female
1981	420-1110	830	—	62.0	56.1	(59.0)	6,641	37.4
1982	580-1250	906	—	58.7	57.0	(58.0)	7,346	40.5
1983	510-1290	972	62.3	62.7	48.1	56.3	13,296	39.2
1984	540-1440	1064	59.4	61.3	53.9	58.4	11,796	45.1
1985	680-1240	1004	53.7	52.4	51.0	52.3	6,757	45.8

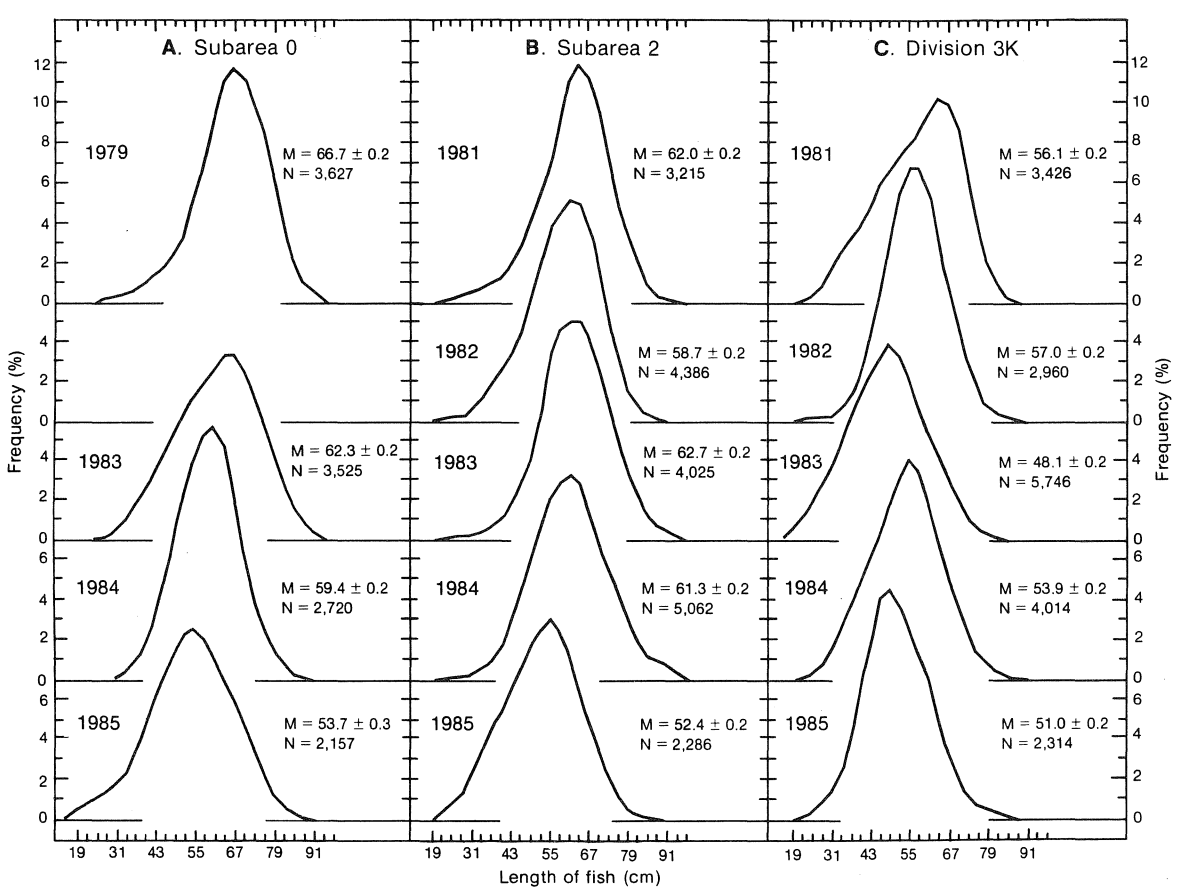

Fig. 8. Length compositions of roundnose grenadier in research vessel catches during autumn surveys of (**A**) Subarea 0 in 1979 and 1983–85, (**B**) Subarea 2 in 1981–85, and (**C**) Div. 3K in 1981–85. (Data are smoothed as defined in the text; mean lengths (cm) with standard errors, and numbers of fish are given.)

(>1,000 m) and were not always available to bottom-trawling during the surveys. Roundnose grenadier made up the bulk of the catches in depths exceeding 1,300 m and were actually inaccessible to efficient bottom-trawling. This may be one of the reasons for the recent decline in the reported catches of roundnose grenadier. Under the effect of changing hydrogical conditions, which occurred over a period of 7-8 years, the length and sex compositions of roundnose grenadier also varied with depth.

Availability of Greenland halibut to bottom-trawling evidently depended on specific hydrological conditons. In hydrologically-cold years, dense concentrations were formed in October-November at 800-1,300 m, thus ensuring a high level of fishing efficiency. By December, the concentrations were displaced to greater depths. In warm years, Greenland halibut were dispersed widely on the shelf and slope, and the absence of dense concentrations resulted in much lower estimates of abundance and biomass indices from the autumn trawl surveys.

On the basis of the long-term variation in the thermal state of the water masses off southern Labrador and the apparent weakening of the Labrador Current in late 1985, a return to near-normal water temperatures will likely occur in 1986 or 1987, but it is unlikely that there will be a marked change in the distribution of commercial fishes within the next few years. Since the major concentrations of Greenland halibut now inhabit depths greater than 1,000 m, the annual surveys in Subareas 0 and 2 to assess the abundance and biomass of that species should extend to a depth of 1,500 m.

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