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MIGRATION AND RECRUITMENT TO THE COMMERCIAL STOCK OF GREENLAND HALIBUT, *REINHARDTIUS HIOPPOGLOSSOIDES* (WALBAUM), IN THE SVALBARD AREA

By[1]

OLAV RUNE GODØ
Institute of Marine Research, Bergen, Norway

and

TORE HAUG
Department of Marine Biology, Tromsø Museum, University of Tromsø, Tromsø, Norway

ABSTRACT

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Results of stratified bottom trawl surveys in the Svalbard area during the period 1983–1985 show that depth distribution of Greenland halibut is size dependent. Higher proportions of large fish are found in deeper strata. The species exhibits geographically heterogeneous length distributions with a relatively high proportion of small fish north of 76°N. This inter-area heterogeneity could be attributed to a southwards migration of larger fish from nursery grounds in the north. Recaptures of fish tagged in the northern area supports this view in that fish not recaptured in the release area had moved south rd. During the period of investigation a general decrease in the abundance of small Greenland halibut was observed in the Svarlbard area. This is interpreted as indicating reduced recruitment success. A possible connection between the decreasing recruitment of Greenland halibut and an increase of yong cod. *Gadhus morhua* (L.), abundance is discussed.

INTRODUCTION

Spawning of the Greenland halibut is thought to occur at depths between 400 and 800 m, and in the eastern Norwegian Sea the spawning areas are probably along the slope of the continental shelf between 66°N and 75°N

[1]) Authorship equal.

(HOGNESTAD 1969, NIZOVTSEV 1969, BREIBY and ELIASSEN 1984). The commercial trawl fisheries for Greenland halibut, which started in 1964, are concentrated in this region (ANON. 1978b). The size and age ranges of the fish caught in the spawning areas are 40–90 cm and 5–15 years (NIZOVTSEV 1969, LAHN-JOHANNESSEN 1972). During the feeding season, large numbers of fish are also found in the more eastern parts of the Barents Sea (MILINSKY 1944).

In the Barents Sea/Svalbard area, younger Greenland halibut, i.e., individuals ranging in size and age from 10–35 cm and 1–5 years, are abundant in coastal areas to the west and north of Spitsbergen. This indicates that these areas may serve as nursery grounds for the species (HOGNESTAD 1961, 1969, HAUG and GULLIKSEN 1982). The first known observations of pelagic 0-group Greenland halibut in the Norwegian Sea/Barents Sea area were reported from the areas west of Spitsbergen (KOEFOED 1907). More recently, large numbers of pelagic Greenland halibut larvae have been found to the west and north of Spitsbergen, and larvae have also been taken between Spitsbergen and Bear Island, and more rarely in the central parts of the Barents Sea (HOGNESTAD 1969, ANON. 1970, 1972, 1973, 1974, 1975, 1976, 1977, 1978a, 1979, 1980, 1981, 1983, 1984a).

It has been suggested that larvae and juvenile Greenland halibut may be carried from southern spawning areas to Spitsbergen coastal waters by the Spitsbergen Atlantic Current (HOGNESTAD 1969, HAUG and GULLIKSEN 1982). If this is correct, older fish would be expected to migrate southwards from the Spitsbergen nursery grounds towards the spawning areas. In the present paper the migration of Greenland halibut in the Svalbard area is examined using

a) trawl indices and length distributions of Greenland halibut caught during stratified bottom trawl surveys along the slope of the continental shelf in the Svalbard area north and south of 76°N, and
b) tagging and recapture of juvenile Greenland halibut in Spitsbergen coastal waters.

MATERIALS AND METHODS

TRAWL INDICES AND LENGTH DISTRIBUTIONS

The fish used to calculate abundance indices and study size distributions were obtained from the yearly stratified bottom trawl surveys in the Svalbard area. The surveys are carried out by the Institute of Marine Research, Bergen. The main objectives of these surveys are to provide data for the management and monitoring of demersal fish stocks in the Svalbard area (RANDA and SMESTAD 1982, 1983, GODØ *et al.* 1984, GODØ 1985, GODØ and NEDREAAS 1986). Our material was obtained from surveys carried out in September–October,

1983, 1984 and 1985. The gear used was a Campelen 1800 mesh shrimp trawl with rubber bobbins, a cod end mesh size of 35 mm, and sweep wires of 80 m. A standard haul consisted of the trawl being towed for three nautical miles at a speed of three knots.

The stratified random trawl survey comprised 22 strata north of 76°N (the northern area) and 23 strata south of this latitude (the southern area) (Fig. 1). Hauls were made at the following depth intervals: 0–100 m, 100–200 m, 200–300 m, 300-400 m and greater than 400 m. The catch data were used to calculate abundance indices which were defined as the stratified mean catch in number per haul:

$$\bar{X}_{st} = (1/A) \sum_{i=1}^{k} a_i \cdot \bar{x}_i$$

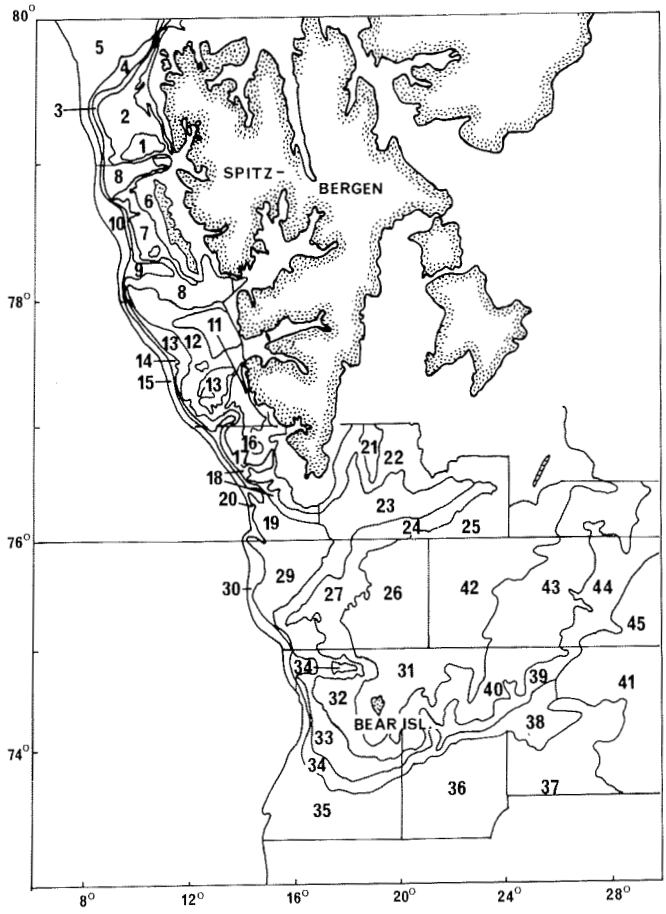

Fig. 1. The area investigated during the stratified trawl surveys with the different strata indicated.

