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Results of the Joint Japan-Greenland Trawl Surveys at West Greenland 1987–95 on Greenland Halibut (*Reinhardtius hippoglossoides*) and Roundnose Grenadier (*Coryphaenoides rupestris*)

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Abstract

During the period 1987–95 Japan Marine Fishery Resources Research Center and Greenland Institute of Natural Resources jointly conducted 12 stratified random bottom trawl surveys and 4 pelagic surveys at West Greenland. The bottom trawl surveys covered the area between Cape Farewell and 72°51'N down to depths approximately 1 500 m. The survey area was restratified in 200 m depth intervals and the biomass and abundance of Greenland halibut (*Reinhardtius hippoglossoides* Walbaum) and roundnose grenadier (*Coryphaenoides rupestris* Gunnerus) were recalculated. The results of all surveys are presented together with information on length, age and sex distribution and, for Greenland halibut, catches in relation to bottom temperature. Roundnose grenadier was recorded in 2 of the pelagic surveys and the vertical distribution was analyzed based on 59 pelagic hauls covering the entire water column at all times of the day. The length distributions from pelagic trawl hauls were compared to those from bottom hauls.

Key words: abundance, age, biomass, Greenland halibut, length, pelagic occurrence, Roundnose grenadier, sex distribution, temperature, trawl surveys, West Greenland.

Introduction

During the period 1987–95 Japan Marine Fishery Resources Research Center (JAMARC) and Greenland Institute of Natural Resources (former Greenland Fisheries Research Institute) jointly conducted 12 bottom trawl surveys and 4 pelagic surveys (Jørgensen, 1997a) at West Greenland as part of a joint venture agreement on fisheries development and fisheries research in Greenland waters. The surveys were primarily aimed at Greenland halibut (*Reinhardtius hippoglossoides*). Roundnose grenadier (*Coryphaenoides rupestris*) was the second most common species and was recorded in 11 of the bottom trawl surveys and 2 of the pelagic surveys. Some of the results have previously been reported to NAFO as a number of Research Documents. (Yamada *et al.*, MS 1988a; Yamada *et al.*, MS 1988b; Yatsu and Jørgensen, MS 1989a; Yatsu and Jørgensen, MS 1989b; Jørgensen and Akimoto, MS 1990; Jørgensen and Akimoto, MS 1991; Yano and Jørgensen, MS 1992; Satani *et al.*, MS 1993; Ogawa *et al.*, MS 1994; Yokawa *et al.*, MS 1995; Yokawa *et al.*, MS 1996).

The bottom trawl surveys were conducted as stratified random surveys. In the stratification schemes used in earlier work the depth range in some of the strata was very broad (601–1 000 m and 1001–1 500 m) due to lack of detailed sea charts. For the more recent surveys, more detailed digitized sea charts have become available, and in the present paper all the surveys in the time series have been restratified in 200 m depth intervals in order to achieve a better description of the distribution of Greenland halibut and roundnose grenadier, and hence more accurate estimates of biomass and abundance. Further, information on length, age and sex distribution, distribution in relation to temperature for Greenland halibut and pelagic occurrence of roundnose grenadier, not previously reported, is given. The digitized sea charts have enabled a more accurate measurement of the survey area.

Materials and Methods

All data and material for this study were collected during 12 bottom trawl surveys and 2 pelagic surveys which were directed mainly at Greenland halibut. The bottom trawl surveys were conducted from 1987 to 1995 at different times between April and December and a total of 1 036 trawl hauls were carried out (Table 1). The surveys covered West Greenland from south of Cape Farewell, 59°27'N, to 72°51'N, between the 3-mile limit and the 200-mile limit or the midline Canada-Greenland, at depths from 34 to 1 497 m. NAFO Div. 1C and 1D were covered by all surveys except one, while areas north of 69°57'N and south of 63°03'N were only covered once (Table 1, Fig. 1 and 2).

In 1990 two pelagic surveys were conducted in the southern part of Div. 1C and in Div. 1D (Table 2). Two pelagic surveys conducted in Div. 1B revealed no roundnose grenadier and these surveys are not dealt with in the present paper, as they were reported earlier (Jørgensen, 1997a).

All surveys were carried out by the Japanese RV *Shinkai Maru*, a 3 395 GRT stern trawler with 5 000 HP.

Bottom trawl surveys:

In the bottom trawl surveys towing time was usually 30 min, but towing times down to 15 min were accepted. Average towing speed was 3.5 knots. Wingspread (w) was estimated as:

$$w = \text{net length} / (\text{hand rope length} + \text{net length}) \times DT$$

where net length = 63 m, hand rope length = 94 m and DT = distance between trawl doors.

DT was measured by an Otter Grap, or, in most cases, estimated as:

$$DT = 10.9 + 13.0 \; ln \; (WL)$$

where WL = warp length.

The wing spread varied between approximately 37 and 45 m. The net height was measured by a Furono Net recorder and varied between 6.5 and 7.5 m. Mesh size was 140 mm with a 30 mm mesh codend liner. Trawling was carried out in daytime only. All catches were standardised to catch per km^2 from the actual towing speed and estimated wing spread. Biomass and abundance estimates were obtained by applying the swept area method taking the catchability coefficient as 1.0.

The survey area was stratified by NAFO Division except Div. 1A, which was divided as 1AN and 1AS, denoting north and south of 70°N, respectively. Prior to the restratification, the NAFO Divisions were subdivided in depth strata: 1–200, 201–400, 401–600, 601–1 000 and 1 001–1 500 m,

TABLE 1. Year and cruise number, number of hauls, area covered, depth range and period covered in the joint Japan Greenland surveys at West Greenland.

Year/ cruise	No. of Hauls	Area	NAFO Div.	Depth range (m)	Date
1987	117	59°27'N–69°57'N	1A–1F	34–998	15 Jul–13 Aug
1988	109	63°06'N–72°51'N	1A–1D	259–1 402	12 Sep–11 Oct
1989	61	63°03'N–65°43'N	1C–1D	494–1 497	30 Apr–17 May
1990 1	75	63°05'N–68°26'N	1B–1D	449–1 482	9 Jun–22 Jun
1990 2	87	63°11'N–69°42'N	1A–1D	422–1 467	27 Aug–12 Sep
1991 1	139	63°07'N–69°57'N	1A–1D	38–1 490	4 Aug–30 Aug
1991 2	51	66°21'N–69°57'N	1A–1B	38–774	12 Nov–27 Nov
1992 1	90	63°04'N–69°45'N	1A–1D	417–1 475	11 Aug–28 Aug
1992 2	49	63°10'N–66°11'N	1C–1D	510–1 400	25 Nov–7 Dec
1993	87	63°11'N–68°25'N	1B–1D	435–1 418	20 Aug–8 Sep
1994	80	63°08'N–68°21'N	1B–1D	439–1 472	2 Aug–19 Aug
1995	91	63°06'N–69°46'N	1A–1D	422–1 463	12 Aug–1 Sep
Total	1 036	59°27'N–72°51'N	1A–1F	34–1 497	30 Apr–7 Dec

except 1AN which was divided in three strata: 201–600, 601–1 000 and 1 001–1 500 m. Based on better digitized charts the survey area was restratified, and Div. 1AN was restratified into 3 strata: 201–500, 501–1 000 and 1 001–1 500 m. NAFO Div. 1AS-1E were restratified in 200 m depth intervals, except the depth stratum 1 401 to 1 500 m. Further, the size of the strata were recalculated (Table 3).

Due to lack of time, bad weather, ice coverage and restratification, some strata have not been covered in some surveys. In surveys used for comparison between years (surveys conducted in July–October), the biomass and abundance in strata without hauls have been estimated by an ANOVA anticipating that the distribution was the same in all years (Jørgensen, 1997b), according to the following:

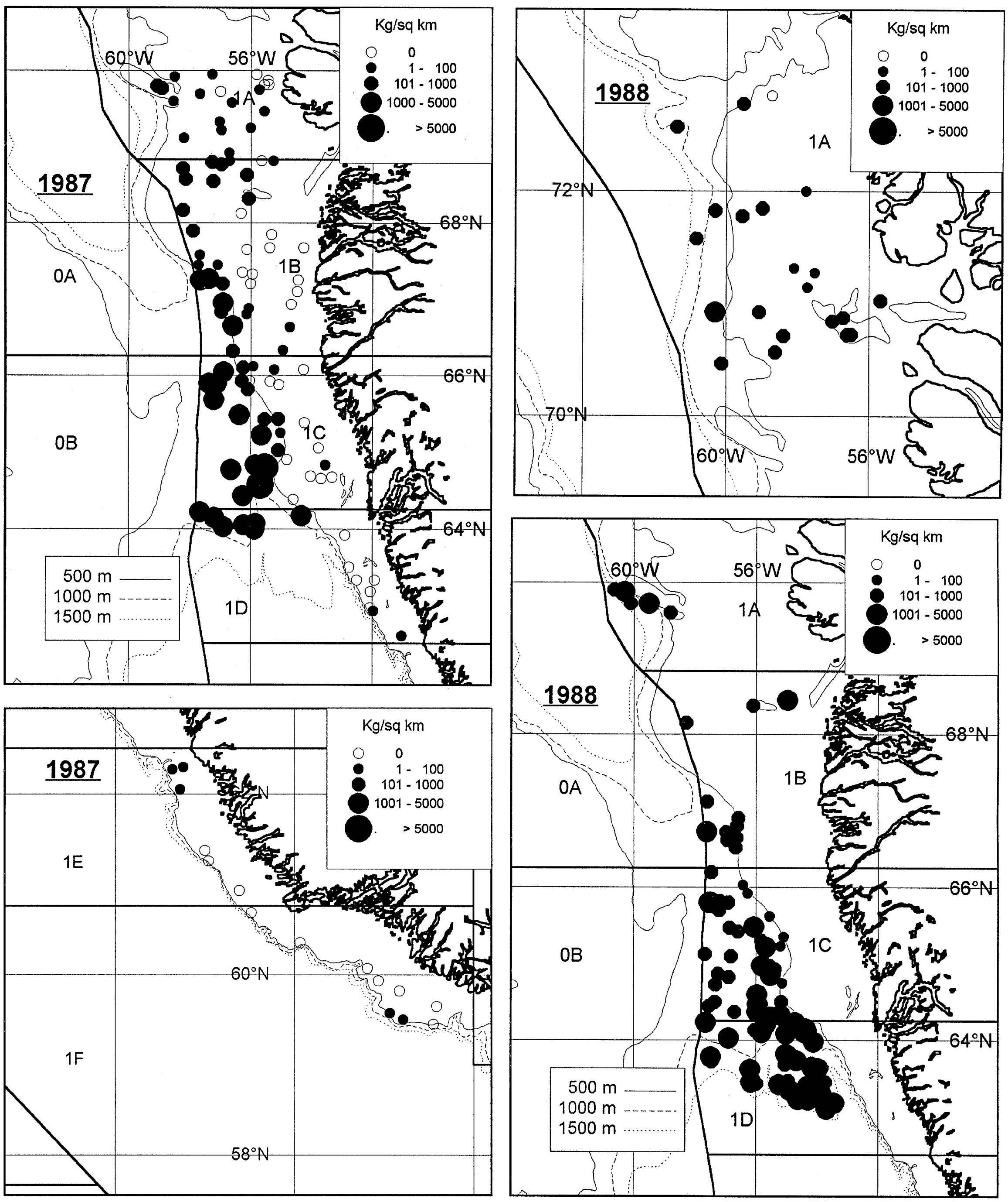

Fig. 1. Distribution of catches of Greenland halibut in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987–95.

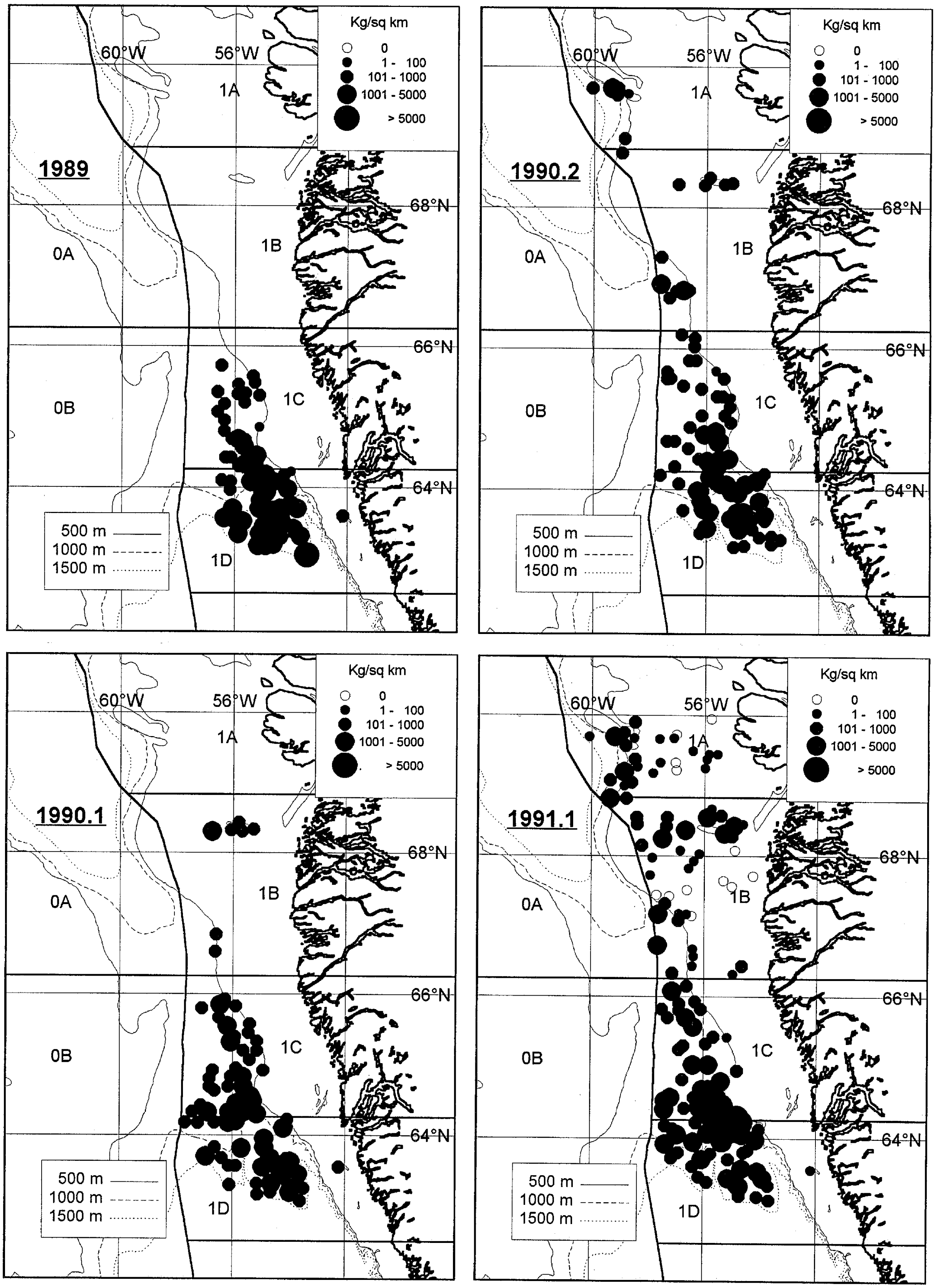

Fig. 1. (Continued). Distribution of catches of Greenland halibut in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987–95.

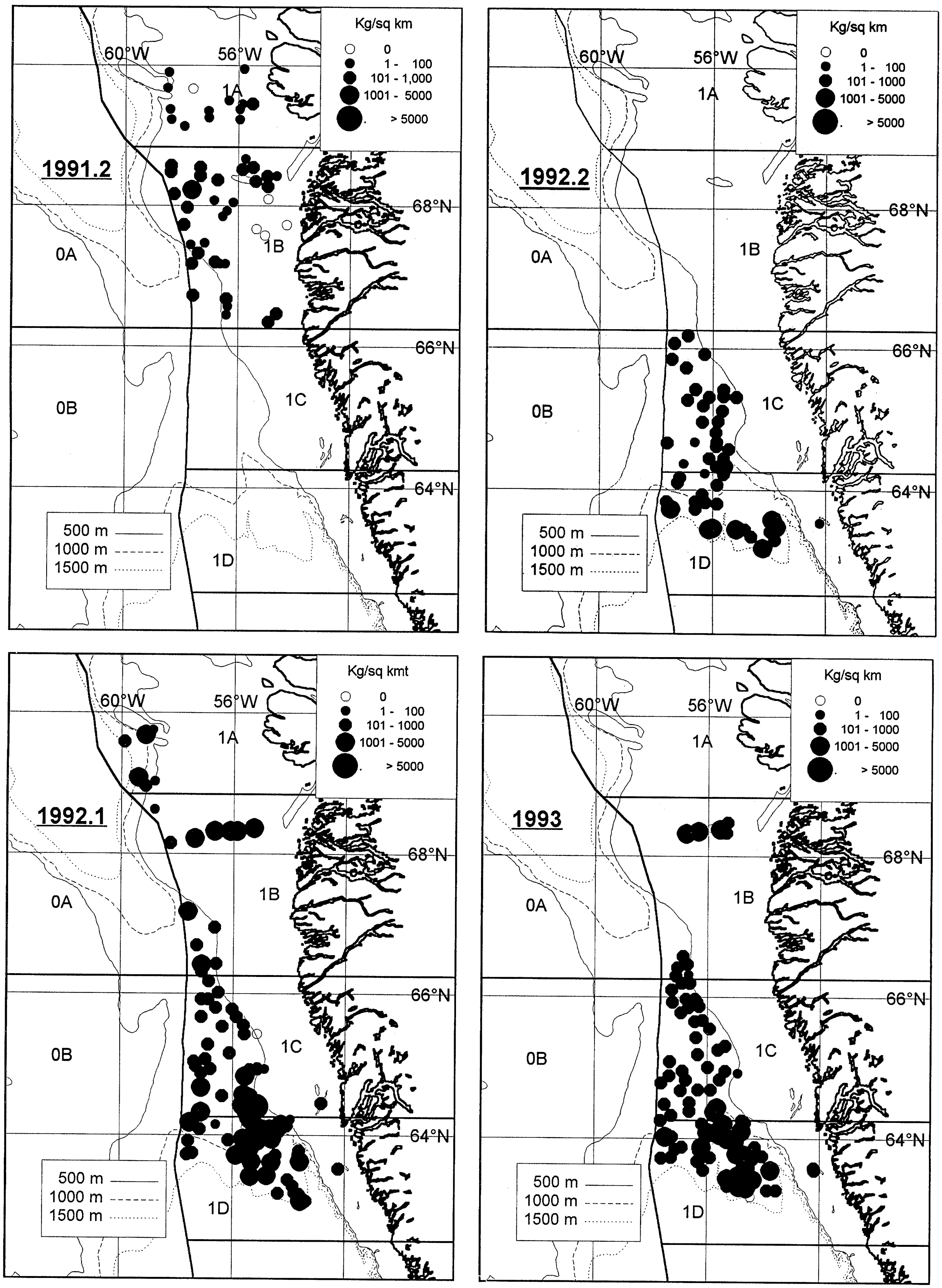

Fig. 1. (Continued). Distribution of catches of Greenland halibut in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987–95.

