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Distribution and Abundance of Young Greenland Halibut (*Reinhardtius hippoglossoides*) in West Greenland Waters

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Abstract

Distribution and abundance of young Greenland halibut (*Reinhardtius hippoglossoides*) at West Greenland are described on the basis of stratified-random bottom-trawl surveys in 1982-84 and research trawling for shrimp during 1968-87. Greenland halibut abundance was low in the offshore areas (south of 67° N) covered by the bottom-trawl surveys and shrimp-trawl operations, but the catch rates tended to increase from south to north. The greatest abundance was found in the offshore north of Store Hellefiske Bank and in Disko Bay (north of 68° N). However, high abundance of young Greenland halibut was found in shrimp-trawl catches in some coastal areas, especially near Holsteinsborg and south of Godthaab, both of which are quite distant from the main areas of distribution in the north. Length distributions by yearly quarter in the Godthaab area indicated the first appearance of 0-group Greenland halibut in the fourth quarter. While young Greenland halibut in the northern areas may originate from the assumed spawning area in Davis Strait, those in the southern coastal waters of West Greenland are postulated to originate from the Iceland-Greenland area, being transported to southern West Greenland by the East Greenland Current.

Introduction

Greenland halibut (*Reinhardtius hippoglossoides* Walb.) are widely distributed along the coast of West Greenland, but the fishery takes place mainly in the fjords and coastal areas of Umanak and Jakobshavn districts (NAFO Division 1A). However, little is known about the distribution and abundance of young Greenland halibut in West Greenland waters. Smidt (1969) reported length frequencies of Greenland halibut from shrimp-trawling in different areas and considered the area west of Disko Island and the coastal area south of Godthaab to be important nursery grounds. Furthermore, he stated that the settlement of post-larvae must occur widely along the West Greenland coast. Jensen (1935) and Smidt (1969) believed that Greenland halibut larvae are transported northward along the coast by the West Greenland Current from the spawning area in deep water between Baffin Island and Greenland south of the Davis Strait Ridge at 67° N. Information on the biology and fishery for Greenland halibut in the Davis Strait region were reviewed by Atkinson *et al.* (1982).

In this paper, the distribution and abundance of young Greenland halibut in West Greenland waters are described on the basis of stratified-random bottom-trawl surveys by the Federal Republic of Germany in 1982-84 and research-vessel shrimp-trawling by the Greenland Fisheries Research Institute in 1968-87.

Materials and Methods

Catch data from stratified-random bottom-trawl surveys off West Greenland in 1982-84 were kindly provided by the Bundesforschungsanstalt für Fischerei, Hamburg, Federal Republic of Germany. The research vessel surveys were especially designed to cover the distribution of Atlantic cod (*Gadus morhua*) on the West Greenland shelf outside the 3-mile (nautical) limit and the continental slope to a depth of 600 m, extending from the southern part of Div. 1B (south of 67° N) southward to Cape Farewell (Div. 1F). The survey area (Fig. 1) was divided into seven main strata, each of which was subdivided into three substrata by 200 m isobaths. The surveys were carried out in late autumn (mid-October to mid-December) with a research bottom-trawl in which the effective mesh size of the codend was 30 mm (stretched). Duration of each tow was 30 min, and towing speed was 4.5 km/hr. Further information on trawl parameters were reported by Cornus *et al.* (MS 1985). Greenland halibut from the 1982 and 1984 surveys were measured as total length to the centimeter below (i.e. 30.0-30.9 = 30 cm), but length measurement data for 1983 are not available at this time.