were $\overline{X}_{st}$ = stratified mean catch per haul. A = total area of all strata, a_i = area of stratum i, $\overline{x}_i$ = sample mean catch in stratum i, and k number of strata. The presented values represent swept area indices $I = \overline{X}_{st} \cdot A \cdot 10^{-6} / SA$, where SA is the area swept by the trawl. Since the main objective of the study was to study north-south differences in fish abundance, pooling of data from a number of strata was performed. The southern area is considerable larger (44600 square nautical miles) than the northern area (9700 square nautical miles). Methodology is more fully described by RANDA and SMESTAD (1982, 1983).

For each haul the total number of Greenland halibut was recorded. Total lengths were measured for all, or, in cases of large catches, for random samples consisting of at least 100 fish.

THE TAGGING EXPERIMENT

Tagging of Greenland halibut was carried out during routine research cruises in Spitzbergen coastal waters performed by the University of Tromsø. A total of 2437 juvenile Greenland halibut were tagged during August in 1983, 1984 and 1985 (Table 3). Fish were caught in four areas: Svensksunddjupet at the entrance to Isfjorden, Isfjordrenna and Rekesøyla just outside Isfjorden, and Kongsfjorddjupet, a trough leading into Kongsfjorden (Fig. 2). Hydrographical data were taken in all areas using a CTD-sonde connected to a Nord-10 computer.

Fish were captured at depths between 260 and 370 m, using a shrimp trawl. The standard haul lasted for 60 minutes, and towing speed was 2.5 knots. Two of the 1984 hauls lasted 180 instead of 60 minutes (Table 2). The trawl was raised very slowly to the surface and as soon as the cod end of the trawl arrived on deck all living Greenland halibut were immediately transferred to a large tank with running sea water. Total fish lengths were measured, and a hydrostatic LEA-tag (see DANNEVIG 1953) was sewn on to the dorsal, anterior part of the eye side of the fish. Tagged fish were held in a flowing sea water tank until released. Only exceptionally were fish less than 20 cm tagged, and larger fish showing injury were also excluded from the tagging experiment. When tagged fish were released, dead small fishes from the catches were thrown overboard in an attempt to draw the attention of glaucous gulls, *Laurus hyperboreus*, away from the tagged fish. Despite these measures some attacks on tagged fish were observed.

RESULTS

TRAWL INDICES

North of 76°N the highest trawl indices were obtained at 200–300 m depth during 1983 and 1984, but in 1985 depths greater than 400 m had by far the

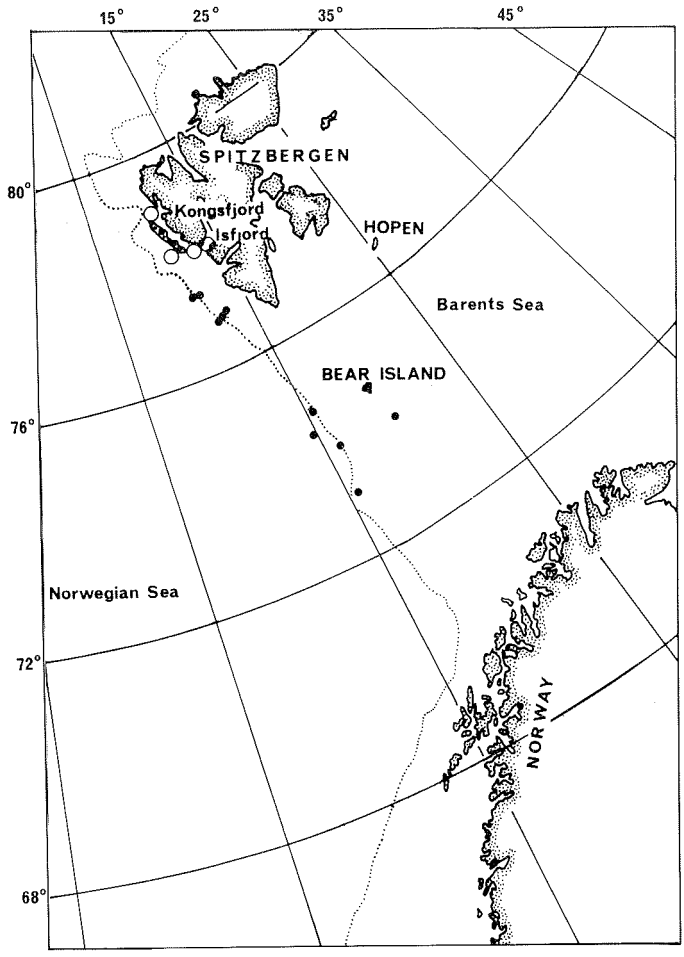

Fig. 2. Results from the Greenland halibut tagging experiments: Open circles indicate the four areas of tagging in Spitzbergen coastal waters, filled circles indicate the long distance migrants where recapture position outside the area of release was given. The dotted line indicates the approximate localization of the edge of the continental shelf as given on a bathymetrical chart by HELLAND-HANSEN and NANSEN (1909).

highest index (Table 1). During the 1983–1985 period there was a general decrease in fish abundance in all depth intervals, except those greater than 400 m where trawl indices clearly had increased.

In the southern area Greenland halibut were always most numerous in the deeper strata, with maximum trawl indices at depths greater than 400 m (Table 1). A general increase in fish abundance was observed in the southern area at 200–300 m depth during the 1983–1985 period.

The total stratified trawl indices (all depths pooled) were higher north of 76°N than south of this latitude in 1983, but a marked increase in fish abundance in the southern area from 1983 to 1984 resulted in higher indices being recorded in the south than in the northern area during the 1984 and 1985 surveys (Table 1).

