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**A PRELIMINARY REPORT ON THE MIGRATION AND RECRUITMENT TO THE
COMMERCIAL STOCK OF GREENLAND HALIBUT, *REINHARDTIUS
HIPPOGLOSSOIDES*, IN THE SVALBARD AREA**

by¹

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ABSTRACT

There are important Greenland halibut, *Reinhardtius hippoglossoides*, nursery areas off the western coast of Spitzbergen. As the fish grow older they are assumed to migrate south- and westwards, and thereby recruit to the main commercial Greenland halibut fishery along the continental slope in the eastern Norwegian Sea. The migration pattern has been studied by the analysis of length distribution and abundance indices of the species in trawl surveys and by tagging of young fish in the nursery areas during the period 1983-84. The stratified trawl indices and the length distributions of fish show that small (< 45 cm) Greenland halibut are far more abundant off the west coast of Spitzbergen than south of 76° N. The length distribution of the northern group of fish is further characterized by the scarcity of large fish (> 50 cm). The recapture of tagged fish can be divided into two groups, a) those recaptured in the same areas in which they were tagged, and b) the long-distance migrants. The latter group were mainly recaptured far south of the tagging area. Both the tagging results and length distributions thus support the hypothesis of a southward migration with increasing age of Greenland halibut in the Svalbard area.

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RÉSUMÉ

D'importantes nourriceries du flétan noir, Reinhardtius hippoglossoides, sont localisées au large de la côte ouest de l'île de Spitzbergen. On suppose qu'avec l'âge ce poisson migre vers sud-ouest et dans la mer de Norvège orientale, le long du talus continental, il devient vulnérable à la plus importante pêcherie du flétan noir. Ce possible modèle de migration a été étudié par l'analyse de distribution de fréquences de longueur et des indices d'abondance, obtenus des données récoltées au cours des campagnes de chalutage, et par les marquages des jeunes dans les nourriceries dans la période 1983-84. Les indices d'abondance, par unité de surface et bathymétrique, et la distribution de fréquences de longueur montrent que les petits flétans noirs (<45 cm) sont beaucoup plus abondants au large de la côte ouest de l'île de Spitzbergen qu'au sud de 76° N. La distribution de fréquences de longueur des poissons du groupe nord est ultérieurement caractérisée par la rareté en poissons de plus grande taille (>50 cm). Les récaptures peuvent être divisées en deux groupes: a) récaptures dans la zone de marquage et b) récaptures loin de la zone de marquage. Dans ce dernier cas, toutes les récaptures se sont vérifiées bien au sud de la zone de marquage. Les résultats obtenus par la méthode des marquages aussi bien que l'analyse de distribution de fréquences de longueur supportent donc l'hypothèse d'une migration vers le sud du flétan noir de la région Svalbard.

INTRODUCTION

Spawning of the Greenland halibut, Reinhardtius hippoglossoides, in the eastern Norwegian Sea is assumed to occur at depths between 400 and 800 m along the slope of the continental shelf between 70° N and 75° N (Hognestad 1969, Nizovtsev 1969). The commercial Greenland halibut trawl fisheries, which started in 1965, occurs in this region (Anon. 1980b). The size and age range of the fish caught in the spawning areas are 40 - 90 cm and 5 - 15 years respectively (Nizovtsev 1969, Lahn-Johannessen 1972). During the feeding season the species is also abundant 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 to 5 years respectively, have been reported to occur in coastal areas west and north of Spitzbergen, where they are quite abundant. 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 made in the areas west of Spitzbergen (Koefoed 1907). More recently, pelagic Greenland halibut larvae have been observed west and north of Spitzbergen, around Bear Island and in the Barents Sea (Hognestad 1969, Anon. 1975, 1979, 1980a).

It has been suggested that larvae and juvenile Greenland halibut may be carried from spawning areas farther south to Spitzbergen coastal waters by The Spitzbergen Atlantic Current (Hognestad 1969, Haug and Gulliksen 1982). If this is correct, the migration route of the recruits from the Spitzbergen nursery grounds would be expected to be southwards 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 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 Spitzbergen coastal waters.

MATERIAL AND METHODS

Trawl indices and length distributions

The material used to study abundance indices and size distributions was obtained from the yearly stratified bottom trawl surveys in the Svalbard area carried out by the Institute of Marine Research, Bergen, Norway. 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 Smedstad 1982, 1983, Godø *et al.* 1984, Godø 1985). Our material was obtained from surveys carried out in September-October, 1983 and 1984. The gear used was a Campelen 1800 mesh shrimp trawl with rubber bobbins, a codend mesh size of 35 mm, and sweepwires of 80 m. During standard hauls the trawl was towed for three nautical miles at a speed of three knots.