After logarithmic transformation (base e) of the N+1 values (where N = number per hour trawling), a three-way analysis of variance was used, where all

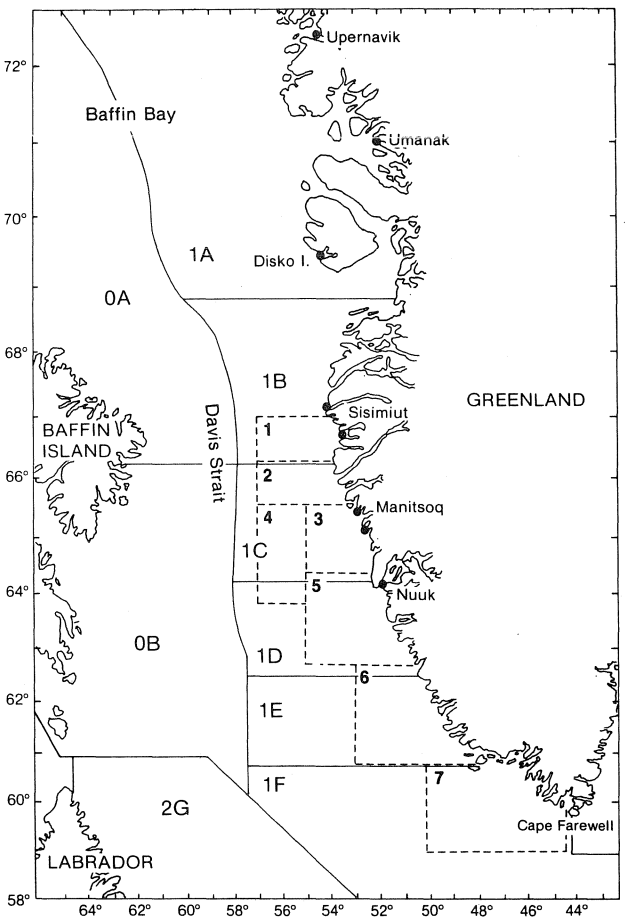

Fig. 1. West Greenland and Davis Strait region, showing the NAFO divisions and the area (strata 1-7) covered by the stratified-random trawl surveys.

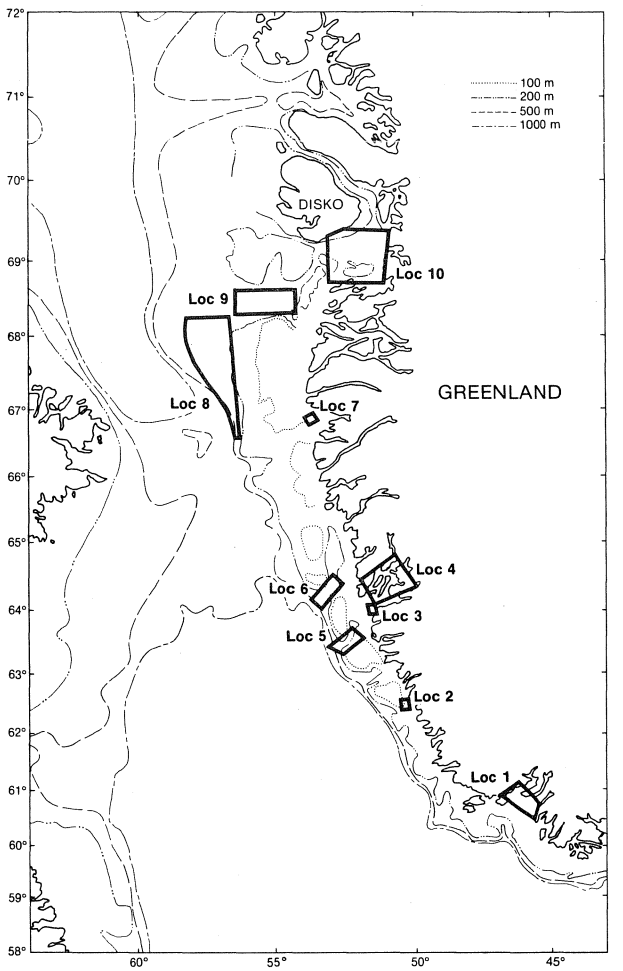

Fig. 2. West Greenland region, showing the localities (Loc. 1-10) where research trawling for shrimp was carried out. (1. Julianehaab; 2. Frederikshaab; 3. South of Godthaab; 4. Godthaab; 5. Godthaab Deep; 6. Sukkertop Deep; 7. Holsteinsborg; 8. West of Store Hellefiske Bank; 9. North of Store Hellefiske Bank; 10. Disko Bay.)

effects (year, stratum and depth) were regarded as deterministic in the modal:

$$Y_{ijkl} = Y + A_i + B_j + C_k + E_{l(ijk)}$$

where $Y_{ijkl} = ln\ (N+1)$, Y = overall logarithmic mean, A_i = year i effect, B_j = stratum j effect, C_k = depth k effect, and $E_{l(ijk)}$ = error.