Table 1. Number of hauls, stratified trawl indices and mean lengths of Greenland halibut in the catches with respect to depth intervals and areas as recorded during the 1983, 1984 and 1985 surveys.

Depth intervals (m)	Number of hauls			Stratified trawl indices			Mean fish length (cm)		
	1983	1984	1985	1983	1984	1985	1983	1984	1985
	North of 76°N								
0 – 100	12	14	13	0.02	0.00	0.00	26.4	–	–
100 – 200	16	17	21	1.91	0.24	0.13	28.2	40.8	38.3
200 – 300	19	16	18	6.48	5.52	2.37	18.1	28.6	35.2
300 – 400	11	12	12	2.25	2.12	0.69	32.2	34.1	41.8
> 400	12	13	13	3.71	4.80	10.74	40.8	43.2	42.2
All depths pooled	70	72	77	14.36	12.68	13.93	27.5	35.3	41.0
	South of 76°N								
0 – 100	14	21	23	0.00	0.00	0.01	–	–	42.5
100 – 200	31	28	38	0.05	0.16	0.05	54.5	44.2	51.4
200 – 300	27	26	23	2.28	4.52	8.73	40.2	40.2	36.5
300 – 400	23	26	23	2.26	8.95	6.46	47.1	38.4	38.9
> 400	22	21	18	7.74	10.33	10.27	54.2	50.7	50.3
All depths pooled	117	122	125	12.33	23.96	25.52	50.3	44.1	42.7

LENGTH DISTRIBUTION

In all surveys there was a general trend for the proportion of larger fish to increase with increasing depth, but the few fish caught between 0–200 m were larger specimens, 40–60 cm in length (Figs 3–5).

During the 1983 survey, the northern samples were characterized by a high proportion of small fish (Fig. 3). Generally, Greenland halibut caught in the southern area were larger than those found in the northern area. Mean fish length (all depths pooled) in the northern area was 27.5 cm and in the southern area 50.3 cm (Table 1). Also, the length distributions of fish in the two areas were highly significantly different (Fig. 3, all depths, $\chi^2_{13} = 14032$, $p<0.005$).

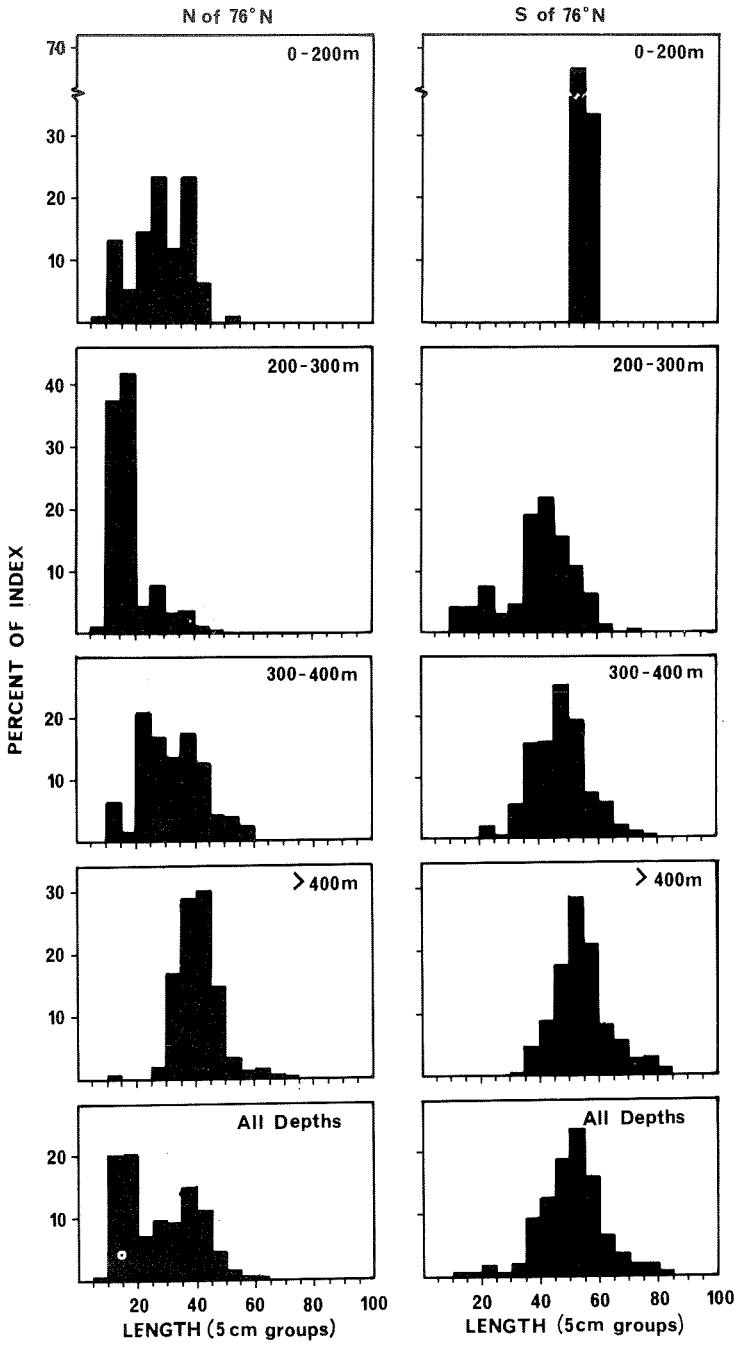

Fig. 3. Length composition of Greenland halibut caught at various depths north (left) and south (right) of 76°N in 1983. Percentages are based on stratified trawl indices per 5 cm length group of fish.