The stratified random trawl survey was designed with 22 strata north of 76° N and 23 strata south of this latitude (Fig. 1). The following depth intervals were chosen: 0-100 m, 100-200 m, 200-300 m, 300-400 m and > 400 m. The catch data were used to calculate abundance indices for the various species in the different strata. As a basic index the stratified mean catch in number per haul was used:

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

where \bar{X}_{st} = stratified mean catch per haul, A = total area of all strata, a_i = area of stratum i, \bar{x}_i = sample mean catch in stratum i, and k = number of strata. The values presented represent swept area indices $I = \bar{X}_{st} A 10^{-6} / SA$. SA is the area swept by the trawl. Since the main objective of the work was to study north-south differences in fish abundance, pooling of data from a number of strata was performed. The southern area was considerable larger (44610.0 square nautical miles) than the northern area which was 9699.4 square nautical miles. Methodology is more fully described by Randa and Smedstad (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 containing at least 100 specimens.

The tagging experiment

Tagging was carried out during the yearly research cruises in Spitzbergen coastal waters performed by the University of Tromsø, Norway. A total of 1439 juvenile Greenland halibut were tagged during August in 1983 and 1984 (Table 2) in four areas: Svenskesunddjupet at the entrance to Isfjorden, Isfjordrenna and Rekesøyla just outside Isfjorden, and Kongsfjordddjupet, a trough leading into Kongsfjorden (Fig. 4). Hydrographical data were taken in all areas using a CTD-sonde connected to a Nord-10 computer.

Fish were captured in 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 lengths of fish were measured and then they were tagged with LEA-tags sewn on to the dorsal, anterior part of the eye side of the fish. For each haul, tagged fish were held in a flowing sea water tank until all fish considered capable of survival had been tagged. Only exceptionally were fish less than 20 cm in total length tagged, and larger fish showing injury were also excluded from the tagging experiment. When tagged fish were released, lots of dead small fishes from the catches were poured overboard in an attempt to draw the attention of glaucous gulls, Larus hyperboreus, away from the tagged fish. Some mortality occurred, however, due to predation by these large birds.

RESULTS

Trawl indices and length distributions

In both 1983 and 1984, north of 76° N the highest trawl indices were obtained in 200-300 m depth, while in the southern area Greenland halibut were found deeper with maximum trawl indices being obtained in depths greater than 400 m (Table 1). The total stratified trawl indices (all depths pooled) were higher north of 76° N than south of this latitude in 1983, while the opposite was observed in 1984 (Table 1).

In 1983, the northern samples taken in shallow water were characterized by small (<40 cm) fish (Fig. 2). This was especially evident in the 200-300 m interval where 80% of the fish were smaller than 20 cm. The 1983 length distributions of Greenland halibut caught south of 76° N differed from those found in the northern sample. In the former, larger fish appeared to be taken in all depth intervals (Fig. 2). The few specimens recorded between 0-200 m were generally large (50 - 60 cm), and the general trend below 200 m depth was the same as that seen in the northern area with an increase in the proportions of larger fish with increasing depth. The mean fish length in the material from the northern area (27.5 cm) was lower than the mean fish length in the southern samples (50.3 cm, Table 1). The length distribution differed, with small fish in the north and large fish in the south

(all depths pooled, Fig. 2). These differences were statistically highly significant ($\chi^2_{13} = 14032.22$, $p < 0.005$).

In the material sampled in 1984 (Fig. 3) small (<40 cm) Greenland halibut characterized the catches taken in the 200-400 m depth interval north of 76° N. Most small fish were observed between 200-300 m (36.6% of the sample). Between 0 and 200 m, most fish were larger than 40 cm, as was also true in the deepest (>400 m) strata. As in 1983, the 1984 material taken south of 76° N contained more large fish than the northern samples. In 1984, mean fish length (all depths pooled) was larger in the southern than in the northern area (44.1 vs. 35.3 cm respectively, Table 1). Although this difference is considerably smaller than that observed in 1983, the length distributions of fish caught in the northern and southern areas were significantly different (all depths pooled, Fig. 3, $\chi^2_{13} = 5495.26$, $p < 0.005$).

Tagging and recaptures

In 1983, 648 individuals were tagged (Table 2). These tagged fish, which were all captured in bottom temperatures ranging between $0.7 - 2.7^{\circ}$ C, ranged in size from 20 to 55 cm (Fig. 5). During the 12 hauls performed in 1984, 1115 fish were captured (Table 2). Of these, 799 individuals, which ranged in size between 15 and 61 cm (Fig. 5), were tagged. During the 1984 tagging survey, the bottom temperatures ranged between $2.2 - 3.2^{\circ}$ C.

By June 1, 1985, a total of 14 tagged fish had been reported recaptured (Table 3). Of these, 5 were from the 1983 taggings. Of the fish tagged in 1984, 9 had been recaptured by June 1, 1985.

Seven of the tagged fish were recaptured by commercial Norwegian shrimp trawlers in the same areas at which they were tagged and released (Table 3). One individual seemed to have moved northwards to the area north of Spitzbergen (c. 80° N), although the information given of this recapture was very unprecise. The remaining 6 fish were taken in bottom trawl hauls performed by Russian trawlers in depths ranging between 520 and 780 m along the edge of the continental slope between $N76^{\circ}54'$ and $N73^{\circ}44'$ (Fig. 4).