Catch data from 716 research-trawl hauls for shrimp (*Pandalus borealis*) by the Greenland Fisheries Research Institute during 1968-87 were analyzed. Detailed analysis of the catch data was not possible due to insufficient standardization (for changes in trawl design, crew, etc., during the period), but some general distributional trends can be deduced. Ten localities have been defined from the areas that were covered by the research-trawl hauls for shrimp (Fig. 2). At most localities in the southern part of the region (2, 3, 4, 5, 6, 7), there were hauls in all months of the year. At the northern localities, ice conditions allowed trawling only from about April-May to August-September. Codend mesh sizes of the shrimp trawls were 18-21 mm (stretched). Again, Greenland halibut were measured as total length to the centimeter below.

Results

Bottom trawl surveys

Greenland halibut from the surveys in 1982 and 1984 ranged in length from 7 to 104 cm (Fig. 3). Dominant modal groups were centered at 24 and 34 cm, and, according to the work of Smidt (1969), these modes represent age-groups 2 and 3 respectively. Although very few were caught, age 1 fish are probably centered at 14-15 cm. Since the major part (83%) of the survey catch consisted of fish less than 40 cm in length, the results from these surveys reflect mainly the distribution and abundance of aged 2 and 3 fish.

There was great variation in catch rate (number per hour trawling) among strata, depth intervals and years (Table 1). In each of the 3 years, the greatest numbers

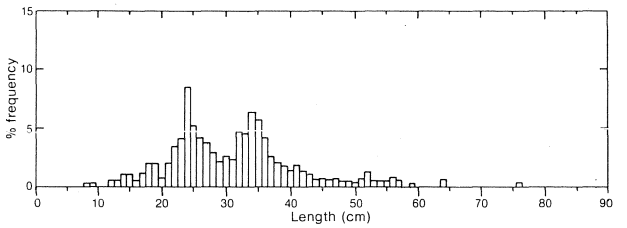

Fig. 3. Length distribution of Greenland halibut from bottom-trawl surveys off West Greenland, 1982 and 1984.

of Greenland halibut were found in the most northerly part of the survey area (stratum 1) at 200–400 m.

Analysis of variance of the trawl-survey catches by numbers (after logarithmic transformation) showed highly significant effects ($P<0.01$) of strata and depths but no significant effects ($P>0.05$) of years (Table 2). The model explained 36% of the total variation. A Newman-Keul's range test (Hicks, 1982) on mean *ln* (N+1) values indicated a significantly higher ($P<0.05$) value for statum 1 than for stratum 2, which in turn was significantly higher than values for the remaining strata. Furthermore, the values for strata 3 and 4 were significantly higher than those for strata 6 and 7. These results indicate a general decrease in catch rate from north to south. For the variation in catch rate with depth, the range test showed that values for 200–400 m were significantly higher than those for the 0–200 and 400–600 m intervals.

TABLE 1. Mean number of Greenland halibut per hour trawling (number of hauls in parentheses) by stratum and depth range from bottom-trawl surveys off West Greenland, 1982–84. (See Fig. 1 for survey coverage.)