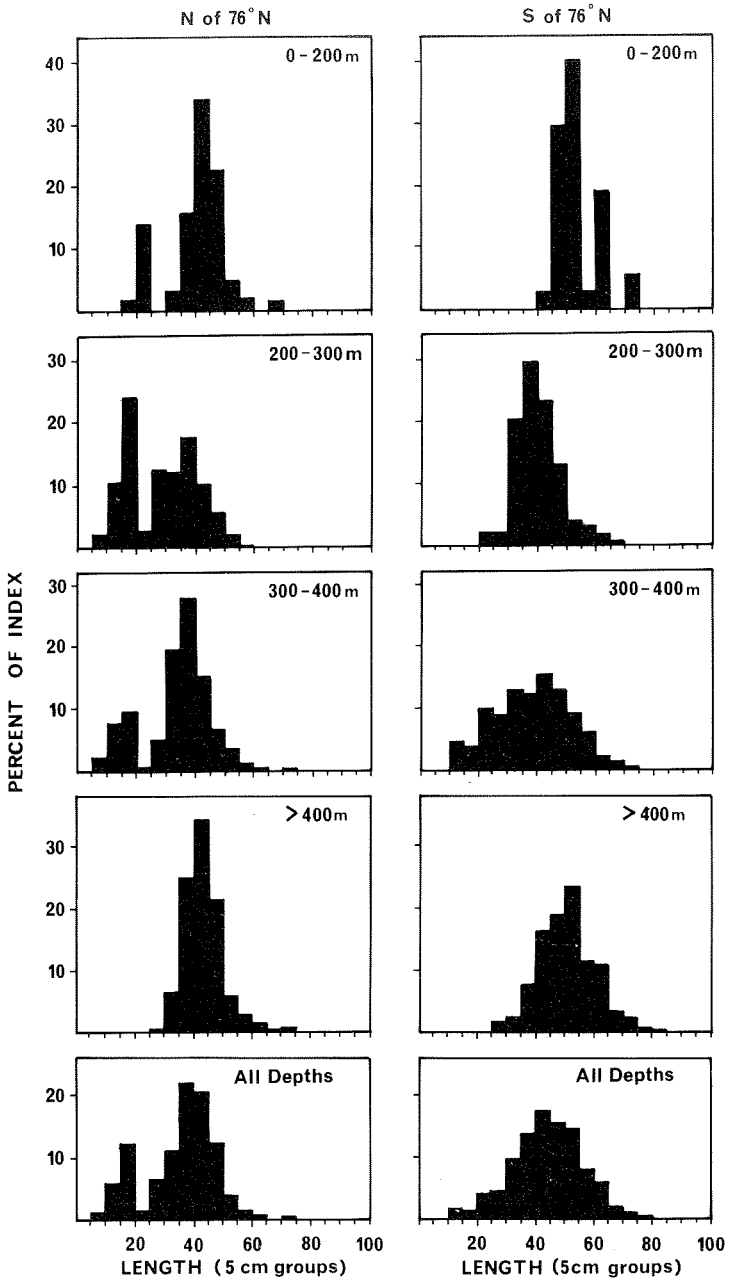

Fig. 4. Length composition of Greenland halibut caught at various depths north (left) and south (right) of 76°N in 1984. Percentages are based on stratified trawl indices per 5 cm length group of fish.

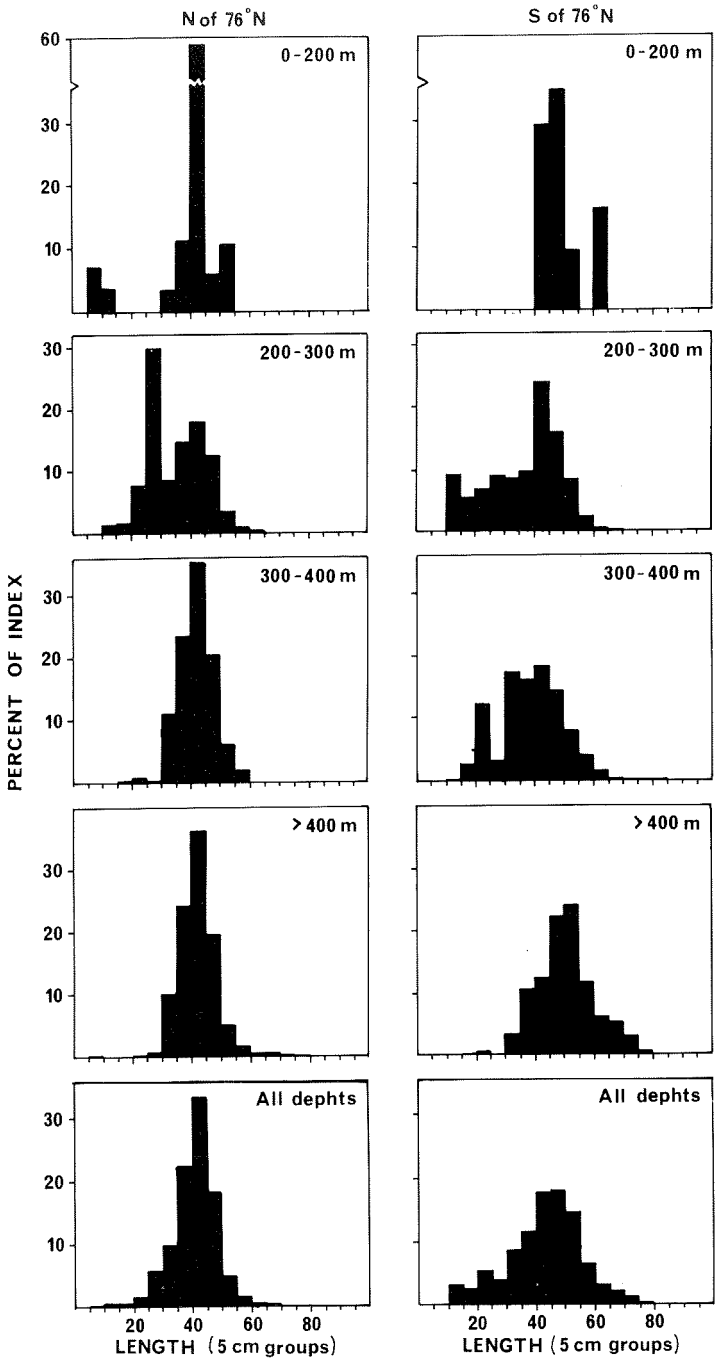

Fig. 5. Length composition of Greenland halibut caught at various depths north (left) and south (right) of 76°N in 1985. Percentages are based on stratified trawl indices per 5 cm length group of fish.

Although the 1984 material taken in the southern area contained more large fish (mean fish length, all depths pooled, 44.1 cm) than the northern area (mean fish length, all depths pooled, 35.3 cm), the difference in size was less than that found in 1983 (Table 1). The length distriubtions of fish caught in the northern and southern areas were significantly different (Fig. 4, all depths, $\chi^2_{13} = 5495$, $p<0.005$).