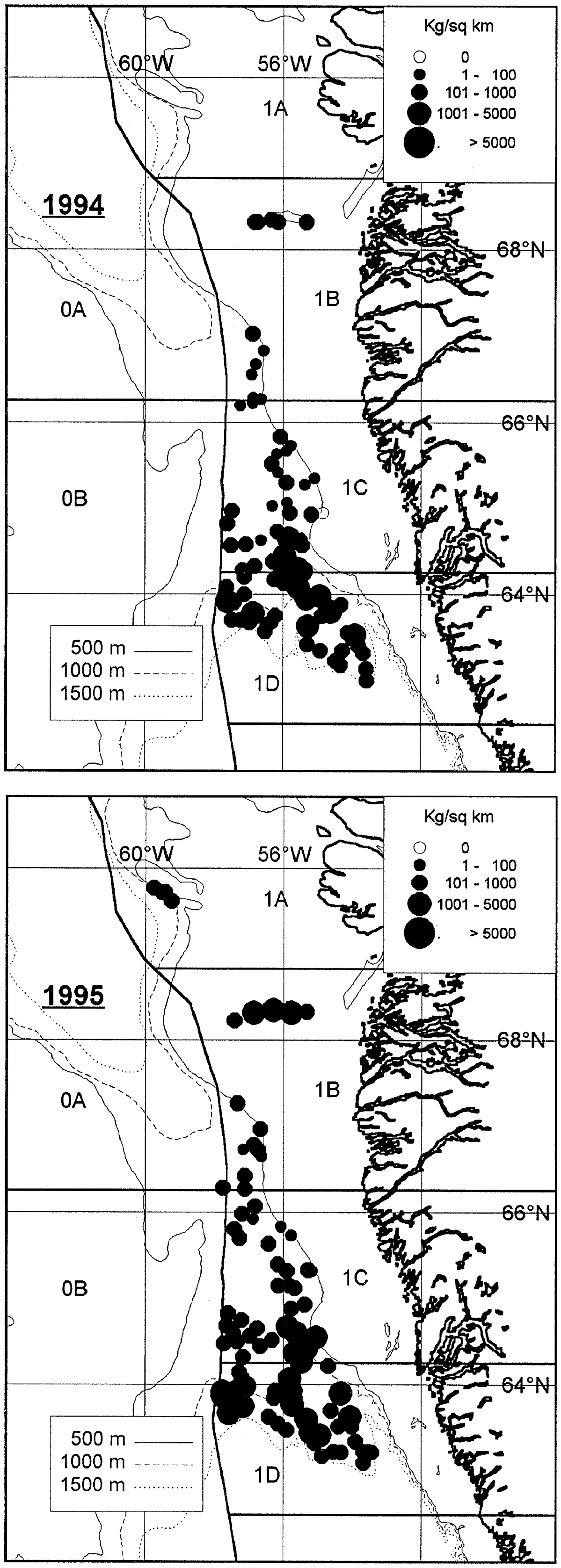

Fig. 1. (Continued). Distribution of catches of Greenland halibut in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987–95.

$$Ln\text{ (biomass or abundance (per km}^2)) = \alpha + \beta_1 Y + \beta_2\, Div + \beta_3\, Dep + \varepsilon$$

where Y = Year, Div = NAFO Division and Dep = Depth stratum.

For Greenland halibut the ANOVA was made by NAFO Division to avoid the possibility that the high biomass and abundance in the shallow strata in Div. 1B could influence the estimation of biomass and abundance in shallow strata without hauls in Div. 1C and 1D where the biomass and abundance usually was low, and *vice versa* in deep water (i.e. a two way ANOVA excluding the variable "NAFO Division"). The model was statistically significant (P>0.01) in all cases and explained between 63% and 91% of the variation in data. Biomass and abundance was primarily estimated in the depth stratum 801–1 000 m in Div. 1B, a rather small stratum (671 km^2) with relatively low biomass and abundance and in depth strata >1 000 m in 1987 (Tables 4 and 5).

For roundnose grenadier the variable NAFO Division included Div. 1C and 1D. The model was statistically significant (P>0.01) and explained 71% of the variation in data. Biomass and abundance was primarily estimated by the ANOVA in depth strata >1 000 m in 1987, but also in some shallow strata in Div. 1D with low biomass and abundance (Tables 6 and 7). In strata where biomass and abundance was estimated by the ANOVA and in strata with only one haul, the Standard Error (S.E.) was estimated from a regression between mean biomass or abundance and S.E.

The Greenland halibut otoliths used for age determination (n = 553–962) were soaked in water and then read under the microscope through transmitted light. Age distributions were estimated using age/length keys, and survey length frequencies pooled in 5 cm groups.

In 1988 scales were collected for age determination (n = 366) of roundnose grenadier. The scales were taken between the dorsal fins above the lateral line. The age was determined using polarized light (Kosswig, MS 1979). Age distribution was estimated using age/length keys and survey length frequencies pooled in 1-cm groups.

Near-bottom temperatures were measured, to 0.1°C, as close as possible to the bottom either by CTD or XBT at 861 of the 1 036 trawl stations.

Pelagic surveys:

In the first pelagic survey, trawling took place

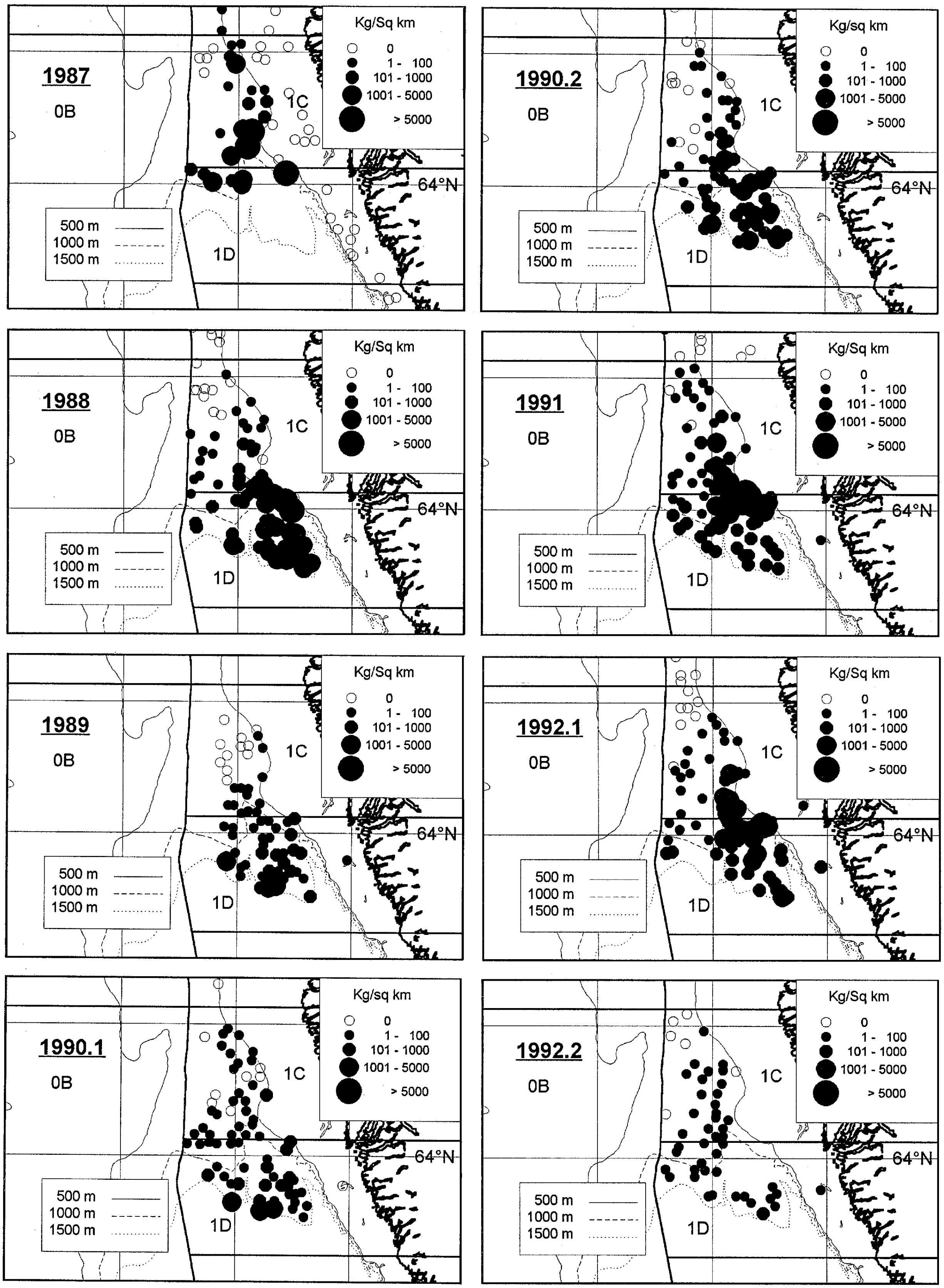

Fig. 2. Distribution of catches of roundnose grenadier in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987–95.

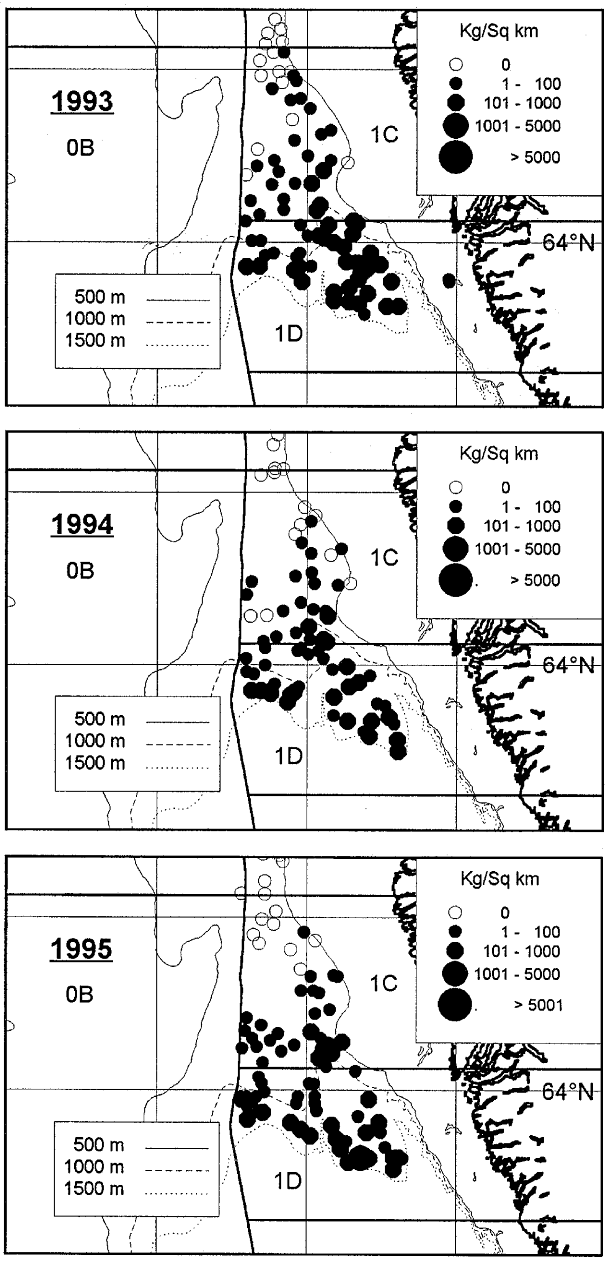

Fig. 2. (Continued). Distribution of catches of roundnose grenadier in kg per km^2 swept in the joint Japan Greenland surveys conducted 1987–95.

within a defined area and the water column was divided into 6 depth strata. Towing time varied between 30 and 90 min, but catches were standardized to catch/hour. In the second pelagic survey fishing took place at three stations with good catches of Greenland halibut and roundnose grenadier in a preceding bottom trawl survey. The water column was divided into four depth strata, further, subdivided into three substrata. These were trawled for 20 min each giving a total fishing time per stratum of 60 min. Towing speed averaged 4.0 knots. The net opening was measured by net sonde and was approximately 30/70 m high and 40/80 m wide, respectively, in the two nets (Table 2). In both net mesh size was 140 mm with a 30 mm mesh codend liner.

In the second pelagic survey the temperatures were measured in the water column by CTD (to the nearest 0.1°C), two times at each of the three pelagic stations.

All surveys:

After each haul the catch was sorted by species and weighed to nearest 0.1 kg, the number of specimens recorded (not in all strata in 1987). Greenland halibut was measured as total length (TL) to 1.0 cm below, and fish above approximately 15 cm were sexed. In 1987 Greenland halibut was measured as fork length, which was transformed to total length by multiplying with 1.02; no fish were sexed. Roundnose grenadier was measured as preanal fin length (AFL) to 0.5 cm below. In the bottom trawl survey, the length distributions were calculated by 1 cm groups for Div. 1C and 1D in the depth intervals 401–800, 801–1 000, 1 001–1 200 and 1 201–1 500 m, respectively.

Results

The majority of the surveys covered Div. 1B–1D at depths between 400 and 1 500 m, at approximately the same time of the year (July–October). This area was used for comparison of between-year variation in biomass and abundance for Greenland halibut, while the area Div. 1C and 1D was used for roundnose grenadier (unless otherwise mentioned). The recalculation of the area size of Div. 1B–1D showed an increase from 53 119 km^2 to 62 132 km^2 (17%) (Table 3) (Yatsu and Jørgensen, MS 1989a).

For roundnose grenadier information on stomach contents, growth, spawning, total length distributions by survey, length-weight relations, relation between total length and preanal fin length, distribution in relation to bottom temperatures, and abundance per km^2 has been reported previously in Jørgensen (1996).

TABLE 2. Outline of pelagic trawl surveys conducted at West Greenland, 1990.

	Period	Area	Bottom depth (m)	No. of hauls	Net opening (m)	Strata (m) surveyed
Survey 1	22–27 June 1990	63°09'N–63°49'N and 53°02'W–53°51'W	916–1 583	24	30 × 40	50*–150 b.s 220–350 b.s 420–550 b.s 380–150 a.b. 20 a.b
Survey 2	14–19 September 1990	64°04'N 54°37'W	1 073	12	70 × 80	50*–300 b.s
		64°19'N 55°38'W	1 079	11		301–550 b.s
		63°35'N 54°29'W	1 119	12		551–800 b.s. 801–20 a.b

* Position of head rope. All other strata limits are position of ground rope. b.s. = below surface a.b. = above sea bottom.

TABLE 3. Areas (km²) by NAFO Division and depth stratum (m). (Note: 1AN had different strata: 201–500 m, 501–1 000 m, 1 001–1 500 m.)

Division	Depth stratum (m) 1–200	201–400	401–600	601–800	801–1 000	1 001–1 200	1 201–1 400	1 401–1 500
1AN	10 102	35 367		17 592			4 894	
1AS	8 523	13 562	1 370	828	919	1 441	1 092	516
1B	23 815	19 052	5 376	3 716	671	63	–	–
1C	17 196	5 314	3 366	16 120	6 066	611	–	–
1D	8 921	3 562	903	1 940	3 874	10 140	6 195	3 091
1E	7 871	2 000	329	341	325			
1F	8 808	3 330	1 211	1 156				

Bottom trawl surveys

1987

The survey was conducted between 15 July and 13 August and covered Div. 1AS to 1F at depths between 34 and 998 m. In total 117 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. The biomass of Greenland halibut in Div. 1B–1D stratum, 401–1 500 m was estimated at 115 158.5 tons (S.E. 25 366.9), which was by far the highest estimate in the time series (Table 4, Fig. 3). However, the estimate was based on 31 hauls only, and the biomass at depths >1 000 m was estimated by an ANOVA. The highest biomass was found in Div. 1C depth strata 801–1 000 and 601–800 m and the biomass was estimated to be high in Div. 1D depth strata 1 001–1 200 and 1 201–1 400 m. The biomass was low at depths <400 m in all Divisions (Table 4), except in Div. 1B stratum 201–400 m (3 354.9 tons, S.E. 866.8). Division 1E and 1F was surveyed only this time in the survey series, but the survey covered shallow waters (<500 m) only, and the estimated biomass was low (Table 8).

The abundance was the highest observed in the time series ($117\ 106.0 \times 10^3$, S.E. $26\ 203.4 \times 10^3$) and the distribution of the abundance resembled the distribution of the biomass (Table 5).

In Div. 1AS and 1B the length distribution was dominated by very distinct modes around 11 and 19 cm. The length distribution in Div. 1C was dominated by fish between 38 and 58 cm with a broad mode around 46 cm, while the distribution in Div. 1D consisted mainly of fish between 42 and 70 cm with several modes (Fig. 4).

Roundnose grenadier. Roundnose grenadier was found in Div. 1C, 1D, in four hauls, (<250 kg per swept km²), in the southern part of Div. 1B depth stratum 401–600 and 601–800 m, and in a single haul in Div. 1F (3 kg per swept km²).