Stratum No.	Depth (m)	Area (nm^2)	Mean number per hour trawling 1982		1983		1984	
1	0–200	2,121	19.8	(8)	12.3	(6)	11.2	(5)
	200–400	506	47.5	(4)	440.0	(1)	589.0	(2)
	400–600	364	12.0	(1)	—		25.0	(2)
2	0–200	2,167	20.4	(5)	1.1	(7)	7.1	(9)
	200–400	313	1.0	(2)	4.0	(2)	15.0	(2)
	400–600	415	—		10.0	(1)	6.0	(2)
3	0–200	2,500	0.4	(11)	7.9	(20)	3.3	(12)
	200–400	988	1.5	(4)	59.3	(9)	17.1	(7)
	400–600	234	0.0	(3)	0.7	(3)	6.0	(5)
4	0–200	17	—		—		4.0	(1)
	200–400	74	0.0	(1)	20.0	(1)	1.0	(2)
	400–600	178	—		—		5.2	(5)
5	0–200	2,350	0.4	(17)	0.0	(25)	0.1	(26)
	200–400	1,018	8.1	(7)	9.8	(13)	18.4	(10)
	400–600	259	1.0	(2)	—		2.0	(2)
6	0–200	1,938	0.0	(10)	0.0	(19)	0.0	(19)
	400–600	742	1.3	(6)	0.0	(7)	0.5	(7)
	400–600	57	—		—		0.0	(1)
7	0–200	2,568	0.3	(16)	0.0	(19)	0.0	(23)
	200–400	971	2.0	(4)	0.2	(10)	0.5	(8)
	400–600	353	—		—		3.0	(2)
	Totals	20,133	(101)		(143)		(152)	

Research trawling for shrimp

Results from research-trawling for shrimp at various localities along the West Greenland coast during 1968–87 by the Greenland Fisheries Research Institute are summarized in Table 3. There was great variation in mean catch (number per haul) of Greenland halibut, with the highest value (604/hr) in Disko Bay (Loc. 10) and the lowest value (25/hr) on the western part of Store Hellefiske Bank (Loc. 8). Also, the frequency distribution of the catch-per-unit-effort (CPUE) ranges varied greatly among localities.

The length distributions of Greenland halibut from the various localities are illustrated in Fig. 4. Those for Nuuk (Loc. 4) are shown separately for depths less than 400 m and greater than 400 m. Greenland halibut ranged in length from 7 to 100 cm but were mainly less than 60 cm, except for some larger fish in Loc. 4, 5 and 6. In some of the length distributions, two or three modal groups (representing the youngest age-groups) can be recognized. Age 1 and older Greenland halibut were assumed to have been caught in a representative way by the small-meshed shrimp trawl.

In the southern part of the region (south of 65° N), mean catches exceeded 100 fish/hr in inshore waters (Loc. 1, 3 and 4), with a high value of 501/hr at Loc. 3 (Table 3). In these areas, there were few hauls with very low numbers of Greenland halibut. The length distribu-

TABLE 2. Results of analysis of variance of Greenland halibut catches (after *ln* transformation) from bottom-trawl surveys off West Greenland, 1982–84 (see text for model.)

Effect	Sum of squares	Degrees of freedom	Mean square	F value	r^2
Model	206.4	10	20.6	21.6	0.36
Year	4.6	2	2.3	2.5	
Stratum	143.1	6	23.9	25.0[a]	
Depth	58.7	2	29.4	30.8[a]	
Error	367.9	386	1.0		

[a] Highly significant with $P<0.01$.

TABLE 3. Summary of Greenland catches (number per hr) from research shrimp-trawling at various localities (see Fig. 2) in West Greenland waters, 1968–87.

Loc. No.	Depth (m)	No. of hauls	Mean catch	% of hauls by catch range 0–10	11–100	101–300	>300
1	250–450	12	149	17	25	50	8
2	205–243	76	29	50	42	8	—
3	203–275	41	501	2	27	37	34
4A	110–390	52	145	27	29	31	14
4B	400–620	29	94	3	66	28	3
5	199–505	124	38	30	63	7	—
6	50–550	80	26	39	58	3	1
7	320–358	7	522	—	29	29	43
8	93–550	79	25	51	42	8	—
9	178–521	103	202	7	46	29	18
10	190–550	113	604	3	9	42	47

tions are characterized by a dominance of small fish (ages 1 and 2), except in the deeper water (400–620 m) in Godthaab Fjord where larger fish prevailed (Fig. 4). In coastal Loc. 2, although the mean catch was quite low (29/fish/hr), there was a dominance of small fish. In the offshore areas (Loc. 5 and 6), there were few hauls with high catches, the means being 38 and 26 fish/hr respectively (Table 3). The fish were spread over a wide