Results from the 1985 survey show a marked change in length distriubtions in the two areas as compared with 1983 and 1984 (Fig. 5). In the northern area the number of small fish had decreased, whilst in the south the proportions of small fish had increased. Thus, the mean fish lengths (all depths pooled) were now 41.0 cm and 42.7 cm in the northern and southern areas, respectively (Table 1). Despite the small differences in mean lengths observed in 1985, the length distributions of fish caught in the southern and northern area were still stignifianctly different (Fig. 5, all depths, $\chi^2_{14} = 4376$, $p<0.005$).

ABUNDANCE OF SMALL FISH

A general impression gained from inspection of the length distributions is that there was a change in relative abundance of small fish during the three years of study. This impression is strengthened by the results presented in Table 2, which show that there was a marked decrease in the trawl indices (both areas pooled) both for fish less than 25 cm and 20 cm in length. Fish less than 25 cm in length are one or two years old, while most of those less than 20 cm in length can be assumed to one year old (HAUG and GULLIKSEN 1982).

Table 2. Stratified trawl indices of small Greenland halibut (all depths and areas pooled) recorded during the 1983, 1984 and 1985 surveys.

Year	Stratified trawl indices	
	Fish < 20 cm	Fish < 25 cm
1983	5.9	7.1
1984	3.2	4.4
1985	1.6	3.2

TAGGING AND RECAPTURES

Of a total catch of 772 Greenland halibut taken in 11 hauls in 1983, 648 individuals were tagged (Table 3). These tagged fish, which were all captured with bottom temperatures between 0.7 and 2.7°C, ranged in size from 20 to 55 cm (Fig. 6).

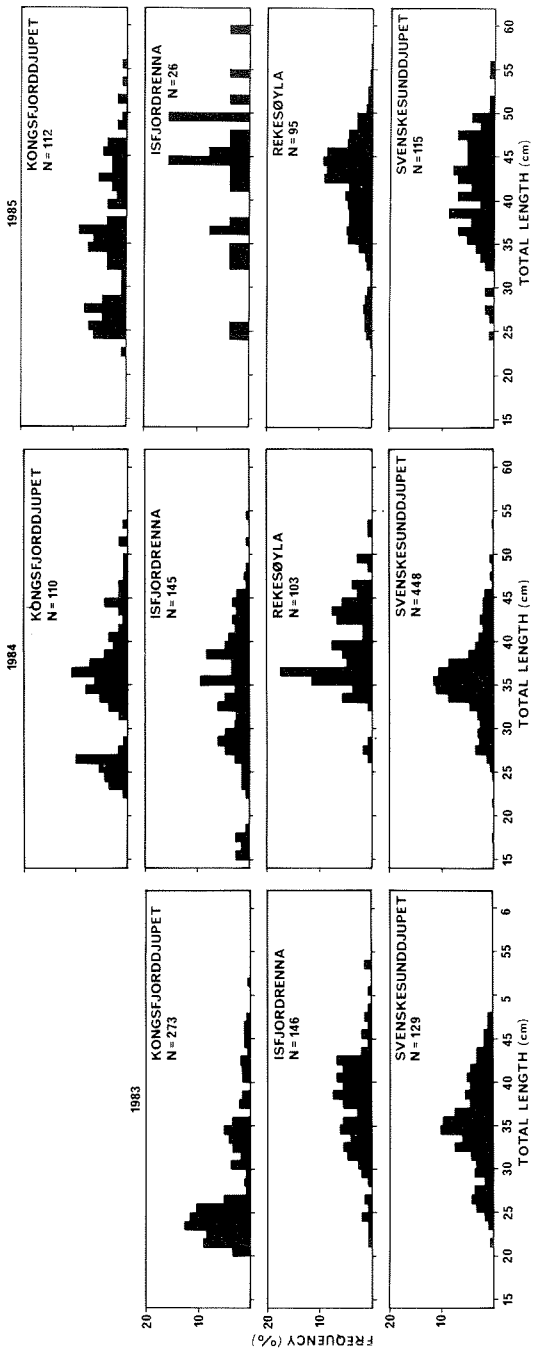

Fig. 6. Length composition of Greenland halibut tagged in Spitzbergen coastal waters during 1983, 1984, and 1985.

Table 3. Trawl hauls from which Greenland halibut were tagged and released in Spitzbergen coastal waters during August in 1983, 1984 and 1985.

Year	Position[1]			Depth (m)	Bottom temp. (°C)	No. of Hauls	No. of fish caught	No. of fish tagged
	N	E						
1983	79°01′	10°57′	(Kongsfjorddjupet)	330		5[2]	357	273
	78°14′	11°00′	(Isfjordrenna)	370	1.7	3	155	146
	78°08′	13°30′	(Svensksunddjupet)	360	2.3	3	260	219
1984	79°01′	10°57′	(Kongsfjorddjupet)	330	2.2	2[3]	260	110
	78°14′	11°00′	(Isfjordrenna)	370	3.2	3	146	145
	78°18′	12°22′	(Rekesøyla)	260	2.7	2	112	103
	78°08′	13°30′	(Svenskunddjupet)	360	2.2	5[3]	598	448
1985	79°01′	10°57′	(Kongsfjorddjupet)	330	0.9	2	155	112
	78°14′	11°00′	(Isfjordrenna)	370	1.5	2	26	26
	78°18′	12°22′	(Rekesøyla)	260	2.0	12	792	745
	78°08′	13°30′	(Svensksunddjupet)	360	0.8	5	115	115

[1] Approximate position of release is given although trawling was performed in various directions around this position.

[2] One of these hauls were performed in Krossfjorden (N79°11′ – E11°49′), 370 m depth, bottom temperature 0.7°C, a side arm of Kongsfjorden; fish were released in Kongsfjorddjupet.

[3] One of these hauls lasted in 3 instead of the usual 1 hour.

From the 12 hauls performed in 1984, 1115 fish were captured (Table 3). Of these, 799 individuals, which ranged in size between 15 and 61 cm (Fig. 6), were tagged. During the 1984 tagging survey, the bottom temperatures ranged between 2.2 and 3.2°C.