DISCUSSION

In their reports from the Norwegian stratified groundfish surveys in the Svalbard area in 1981-83, Randa and Smedstad (1982, 1983) and Godø et al. (1984) concluded that the proportions of larger Greenland halibut in the catches increased with increasing depth, and that Greenland halibut were generally larger south of 76°N than north of this latitude. Results of the present more detailed study supports these conclusions.

Samples from the 0-200 m depth interval were dominated by large fish, but abundance of Greenland halibut in waters shallower than 200 m was low. Possibly, the few large individuals recorded here could be a result of feeding migration of fish from the deeper strata. Greenland halibut is known to undertake such vertical movements (Chumakov 1969, Smidt 1969).

The largest concentrations of Greenland halibut occurred below 200 m depth, but trawl indices appeared to differ with depth in the northern and southern areas. The trawl indices increased continuously with depth in the southern area, but reached a maximum in the 200-300 m depth interval in the north. In the southern area both trawl indices and proportions of large fish in the catches increased with increasing depth. The southern area, therefore, was dominated by large fish, and a large proportion of the fish were over 40 cm in length in this area in both 1983 and 1984. By contrast, in the northern area the depth of maximum fish abundance was one containing a large proportion of small fish (< 40 cm). Therefore, the northern area was dominated by small fish under 40 cm in length.

The length distribution data from 1981 and 1982 (Randa and Smedstad 1982, 1983) appears to be in general agreement with our 1983 observations, but in the 1984 material the size differences between the northern and southern areas were much less evident than previously. This was due partly to a reduced dominance of small fish in the 200-400 m depth intervals in the northern area, and partly to an increase in the proportions of small fish in the southern area 300-400 m depth interval in 1984 compared to 1983. Also, there was a general increase in the trawl indices in the southern area from 1983 to 1984. A comparable change in this area was observed also from 1981 to 1982 (Smedstad and Randa 1983) such

that this index has increased from a 1981 level of 6.49 to the 1984 level of 23.96. The indices in the northern area has remained roughly unchanged (12.68 - 14.36) during the same period (see Godø et al. 1984).

The observed changes from 1983 to 1984 did not overshadow, however, the more general trend: The northern samples of Greenland halibut exhibit length distributions with small proportions of large fish and the southern samples contain relatively low numbers of small fish. The most reasonable explanation for this is that the northern area serves as a nursery ground, and that a southward migration of larger fish takes place.

The preliminary results from the tagging experiment support this explanation even though very few fish have been recaptured till now. 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. Some of the fish had migrated to the south of Bear Island. It should be noted that only larger fish (30 - 46 cm) have been observed to leave the Spitzbergen nursery areas. Greenland halibut live to a considerable age, and tagged individuals may be caught in several years to come.

The presence of some small Greenland halibut in the southern area, especially in 1984, 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. Unpublished data (Institute of Marine Research, Bergen, Norway) indicate that juvenile (< 30 cm) Greenland halibut occur in the Bear Island - Hopen area and in the eastern Barents Sea. Thus, recruitment to the southern area from these areas is also possible. Furthermore, spawning of Greenland halibut may occur as far south as the Træna bank (66⁰ - 67⁰ N, Breiby and Eliassen 1984), and it is possible that settlement of larvae may take place in areas south of 76⁰ N.

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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 and 1984 surveys.

Depth intervals (m)	Number <u>of hauls</u>		Stratified <u>trawl indices</u>		Mean fish <u>length (cm)</u>	
	1983	1984	1983	1984	1983	1984
<u>North of 76° N</u>						
0 - 100	12	14	0.02	0.00	26.4	-
100 - 200	16	17	1.91	0.24	28.2	40.8
200 - 300	19	16	6.48	5.52	18.1	28.6
300 - 400	11	12	2.25	2.12	32.2	34.1
> 400	12	13	3.71	4.80	40.8	43.2
All depths pooled	70	72	14.36	12.68	27.5	35.3
<u>South of 76° N</u>						
0 - 100	14	21	0.00	0.00	-	-
100 - 200	31	28	0.05	0.16	54.5	44.2
200 - 300	27	26	2.28	4.52	40.2	40.2
300 - 400	23	26	2.26	8.95	47.1	38.4
> 400	22	21	7.74	10.33	54.2	50.7
All depths pooled	117	122	12.33	23.96	50.3	44.1

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Table 2. Trawl hauls from which Greenland halibut were tagged and released in Spitzbergen coastal waters in 1983 and 1984.