TABLE 4. Biomass (tons) of Greenland halibut, number of hauls and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Biomass figures in **bold** are estimated from a two-way ANOVA and S.E. in **bold** are estimated from a regression between biomass and S.E. (see text).

Div.	Date: Depth (m)	1987 15 Jul– 13 Aug	1988 12 Sep– 11 Oct	1989 30 Apr– 17 May	1990 9 Jun– 22 Jun	1990 27 Aug– 12 Sep	1991 4 Aug– 30 Aug	1991 12 Nov– 27 Nov	1992 11 Aug– 28 Aug	1992 25 Nov– 7 Dec	1993 20 Aug– 8 Sep	1994 2 Aug– 19 Aug	1995 12 Aug– 1 Sep
1AS	0–200	6.4					9.9	26.2					
		8/4.5					3/5.0	3/18.2					
	201–400	441.6					522.8	517.8					
		9/133.4					15/207.8	11/271/3					
	401–600	481.4	239.5			156.8	429.6		79.3				
		2/66.1	1/**52.7**			2/66.1	3/184.0		2/0.7				
	601–800						1403.5		529.9				
							1/**308.8**		1/**116.6**				
	801–1000		3302.6			1355.1	1969.6		2133.2				214.5
			2/518.8			2/498.6	1/**433.3**		1/**469.3**				2/22.2
	1001–1200					1234.8							206.5
						1/**271.7**							2/155.2
	1201–1400		601.7			331.9	377.3		1907.8				
			2/165.3			1/**73.0**	2/310		1/**419.7**				
	1401–1500								70.0				
									1/**15.4**				
1B	0–200	20.9					29.3	269.9					
		15/15.1					3/24.1	8/164.7					
	201–400	3354.9					2477.3	5061.3					
		14/866.8					22/551.0	21/1052.2					
	401–600	5564.4	3013.5		3541.4	3051.6	5745.2	3538.4	7439.1		4678.8	1605.9	4013.4
		5/1266.8	7/774.8		7/650.1	8/520.3	8/1109.1	6/703.9	9/2171.9		7/1339.0	8/415.7	9/1159.1
	601–800	4548.3	3553.7			3871.7	4463.0	1948.1	4033.8		1951.9	339.2	920.9
		3/810.9	3/1284.7			3/547.4	3/716.1	2/273.3	4/730.1		3/577.2	4/199.1	5/279.6
	801–1000	**1033.4**	557.2			802.9	1103.5		**1125.3**		**620.8**	**151.6**	**394.9**
		/227.4	1/**122.6**			1/**176.6**	1/**242.8**		**/247.6**		**/136.6**	**/33.4**	**/86.9**
1C	0–200	17.3											
		10/14.4											
	201–400	214.2											
		6/118.2											
	401–600	838.1	152.5	570.3	1936.4	339.4	672.2		853.5	506.7	630.7	154.8	129.2
		3/299.2	5/60.7	4/107.3	5/307.7	5/66.6	5/156.1		5/433.9	2/115.0	4/262.2	4/141.4	3/67.2
	601–800	19617.4	10324.2	4415.0	12450.9	6504.0	14136.7		6824.1	4579.3	5059.6	2195.7	5180.2
		8/2909.0	8/1434.9	10/454.3	13/1775.3	16/796.9	16/1602.0		20/828.0	14/419.4	22/461.3	16/520.6	16/628.2
	801–1000	23474.5	8704.1	6263.0	11161.0	6255.2	20079.9		20488.6	4054.0	3887.1	6814.7	7625.6
		5/6946.7	11/1310.0	8/1367.5	13/3272.5	11/1046.0	11/3373.4		7/4785.9	8/912.3	9/683.1	10/2666.5	14/1531.0
	1001–1200	**4464.1**	1128.6	900.3	969.9	1907.7	1786.1		1061.4	1276.9	1921.4	2014.3	1771.0
		/982.1	2/675.1	2/60.5	2/53.0	2/254.3	2/202.5		2/186.7	2/607.9	2/445.0	2/261.5	2/711.0

TABLE 4. (Continued). Biomass (tons) of Greenland halibut, number of hauls and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Biomass figures in **bold** are estimated from a two-way ANOVA and S.E. in **bold** are estimated from a regression between biomass and S.E. (see text).

Div.	Date: Depth (m)	1987 15 Jul– 13 Aug	1988 12 Sep– 11 Oct	1989 30 Apr– 17 May	1990 9 Jun 22Jun	1990 27 Aug– 12 Sep	1991 4 Aug– 30 Aug	1991 12 Nov– 27 Nov	1992 11 Aug– 28 Aug	1992 25 Nov– 7 Dec	1993 20 Aug– 8 Sep	1994 2 Aug– 19 Aug	1995 12 Aug– 1 Sep
1D	0–200	0.0											
		5/0.0											
	201–400	12.7											
		3/9.9											
	401–600	**372.4**	**237.4**	214.6	125.0	249.7	27.8		295.1	147.5	334.3	**127.6**	**176.6**.
		/**81.9**	/**52.2**	2/145.0	2/5.5	1/**54.9**	2/27.8		2/254.9	1/**32.5**	2/27.2	/**28.1**	/**38.9**
	601–800	3748.5	**1843.4**	272.9	1933.6	2370.7	1220.7		714.4	417.7	**1370.8**	646.4	**1395.4**
		1/**824.7**	/**405.5**	1/**60.0**	3/124.9	1/**521.6**	3/170.5		3/268.5	2/270.7	/**301.6**	2/146.2	/**307.0**
	801–1000	7340.6	5735.6	2015.2	8155.9	4189.5	8910.0		6326.1	2285.3	3213.2	2624.1	4098.0
		6/1303.8	7/684.6	3/560.4	4/3242.2	7/955.9	5/3369.0		4/2472.8	3/531.2	7/500.6	4/298.7	8/1034.9
	1001–1200	**29794.4**	12834.5	26886.3	18816.7	15523.2	16863.3		16658.6	19846.9	11967.9	11129.3	11550.2
		/**6554.8**	17/1428.5	14/3468.2	14/2394.9	20/1830.2	15/1979.3		16/2134.2	12/4066.4	19/1272.8	14/1550.3	15/1415.9
	1201–1400	**12333.4**	8676.4	17636.1	5447.5	5520.6	5084.5		6679.1	17748.8	5123.3	5211.0	4129.0
		/**2713.3**	11/485.3	14/4885.5	9/1613.6	4/2200.5	10/1758.7		11/1349.0	5/4615.8	11/1101.4	13/935.1	13/928.7
	1401–1500	**2029.0**	1886.4	9911.9	1782.0	1158.1	1626.5		89.5		0	943.9	2024.1
		/**446.4**	1/**415.0**	3/2746.7	3/676.5	2/325.5	2/652.8		1/**19.7**		1/0	3/341.0	2/1258.4
	Sum 1B–1D	115158.5	58647.5	69085.6	66320.3	51744.3	81746.4		72588.6	50863.1	40759.8	33958.5	43408.5
	401–1500	31/25366.9	83/9133.9	61/13855.4	75/14116.2	81/9296.7	83/15360.1		84/15883.2	49/11571.2	87/7108.0	80/7537.6	87/9446.8

TABLE 5. Abundance ('000) of Greenland halibut and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Abundance figures in **bold** are estimated from a two-way ANOVA and S.E. in **bold** are estimated from a regression between abundance and S.E. (see text).

Div.	Date: Depth (m)	1987 15 Jul– 13 Aug	1988 12 Sep– 11 Oct	1989 30 Apr– 17 May	1990 9 Jun– 22 Jun	1990 27 Aug– 12 Sep	1991 4 Aug– 30 Aug	1991 12 Nov– 27 Nov	1992 11 Aug– 28 Aug	1992 25 Nov– 7 Dec	1993 20 Aug– 8 Sep	1994 2 Aug– 19Aug	1995 12 Aug– 1 Sep
1AS	0–200						149.7	1317.6					
							115.1	326.1					
	201–400	10476.2					3761.6	6148.0					
		3555.7					835.1	1868.6					
	401–600	861.1	455.5			770.8	722.3		276.1				
		352.6	**109.3**			585.5	196.2		135.2				
	601–800						2478.2		1521.9				
							594.8		**365.3**				
	801–1000		5222.7			1984.6	2918.9		3734.8				332.1
			565.0			785.8	**700.5**		**896.4**				52.0
	1001–1200					1465.2							217.7
						351.6							156.6
	1201–1400		742.3			553.2	613.2		1984.2				
			105.0			**132.8**	519.1		**476.2**				
	1401–1500								111.5				
									26.8				
1B	0–200						631.8	24330.6					
							492.5	14077.1					
	201–400	32574.5					20171.7	49413.8					
		8422.9					6216.1	10802.1					
	401–600	13688.2	19532.2		9852.2	9799.4	23014.7	29300.2	35306.8		19797.9	8114.4	26689.7
		2992.4	8271.5		2561.2	1707.0	5368.9	4325.7	11588.2		5578.5	2314.7	8538.4
	601–800	5497.5	4134.8			5072.6	6601.2	5324.0	6749.4		2711.7	843.2	2896.4
		1127.4	1765.0			1027.5	1290.1	1385.0	988.8		631.7	466.7	1017.3
	801–1000	**2664.6**	570.2			788.1	1337.4		**4208.4**		**671.4**	**239.7**	**805.7**
		639.5	**136.8**			**189.1**	**321.0**		**1010.0**		**161.1**	**57.5**	**193.4**
1C	201–400	238.1											
		131.3											
	401–600	911.6	342.0	771.2	2091.0	713.6	938.4		1882.0	827.6	1007.1	278.3	331.1
		279.2	130.1	204.5	310.2	190.8	231.7		1264.3	271.7	341.5	212.1	175.6
	601–800	24976.0	13446.4	6175.1	11824.9	9290.4	16235.2		8428.8	8777.5	7219.4	2784.7	6716.6
		4610.9	2017.5	617.9	1576.8	1613.3	1604.5		862.3	839.4	940.4	508.0	598.0
	801–1000	15491.5	7688.9	7000.8	9395.2	6105.4	16331.5		19443.5	5717.6	4164.0	6862.6	7259.2
		3610.9	1125.7	1419.4	2776.5	945.9	2431.7		4375.3	1232.6	692.1	2576.3	1280.2
	1001–1200	**3536.4**	660.9	851.4	744.6	1635.3	1088.1		918.4	1606.3	1891.7	1205.6	1303.6
		848.7	361.9	18.3	56.5	279.7	70.8		171.1	711.6	426.3	147.0	676.6
1D	401–600	**1105.1**	**550.7**	233.5	169.9	292.7	82.1		874.6	218.5	1116.1	**272.9**	**411.3**
		265.2	**132.2**	145.8	9.2	**70.2**	82.1		779.7	**52.4**	102.9	**65.5**	**98.7**

TABLE 5. (Continued). Abundance ('000) of Greenland halibut and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Abundance figures in **bold** are estimated from a two-way ANOVA and S.E. in **bold** are estimated from a regression between abundance and S.E. (see text).

Div.	Date: Depth (m)	1987 15 Jul– 13 Aug	1988 12 Sep– 11 Oct	1989 30 Apr 17 May	1990 9 Jun– 22 Jun	1990 27 Aug– 12 Sep	1991 4 Aug– 30 Aug	1991 12 Nov– 27 Nov	1992 11 Aug– 28 Aug	1992 25 Nov– 7 Dec	1993 20 Aug– 8 Sep	1994 2 Aug– 19 Aug	1995 12 Aug– 1 Sep
1D	601–800	**3544.6**	**1766.5**	352.1	1663.6	2013.4	1307.7		928.6	532.5	**1417.6**	636.7	**1319.2**
		850.7	**424.0**	**84.5**	145.5	**483.2**	124.6		386.6	365.4	**340.2**	116.8	**316.6**
	801–1000	6896.0	4604.0	2325.5	7034.5	3816.4	7245.2		6328.9	2994.3	2984.1	2413.5	3682.6
		1667.9	456.0	584.0	3347.6	964.2	2262.3		2562.8	539.4	433.0	174.3	868.1
	1001–1200	**27076.8**	8039.7	23889.4	14355.2	10694.7	11658.8		12355.0	20039.9	9220.4	8136.1	8275.4
		6498.4	1069.1	3014.0	1866.70	1194.8	1395.5		1582.6	3973.8	1134.7	1228.5	1203.6
	1201–1400	**10304.6**	5335.6	11544.6	3199.5	2920.7	3459.8		4818.2	17381.4	3510.6	3743.1	2604.1
		2473.1	458.5	2625.7	1102.7	1381.3	1154.3		990.4	4229.5	837.6	817.7	719.3
	1401–1500	**1413.1**	1449.2	4382.1	731.7	468.8	674.7		83.3		0	322.8	1121.4
		339.1	**347.8**	2402.7	271.6	13.4	270.7		**20.0**		0	57.4	766.5
	Sum 1B–1D	117106.0	68121.1	57525.7	61062.3	53611.5	89974.8		102325.8	58095.6	55712.0	35853.6	63416.3
	401–1500	26203.4	16696.1	11116.8	14024.5	10060.4	16608.2		26582.1	12215.8	11620.0	8742.5	16452.3

TABLE 6. Biomass (tons) of roundnose grenadier, number of hauls and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Biomass figures in **bold** are estimated from a three-way ANOVA and S.E. in **bold** are estimated from a regression between biomass and S.E. (see text).

Div.	Date: Depth (m)	1987 15 Jul– 13 Aug	1988 12 Sep– 11 Oct	1989 30 Apr– 17 May	1990 9 Jun– 22 Jun	1990 27 Aug– 12 Sep	1991 4 Aug– 30 Aug	1992 11 Aug– 28 Aug	1992 25 Nov– 7 Dec	1993 20 Aug– 8 Sep	1994 2 Aug– 19 Aug	1995 12 Aug– 1 Sep
1C	0–200	0										
		10/0										
	201–400	63.1										
		6/44.0										
	401–600	2209.3	25.6	3.9	200.5	14.5	8.0	24.3	0	0	0	1.1
		3/801.8	5/18.9	4/1.6	5/149.4	5/13.9	5/4.0	5/19.7	2/0	4/0	4/0	3/1.1
	601–800	835.0	333.0	0	55.7	188.2	1719.6	181.6	26.7	19.0	32.3	30.4
		8/499.7	18/185.6	10/ 0	13/36.6	16/76.0	16/1059.4	20/151.6	14/11.3	22/13.5	16/17.4	16/11.3
	801–1000	29256.3	1483.0	37.9	53.0	1288.0	12653.7	14513.8	151.9	851.0	294.6	1150.3
		5/13118.3	11/581.7	8/30.2	13/36.0	11/614.5	11/4529.7	7/3911.9	8/34.0	9/532.4	10/139.0	14/666.8
	1001–1200	**752.2**	1745.4	1.8	2.7	570.9	1813.4	517.9	25.4	252.8	200.8	81.3
		-/331.0	2/1553.8	2/0.3	2/0.4	2/89.3	2/650.7	2/94.4	2/3.0	2/164.1	2/70.1	2/50.8
1D	0–200	0.0										
		5/0										
	400–400	0										
		3/0										
	401–600	**37.1**	**4.0**	89.1	74.9	226.0	254.2	120.3	63.7	16.9	**0.4**	**0.5**
		-/16.3	**-/1.8**	2/13.9	2/74.9	1/**99.4**	2/253.0	2/41.5	1/**28.0**	2/6.1	-/**0.2**	-/**0.2**
	601–800	1096.8	**13.8**	4.4	0.4	21.8	1895.6	3693.0	10.0	**2.2**	7.0	**1.8**
		1/**482.6**	-/**6.1**	1/**1.9**	3/0.4	1/**9.6**	3/1814.9	3/1920.2	2/6.6	-/**1.0**	2/2.8	-/**0.8**
	801–1000	10814.5	6949.7	99.0	319.3	1586.5	5914.0	5016.8	26.2	169.9	22.7	66.3
		6/3240.7	7/3754.4	3/83.5	4/304.6	7/1498.6	5/4533.1	4/4893.8	3/3.7	7/90.7	4/11.2	8/20.1
	1001–1200	**27928.4**	23807.4	1138.0	706.9	9605.6	12186.1	13810.3	363.9	3549.0	890.5	1576.3
		-/**12288.5**	17/6356.6	14/395.6	14/118.8	20/2215.5	15/2625.1	16/2606.0	12/67.4	19/576.2	14/218.9	15/428.0
	1201–1400	**9348.3**	7006.8	1421.1	1389.1	3301.5	3845.1	5119.1	433.7	3153.7	1094.0	2453.7
		-/**4113.3**	11/638.5	14/501.2	9/879.7	4/1019.9	10/455.4	11/1493.8	5/187.7	11/285.9	13/296.8	13/435.1
	1400–1500	**1500.3**	2866.4	5354.5	6382.0	2359.0	1601.1	135.4		14.8	602.1	1825.5
		-/**660.1**	1/**1261.2**	3/1871.8	3/4162.1	2/851.3	2/197.1	1/**59.6**		1/**6.5**	3/153.0	2/831.5
	Sum 1C–1D	83778.2	44235.1	8149.7	9184.5	19162.0	41890.8	43132.5	1101.5	8029.3	3144.4	7187.2
	401–1500	23/35552.3	72/14358.6	61/2900.0	68/5762.9	69/6488.0	71/16122.4	71/15192.5	49/341.7	77/1676.4	68/909.4	73/2445.7

TABLE 7. Abundance ('000) of roundnose grenadier and Standard Error (S.E.) by NAFO Division, depth stratum, year and cruise number. Abundance figures in **bold** are estimated from a three-way ANOVA and S.E. in **bold** are estimated from a regression between abundance and S.E. (see text).