The bottom temperatures recorded during the 1985 survey were considerably lower (0.8 – 2.0°C) than those recorded during the previous two years (Table 3). The 21 trawl hauls performed in 1985 yielded 1088 Greenland halibut, of which 998 were tagged (Table 3). These ranged in size between 22 and 61 cm (Fig. 6).

By 26 February 1987, a total of 28 tagged fish had been reported recaptured (Table 4). Five of the recaptured fish were from the 1983 taggings, 19 from the 1984 taggings, and 4 from the fish tagged in 1985.

Eleven of the tagged fish were recaptured close to the area of release by commercial Norwegian shrimp trawlers (Table 4). One individual appears to have moved northwards to the area north of Spitsbergen (c. 80°N), but information given about this recapture may have been inexact. Another tag found north of Spitsbergen was observed among the remains of a ringed seal, *Pusa hispida*, found on the beach in Wijdefjorden. Of the remaining recaptured fish, most were reported by Soviet and East German trawlers. Eight fish were caught in depths ranging beteween 470 and 800 m along the edge of the

Table 4. Details of site of release, recapture and size of the recaptured tagged Greenland halibut.

TAGGING					RECAPTURE						Time since release
Date	Position N	Position E	Depth (m)	Length (cm)	date	Position N	Position E	Depth (m)	Gear	Length (cm)	(days)
Recaptures within the release area											
84.15.08	78°08′	13°30′	360	42	84.21.09	78°14′	10°53′	310	Trawl	43	37
84.18.08	78°18′	12°22′	260	38	84.10.10	78°03′	12°10′		Trawl	37	53
84.15.08	78°08′	13°30′	360	37	84.13.10	78°08′	11°05′	260	Trawl	39	59
84.17.08	78°18′	12°22′	260	49	84.14.10	78°05′	11°45′	245	Trawl	43	58
84.15.08.	78°08′	13°30′	360	38	84.16.10	78°07′	13°30′	320	Trawl	38	62
84.15.08	78°08′	13°30′	360	30	84.25.11	78°10′	13°30′	325	Trawl	32	102
84.15.08	78°08′	13°30′	360	44	84.10.12	78°07′	13°35′		Trawl	44	117
84.15.08	78°08′	13°30′	360	41	85.03.03.	Isfjordrenna		337	Trawl	46	200
85.16.08	78°18′	12°22′	260	40	85.18.08	78°16′	12°19′	260	Trawl	40	2
85.18.08	78°18′	12°22′	260	41	85.22.08	78°12′	12°25′	290	Trawl	41	4
85.15.08	78°08′	13°30′	360	51	85.26.08	Isfjorden		300	Trawl		1
Recaptures outside the release area											
83.16.08	78°08′	13°30′	360	33	83.08.10	76°54′	12°40′	520	Trawl	37	53
83.17.08	79°01′	10°57′	330	47	83.12.11	Barents Sea		600	Trawl	50	87
83.16.08	78°08′	13°30′	360	44	84.17.01	74°43′	15°42′	780	Trawl	44	154
83.16.08	78°08′	13°30′	360	46	84.02.04	73°55′	15°50′	620	Trawl	48	230
83.16.08	78°08′	13°30′	360	43	84.19.05	76°53′	12°43′	520	Trawl	37	277
84.17.08	78°18′	12°22′	260	46	84.??.10	80° (N of Sp.bergen)			Trawl		
84.15.08	78°08′	13°30′	360	36	84.28.11	73°44′	19°46′	305	Trawl		105
84.15.08	78°08′	13°30′	360	32	84.18.12	76°50′	13°00′	620		34	125
84.17.08	78°18′	12°22′	260	36	84.22.12	77°24′	11°13′	580		34	127
84.15.08	78°14′	11°00′	370	43	84.27.12	Barents Sea		800		48	134
84.15.08	78°08′	13°30′	360	46	85.??.??	Soviet recapt. No info. given					
84.15.08	78°14′	11°00′	370	42	85.04.03	Barents Sea			Trawl	50	201
84.17.08	78°18′	12°22′	260	42	85.16.06	74°25′	14°23′	500	Trawl	48	303
84.17.08	78°18′	12°22′	260	45	85.18.07	77°33′	10°58′	600		50	335
84.14.08	78°08′	13°30′	360	36	85.04.08	Soviet recapt. no info. given					354
85.15.08	78°08′	13°30′	360	46	85.20.12	73°04′	16°28′	470	Trawl	42	127
84.18.08	78°18′	12°22′	260	36	86.23.08	78°55′	16°30′	0[1]			743

[1] The tag was found among the remains of a ringed seal, *Pusa hispida*, on the beach in Wijdefjorden, northern Spitzbergen.

continental slope between N77°33′ and N73°04′, and one fish was taken at 305 m depth southeast of Bear Island (Fig. 2). Five further Soviet recaptures were reported of which three fish were taken in the Barents Sea (at least two of them along the slope of the continental shelf), and two were without any information of recapture site.

Generally, fish recaptured in the release area were taken relatively shortly after release wheras those taken at more distant sites had been free for several weeks or months (Table 4). This may reflect a trend of radiation away form the site of release. To date, none of the smallest fish (20 – 30 cm) has been recaptured.

DISCUSSION

Polish investigations on Greenland halibut conducted in the northeast Arctic in 1973 showed that fish from the western slopes of the Bear Island grounds were generally larger than those from the areas west of Spitsbergen (KOSIOR 1975). A similar trend was observed in the results of groundfish surveys conducted in the Svalbard area during 1982–83 (RANDA and SMEDSTAD 1982, 1983, GODØ *et al.* 1984). These authors also found that the proportions of larger Greenland halibut increased with increasing depth. Results of the present study support these earlier findings. The north-south heterogeneity was clearly evident in the 1983 material, but in 1984 and 1985, however, the size differences between the northern and southern areas were less pronounced than in previous years.

The abundance of Greenland halibut in waters shallower than 200 m was low both north and south of 76°N, and samples from these depths were generally dominated by large fish. Greenland halibut is known to undertake vertical movements (CHUMAKOV 1969, SMIDT 1969), and the few large fish taken at shallow depths could have been participating in feeding migrations.