Date	Position ¹		Depth (m)	Bottom temp. (°C)	No. of fish	
	N	E			caught	tagged
08/16/83	78° 08'	13° 30'	(Svenskesunddjupet) 360	2.3	100	80
	78° 08'	13° 30'	(Svenskesunddjupet) 360	2.3	60	55
	78° 08'	13° 30'	(Svenskesunddjupet) 360	2.3	100	84
	78° 14'	11° 00'	(Isfjordrenna) 370	2.7	70	63
	78° 14'	11° 00'	(Isfjordrenna) 370	2.7	10	8
08/17/83	79° 01'	10° 57'	(Kongsfjorddjupet) 330	1.7	90	75
	79° 01'	10° 57'	(Kongsfjorddjupet) 330	1.7	112	68
08/18/83	79° 01'	10° 57'	(Kongsfjorddjupet) ² 330	0.7	25	13
	79° 01'	10° 57'	(Kongsfjorddjupet) 330	1.7	100	92
	79° 01'	10° 57'	(Kongsfjorddjupet) 330	1.7	30	25
08/21/83	78° 14'	11° 00'	(Isfjordrenna) 370	1.7	75	75
08/14/84	78° 08'	13° 30'	(Svenskesunddjupet) 360	2.2	30	29
08/15/84	78° 08'	13° 30'	(Svenskesunddjupet) 360	2.2	58	58
	78° 08'	13° 30'	(Svenskesunddjupet) 360	2.2	135	133
	78° 14'	11° 00'	(Isfjordrenna) 370	3.2	71	71
	78° 14'	11° 00'	(Isfjordrenna) 370	3.2	45	45
	78° 14'	11° 00'	(Isfjordrenna) 370	3.2	30	29
08/16/84	78° 08'	13° 30'	(Svenskesunddjupet) ³ 360	2.2	141	141
08/17/84	78° 08'	13° 30'	(Svenskesunddjupet) ³ 360	2.2	234	86
	78° 18'	12° 22'	(Rekesøyla) 260	2.7	57	57
08/18/84	78° 18'	12° 22'	(Rekesøyla) 260	2.7	55	47
08/19/84	79° 01'	10° 57'	(Kongsfjorddjupet) ³ 330	2.2	53	49
08/20/84	79° 01'	10° 57'	(Kongsfjorddjupet) ³ 330	2.2	207	52

¹ Approximate position of liberation is given although trawling were performed in various directions around this position.

² This haul was performed in Krossfjorden, a side arm of Kongsfjorden (N79° 11' - E11° 49', 370 m depth); liberation of the fish, however, took place in Kongsfjorddjupet.

³ These two hauls lasted in 3 instead of the usual 1 hour.

Table 3. Review of the recaptured tagged Greenland halibut.

TAGGING					RECAPTURE					
Date	Position		Depth (m)	Length (cm)	Date	Position		Depth (m)	Gear	Length (cm)
	N	E				N	E			
08/16/83	78 ⁰ 08'	13 ⁰ 30'	360	33	10/08/83	76 ⁰ 54'	12 ⁰ 40'	520	Trawl	37
08/17/83	79 ⁰ 01'	10 ⁰ 57'	330	47	11/12/83	Barents Sea		600	Trawl	50
08/16/83	78 ⁰ 08'	13 ⁰ 30'	360	44	01/17/84	74 ⁰ 43'	15 ⁰ 42'	780	Trawl	44
08/16/83	78 ⁰ 08'	13 ⁰ 30'	360	46	04/02/84	73 ⁰ 55'	15 ⁰ 50'	620	Trawl	48
08/16/83	78 ⁰ 08'	13 ⁰ 30'	360	43	05/19/84	76 ⁰ 53'	12 ⁰ 43'	520	Trawl	37
08/18/84	78 ⁰ 18'	12 ⁰ 22'	260	38	10/10/84	78 ⁰ 03'	12 ⁰ 10'	250	Trawl	37
08/15/84	78 ⁰ 08'	13 ⁰ 30'	360	37	10/13/84	78 ⁰ 08'	11 ⁰ 05'	260	Trawl	39
08/17/84	78 ⁰ 18'	12 ⁰ 22'	260	49	10/14/84	78 ⁰ 05'	14 ⁰ 45'	245	Trawl	43
08/15/84	78 ⁰ 08'	13 ⁰ 30'	360	38	10/16/84	78 ⁰ 07'	13 ⁰ 30'	320	Trawl	38
08/17/84	78 ⁰ 18'	12 ⁰ 22'	260	46	10/??/84	80 ⁰ (N of Sp.bergen)			Trawl	
08/15/84	78 ⁰ 08'	13 ⁰ 30'	360	30	11/25/84	78 ⁰ 10'	13 ⁰ 30'	325	Trawl	32
08/15/84	78 ⁰ 08'	13 ⁰ 30'	360	36	11/28/84	73 ⁰ 44'	19 ⁰ 46'	305	Trawl	
08/15/84	78 ⁰ 08'	13 ⁰ 30'	360	44	12/10/84	78 ⁰ 07'	13 ⁰ 35'		Trawl	44
08/15/85	78 ⁰ 08'	13 ⁰ 30'	360	41	03/03/85	Isfjordrenna		337	Trawl	46

