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Fishery and Some Biological Aspects of Greenland Halibut (*Reinhardtius hippoglossoides*) in West Greenland Waters

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Abstract

A review of available information is presented of recent investigations on the fishery and biology of Greenland halibut (*Reinhardtius hippoglossoides*) in West Greenland waters. Biological aspects are discussed mainly in relation to the recruitment to West Greenland area and the connection between the stocks in the West Greenland fjords and the stock complex in the Davis Strait.

Larval drift is discussed relating the distribution of pelagic larvae and young demersal stages to the ocean current patterns in the area. Although the main drift pattern seems to be from the assumed spawning area in the Davis Strait to the West Greenland area, it also seems likely that larvae drift from the East Greenland/Iceland area to the southern part of West Greenland.

Length frequencies at different places in the West Greenland area seem to indicate that as they grow they migrate deeper, both to the fjords and the continental slope in the Davis Strait. Recaptures from tagging experiments in the inshore area have all been near the tagging site, except for two examples of long distance migrations. A spawning migration from the fjords to the Davis Strait area have not been confirmed by tagging experiments. The recapture rates are shown to be independent of the length of fish. The sex ratios in the fjords at West Greenland show the proportion of females as generally being the higher and that it is very similar to observed sex ratio on the continental slope of the Davis Strait. Observations on maturity show that a small proportion of the females and a larger proportion of the males in the West Greenland fjords are found in maturity stages just before or at spawning, suggesting that spawning, to some extent, takes place in the fjords. It is therefore proposed that Greenland halibut in the West Greenland fjords are mainly stationary and do not participate in the spawning in the deeper areas of the Davis Strait south of 67°N.

Introduction

Greenland halibut (*Reinhardtius hippoglossides* Walb.) is widely distributed in the Northwest Atlantic. Spawning is believed to take place in the deeper waters south of the submarine ridge between Greenland and Baffin Island at about 67°N (Jensen, 1935; Smidt, 1969). The larvae are dispersed by ocean currents both to the west coast of Greenland and to eastern Canada (Templeman, 1973). In the eastern Canada area the larvae colonize the continental banks and slopes. As they approach sexual maturity, they are believed to move into deeper water and migrate northward to the spawning area in Davis Strait (Atkinson *et al.*, 1982). In the West Greenland area the larvae seek the bottom in the autumn, after which the young fish migrate into deeper water of the fjords (Smidt, 1969). In this area they are also assumed to migrate to the Davis Strait when they reach maturity, and according to Smidt (1969) they probably migrate back to the West Greenland fjords after spawning.

Several studies deal with stock identification in the Northwest Atlantic. Templeman (1970) and Misra and Bowering (1984) have analyzed meristic characters, Fairbairn (1981) has investigated frequencies of electrophoretic protein loci, and Khan *et al.* (1982) deal with blood protozoa used as biological tags. They all suggest that Greenland halibut form a single interbreeding stock throughout the area. However, there is evidence that the Gulf of St. Lawrence and Fortune Bay support separate stocks (Bowering, MS 1982). It is necessary to note, that all samples from the West Greenland area, which have been included in some of these studies, are from the offshore areas and therefore do not include the adults from the West Greenland fjords.

The fishery has been expanding at West Greenland in recent years, increasing from about 2,600 tons in 1964 to about 9,000 tons in 1987 with some fluctuations over the period. Catches in NAFO Div. 1A make up the largest part of the fishery, about 88% of the 1987 total catch of Greenland. In Div. 1B-1F annual catches have

varied between about 1,500 and 2,500 tons since 1964 and in each of these Divisions, catches have varied considerably. The fishery takes place in the inshore area, and is mainly carried out with longlines and gillnets, of which the former has been the traditional form of fishery. The fishery is normally conducted year-round and very often takes place in restricted areas in the innermost parts of fjords, typically at depths of 400–800 m.

Since the description by Smidt (1969), little work has been done on Greenland halibut in West Greenland waters. However, in recent years there has been a growing interest on the resource and investigations on the exploitation and biology of this species have been initiated. This paper gives a summary of the present knowledge of the biology of Greenland halibut in West Greenland waters (Fig. 1) and focuses on the recruitment to the West Greenland area in relation to the distribution of pelagic larvae and demersal young and the ocean current patterns in the area. The connection between the West Greenland inshore populations and the stock complex in the Davis Strait is discussed on the basis of length distributions, tagging experiments, sex ratio and maturity observations.