The largest concentrations of Greenland halibut occurred below 200 m depth. Generally, the proportions of larger Greenland halibut increased with increasing depth. The trawl indices varied with depth, but there were differences between the two areas. In 1983 and 1984 the indices increased continuously with depth in the southern area. Since the proportion of large fish in the catches also increased with increasing depth, the 1983 and 1984 catches in the southern area were dominated by large fish (larger than 40 cm). By contrast, in the northern area the maximum fish abundance in 1983 and 1984 was found in the 200–300 m depth interval, and catches were dominated by small fish (less than 40 cm) with a considerable proportion being smaller than 20 cm.

The differences between the northern and southern areas observed in 1983

and 1984 were much less pronounced in 1985. Thus, the 1983 – 1985 changes in trawl indices/size distributions can be interpreted as reflecting an overall decrease in the abundance of small fish and an increase in number of large fish in the north, accompanied by an increase in the number of small fish in the south.

In addition, a general increase in the pooled trawl indices occurred in the southern area from 1983 to 1984/1985. If the results from the 1981 and 1982 surveys (SMEDSTAD and RANDA 1983) are included, the index has increased from 6.49 in 1981 to 25.52 in 1985. The indices in the northern area have remained almost unchanged (12.68 – 14.36) during the same period (see GODØ *et al.* 1984). These changes may be a result of changes in recruitment. A severe reduction in abundance of Greenland halibut occured in the Norwegian -Barents Sea stock due to heavy fishing in the 1970's. This led to increased individual growth rate and reduced age at maturity of the species (KOVTSOVA and NIZOVTSEV 1985). Quotas imposed on the fishery in 1978 (ANON 1978b) have resulted in a steady increase in stock size (ANON. 1985). The increased abundance indices in the southern area may be attributable to increasing stock size. The lack of small fish in the norhern area in 1985 could, however, indicate low recruitment success. The increase in the proportion of small fish in the southern area in 1985 was insufficient to compensate for the recruitment reduction observed in the north. One can only speculate about possible reasons for this recruitment failure. The 0-group indexes for Greenland halibut in 1982, 1983 and 1984 were 17.0, 15.8 and 40.4 respectively (ANON 1984b). Normally, the large 1984-value would be taken to indicate good recruitment. There seems to be no correlation, however, between the 0-group index and the abundance index of fish shorter than 20 cm, i.e., one-year-old fish (see HAUG and GULLIKSEN 1982), the following year. Factors such as the heavy trawling with prawn trawl which now takes place in Spitzbergen coastal areas (ANON. 1986), and/or the increase in the stock of cod which has occurred in the Svalbard area in recent years (GODØ and NEDREAAS 1986), may have resulted in large mortalities of small fish and thereby have contributed to the low indices of young fish. High abundances of respectively Atlantic, *Gadus morhua*, and Pacific, *G. macroephalus*, cod have been shown to coincide with declining recruitment of Greenland halibut in the western North Atlantic (SMIDT 1969) and in the Bering Sea (RICHARD BAKKALA. pers. commn). Further investigation is necessary, however, before firm conclusions can be drawn.

The recent changes in stock structure and the low recruitment success in the 1985 season do not mask the general trend of the northern samples of Greenland halibut exhibiting lenght distributions with many small fish and small proportions of large fish, whilst the southern samples contain relatively low numbers of small fish. One explanation for this could be that the northern

area serves as a nursery ground, and that a migration of larger fish takes place towards the southern areas.

The results from the tagging experiment tend to support this explanation, although few fish have been recaptured. With the exception of one specimen, which had moved northwards to the prawn trawl areas north of Spitzbergen, all fish not recaptured in the area of release had moved southwards. We suggest that this is a reflection of a real southward migration rather than an effect of commercial fishery pressure, since extensive commercial fisheries take place both to the north and to the south of the release area. Some of the fish had migrated south of Bear Island. Only larger fish (30 – 46 cm) were observed to leave the Spitsbergen area. These results are, however, not unequivocal since none of the tagged Greenland halibut released as small fish (20–30 cm) has yet been recaptured.

The presence of some small Greenland halibut in the southern area, especially in 1984 and 1985, and the lack of correspondence in the change in trawl indices in north and south suggest that not all recruits to the southern area come from the north. The occurrence, in some years, of considerable numbers of pelagic 0-groups Greenland halibut south of 76°N in the Bear Island – Hopen area (ANON. 1981, 1983, 1984a) points towards possible recruitment also from these sites. Spawning of Greenland halibut may occur as far south as the Træna bank, 66° – 67°N (BREIBY and ELIASSEN 1984), and as far north as 75°N (HOGNESTAD 1969). Such large north–south extensions of the spawning area opens the possibility of considerable north–south variation in the settlement of larvae, which would be dependent upon factors such as velocity of larvae-carrying currents and whether the bulk of spawning occurred in the northern or southern parts of the spawning area.

Migration of Greenland halibut from the areas southwest of Bear Island, i.e., where the most longdistance migrants from the present tagging experiment were recaptured, were studied by SOROKIN (1967). His recaptures showed that longdistance migrants penetrated far into the Barents Sea in an easterly direction as well as south- and southwestwards towards the areas off the west coast of north Norway. No northward migration, e.g., to the areas to the west of Spitzbergen, was, however, observed.

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REFERENCES

ANON. 1970. Report to the 0-group fish survey in the Barents Sea and adjacent waters in August–September 1969. *Annls biol., Copenh., 26*: 287–300.

ANON. 1972. Preliminary report of joint Soviet-Norwegian 0-group fish survey in the Barents Sea and adjacent waters in August and September 1970. *Annls biol., Copenh., 27*: 216–222

ANON. 1973. Report of the international 0-group fish survey in the Barents Sea and adjacent waters in August–September 1971. *Annls biol., Copenh., 28*: 239–246.

ANON. 1974. Preliminary report of the international 0-group fish survey in the Barents Sea and adjacent waters in August–September 1972. *Annls biol., Copenh., 29*: 205–210.

ANON. 1975. Preliminary report on the international 0-group fish survey in the Barents Sea and adjacent waters in August–September 1973. *Annls biol., Copenh., 30*: 234–240.

ANON. 1976. Preliminary report on the international 0-group fish survey in the Barents Sea and adjacent waters in August–September 1974. *Annls biol., Copenh., 31*: 202–210.

ANON. 1977. Report on the international 0-group fish survey in the Barents Sea and adjacent waters in August-September 1975. *Annls biol., Copenh., 32*: 199–205.