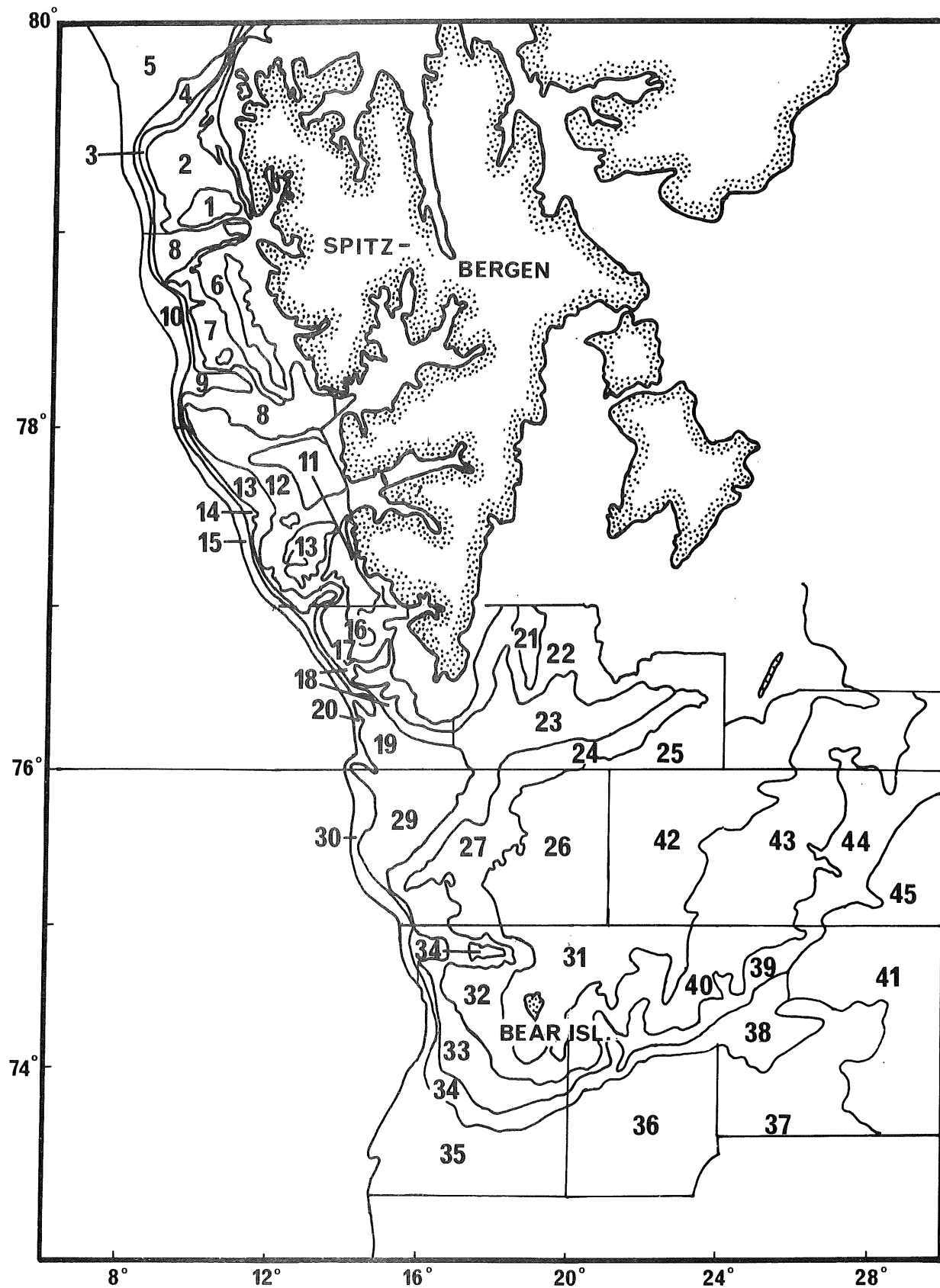


Fig. 1. The area investigated during the stratified trawl surveys with the different strata indicated.