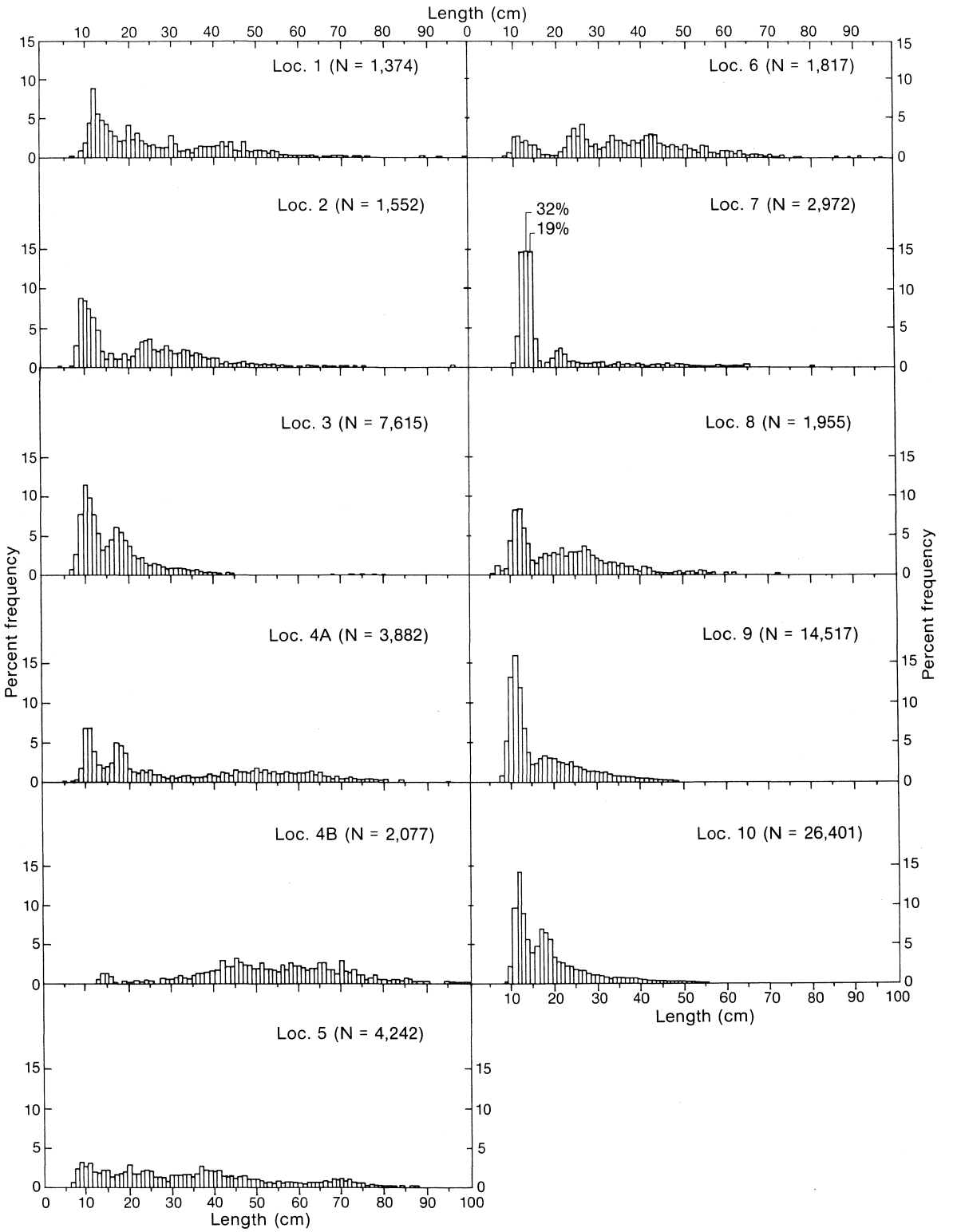

Fig. 4. Length distributions of Greenland halibut from shrimp-trawling at various localities along the West Greenland coast, based on combined data for 1968–87. (N = number of fish sampled.)

range of length, with no dominance of young year-classes (Fig. 4).