ANON. 1978a. Report on the international 0-group fish survey in the Barents Sea and adjacent waters in August–september 1976. *Annls biol., Copenh., 33*: 213–219.

ANON. 1978b. Ressursoversikt for 1978. *Fisken Hav., 1978* (Særnr. 2): 1–97.

ANON 1979. Report to the international 0-group fish survey in the Barents Sea and adjacent waters in August/September 1977. *Annls biol., Copenh., 34*: 251–257.

ANON. 1980. Report to the international 0-group fish survey in the Barents Sea and adjacent waters in August/September 1978. *Annls biol., Copenh., 35*: 273–280.

ANON. 1981. Report on the international 0-group fish survey in the Barents Sea and adjacent waters in August/September 1979. *Annls biol., Copenh., 36*: 219–226.

ANON. 1983. Preliminary report on the international 0-group fish survey in the Barents Sea and adjacent waters in August/September 1980. *Annls biol. Copenh., 37*: 259–266.

ANON. 1984a. Report of the international 0-group fish survey in the Barents Sea and adjacent waters in August/September 1981. *Annls biol., Copenh., 38*: 228-236.

ANON. 1984b. Preliminary report on the international 0-group fish survey in the Barents Sea and adjacent waters in August-September 1984. *Coun. Meet. int. Coun. Explor. Sea. 1984* (H:36): 1–28.

ANON. 1985. Ressursoversikt for 1985 og tilstanden i havmiljøet for noen år fram til 1985. *Fisken Hav., 1985* (Særnr. 1): 1–84.

ANON. 1986. Ressursoversikt for 1986. *Fisken Hav., 1986* (Særnr. 1): 1–68.

BREIBY, A. and ELIASSEN, J.-E. 1984. Forsøksfiske etter isgalt og blåkveite i 1984. *Inst. Fiskerifag. Univ. Tromsø, Ser. B: Ressursbiol., 1984* (2): 1–25.

CHUMAKOV, A. K. 1969. The Greenland halibut *Reinhardtius hippoglossoides* (Walbaum) in the Iceland area – the halibut fisheries and tagging. *J. Ichthyol., 9*: 909–912.

DANNEVIG, G. 1953. Tagging experiment on cod, Lofoten 1947–1952: Some preliminary results. *J. Cons. int. Explor. Mer. 19*: 195–203.

GODØ, O. R. 1985. Preliminary report of the Norwegian groundfish survey at Bear Island and West-Spitzbergen in the autumn 1984. *Coun. Meet. int. Coun. Explor. Sea, 1985* (G:65): 1–17.

GODØ, O. R. and NEDREAAS, K. 1986. Preliminary report of the Norwegian groundfish survey at Bear Island and West-Spitzbergen in the autumn 1985. *Coun. Meet. int. Coun. Explor. Sea. 1986* (G:81): 1–30.

GODØ, O. R., RANDA, K. and SMEDSTAD, O. M. 1984. Preliminary report of the Norwegian groundfish survey at bear Island and West Spitzbergen in the autumn 1983. *Coun. Meet. int. Coun. Explor. Sea. 1984* (G:46): 1–18.

HAUG, T. and GULLIKSEN, B. 1982. Size, age, occurrence, growth, and food of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum) in coastal waters of western Spitzbergen. *Sarsia' 68*: 293–297.

HELLAND-HANSEN, B. and NANSEN, F. 1909. The Norwegian Sea: Its physical oceanography based upon the Norwegian research 1900–1904. *FiskDir. Skr. Ser. HavUnders., 2*(2): 1–360.

HOGNESTAD, P. T. 1961. Contributions to the fish fauna of Spizbergen, I. The fish fauna of Isfjorden. *Acta Borealia, A. Scientia, 18*: 1–36.

HOGNESTAD, P. T. 1969. Notes on Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in the eastern Norwegian Sea. *FiskDir. Skr. Ser. HavUnders., 15* (3): 139–144.

KOEFOED, E. 1907. Poissons. Memoire. P. 485–500 in D'ORLEANS, L., ed. *Croisier Oceanographique accomplie a bord de la Belgica dans la Mer du Grønland 1905*. Bruxelles.

KOSIOR, A. 1975. Polish investigations on Greenland halibut in the northeast Arctic in 1973. *Annls biol., Copenh., 30*: 172–173.

KOVTSOVA, M. V. and NIZOVTSEV, G. P. 1985. Pecularities of growth and maturation of Greenland halibut in the Norwegian-Barents Sea stock in 1971–84. *Coun. Meet. int. Coun. Explor. Sea. 1985* (G:7/Sess. S): 1–17.

LAHN-JOHANNESSEN, J. 1972. Recent development of the fisheries for Greenland halibut *(Reinhardtius hippoglossoides*, (Walbaum) in northeast Atlantic waters. *Coun. Meet. int. Coun. Explor. Sea, 1972* (F:39): 1–8.

MILINSKY, G. I. 1944. On the biology and fisheries of *Reinhardtius hippoglossoides* (Walbaum) of the Barents Sea. *Trdy. Polyar., nauchno – issled. Inst. morsk. ryb. Khoz. Okeanogr., 8*: 375–387.

NIZOVTSEV, G. 1969. Soviet investigations on Greenland halibut in the Barents Sea, 1964–1967. *Annls. biol., Copenh., 25*: 239– 242.

RANDA, K. and SMEDSTAD, O. M. 1982. The Norwegian groundfish survey at Bear Island and west Spizbergen in the autumn 1981. *Coun. meet. int. Coun. Explor. Sea, 1982* (G:42): 1–17.

RANDA, K. and SMEDSTAD, O. M. 1983. Preliminary report of the Norwegian groundfish survey at Bear Island and West-Spizbergen in the autumn 1982. *Coun. Meet. int. Coun. Explor. Sea, 1983* (G:34): 1–19.

SMIDT, E. L. B. 1969. The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), biology and exploitation in Greenland waters. Meddr Danm. Fisk.- og Havunders., N.S., 6 (4): 79–148.

SOROKIN, V. P. 1967. Some features of biology of Greenland halibut *Reinhardtius hippoglossoides* (Walbaum) in the Barents Sea. *Materialy sessii ucenogo sovita PINRO, 8*: 44–67.

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