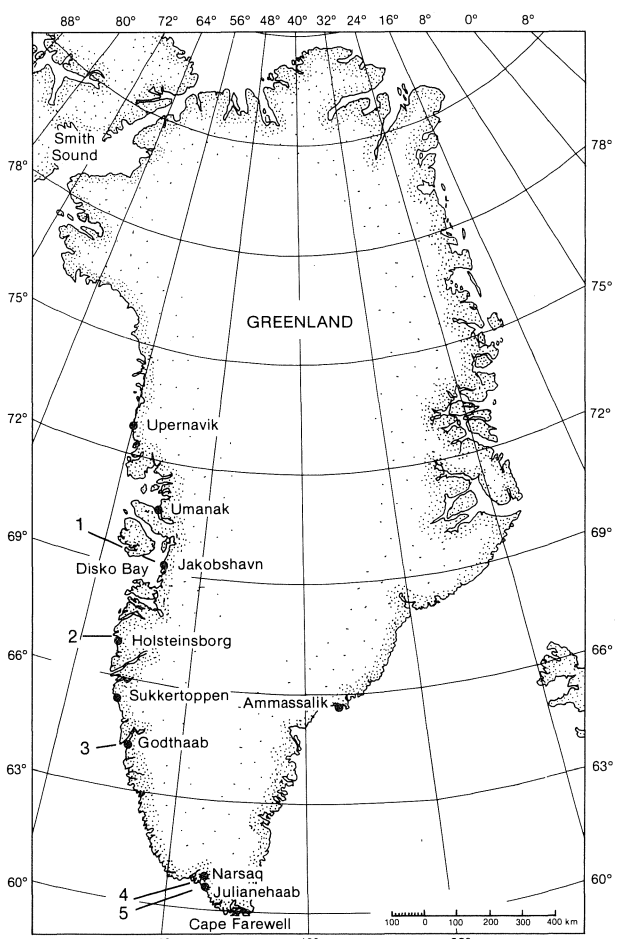

Fig. 1. Map showing localities mentioned in the text; inshore tagging locations are marked from 1 to 5.

Recruitment to the West Greenland area

The spawning area is considered to be south of the submarine ridge between Greenland and Baffin Island at about 67°N (Jensen, 1935). Spawning occurs in spring in the deep warm waters south of the ridge where tempeatures are between 3° and 4°C at about 1,000 m depth. The eggs and tiny larvae are bathypelagic but later the larvae rise towards the surface and live pelagically (Jensen, 1935). The larvae are believed to disperse in the Northwest Atlantic, northward to the West Greenland area by the West Greenland Current and southward along the Baffin, Labrador and Newfoundland east coast by the Labrador Current (Templeman, 1973). In Icelandic waters the spawning grounds are found at the continental slope off the west coast of Iceland at depths of about 1,000 m (Sigurdsson, 1979). The larvae are assumed to drift with the currents westward, to the East Greenland shelf and also northeastward to the Icelandic north coast (Sigurdsson and Magnusson, MS 1980).

Distribution of pelagic larvae

Jensen (1935) and Smidt (1969) described the distribution of pelagic larvae in the Greenland area and summarized the results from several expeditions (Fig. 2), of which NORWESTLANT in 1963 is the most important. In the West Greenland area, the densest occurrence is between 62°39'N and 66°15'N. In the East Greenland–Iceland area and off the southernmost part of West Greenland, the number of larvae caught was very low. However, it should be noted that pelagic larvae were caught in southwestern Greenland area in the *Godthaab* expedition in 1928 (Jensen, 1935).

Quantitative comparisons between the West Greenland and East Greenland areas are difficult because the average length of larvae in the samples in the NORWESTLANT Survey was much greater in the East Greenland–Iceland area (48 mm) than in the West Greenland area (27 mm) (in the same year and month), indicating different spawning times in the two areas. This implies that the reduction in numbers due to natural mortality may be greater in the East Greenland–Iceland area compared to the West Greenland area. Also compared to the main West Greenland area, the catchability of larvae was presumably lower in the East Greenland–Iceland area and in the southernmost West Greenland area due to a higher gear avoidance of larger larvae.