Div.	Date: Depth (m)	1988 12 Sep– 11 Oct	1989 30 Apr– 17 May	1990 9 Jun– 22 Jun	1990 27 Aug– 12 Sep	1991 4 Aug– 30 Aug	1992 11 Aug– 28 Aug	1992 25 Nov– 7 Dec.	1993 20 Aug– 8 Sep	1994 2 Aug– 19 Aug	1995 12 Aug– 1 Sep
1C	401–600	296.7	61.1	1403.1	329.5	180.4	339.3	19.0	12.5	12.9	53.1
		231.0	31.4	1112.6	250.4	58.3	243.9	19.0	7.2	12.9	28.8
	601–800	3449.7	41.5	535.8	4606.1	27870.3	3520.4	1910.9	570.2	1400.4	954.5
		1579.8	41.5	243.2	1833.9	18085.3	2612.9	638.6	272.7	701.5	322.6
	801–1000	15150.3	2074.5	624.0	12994.2	88985.0	150859.0	5083.6	9503.6	3553.1	12264.1
		4785.3	1583.7	407.2	6098.5	31332.9	45218.9	920.4	4947.4	1611.4	6757.3
	1001–1200	11153.5	83.3	46.2	2737.3	8697.4	2469.2	791.2	1897.3	1022.2	537.4
		9952.4	16.7	6.7	493.0	2471.2	454.3	38.8	1258.9	250.4	389.1
1D	401–600	**218.7**	530.6	620.3	1335.6	3153.6	882.5	418.8	87.4	**29.3**	**46.0**
		113.7	253.0	620.3	**694.5**	3136.6	525.1	**217.8**	24.1	**15.2**	**23.9**
	601–800	**1960.6**	220.1	31.7	163.3	22664.4	44294.0	533.1	**279.9**	427.5	**400.8**
		1019.5	**114.5**	12.8	**84.9**	21553.5	22110.7	98.8	**145.5**	134.5	**208.4**
	801–1000	42115.9	1143.5	2729.5	11885.3	27018.3	40225.6	1224.2	1716.2	413.3	733.8
		20512.5	755.4	2501.1	11443.4	18650.2	39017.2	219.1	966.6	76.7	126.4
	1001–1200	78363.3	12930.6	4574.2	33304.4	50037.0	56056.8	6788.8	15939.5	4442.6	6823.2
		26692.0	2864.5	656.2	6395.3	11876.3	11631.7	1092.1	3185.0	1125.7	1727.3
	1201–1400	11492.5	6800.5	2950.9	5844.7	9479.5	13135.0	5487.1	10181.0	4215.7	6637.1
		983.7	1458.8	1435.6	1096.6	1770.3	3612.9	2312.4	3002.3	1732.4	1986.6
	1400–1500	4273.8	12229.3	11294.8	3690.4	2636.5	187.4		21.2	1165.0	3295.2
		2222.4	17.3	7231.5	1316.7	535.6	**97.4**		**11.0**	324.9	1445.9
	Sum 1C–1D	168475.0	36115.0	24810.5	76890.8	240722.4	311969.2	22256.7	40208.8	16682.0	31745.2
	401–1500	68092.3	7136.8	14227.2	29707.2	109470.2	125525.0	5557.0	13820.7	5985.6	13016.3

TABLE 8. Biomass of Greenland halibut (tons), number of hauls/Standard Error in NAFO Divisions 1E and 1F by depth stratum in 1987. (No abundance data).

Div.	Depth(m)	Biomass
1E	1–200	5.0 3/5.0
	201–400	35.9 2/29.5
1F	1–200	0.0 5/0.0
	201–400	0.0 2/0.0
	401–600	10.8 2/1.14

The biomass of roundnose grenadier in Div. 1C–1D stratum, 401–1 500 m was estimated at 83 778.2 tons (S.E. 35 552.3), which was by far the highest estimate in the time series (Table 6, Fig. 2 and 5). However, the estimate was based on 23 hauls only, and the biomass at depths >1 000 m (47% of the total) was estimated by an ANOVA. The highest biomass was found in Div. 1C depth stratum 801–1 000 m. Roundnose grenadier occurred only sporadically at depths <400 m in Div. 1C, and the biomass was estimated at only 63.1 tons.

Due to incomplete sampling it was not possible to make estimates of abundance.

The lengths ranged between 2 and 16 cm (AFL) and the length distributions were dominated by modes around 9 and 10 in depth strata 401–800 and 801–1 000 m (Fig. 6).

1988

The survey was conducted between 12 September and 11 October and covered Div. 1AN to 1D at depths between 422 and 1 402 m (259–1 398 m in 1AN). In total 109 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. The biomass of Greenland halibut in Div. 1B–1D stratum, 401–1 500 m was estimated at 58 647.5 tons (S.E. 9 133.9), which was only half the estimate in 1987, but the difference was not statistically significant (95 % level) due to large variation in data (Fig. 3, Table 4). The highest biomass was found in Div. 1C depth strata 601–800 and 801–1 000 m, and in Div. 1D depth strata 1 001–1 200 and 1 201–1 400 m. Division 1AN was surveyed only this time in the survey series, and 21 hauls were made in the area. The biomass was estimated at 19 335.2 tons (S.E. 4 694.9) of which the larger part (10 017.8 tons) was found in depth stratum 501–1 000 m (Fig. 1, Table 9).

The abundance in Div. 1B–1D (401–1 500 m) dropped from 117 106.0 × 10^3 (S.E. 26 203.4 × 103) in 1987 to 68 121.1 × 10^3 (S.E. 16 696.1 × 10^3) in 1988 (statistically insignificant (95% level)) (Table 5, Fig. 3). The distribution of the abundance resembled the distribution of the biomass, except that a high abundance was observed in Div. 1B depth stratum 401–600 m. In Div. 1AN the abundance was estimated at 98 056.8 × 103 specimens (S.E. 10 614.3 × 10^3) of which more than 50% was found in depth stratum 201–500 m (Table 9).

In Div. 1AN and 1B the length distribution was dominated by three very distinct modes around 11, 19 and 24 or 28 cm. The length distribution in 1AS was dominated by a mode around 25 cm and a broad mode between 34 and 52 cm, reflecting a dominance of hauls in the deeper strata. The length distribution in Div. 1C was dominated by fish between 38 and 58 cm with a broad mode around 50 cm, while the distribution in Div. 1D consisted mainly of fish between 42 and 70 cm with a mode around 52 cm (Fig. 4).

The age distribution in Div. 1A (1AN + 1AS) consisted of fish age 1 to 7, where the younger fish were mainly found in Div. 1AN, while the older fish mainly came from Div. 1AS. Division 1B was dominated by young fish <5 years, while the age distributions in Div. 1C and 1D were unimodal with modes around 7 and 8 years, respectively (Fig. 7). (The otoliths have been reread after the material given in Yatsu and Jørgensen (1989b)).

Roundnose grenadier. Besides a single specimen caught at 70°44'N (Div. 1A) roundnose grenadier was found in Div. 1C and 1D, only. The biomass in Div. 1C–1D, 401–1 500 m, was estimated at 44 235.1 tons (S.E. 14 358.6) which was only about half the estimate in 1987 but the difference was not statistically significant (95% level) due to large variation in data (Fig. 2 and 5, Table 6). The largest decrease in biomass was seen in Div. 1C, especially in depth stratum 801–1 000 m where the biomass was reduced from about 29 000 tons in 1987 to about 1

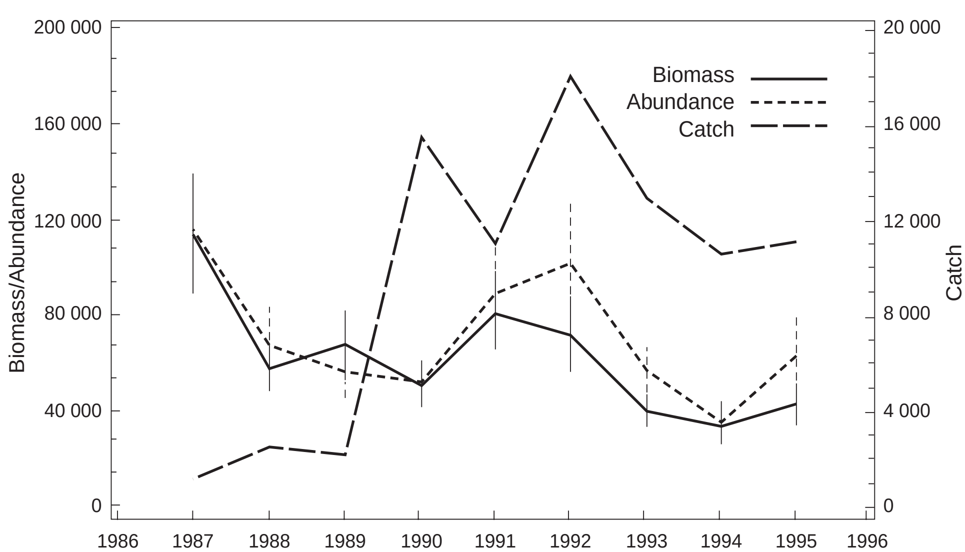

Fig. 3. Estimated biomass (tons) and abundance ('000) of Greenland halibut in Div. 1B–1D at depths between 401 and 1 500 m in the period 1987–95 with +/- Standard Error. The survey in 1989 covered 1C–1D only and was conducted in May, all other surveys were conducted in July–October. The offshore catches (tons) in Subarea 0B and 1 are shown.

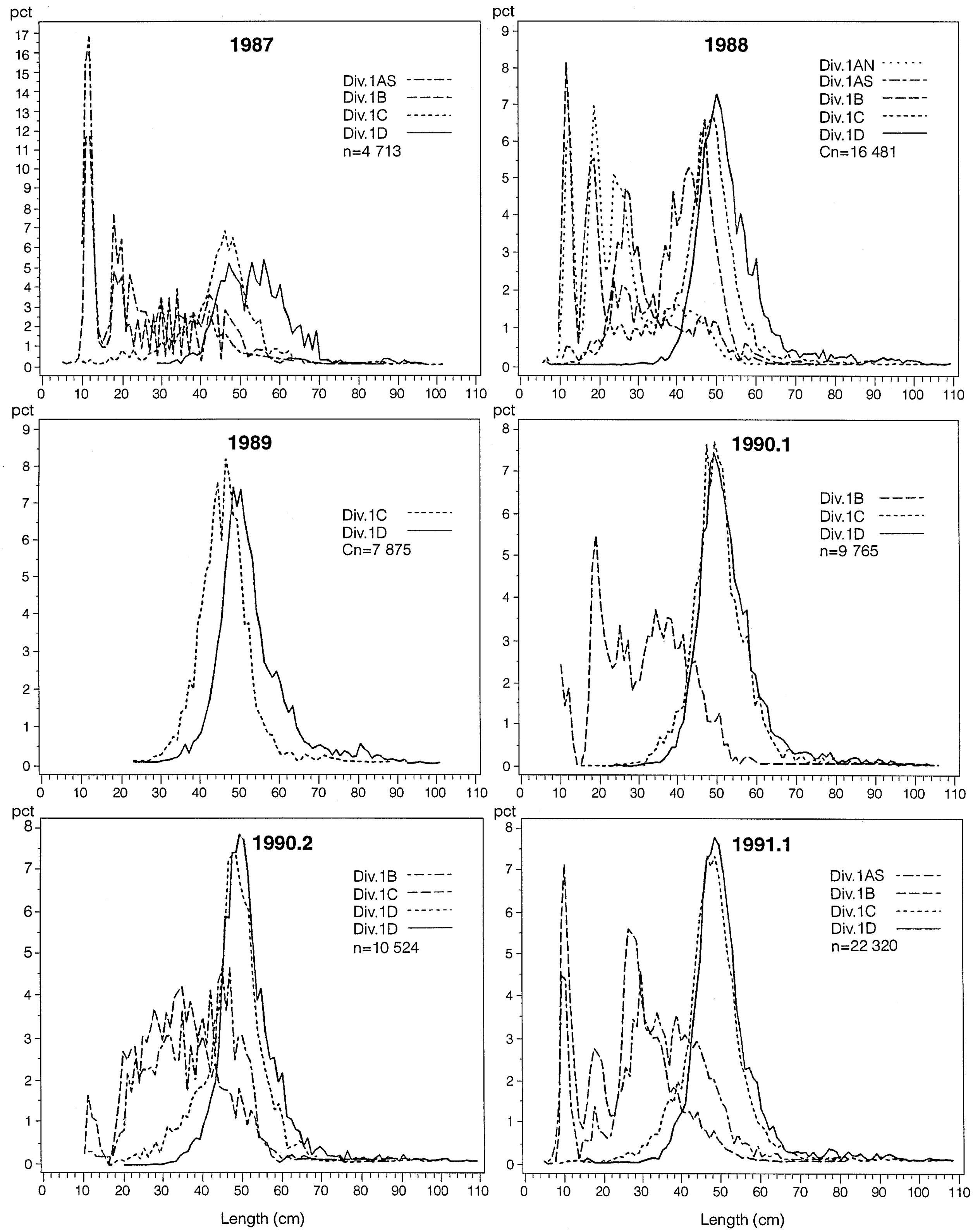

Fig. 4. Length distribution of Greenland halibut by survey and NAFO Division.

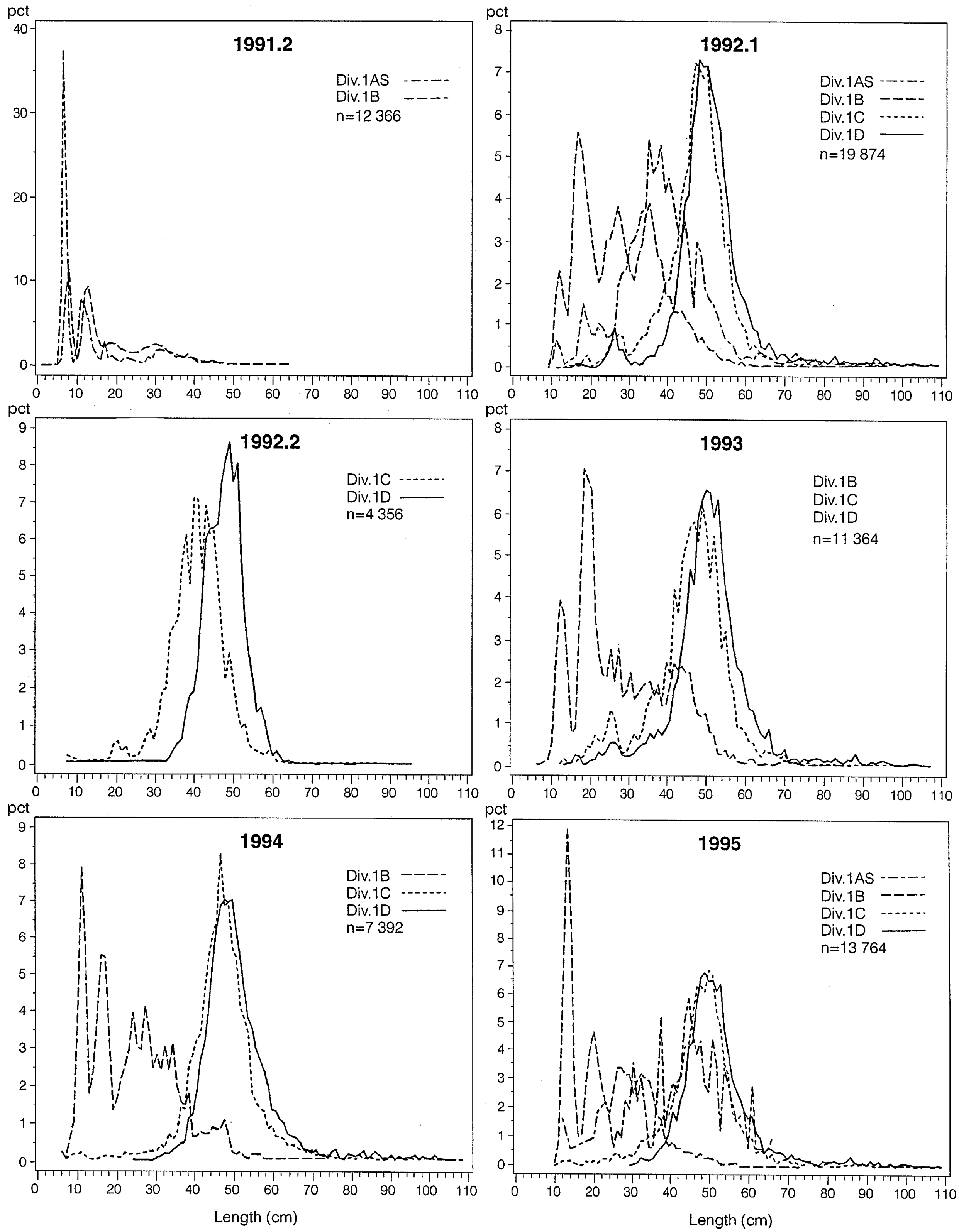

Fig. 4. (Continued). distribution of Greenland halibut by survey and NAFO Division.

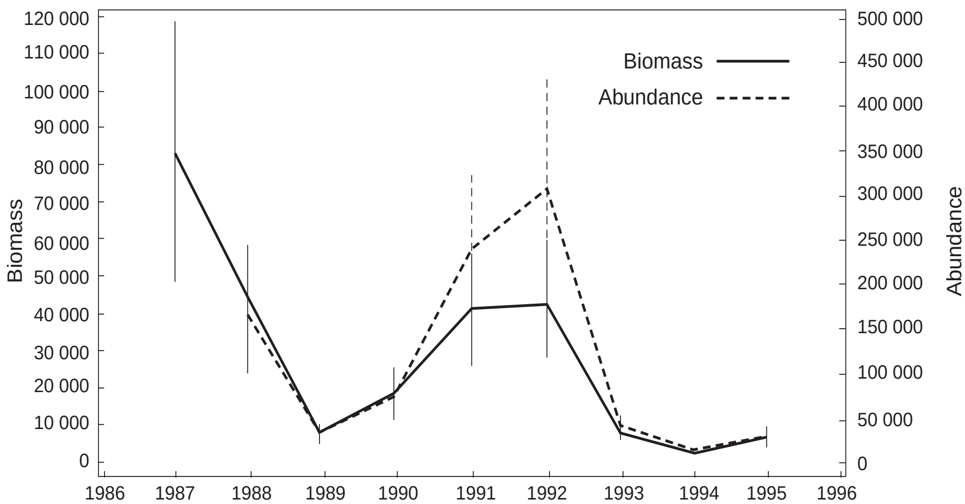

Fig. 5. Estimated biomass and abundance of roundnose grenadier in Div. 1C–1D at depths between 401 and 1 500 m in the period 1987–95 with +/- Standard Error. The survey in 1989 was conducted in May, all other surveys were conducted in mid July–mid October. No abundance data from 1987.