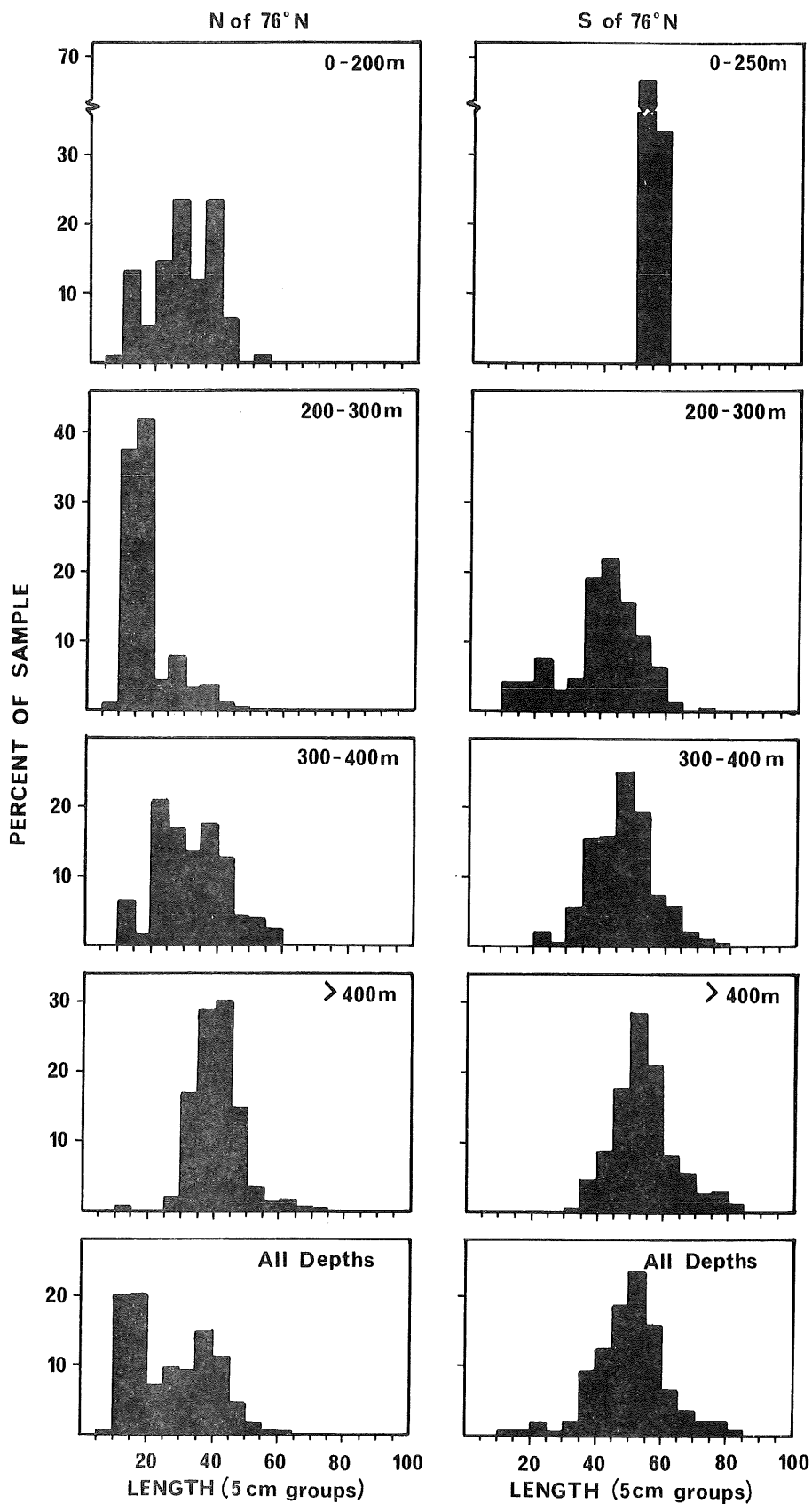


Fig. 2. Length composition of Greenland halibut caught at various depths north (left) and south (right) of 76°N in 1983. Percentages are based on stratified trawl indices per 5 cm length group of fish.