In the northern part of the region (north of 66° N), mean catches of Greenland halibut in the two inshore areas (Loc. 7 and 10) exceeded 500 fish/hr. Of 113 hauls in Disko Bay (Loc. 10), catches in about 90% of them exceeded 100 fish/hr (Table 3). The length distributions from both localities were dominated by 1-year-old fish (Fig. 4). In the offshore areas, catches were usually very small (mean 22 fish/hr) on the western slope of Store Hellefiske Bank (Loc. 8) but were much larger (mean 202/hr) north of the bank (Loc. 9) where seveal hauls yielded high catches (Table 3). Young (age 1) fish were prevalent in both areas, but there were relatively more larger fish in Loc. 8 than in Loc. 9 (Fig. 4).

In Godthaab Fjord (Loc. 4), the mean catch from hauls in shallower depths (<400 m) was somewhat higher than the mean from hauls in deeper water (>400 m) (Table 3). Furthermore, the overall range of catches from shallow depths was greater than the range of catches from deeper water. Although the ranges of the length distributions were quite large in both cases, small fish (ages 1 and 2) were prevalent in depths less than 400 m (Loc. 4A) but were poorly represented at greater depths (Loc. 4B) (Fig. 4).

Length distributions of Greenland halibut from Loc. 3 and 4 by quarter of year reflect seasonal variation in size (Fig. 5). In the first quarter (Fig. 5A), pronounced modes occur at 10 and 18 cm, representing age-groups 1 and 2. These two modal groups can be followed in subsequent quarters, with the modes at 15 and 26 cm in the fourth quarter (Fig. 5D). In this quarter, a new modal group centered at 9 cm (representing the 0-group) can be recognized. Analysis of the monthly length frequencies for the fourth quarter (not illustrated) indicated that 0-group fish did not appear in the catches until December.

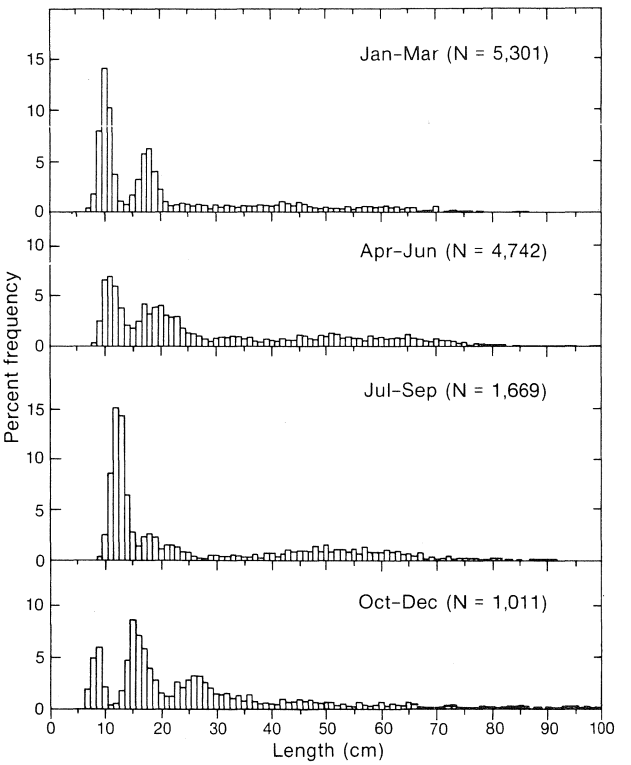

Fig. 5. Length distributions of Greenland halibut by quarter of year from shrimp-trawling in the Godthaab area (Loc. 3 and 4), based on combined data for 1968-87. (N = number of fish sampled.)

Discussion

According to Smidt (1969), the smallest bottom-stage Greenland halibut is about 7 cm long. Since the mesh size of the codend in the bottom-trawls that were used for the stratified-random surveys was 30 mm (stretched), it is not surprising that very few of the youngest Greenland halibut (age-group 0, and age-group 1 to some extent) were caught (Fig. 3). In research trawling for shrimp, however, the codend mesh size was smaller (18-21 mm), and only the smallest 0-group Greenland halibut would have escaped through the meshes.