500 tons in 1988. The highest biomass was found in Div. 1D depth stratum 1 001–1 200 m.

The abundance in Div. 1C–1D, 401–1 500 m, was estimated at 168 475.0 × 10^3 (S.E. 68 092.3 × 10^3) and the distribution of the abundance resembled the distribution of the biomass, i.e. the highest abundance was found in Div. 1D depth stratum 1 001–1 200 m (Table 7).

The lengths ranged from 2 to 22 cm (AFL) and there was a clear increase in length by depth with modes at 6, 9, 9.5 and 14 cm in the four depth intervals (Fig. 6).

The ages ranged from 4 to 20 years and age 7 was the most dominant in both Div. 1C and 1D (Fig. 8). Generally the fish seemed to be older in Div. 1D, probably reflecting that the size (age) was increasing by depth. The maximum depth in Div. 1C is about 1 200 m and fish were sampled at depths down to 1 500 m in Div. 1D. The smallest fish in the age/length key were 6 cm, which implies that fish in the length range 2–5 cm AFL, which constituted 18.5% of the fish in Div. 1C and 3.7% of the fish in Div. 1D, have not been included in the age composition.

1989

The survey was conducted between 30 April and 17 May and covered Div. 1C and 1D at depths between 494 and 1 497 m. In total 61 successful hauls were made (Fig. 1, Table 1). Divisions 1AS, 1B and the western part of Div. 1C and 1D were not surveyed due to ice.

Greenland halibut. The biomass of Greenland halibut in Div. 1C–1D stratum, 401–1 500 m was estimated at 69 085.6 tons (S.E. 13 855.4), which was a statistically insignificant (95% level) increase in biomass on approximately 17 000 tons compared to the estimate for the same area in 1988. The two surveys were, however, conducted at different time of the year which makes comparison difficult (Fig. 3, Table 4). The highest biomass was found Div. 1D depth strata 1 001–1 200 and 1 201–1 400 m as in the previous years. The biomass was, however, concentrated more southerly and at greater depths compared to 1987 and 1988, probably reflecting annual movements between the spawning ground and feeding areas (Jørgensen, 1997a).

The abundance in Div. 1C–1D, 401–1 500 m, was estimated at 57 525.7 × 10^3 (S.E. 111 16.8 × 10^3) which was an increase from 43 883.9 × 10^3 compared to the same area in 1988. The distribution of the abundance resembled the distribution of the biomass in a more southerly and deeper distribution compared to previous year (Fig. 3, Table 5).

Fish were generally larger in Div. 1D compared to 1C and the distributions were unimodal with modes around 50 and 48 cm, respectively (Fig. 4).

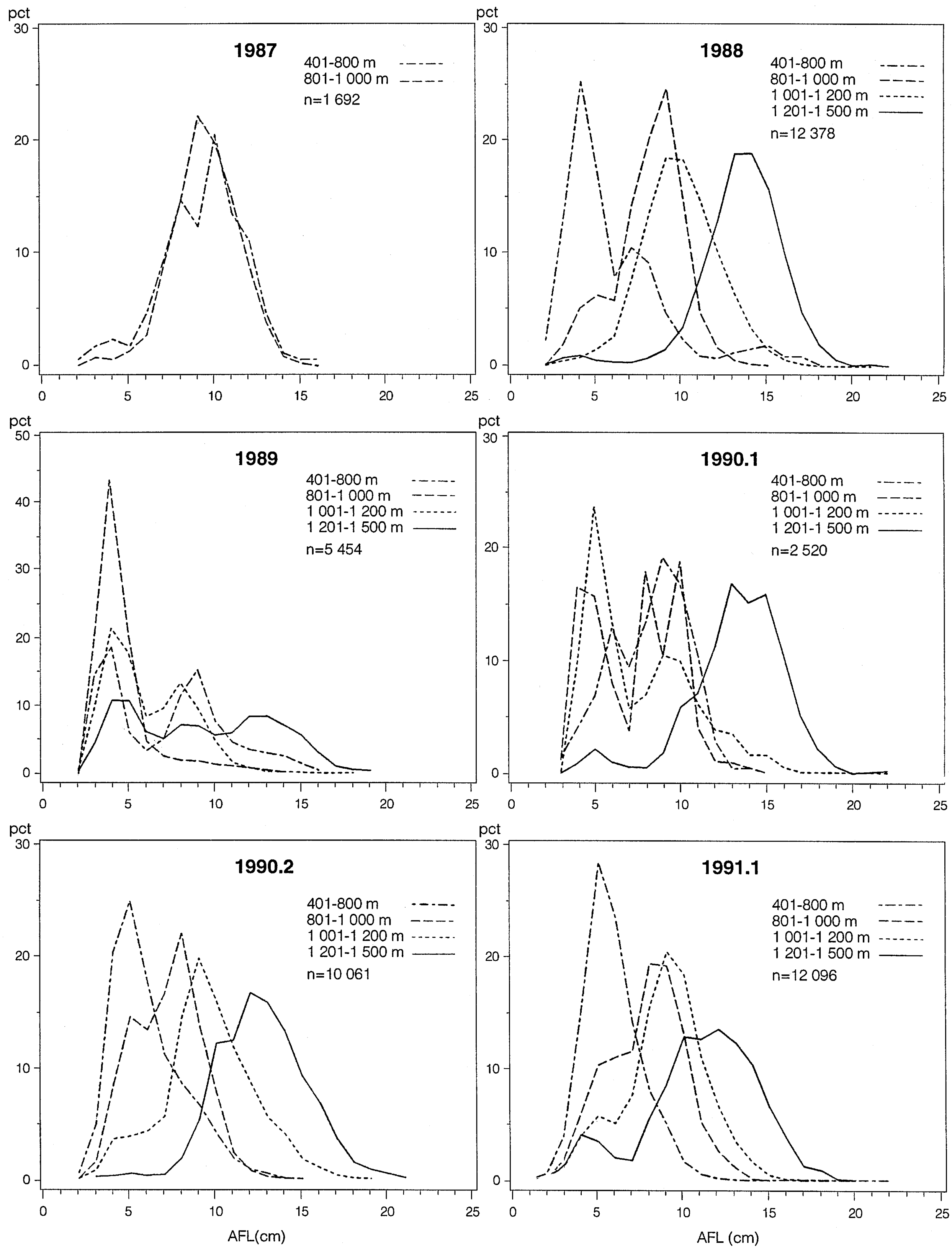

Fig. 6. Length distribution of roundnose grenadier by survey, NAFO Division and depth.

TABLE 9. Biomass of Greenland halibut (tons), number of hauls and Standard Error (S.E.) and abundance ('000) and S.E. in Division 1AN in 1988 by, depth stratum. S.E. in **bold** are estimated from a regression between biomass (or abundance) and S.E. (see text).

Depth (m)	Biomass	Abundance
201–500	5502.4	59236.8
	9/2197.8	2335.0
501–1000	10017.8	35604.3
	11/1657.8	7483.5
1001–1500	3815.0	3315.7
	1/839.3	**795.8**

The age distributions in Div. 1C and 1D were unimodal with modes around 7 and 8 years, respectively, as in 1988, but there were fewer young fish in Div. 1C compared to 1988 (Fig. 7).

Roundnose grenadier. The biomass in Div. 1C–1D stratum, 401–1 500 m was estimated at 8 149.7 tons (S.E. 2 900.0) which was a statistically significant (95% level) drop in biomass on approximately 35 000 tons compared to the estimate in 1988. The two surveys were, however, conducted at different time of the year which makes comparison difficult (Fig. 2 and 5, Table 6). Roundnose grenadier was almost absent from Div. 1C and more than 60% of the biomass was found in the small depth stratum 1 401–1 500 m in Div. 1D (3 091 km^2), where the biomass increased compared to 1988.

The abundance in Div. 1C–1D stratum, 401–1 500 m was estimated at 36 115.0 × 10^3 (S.E. 7 136.8 × 10^3) which was a marked, but statistically insignificant, decrease compared to about 155 000 × 10^3 in 1988. The highest abundance was found in Div. 1D depth stratum 1 001–1 200 m. (Fig. 5, Table 7).

The lengths ranged from 2 to 19 cm (AFL) but the length distribution was dominated by small fish with a mode around 4.5 cm (AFL) in all depth strata. A mode around 8–9 cm (AFL) was also seen in all depth strata except stratum 801–1 000 m. Further, a broad mode at 12–15 cm (AFL) was seen in the deepest depth stratum (Fig. 6).

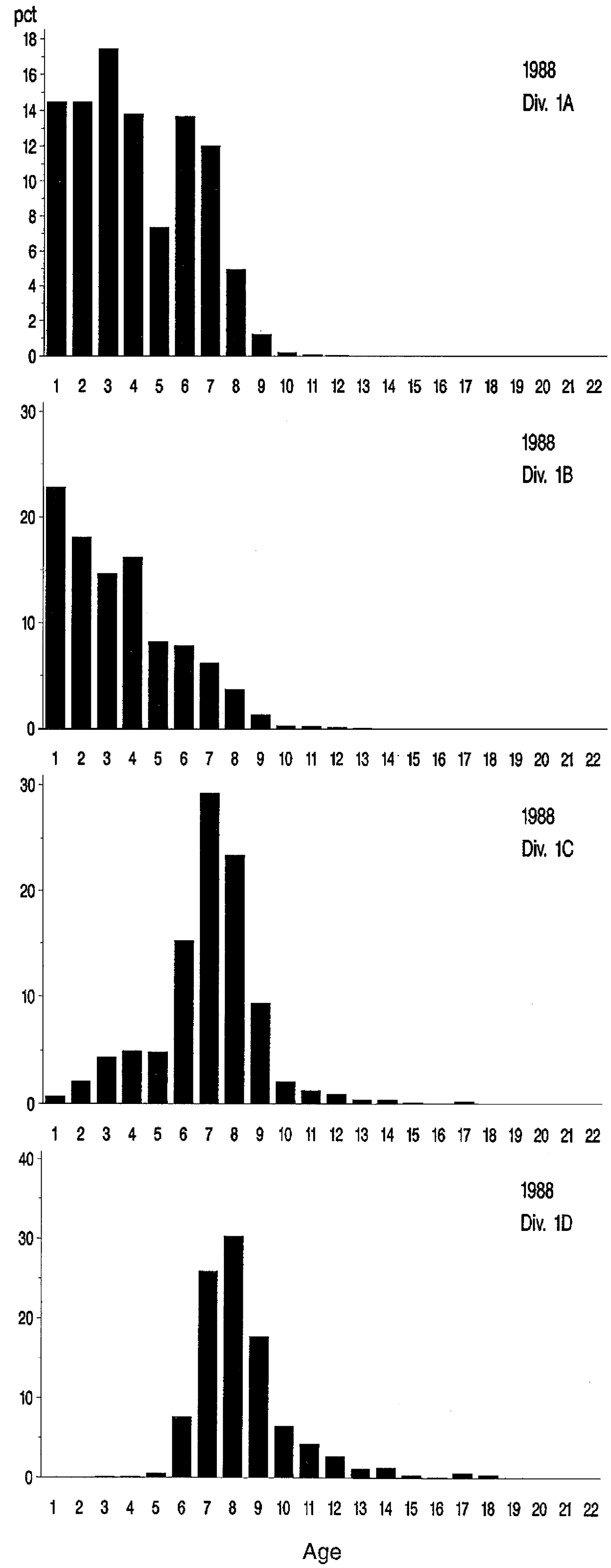

Fig. 7. Age distribution of Greenland halibut by survey and NAFO Division.

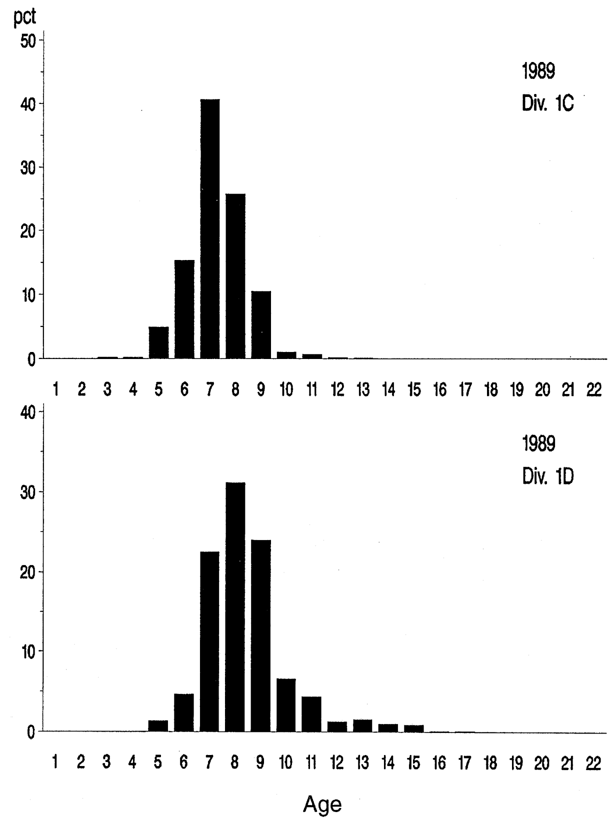

Fig. 7. (Continued). Age distribution of Greenland halibut by survey and NAFO Division.

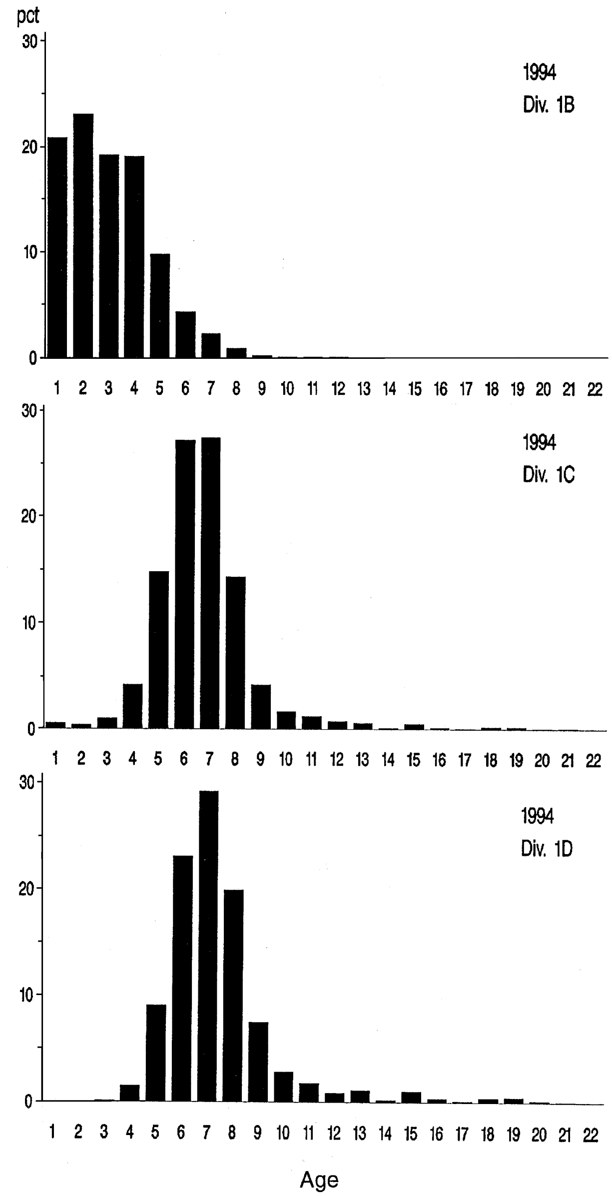

Fig. 7. (Continued). Age distribution of Greenland halibut by survey and NAFO Division.

1990

In 1990 two surveys were conducted. The first survey took place between 9 June and 22 June and covered Div. 1B to 1D at depths between 449 and 1 482 m. In Div. 1B only depth stratum 401–600 m was covered. In total 75 successful hauls were made, (Fig. 1, Table 1). The second survey took place between 27 August and 12 September and covered Div. 1AS to 1D at depths between 422 and 1 467 m and in total 87 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. In the first survey, the biomass of Greenland halibut in Div. 1C–1D stratum, 401–1 500 m was estimated at 62 778.9 tons (S.E.13 466.1), which was close to the 69 000 tons estimated in the same area in 1989, where the survey took place approximately a month earlier (Table 4). The main biomass was found at depths between 601 and 1 000 m, and generally on shallower water and more northerly compared to 1989.

In the second survey the biomass in Div. 1B–1D stratum, 401–1 500 m was estimated at 51 744.3 tons (S.E. 9 296.7), which was comparable to the estimated 58 647.2 tons in approximately the same period in 1988 (Fig. 3, Table 4). The estimate for Div. 1C–1D was 44 018.1 tons, which was substantially, although not statistically significant, lower than in the comparable areas in the first survey in 1990 (62 778.9 tons) and in 1989 (69 085.6 tons). The highest biomass was found in Div. 1C depth strata 601–800 and 801–1 000 m and in Div. 1D depth strata 1 001–1 200 and 1 201–1 400 m.