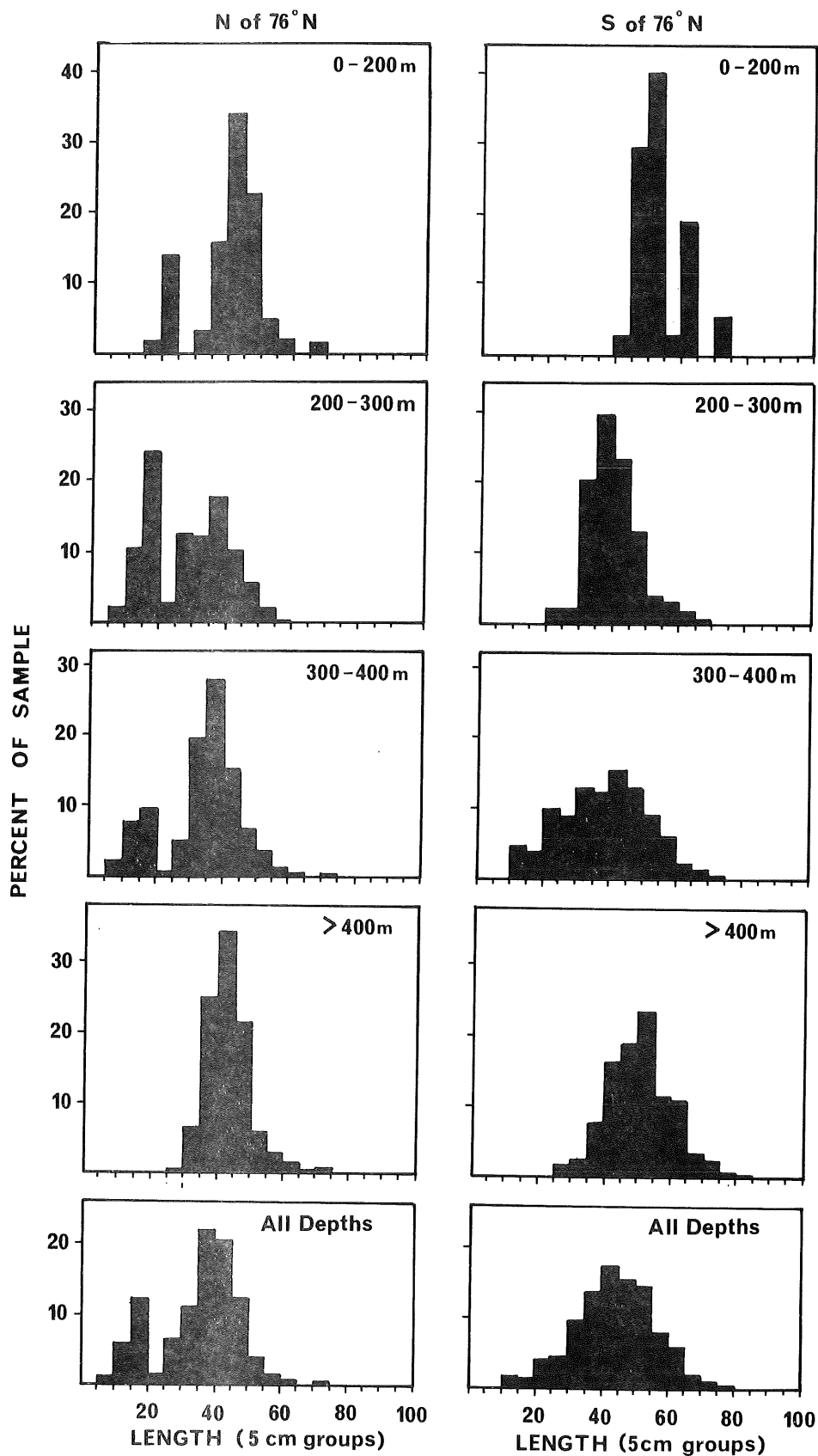


Fig. 3. Length composition of Greenland halibut caught at various depths north (left) and south (right) of 76°N in 1984. Percentages are based on stratified trawl indices per 5 cm length group of fish.