Young Greenland halibut seem to prefer living in depths down to about 400 m, which is evident from the bottom-trawl survey data and the research trawling in the Godthaab area. This is in accordance with a statement by Smidt (1969) that the young stages settle in depths of 200-300 m and gradually migrate to deeper areas as they grow.

From research trawling for shrimp in the Godthaab area, 0-group Greenland halibut were first evident in the catches in December. During shrimp-trawling in 1953-63, Smidt (1969) found 0-group Greenland halibut to be relatively numerous in September-October, but he gave no measure of the mesh size in the codend used for these trawling operations. Therefore, it is possible that the difference in time of occurrence of 0-group fish may be due to the use of codends in the two studies with different mesh sizes.

In southern West Greenland (south of 67 °N), the abundance of Greenland halibut seems to be low outside 3 naut. miles from the coast, as indicated by data from the bottom-trawl surveys, although there is a clear tendency of increasing abundance towards the north. These results are confirmed by the low shrimp-trawl catches of Greenland halibut in this offshore area (Loc. 5 and 6) as well as by low catches in a few bottom-trawl hauls (not shown) on the offshore banks. Furthermore, length distributions of Greenland halibut in shrimp-trawl catches did not show pronounced dominance of

young (age 1) fish in this area.

In contrast to the low abundance of Greenland halibut on the offshore grounds of southwestern Greenland, research trawling in coastal areas indicated high abundance (>500 fish/hr) at Hosteinsborg (Loc. 7) and south of Gothaab (Loc. 3), and moderate abundance (>100 fish/hr) at Julianehaab (Loc. 1) and in Godthaab Fjord (Loc. 4). Young Greenland halibut (age 1) were particularly abundant at these localities. Also, Smidt (1969) found this age-group to be very numerous in these areas, especially in the area just south of Godthaab. The coastal areas at Holsteinsborg and south of Godthaab are both located near fjord systems where important commercial fisheries for Greenland halibut occur or have occurred. Other areas probably exist along southwestern Greenland where young Greenland halibut are very numerous and from which recruitment to different fjord stocks takes place.

Young Greenland halibut were found to be highly abundant in Disko Bay and in the offshore area north of Store Hellefiske Bank. Smidt (1969) found high density of age 1 Greenland halibut at localities west of Disko Island (not covered by this study) and regarded the area as a very important nursery ground. Farther north in the offshore area west of Umanak (71° N), Danish research vessel *Dana* found larger numbers of young Greenland halibut in shrimp-trawl catches in July 1971. Likewise, great numbers of young fish are caught in the recently-developed shrimp fishery between 71° N and 73° N.

The distribution and abundance of young Greenland halibut from this study, together with the results of Smidt (1969), indicate that the main areas of distribution of young Greenland halibut are from about 68° N northward, but the northern limit of distribution is unknown. This main area of distribution fits Jensen's (1935) assumption of a spawning area for Greenland halibut in Davis Strait south of 67° N and Smidt's (1969) results about the distribution of pelagic larvae with densest occurrence between 62° 30′N and 66° 15′N.

The relatively high abundance of young Greenland halibut in some coastal areas of southwestern Greenland cannot, however, be explained by passive transport of larvae by currents from the Davis Strait spawning area, because water masses from that area are not believed to be transported to the southernmost coastal areas of West Greenland (E. Buch, Greenland Fish. Res. Inst., pers. comm.). It is the authors' view that young Greenland halibut in the southernmost coast areas do not originate from the same spawning grounds as those in the northern part of West Greenland. It is noteworthy that pelagic 0-group Greenland halibut are well-represented in pelagic fish surveys carried out annually in Denmark Strait (Vilhjalmsson and Magnússon, MS 1981). Therefore, the possibility exists that young Greenland halibut are transported by the East Greenland Current from Denmark Strait to the southernmost areas of West Greenland.

Further investigation must focus on the possibilities (a) that young Greenland halibut, which occur numerously in some coastal areas of southwestern Greenland, are isolated from the main area of distribution in the north, and (b) that there is an influx of young Greenland halibut from East Greenland waters. In the latter case, the importance of such an influx of young fish should be studied.

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