In the first survey the abundance in Div. 1C–1D stratum, 401–1 500 m was estimated at 51 210.1

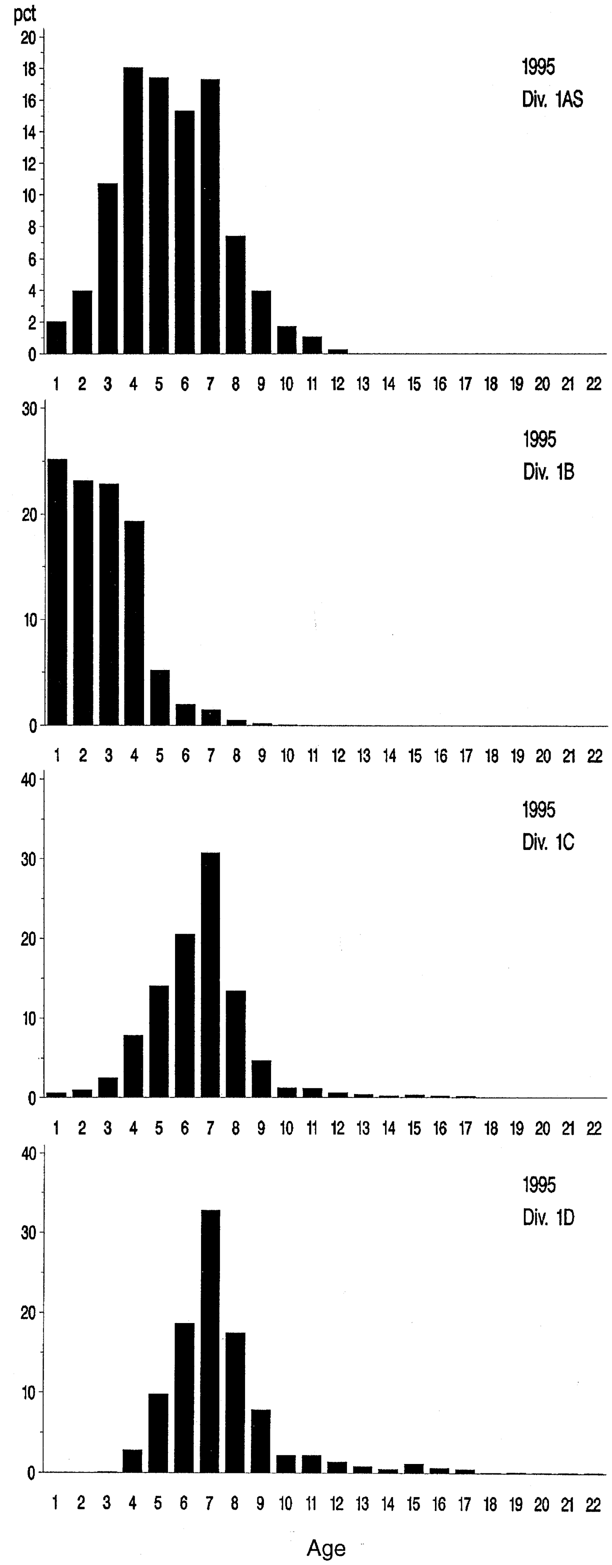

Fig. 7. (Continued). Age distribution of Greenland halibut by survey and NAFO Division.

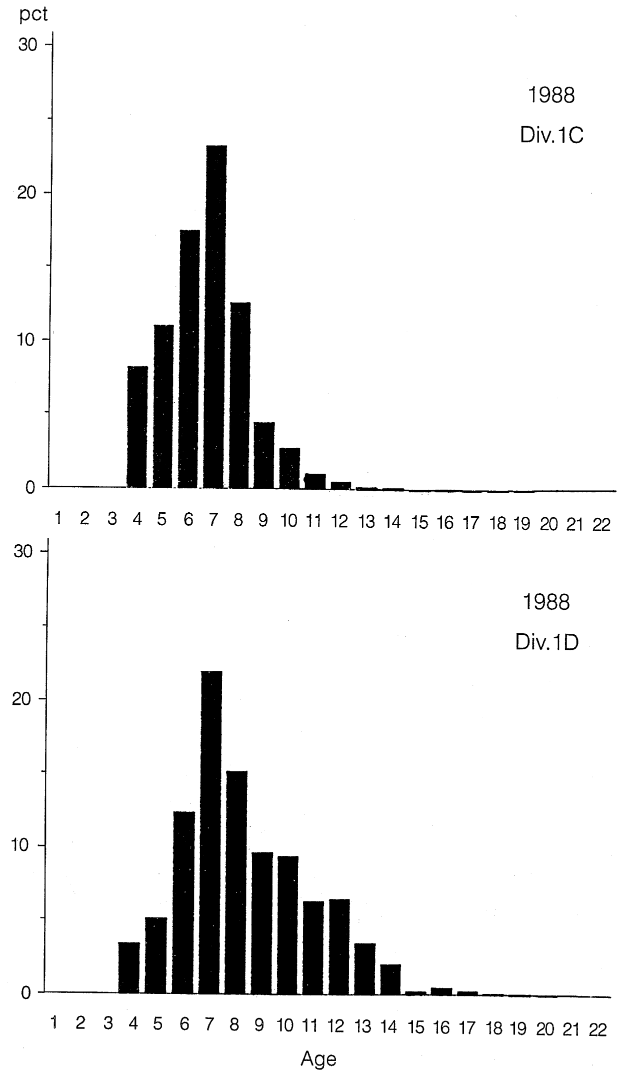

Fig. 8. Age distribution of roundnose grenadier 1988 in NAFO Div. 1C and 1D.

$\times 10^3$ (S.E. 11 463.3 $\times 10^3$), which was a little lower than in the same area in 1989 (57 525 $\times 10^3$) (Table 5). The derivation of the abundance resembled the distribution of the biomass i.e. the main abundance was found at depths between 601 and 1 000 m. Compared to 1989 the abundance was generally found on shallower water and more northerly.

In the second survey the abundance in Div. 1B–1D stratum, 401–1 500 m was estimated at 53 611.5 $\times 10^3$ (S.E. 10 060.4 $\times 10^3$), which was somewhat lower than the estimate of 68 121.1 $\times 10^3$ from approximately the same period in 1988 (Fig. 3, Table

5). The estimate for Div. 1C–1D was 37 951.4 × 10^3 (S.E. 7 136 × 10^3), which was substantially lower, although not statistically significant, than the comparable areas in the first survey in 1990 (51 210.1 × 10^3) and 1989 (57 525.7 × 10^3). The highest abundance was found in Div. 1B depth stratum 401–600 m, Div. 1C depth strata 601–800 and 801–1 000 m and in Div. 1D depth strata 801–1 000 and 1001–1 200 m.

In the first survey the length distribution in Div. 1B was dominated by three modes around 10, 19 and 24 and a broader mode around 34 cm. The length distribution in Div. 1C and 1D was dominated by fish between approximately 40 and 65 cm with clear modes around 50 cm, but with a tendency towards slightly larger fish in Div. 1D (Fig. 4).

In the second survey the length distribution in Div. 1B was dominated by the same four modes as in the first survey, but the fish seemed to have grown 2–3 cm between the two surveys. The length distribution in Div. 1C and 1D was dominated by fish between approximately 40 and 65 cm with clear modes around 50 and 52 cm in Div. 1C and 1D, respectively. There was a tendency towards slightly larger fish in Div. 1D. In Div. 1AS fish were generally between 20 and 50 cm, with several unclear modes (Fig. 4).

Roundnose grenadier. In both surveys roundnose grenadier was found in Div. 1C and 1D only (Fig. 2).

In the first survey the biomass of roundnose grenadier in Div. 1C–1D stratum, 401–1 500 m was estimated at 9 184.5 tons (S.E. 5 762.9), which was close to the 8 149.7 tons estimated in the same area in 1989 where the survey took place approximately a month earlier. The bulk of the biomass was found in Div. 1D depth stratum 1 401–1 500 m as in 1989. The biomass in Div. 1C was very low but had increased slightly compared to 1989 (Table 6).

In the second survey the biomass in Div. 1C–1D stratum, 401–1 500 m was estimated to 19 162.0 tons (S.E. 6 488.0), which was more than a doubling compared to the survey about two months earlier, but only about the half of the estimate in the comparable survey in 1988 (44 235.1 tons). The highest biomass was found in Div. 1D depth stratum 1 001–1 200 m indicating that the fish had moved towards shallow water in the period since the first survey, where the highest biomass was found in depth stratum 1 401–1 500 m (Table 6, Fig. 5).

In the first survey the abundance in Div. 1C–1D stratum, 401–1 500 m was estimated at 24 810.5 × 10^3 (S.E. 14 227.2 × 10^3), which was a little lower than in the same area in 1989 (36 115.0 × 10^3), despite the increase in biomass. The distribution of the abundance resembled the distribution of the biomass, i.e. the main abundance was found in depth stratum 1 401–1 500 m (Table 7).

In the second survey the abundance in Div. 1C–1D stratum, 401–1 500 m was estimated at 76 890.8 × 10^3 (S.E. 29 707.2 × 10^3), which was about three times the estimate in the first survey (24 810.5 × 10^3), although the biomass only was doubled, indicating an influx of small fish, which was also reflected in the length distribution (Fig. 5 and 6). The estimate in the second survey was about half the estimate in the comparable survey in 1988 (168 475.0 × 10^3). The highest abundance was found in Div. 1D depth stratum 1 001–1 200 m.

In the first survey the lengths ranged between 3 and 22 cm (AFL) (Fig. 6). The increase in size by depth seen in most other surveys could not be observed in this survey, except that fish in the deepest depth stratum generally seemed to be the largest and the length distribution was dominated by a broad mode around 15 cm (AFL). The distributions in the three shallow strata were dominated by a number of modes without any clear trends.

In the second survey the lengths ranged from 2 to 21 cm (AFL) and the length distributions in the four depth strata were dominated by modes at 5, 8, 9 and 12 cm indicating a clear increase in size by depth, as also seen in the comparable survey in 1988 (Fig. 6).

1991

In 1991 two surveys were conducted. The first survey took place between 4 August and 30 August and covered Div. 1AS to 1D at depths between 38 and 1 490 m. In total 139 successful hauls were made (Fig. 1, Table 1). The second survey took place between 12 November and 27 November and covered Div. 1AS and 1B at depths between 38 and 774 m. In total 51 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. In the first survey the biomass of Greenland halibut in Div. 1B–1D stratum, 401–1 500 m was estimated at 81 746.4 tons (S.E. 15 360.1), which was the second largest estimate in the time series, and although not statistically significant (95% level), an increase of approximately 30 000 tons compared to the second survey in 1990 (Fig. 3, Table 4). Almost all the increase was observed in Div. 1C in depth strata 601–800 m and 801–1 000 m, while the estimates from the other strata were at approximately the same level as the year before. The reason for the increase is unclear. The coverage was the same in the two years. The main biomass was found at depths between 601 and 1 000 m in Div. 1C and 1 001–1 200 m in Div. 1D.

In the second survey the biomass in Div. 1AS (0–400 m)–1B (0–800 m) was estimated at 11 361.7 tons (S.E. 2 483.6) which was a little lower compared to 13 247.5 tons (S.E. 2 613.1) in the same area in the first survey in 1991. The bulk of the biomass was found in Div. 1B at depths between 201 and 800 m in both surveys, but the biomass seemed to be distributed at shallower depths compared to the first survey (Table 4).

In the first survey the abundance in Div. 1B–1D stratum, 401–1 500 m was estimated at 89 974.8 $\times 10^3$ (S.E. 16 608.2 $\times 10^3$), which was a large, although not statistically significant, increase compared to the year before (53 611.5.7 $\times 10^3$) (Fig. 3, Table 5). Almost all the increase was seen in Div. 1B depth stratum 401–600 m and Div. 1C depth strata 601–800 m and 801–1 000 m. The increase was statistically significant (95% level) in the two latter strata.

In the second survey the abundance in 1AS (0–400 m)–1B (0–800 m) was estimated at 115 834.2 $\times 10^3$ (S.E. 32 784.6 $\times 10^3$) which was about twice the estimate of 54 330.7 $\times 10^3$ in same area in the first survey (Table 5). The increase was primarily seen in depth strata 0–201 and 201–400 m especially in Div. 1B, and was mainly caused by settling of a great number of age 0+ fish.

In the first survey the length distribution in Div. 1B was dominated by three very distinct modes at 11, 18 and 27 cm, while the length distribution in Div. 1C and 1D was dominated of fish between approximately 40 and 60 cm with clear modes around 50 cm, but with and a tendency towards slightly larger fish in Div. 1D. In Div. 1AS, the first two modes seen in Div. 1B (11 and 18 cm) were also noticed. Further, three modes at 30, 34 and 39 cm were seen (Fig. 4).

In the second survey the length distribution in Div. 1AS and 1B was dominated by two modes at 7–8 and 12–13 cm, respectively, of which the first mode represented newly settled age 0+ fish. The larger fish seen in the first survey were probably missing due to lack of hauls in the deeper strata in Div. 1AS (Fig. 4).

Roundnose grenadier. Roundnose grenadier was only recorded at the first survey. All the biomass was found in Div. 1C–1D stratum, 401–1 500 m, except a single specimen caught in depth stratum 601–800 m in Div. 1B. The biomass was estimated at 41 890.8 tons (S.E. 16 122.4), which was a doubling compared to the second survey the year before, but at the same level as the comparable survey in 1988. The increase in biomass compared to the survey in 1990 was mainly seen in Div. 1C depth stratum 801–1 000 m, where also the largest biomass was found. A significant proportion of the biomass was also found in Div. 1D depth stratum 1 001–1 200 m (Fig. 2 and 5, Table 6).

The abundance in Div. 1C–1D stratum, 401–1 500 m was estimated at 240 722.4 $\times 10^3$ (S.E. 109 470.2 $\times 10^3$), which was a marked, although not statistically significant, increase compared to the year before (76 890.8 $\times 10^3$) (Fig. 5, Table 7). The largest increase in abundance was seen in Div. 1C depth strata 601–800 and 801–1 000 m, where the largest abundance was found, and in the two shallow strata in Div. 1D, indicating an influx of small fish which was also reflected in the length distributions (Fig. 6).

The lengths ranged between 1 and 22 cm (AFL) and the length distribution in the four depth strata were dominated by modes around 5, 8, 9 and 12 cm as seen in the second survey in 1990.

1992

In 1992 two surveys were conducted. The first survey took place between 11 August and 28 August and covered Div. 1AS to 1D at depths between 417 and 1 475 m. In total 90 successful hauls were made (Fig. 1, Table 1). The second survey was conducted between 25 November and 7 December and covered Div. 1C–1D at depths between 510 and 1 400 m. In total 49 successful hauls were made (Fig. 1, Table 1). Due to severe damage of the trawl in the second survey, the trawl was replaced at haul 15. Although the two trawls were almost identical, there was a statistically significant difference found in the catchability of Greenland halibut in the two trawls (Satani *et al.*, MS 1993). All catches after haul 15 were therefore multiplied by 2.4. The difference in the catchability of roundnose grenadier was a factor of 3.1 but the difference was not statistically significant due to large variation in data.

Greenland halibut. In the first survey the biomass of Greenland halibut in Div. 1B–1D stratum, 401–1 500 m was estimated at 72 588.6 tons (S.E. 15 883.2), which was a statistically insignificant drop compared to 81 746.4 tons in the first survey in 1991 (Fig. 3, Table 4). The decrease was primarily seen in Div. 1C depth stratum 601–800 m (statistically significant at 95% level) and in Div. 1D depth strata 801–1 000 m and 1 401–1 500 m (statistically significant at 95% level), while the estimates were more or less at the same level in the remaining depth strata. The largest biomasses were found in Div. 1C depth stratum 801–1 000 m, Div. 1D depth stratum 1 001–1 200 m and in Div. 1B depth stratum 401–600 m, where the biomass estimate was the largest in the time series.

In the second survey the biomass in Div. 1C–1D stratum, 401–1 400 m was estimated at 50 863.1 tons (S.E. 11 571.2), which was an insignificant drop compared to 59 900.9 tons (S.E. 12 713.9) in the same area in the first survey in 1992 (Table 4). The bulk of the biomass was found in Div. 1D at depths between 1 001 and 1 401 m. Generally the biomass was found at greater depths in the second survey compared to the first, probably due to annual migrations when some fish might have migrated into deeper water outside the survey area (Jørgensen, 1997b).

In the first survey the abundance in Div. 1B–1D stratum, 401–1 500 m was estimated at 102 325.9 $\times 10^3$ (S.E. 26 582.1 $\times 10^3$), which was the second largest estimate in the survey series. The increase in abundance was, however, not statistically significant compared to the 89 974.8 $\times 10^3$ estimated in 1991. Almost all the increase was seen in Div. B depth stratum 401–600, while there was a marked drop in abundance in Div. 1C depth stratum 601–800 m. The changes in the other strata were limited. (Fig. 3, Table 5).

In the second survey the abundance in Div. 1C–1D stratum, 401–1 400 m was estimated at 58 095.6 $\times 10^3$ (S.E. 12 215.8 $\times 10^3$), which was at the same level (55 978.0 $\times 10^3$) as in same area in the first survey, but the main distribution was deeper and more southerly i.e. in Div. 1D at depths between 1 001 and 1 400 m.

In the first survey the length distribution in Div. 1B was dominated by four distinct modes at 12, 18, 27 and 35 cm, respectively. The length distribution in Div. 1C and 1D was dominated of fish between approximately 40 and 60 cm with clear modes around 50 cm, however, with and a tendency towards slightly larger fish in Div. 1D. The first two modes seen in Div. 1B (12 and 18 cm) were also observed in Div. 1AS. Further, a broad mode around 36–40 cm and a mode at 48 cm were seen (Fig. 4).

In the second survey the length distribution in Div. 1C was dominated by modes at 38, 40 and 44 cm, while the length distribution in Div. 1D was dominated by a single mode around 49 cm, indicating a migration of larger fish towards deeper water compared to the first survey (Fig. 4).

Roundnose grenadier. Roundnose grenadier was found in Div. 1C and 1D only, in the two surveys. In the first survey the biomass was estimated at 43 132.5 tons (S.E. 15 192.5), which was at the same level as the survey in 1991 (41 890.8 tons) and the distribution of the biomass in the two surveys was very much alike, i.e. with the highest biomass in Div. 1C depth stratum 801–1 000 m closely followed by Div. 1D depth stratum 1 001–1 200 m (Fig. 2 and 5, Table 6).

In the second survey the biomass dropped significantly (95% level) to only 1 101.5 tons (S.E. 341.7) compared to the survey three month earlier (43 132.5 tons) (Fig. 2, Table 6). The highest biomass was found in depth stratum 1 201–1 400 m. Depth stratum 1 401–1 500 m was not covered in this survey. The biomass in this stratum was, however, estimated at 135 tons only in the first survey. On the other hand relatively high biomass had been recorded in the stratum in the spring in 1989 and 1990, when the overall biomass was low.