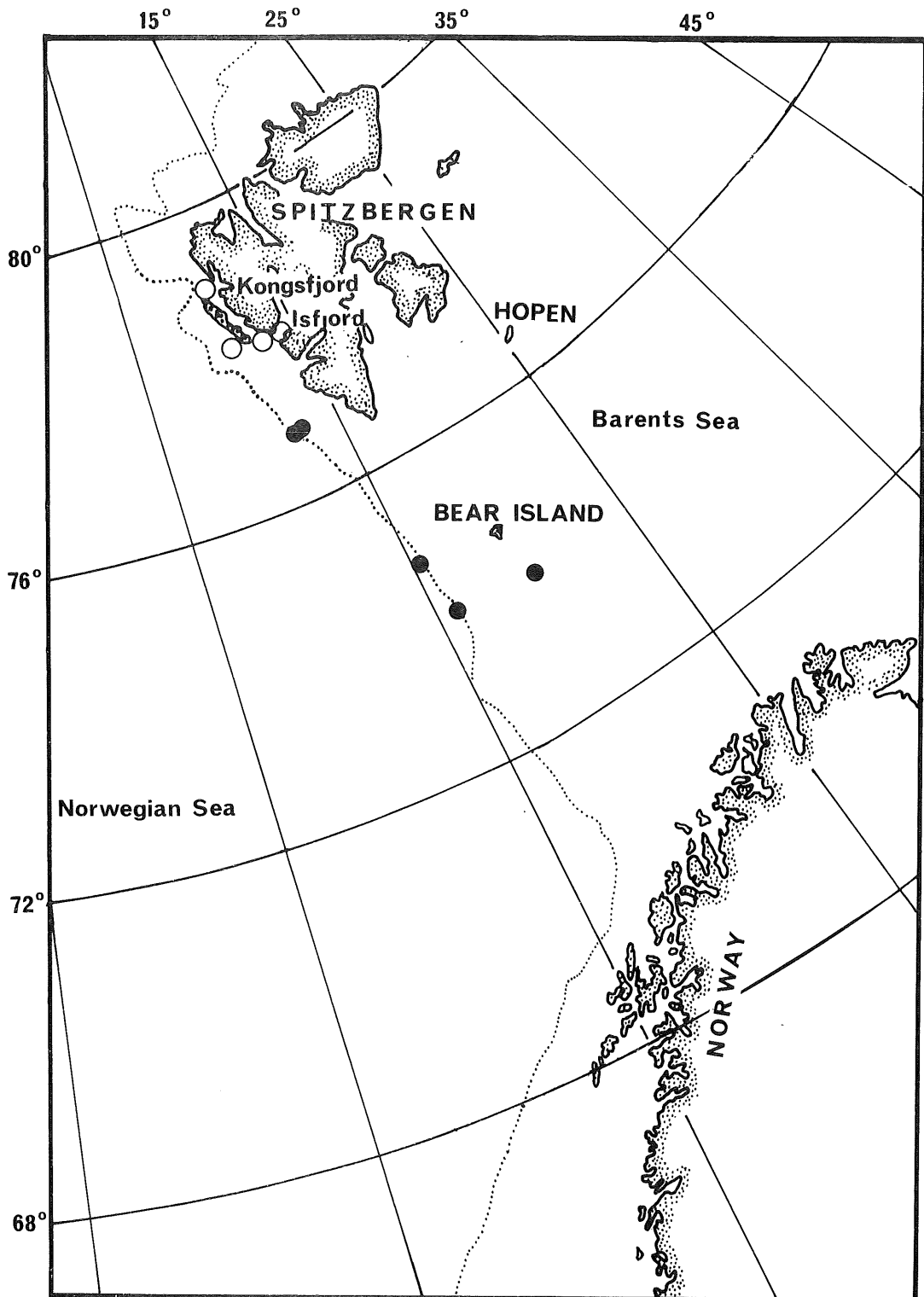


Fig. 4. Results from the Greenland halibut tagging experiments: Open circles indicate the four areas of tagging in Spitzbergen coastal waters, filled circles indicate the long distance migrants which were recaptured outside the area of release. The dotted line indicates 600 m depth at the edge of the continental shelf.

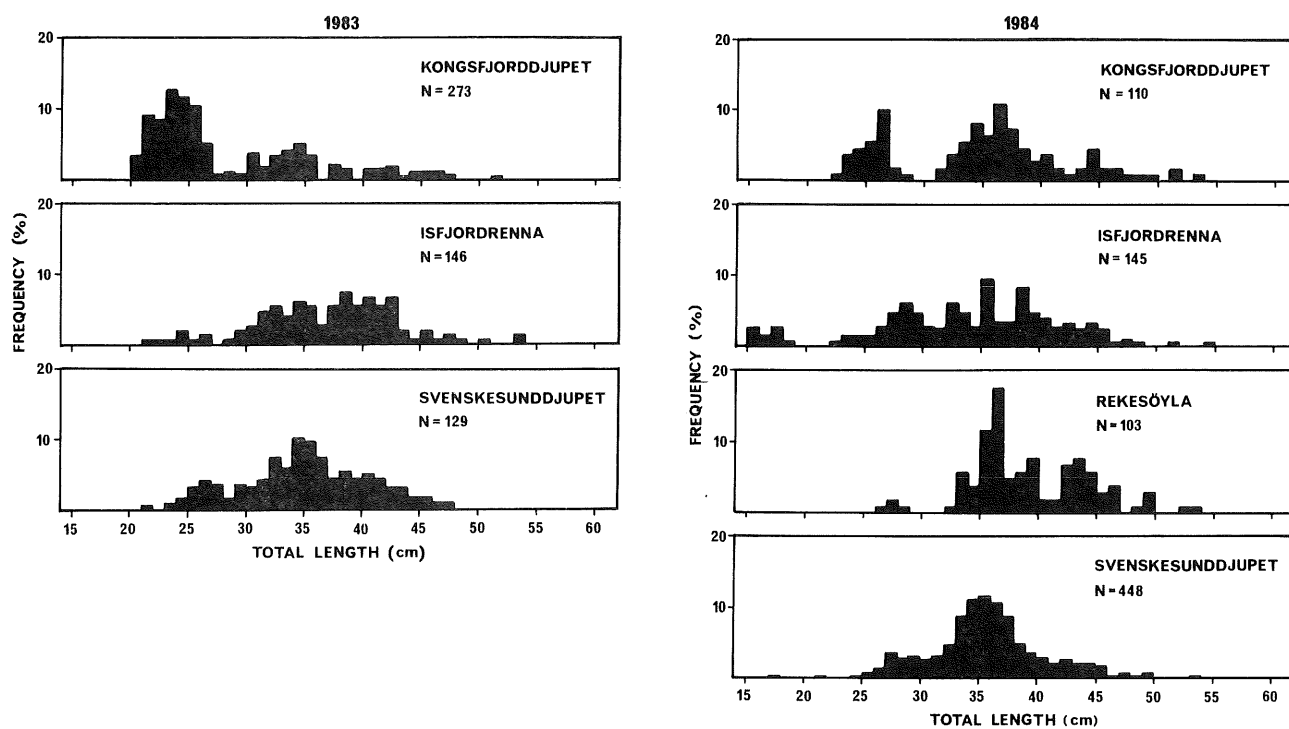


Fig. 5. Length composition of Greenland halibut tagged in Spitzbergen coastal waters during 1983 (left) and 1984 (right).