In the first survey the abundance in Div. 1C–1D stratum, 401–1 500 m was estimated at 311 969.2 $\times 10^3$ (S.E. 12 525.0 $\times 10^3$), which was a minor increase compared to about 240 000 $\times 10^3$ in 1991. The highest abundance, 150 859 $\times 10^3$, was found in Div. 1C, depth stratum 801–1 000 m. (Fig. 5, Table 7).

In the second survey the abundance in Div. 1C–1D stratum, 401–1 400 m was estimated at 22 256.7 $\times 10^3$ (S.E. 5 557.0 $\times 10^3$), which was a statistically significant drop compared to the first survey (311 969.2 $\times 10^3$ S.E. 125 525.0 $\times 10^3$). The highest abundance was found in the two deepest strata surveyed in Div. 1D (1 001–1 400 m) (Table 7).

In the first survey the lengths ranged between 1 and 19 cm (AFL) and the length distributions in the four depth strata were dominated by modes around 6, 9 and 11 cm similar to what was seen in previous surveys conducted at the same time of the year (Fig. 6).

In the second survey the lengths ranged between 1 and 15 cm (AFL). Clear modes were also seen in the four depth strata but they were now located around 4 and 6 cm (AFL) in the two shallow and the two deep strata, respectively (Fig. 6).

1993

The survey was conducted between 20 August and 8 September and covered Div. 1B to 1D at depths between 435 and 1 418 m. In total 87 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. The biomass of Greenland halibut in Div. 1B–1D stratum, 401–1 500 m, was estimated at 40 759.8 tons (S.E. 7 108.0), which was a marked, but statistically insignificant, decrease compared to 1992 (I) (72 588.6 tons S.E. 15 883.2) (Fig. 3, Table 4). The reduction in biomass was seen in almost all depth strata, but most pronounced in Div. 1C depth stratum 801–1 000 (statistically significant at 95% level). The highest biomass was found in Div. 1D depth stratum 1 001–1 200.

The abundance in Div. 1B–1D stratum, 401–1 500 m was almost halved from 102 325.9 $\times$ 10^3 (S.E. 26 582.1 $\times$ 10^3) in 1992 (I) to 55 712.0 $\times$ 10^3 (S.E. 11 620.0 $\times$ 10^3) in 1993 (statistically insignificant at 95% level) (Table 5, Fig. 3). The distribution of the abundance resembled the distribution of the biomass, i.e. a reduction in almost all depth strata and a significant reduction in abundance in Div. 1C depth stratum 801–1 000 m. The highest abundance was observed in Div. 1B depth stratum 401–600 m as in the previous two years.

In Div. 1B the length distribution was dominated by two very distinct modes around 12 and 18 cm. The length distribution in Div. 1C was dominated by fish between 38 and 58 cm with a mode around 48 cm, while the distribution in Div. 1D mainly consisted of fish between 40 an 60 cm with a mode around 50 cm (Fig. 4).

Roundnose grenadier. Roundnose grenadier was found in Div. 1C–1D only, and the biomass was estimated at 8 029.3 tons (S.E. 1 676.4), which was a marked but statistically insignificant decrease compared to 1992 (I) (43 132.5 tons S.E. 15 192.5) (Fig. 2 and 5, Table 6). The reduction in biomass was seen in almost all depth strata but it was most pronounced in Div. 1C depth stratum 801–1 000 m (statistically significant at 95% level). The highest biomass was found in Div. 1D depth stratum 1 001–1 200 m.

The abundance in Div. 1C–1D stratum, 401–1 500 m was reduced statistically insignificantly, to 40 208.8 $\times$ 10^3 (S.E. 13 820.7 $\times$ 10^3) compared to 311 969.2 $\times$ 10^3 (S.E. 125 525.0 $\times$ 10^3) in 1992 (I). The reduction in abundance was seen in all depth strata. The highest abundance was found in Div. 1D depth stratum 1 001–1 200 m, where it used to be located in Div. 1C depth stratum 801–1 000 m at this time of the year (Table 7, Fig. 5).

The lengths ranged from 2 to 19 cm (AFL) and the length distribution in the four depth strata resembled the distribution in the comparable surveys in having modes at 3.5, 6, 9 and around 11 cm, respectively, although the position of the modes varied slightly between years. Further, minor modes were seen at 6 cm in depth stratum 401–800 m and a mode at 4 cm in depth stratum 1 201–1 500 m (Fig. 6).

1994

The survey was conducted between 2 August and 19 August and covered Div. 1B to 1D at depths between 439 and 1 472 m. In total 80 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. The decrease in biomass seen since 1991 continued in 1994 and the lowest estimated biomass in the time series was observed. The biomass in Div. 1B–1D stratum, 401–1 500 m was estimated at 33 958.5 tons (S.E. 7 537.6), which was significantly (95% level) lower than the 81 746.4 tons (S.E. 15 360.1) estimated in 1991, and somewhat lower than the estimate on 40 759.8 tons (S.E. 7 108) in 1993 (Fig. 3, Table 4). The reduction in biomass was seen in almost all depth strata except Div. 1C depth stratum 801–1 000 and Div. 1D depth strata 1 201–1 400 m and 1 401–1 500 m where small increases were observed. The highest biomass was found in Div. 1D depth stratum 1 001–1 200 m as in the previous three years.

The decrease in abundance seen since 1991 continued in 1994 and the estimated abundance in Div. 1B–1D, 401–1 500 m, 35 853.6 × 10^3 (S.E. 8 742.5 × 10^3) was significantly (95% level) lower than the estimate from 1991 (89 974.8 × 10^3 S.E. 16 608.2 × 10^3) (Table 5, Fig. 3). The estimated abundance in 1992 was 102 325.8 × 10^3 (S.E. 26 582.1 × 10^3) but this figure was not significantly different from the 1994 figure. The 1994 estimate was also markedly lower than the estimate in 1993 (55 712.0 × 10^3 S.E. 11 620.0 × 10^3). The largest decrease in abundance compared to 1993 was seen in Div. 1B depth stratum 401–600 m, where the lowest abundance seen in the time series was observed. In contradiction to the previous years, the highest abundance was found in Div. 1D depth stratum 1 001–1 200 m and not in Div. 1B depth stratum 401–600 m.

In Div. 1B the length distribution was dominated by four modes around 12, 18, 24 and 29 cm of which the two first modes were seen in all surveys. The length distribution in Div. 1C was dominated by fish between 38 and 58 cm with a clear mode around 48 cm, while the distribution in 1D consisted mainly of fish between 40 and 60 cm with a mode around 50 cm (Fig. 4).

The age distribution in Div. 1B was dominated by fish age 1 to 4 corresponding to the four modes in the length distribution. The age distribution in Div. 1C was dominated by fish age 6 and 7, where fish age 6 were more frequent compared to 1988 and 1989. In Div. 1D the age distribution was dominated by fish between 6 and 8 years and as in Div. 1C. The mode in the age distribution had, however, changed a year from age 8 to age 7 compared to the late-1980s (Fig. 7).

Roundnose grenadier. Roundnose grenadier was found in Div. 1C and 1D only. The decrease in biomass seen since 1992 continued in 1994 and the biomass in Div.1C–1D stratum, 401–1 500 m was estimated at 3 144.4 tons (S.E. 909.4), which was the lowest estimated biomass in comparable surveys in the time series, and lower (statistically significant at 95% level) than the estimate on 43 132.5 tons in 1992. Compared to 1993, the reduction in biomass was seen in all depth strata. The highest biomass was found in Div. 1D depth stratum 1 201–1 400 m, where it was found in depth stratum 1 001–1 200 m in 1993 (Fig. 2 and 5, Table 6).

The abundance was estimated to an all time low, 16 682.0 × 10^3 (S.E. 5 985.6 × 10^3), which was lower (statistically significant at 95% level) than the estimate from 1992 (311 969.2 × 10^3 S.E. 125 525.0 × 10^3), and less than half of the estimate in 1993 (40 208.8 × 10^3) (S.E. 13 820.7 × 10^3). The reduction in abundance compared to 1993 was seen in almost all strata but was most pronounced in Div. 1D depth strata 1 001–1 200 m and 1 200–1 400 m. As in 1993, the highest abundance was seen in Div. 1D depth stratum 1 001–1 200 m (Table 7, Fig. 5).

The lengths ranged between 1 and 18 cm (AFL). As in the previous survey at this time of the year the length distribution in the four depth strata were dominated by modes at 4 cm, around 6 cm, 8 cm and, in the deepest stratum, a broad mode ranging from 8 to 12 cm. The position and width of the modes were, however, varying between years (Fig. 6).

1995

The survey was conducted between 12 August and 1 September and covered Div. 1AS to 1D at depths between 422 and 1 463 m. In total 91 successful hauls were made (Fig. 1, Table 1).

Greenland halibut. The decrease in biomass seen since 1991 seemed to have stopped in 1995 and the estimated biomass in Div. 1B–1D stratum, 401–1 500 m had stabilized at 43 408.5 tons (S.E. 9 446.8) compared to 33 958.5 tons (S.E. 7 537.6) in 1994 (Fig. 3, Table 4). The increase in biomass was seen in almost all depth strata except Div. 1C depth strata 401–600 m and 1 001–1 200 m and Div. 1D depth stratum 1 201–1 400 m, where small decreases were observed. The highest biomass was found in Div. 1D depth stratum 1 001–1 200 m as in the previous four years.

The decrease in abundance seen since 1991 also seemed to have stopped in 1995 where the abundance in Div. 1B–1D stratum, 401–1 500 m was estimated at 63 416.3 × 10^3 (S.E. 16 452.3 × 10^3) which was marked, but not significantly higher, than the estimate from 1994 (35 853.6 × 10^3 S.E. 8 742.5 × 10^3). The increase in abundance was seen in all strata, except Div. 1D depth stratum 1 201–1 400 m and with the highest increase in Div. 1B depth stratum 401–600 m, where the highest abundance also was observed. (Table 5, Fig. 3).

The length distribution in Div. 1B was dominated by four modes around 12, 20, 26 and 32 cm of which the two first modes were seen in all surveys. The length distribution in Div. 1C was dominated by fish between 38 and 58 cm with a mode around 48 cm, while the distribution in Div. 1D consisted mainly of fish between 40 and 60 cm with a mode around 50 cm. The length distribution in Div. 1AS consisted of several more or less well defined modes at 23, 30, 37, 44, 50, 54 and 59 cm (Fig. 4).

The age distribution in Div. 1B was dominated by fish age 1 to 4 (Fig. 7) corresponding to the four modes in the length distribution (Fig. 4). The age distribution in Div. 1C was dominated by fish age 7 and the relative importance of age 6 had decreased compared to 1994. In 1988 and 1989 the age distribution was dominated by age 7 and age 8. In 1995 it was still age 7 that was the most dominant but age 6 was now more dominant than age 8. In Div. 1D the age distribution was dominated by fish between 6 and 8 years with a clear mode at age 7 and ages 6 and 8 being equally dominant. The same pattern was seen in the late-1980s, except that it was age 8 that was the most dominant and ages 7 and 9 were also dominantly represented. The age distribution in Div. 1AS was dominated by the ages 3 to 8, probably corresponding to the six modes at 30–59 cm. Hence the annual increase is likely to be around 5 cm with the greatest increase at the younger ages.

Roundnose grenadier. Roundnose grenadier was found in Div. 1C and 1D only. The decrease in biomass seen since 1992 seemed to have stopped and the estimated biomass in Div. 1C–1D stratum, 401–1 500 m increased from 3 144.4 tons (S.E. 909.4) in 1994 to 7 187.2 tons (S.E. 2 445.7) in 1995 (Fig. 2 and 5, Table 6). The increase in biomass was seen in almost all depth strata. The highest biomass was found in Div. 1D depth stratum 1 001–1 200 m as in 1994.

The abundance in 1995 also increased from 16 682.0 $\times 10^3$ (S.E. 5 985.6 $\times 10^3$) in 1994 to 31 745.2 $\times 10^3$ (S.E. 13 016.3 $\times 10^3$). The increase in abundance was seen in almost all strata, but was most pronounced in Div. 1C depth stratum 601–800 m, where the highest abundance was observed as in the beginning of the time series (Table 7, Fig. 5).

The lengths ranged from 2 to 21 cm (AFL) and the length distribution in the two shallow strata were dominated by clear modes at 4.5 and 7 cm, respectively. In depth stratum 1 001–1 200 m were seen three modes at 4, 9 and 11 cm, and in depth stratum 1 201–1 500 m two modes at 4 cm and around 12 cm were seen. (Fig. 6).

Sex ratio

Greenland halibut. Although there were variations between years the trend in the sex distribution was the same through the period. The sex ratio was about 50:50 at depths < about 600 m. The percentage of males gradually increased by depth until about 1 000 m where males made up around 75% in Div. 1C and 1D, somewhat less in the more northerly Divisions (Table 10). At greater depths the number of males declined gradually by depth and the sex ratio was again about 50:50 at depths above 1 400 m. These differences could be due to differences in migration patterns by males and females and by the fact that males are shorter lived than females. Catches at great depth were thus dominated by large (old) fish (Jørgensen, 1997b).

Roundnose grenadier. Although there were variations between years the trend in the sex ratio was the same throughout the period in surveys conducted in the summer time (July–October). (There were too few observations in the spring and autumn surveys to draw any conclusions about the variation in sex ratio by season). The percentage of males gradually decreased by depth from 70.3% at depth stratum 801–1 000 m to about 50% at depths >1 400 m (Table 11). (Note: the figure of 52.1% males at depth stratum 601–800 m was based on 7 fish only). Overall 59.2% of the sexed specimens were males in the summer surveys. When all surveys were compounded, 56.1% of the specimens were males. Atkinson and Power (MS 1987b) also found a dominance of males (64%) in Subarea 1, but without any trends in the distribution by depth.

Distribution of Greenland halibut in relation to bottom temperature

The near bottom temperatures in the survey area ranged between -2.1 and 4.9°C (Table 12). Temperatures were generally low in shallow waters due to the influence of the cold West Greenland Current. In the northern part of the survey area the temperature was highest on the banks in Div. 1B, 2–3°C, and decreased gradually towards deeper water and northward. In Div. 1C and 1D the temperature increased by depth to 401–600 m (3.9°C), and then decreased gradually by depth to about 3.1°C at 1 401–1 500 m. In Div. 1E and 1F the data were scarce but the temperature was indicated to increase by depth to 4.6–4.8°C at 401–600 m. In depth strata <800 m in Div. 1B and 1C and <200 m in Div. 1D–1F the range in the temperature was considerable, probably because the West Greenland Current only covered parts of these depth strata (i.e. a rather steep temperature gradient within the stratum), and because the extension of the current was varying both within years and between years. In Div. 1C at depths >800 m and in Div. 1D at depths >200 m the bottom temperatures seemed to be rather constant around 3–4°C. The largest catches (in kg/km^2) were generally made at temperatures between 3 and 4°C (in Div. 1C and 1D), but a number of relatively good catches were also made at temperatures around 1°C (primarily in Div. 1B but also in 1AS) (Fig. 9.). Good catches in numbers per km^2 were made in the temperature range 1–4°C. High densities of small fish, <20 cm, were primarily found in shallow cool waters in Div. 1B and 1AS and larger fish, 45–55 cm, were primarily found at depths between 800 and 1 200 m in the warmer water in Div. 1C and 1D (Fig. 10).

Pelagic surveys

Roundnose grenadier. In total 59 pelagic hauls were made in the two pelagic surveys (Table 2). In the first survey roundnose grenadier was caught in 4 of the 24 hauls. In the stratum closest to the bottom 2 (0.2 kg) and 6 (0.2 kg) specimens were taken at noon and sunset, respectively. In the stratum 420–550 m from the surface (approximately in the middle of the water column) 2 676 (389.4 kg) and 1 specimen (0.3 kg) were taken at midnight and noon, respectively. The lengths ranged from 2 to 16 cm with a mode around 9 cm (n = 352). The catches of roundnose grenadier at two bottom trawl stations in the pelagic survey area in the preceding bottom trawl survey were rather poor, 4.7 and 53.2 kg per swept km^2, and the length distribution was bimodal with modes around 5 and 14 cm (n = 44) (Fig. 11).

In the second survey roundnose grenadier was caught in 18 of the 35 hauls. The largest catch was 365 specimens (63.9 kg). Roundnose grenadier was taken in all four depth strata, but it was most common in the depth stratum closest to the bottom, where it was taken at all times of the day (Tables 13 and 14). It was also taken at all times of the day in depth stratum 550–800 m with the largest catch at midnight. The catches in the two upper depth strata were all low and without any clear trend in the catch distribution by the time of the day. As the length distributions in all strata at all times of the day were very much alike, the length frequency data have been pooled. The length ranged from 2 to 17 cm with a mode around 9 cm (n = 1 711), which resembled the length distribution at the three bottom trawl stations at the same position as the pelagic stations (n = 934) (Fig. 11). The catches on the bottom at the three stations varied between 788.1 and 2 259.6 kg per swept km^2. The temperature ranges were 2.5–5.2, 3.9–4.5, 3.7–4.5 and 3.2–3.9ºC in the four depth strata, respectively.

Discussion

Bottom trawl surveys

Greenland halibut. Greenland halibut was found all over the area surveyed. The largest biomasses were generally found in Div. 1C at depths between 601 and 1 000 m and in Div. 1D at depths between 801 and 1 200 m, where also the highest abundance was found. High abundances were also found in 0–600 m depths in Div. 1B and 1AS. The population in this area consisted mainly of small fish and the abundance was probably severely underestimated, because a large part of the stock was distributed in the water column (Jørgensen, 1997a). In Div. 1C and 1D Greenland halibut was scarce at depths <200 m. This probably also applies to Div. 1E and 1F, but the number of hauls were few in the area and it was only covered down to about 500 m.

The estimated biomass and abundance fluctuated during the period but with a decreasing trend after 1991 coinciding with the increase in the offshore fishery in Div. 0B and 1C–1D (Fig. 3). The highest biomass and abundance in the time series was observed in 1987, however, as the biomass and abundance at depths >1 000 m was estimated by an ANOVA and as 1987 was the first year in the time series, the estimate is uncertain. On the other hand the observed biomasses and abundances in all strata at depths <1 000 m were either the highest or among the highest ever observed in the time series. Although Greenland halibut seems to be distributed in the same area year after year during the summertime (Jørgensen, 1997b), it can not be excluded that the distribution in 1987 was exceptional.

The biomass and abundance was primarily estimated by the ANOVA in depth stratum 801–1 000 m in Div. 1B, and in depth strata 401–800 m in Div. 1D. These strata are, however, small and the figures estimated by the ANOVA contributed only little to the total estimates (Tables 4 and 5).

The length and age distribution in Div. 1AN (data from 1988 only) was dominated by young fish

TABLE 10. Sex ratio (percent males) of Greenland halibut by NAFO Division and depth. All surveys combined. n = number of fish sexed.

Div.	Depth (m)	Percent males	n
1AN	200–500	51.8	1 056
	501–1000	54.7	2 207
	1001–1500	45.8	83
1AS	0–200	49.3	2
	201–400	44.1	372
	401–600	51.5	398
	601–800	57.0	637
	801–1000	62.4	2 616
	1001–1200	60.9	191
	1201–1400	55.6	670
	1400–1500	46.9	32
1B	0–200	39.9	29
	201–400	47.4	4 610
	401–600	48.0	18 120
	601–800	61.5	4 205
	801–1000	65.0	516
1C	401–600	60.0	1 524
	601–800	67.9	11 977
	801–1000	74.4	18 297
	1001–1200	74.2	4 796
1D	401–600	50.2	758
	601–800	73.9	1 224
	801–1000	77.4	8 269
	1001–1200	74.9	22 865
	1201–1400	70.0	10 186
	1400–1500	53.8	752

TABLE 11. Sex distribution (percent males) of roundnose grenadier in surveys conducted in the period July–October combined. n = number of fish sexed.

Depth (m)	Percent males	n
601–800	52.1	7
801–1000	70.3	275
1001–1200	63.4	2 730
1201–1400	52.7	2 439
1401–1500	51.0	801
Overall	59.2	6 252

(1–3 years of age), mainly from depth stratum 201–500 m. There was, however, only a single haul at depths >1 000 m, thus the number of larger/older fish in the area was probably underestimated (Fig. 4 and 7). In Div. 1AS the length distribution was dominated by fish between 10 and 50 cm, but the distribution varied between years, probably reflecting the distribution of the hauls (Table 4), as small fish were found in shallow water and they were getting larger with increasing depth (Jørgensen, 1997b). The length distribution in Div. 1B was dominated by small fish and usually modes around 11, 19 and 26 cm were seen corresponding to ages 1–3. In all surveys Div. 1C and 1D were dominated by fish between 40 and 60 cm with one clear mode around 48–50 cm. Despite the frequent sampling from research catches through the years, no growth of year-classes could be observed in the size distributions. This could be caused by a migration of larger fish out of the survey area. However, the length distribution in both commercial and trial long line catches showed that larger fish were present in the area, indicating that the larger fish are capable of escaping a bottom trawl towed with 3.5 knots (Jørgensen, 1995; Jørgensen and Bech, MS 1996). In Div. 1C and 1D the age distributions were dominated by fish age 6–9. From the beginning to the end of the time series there has been a shift towards slightly younger fish, but the age reading in the two periods had been done by two different age readers, which may have influenced the estimated age composition.

The southern part of Div. 1AS and especially the northern part of Div. 1B are considered as the most important nursery areas at West Greenland. This is in accordance with Smidt (1969), although he considered the area west of Disko Island (Div. 1AS) to be by far the most important. Smidt (1969) also mentions the area south of Nuuk (64°N) as an important nursery area, but there has been no indication of small fish in greater numbers. The coverage of the area was, however, poor. During the survey in 1988 a high abundance of small fish in Div. 1AN was found. The importance of this area as a nursery area is, however, unknown as only one survey was carried out.

Roundnose grenadier. Roundnose grenadier was distributed from the southern part of Div. 1B and southward, apart from a single occurrence in Div. 1A at 70°44'N. It was usually found at depths >400 m and most common at 1 000–1 200 m, but the depths with greatest abundance varied between years and by year. Roundnose grenadier was not found in Div.

TABLE 12. Mean temperature (°C), range (°C), number of observations and Standard Error (S.E.) by NAFO Division and depth stratum (m). All surveys combined. Div. 1AN: see foot note.

Div./Depth	1AS	1B	1C	1D	1E	1F
1–200	-0.12 -1.3–1.1 14/0.23	1.58 -0.9–4.1 32/0.23	0.7 -2.1–1.5 10/0.34	0.94 0.4–1.6 5/0.19	2.57 1.8–3.2 3/0.41	2.92 2.3–3.7 5/0.29
201–400	1.32 0.1–2.6 32/0.13	2.35 0.3–4.5 52/0.13	3.00 1.6–3.9 6 / 0.42	3.77 3.1–4.5 3/0.41	4.55 4.2–4.9 2/0.35	4.55 4.5–4.6 2/0.05
401–600	2.03 1.6–2.3 10/0.09	2.82 0.9–4.1 58/0.10	3.94 3.3–4.9 34/0.05	3.85 2.7–4.6 8/0.22		4.70 4.6–4.8 2/0.10
601–800	1.80 1.7–1.8 2/0.10	1.43 0.9–3.8 23/0.16	3.38 1.1–4.3 145/0.05	3.67 3.4–4.0 15/0.04		
801–1000	1.07 0.8–1.5 7 / 0.08	1.57 0.9–1.4 3/0.15	3.48 3.2–4.0 85/0.02	3.48 3.0–3.9 49/0.03		
1001–1200	0.73 0.7–0.8 3/0.03		3.36 3.1–3.6 14/0.05	3.26 2.9–3.6 117/0.01		
1201–1400	0.30 0.1–0.4 5/0.05			3.19 2.9–3.9 82/0.02		
1401–1500	0.00 0.0–0.0 1/			3.14 3.0–3.3 13/0.03		

1AN 201–500 m: Mean = 1.59, Range = 1.0–2.2, n = 7, S.E.= 0.19. 501–1 000 m: Mean = 1.67, Range = 1.1–2.0, n = 11, S.E.= 0.09. 1 001–1 500 m: Mean 0.1, Range 0.1–0.1, n = 1, S.E.-.

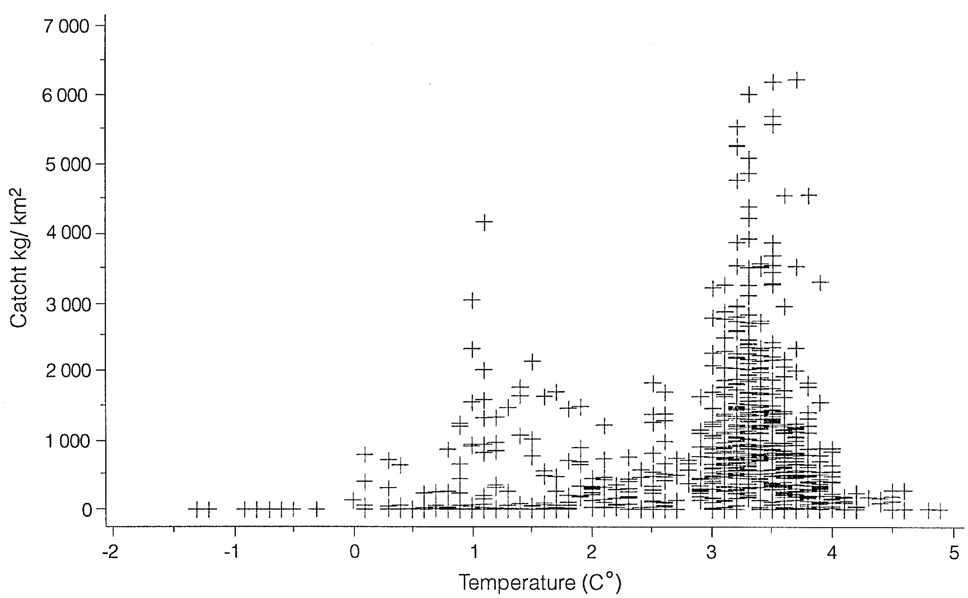

Fig. 9. Relation between catch of Greenland halibut in kg per swept km² and bottom temperature (C). Two outlier catches of 1.8 kg at -2.1 C and 12 700.2 kg at 3.1 C have been excluded.

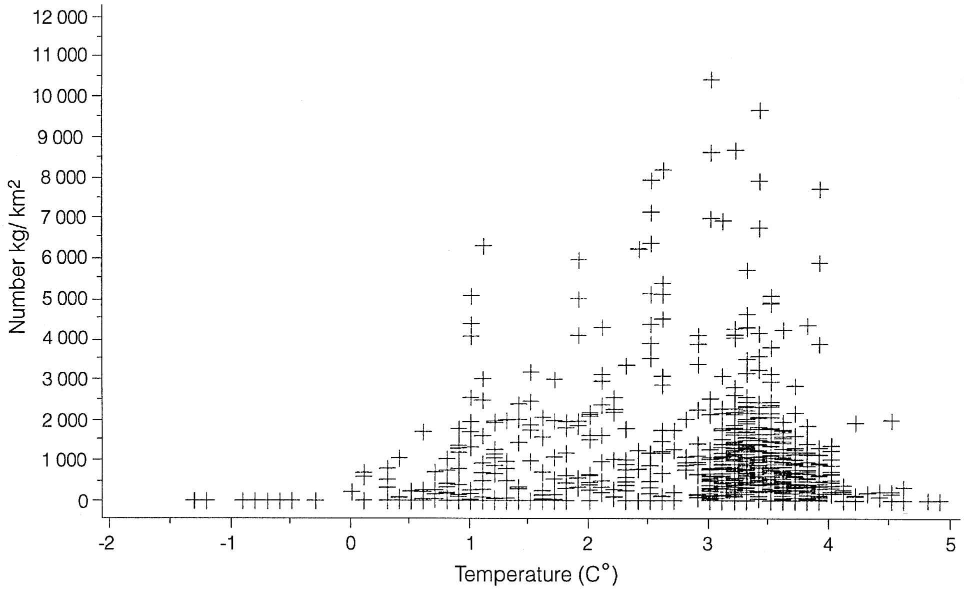

Fig. 10. Relation between catch in numbers of Greenland halibut per swept km² and bottom temperature (°C). Two outlier catches of 13511.4 specimens at 3.2°C and 19 743.7 specimens at 3.0°C have been excluded.

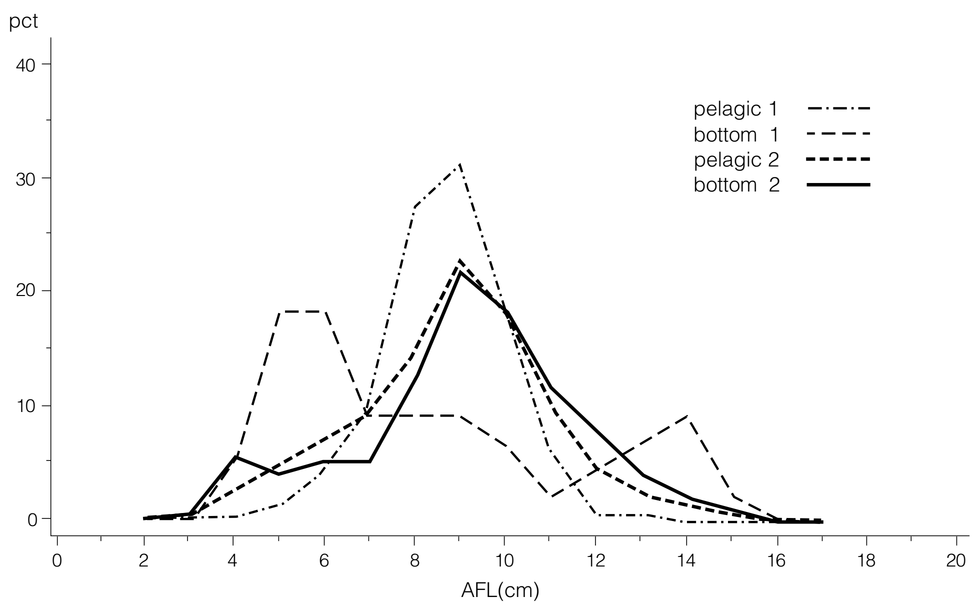

Fig. 11. Length distribution of roundnose grenadier in two pelagic surveys and on bottom trawl stations in the survey areas.

1E and only sporadically in Div. 1F, but this was probably because the coverage of the relevant depths was very poor.

The highest estimated biomass was observed in 1987 (84 000 tons in Div. 1C–1D). The estimate was however based on 23 hauls only, and the biomass at depths >1 000 m (47% of the total) was estimated from an ANOVA, in which 1987 was the first year in the time series. On the other hand, the biomass in the area (including the southern part of Div. 1B) was estimated at about 100 000 tons, by a Canadian survey

TABLE 13. Mean catches of roundnose grenadier (kg/hour), Standard Deviation (STD) and number of hauls (n) distributed by depth stratum and time of day.

Time	Midnight			Sunrise			Noon			Sunset		
Depth (m)	kg/hr	STD	n	kg/hr	STD	n	kg/hr	STD	n	kg/hr	STD	n
50–300	0.3	0.3	3	0	0	2	0.1	0.1	3	0.6		1
301–550	0	0	3	2.9		1	0	0	3	0.2	0.3	2
551–800	20.8	29.4	2	0.8	1.1	2	0.6	1.1	3	0.2		1
801–bottom	38.3	36.3	2	29.4		1	36.2	16.1	3	17.2	10.7	3

TABLE 14. Mean catches of roundnose grenadier (numbers/hour or No./hr), Standard Deviation (STD) and number of hauls (n) distributed by depth stratum and time of day.

Time	Midnight			Sunrise			Noon			Sunset		
Depth (m)	No./hr	STD	n	No./hr	STD	n	No./hr	STD	n	No./hr	STD	n
50–300	30	2.6	3	0	0	2	0.3	0.6	3	1.0		1
301–550	0	0	3	13		1	0	0	3	1	1.4	2
551–800	109	154	2	3	4.2	2	4.7	8.1	3	1		1
801–bottom	2103	220	2	101		1	181	75.4	3	128	85.1	3

in 1986 (Atkinson and Power, MS 1987a). The biomass was almost halved to 44 000 tons between 1987 and 1988, and the biomass remained at this level with some fluctuations until 1992. Since then the biomass decreased to about 8 000 tons in 1995. The reason for this decrease is not known. The bottom temperatures in the area have been stable throughout the period (Table 12). The trawl fishery for Greenland halibut in the area has been increasing during the period. The reported catches of roundnose grenadier have been very low (<300 tons, Anon, 1997). It can, however, not be excluded that the fishery for Greenland halibut has had a negative influence on the roundnose grenadier stock. Most of the roundnose grenadier in the area are small and will probably escape through the 140 mm net used in the Greenland halibut fishery, but roundnose grenadier is rather fragile and might be lethally injured in that process. The area off West Greenland seems to be a feeding area for roundnose grenadier, which to a large extent feeds on pelagic Crustacea (Jørgensen, 1996). Decrease in the primary and secondary production could, on the other hand, have changed the availability of food and hence caused the observed decrease in the abundance of roundnose grenadier.

The estimates of biomass and abundance were encumbered with great uncertainty due to large variations in the catches within the single stratum. This made it hard to make any firm conclusions about variations in biomass and abundance. From the biomass estimates from different times of the year, however, a certain movement pattern could be indicated. The biomass was low and found mainly at deep water, primarily in Div. 1D, in the spring (the survey in 1989 and the first survey in 1990). Roundnose grenadier then gradually moved to shallow water and towards Div. 1C, where it was found during the summer. In the autumn roundnose grenadier moved towards deeper water and left the survey area (the surveys in 1992) (Fig. 2). These movements were probably related to feeding.

In most of the surveys conducted during the summer a clear increase in length by depth is observed, but generally the fish were small with modes at 12–14 cm (AFL) in the deepest stratum. This increase by depth was also observed by Atkinson and Power (MS 1987a).

The age distribution in 1988 was dominated by age 7 which corresponds to an AFL length of 9 cm (Jørgensen, 1996) and indicates a rather slow growth. The age reading was based on scales but this method has never been validated. Savvatimsky *et al.* (1977) found a good agreement between age readings done by means of scales and otoliths, while Atkinson *et al.* (1982) found great discrepancies in the results of the two methods. The best study was made by Bergstad (1990), who found marked discrepancies in the results based on the two methods, when he compared age readings based on scales and otoliths from the same fish. The oldest age read from scales was 20 years, while the oldest age read from otoliths was 50 years. In an analysis of the age structure of roundnose grenadiers in Skagerrak by means of otoliths he found 72 years old fish, and ages of 40–50 years were not unusual. Bergstad (1990) recommended otoliths for age readings because he found it difficult to read scales from small fish and he often overestimated the age of small fish compared to what seemed to be reasonable in relation to the length of the fish. Fish older than 10–13 years were also difficult to read on scales, and there was a tendency to underestimate the age of older fish based on scales compared to the age obtained from otoliths, probably because the growth of the scales ceases when the somatic growth rate is reduced by age.

Pelagic surveys

Roundnose grenadier. The biomass estimate in the first bottom trawl survey in 1990 was low (9 000 tons) and the catches in the following pelagic survey were also low except in a single haul. Due to the low catches, it was not possible to deduce any pattern in the distribution in relation to depth and time of the day. The length distribution on the bottom differed from the distribution in the water column, the pelagic fish generally being larger compared to fish taken on the bottom. The number of fish taken on the bottom were, however, scarce.

In the second bottom trawl survey the biomass had increased to 19 000 tons (Table 6) and the pelagic net used in the first survey was replaced by a larger one in the second survey (Table 2). The higher biomass (abundance) and the larger net in combination was probably the reason for the better catches in the second pelagic survey. Roundnose grenadier was caught all over the water column, but the best catches were made in the near bottom stratum and in the stratum above (Tables 13 and 14). There was a tendency towards better catches during the night, but the number of hauls and the variation in data did not allow any firm conclusions. The length distributions on the bottom and pelagic surveys were very much alike implying that the entire population makes migrations into the water column probably for feeding (Jørgensen, 1996).

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