In 0-group fish surveys carried out by Iceland annually since 1970, 0-group Greenland halibut are observed mainly along the shelf region off East Greenland (Fig. 3) (Sigurdsson and Magnusson, MS 1980; Vilhjalmsson and Magnusson, MS 1982, MS 1983, MS

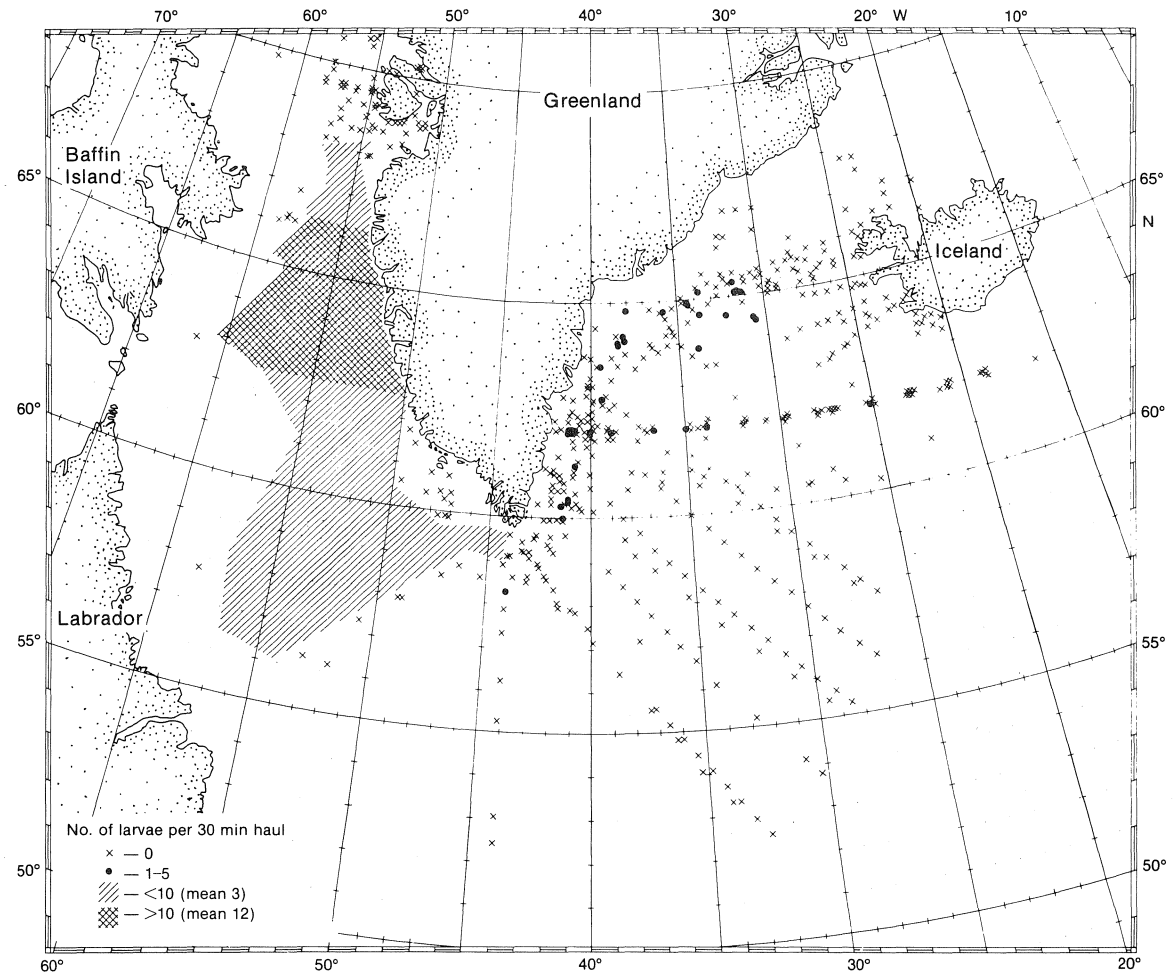

Fig. 2. Map showing station locations of pelagic larval surveys conducted from 1908 to 1964 in West Greenland water and 1925–64 in East Greenland-Icelandic waters.

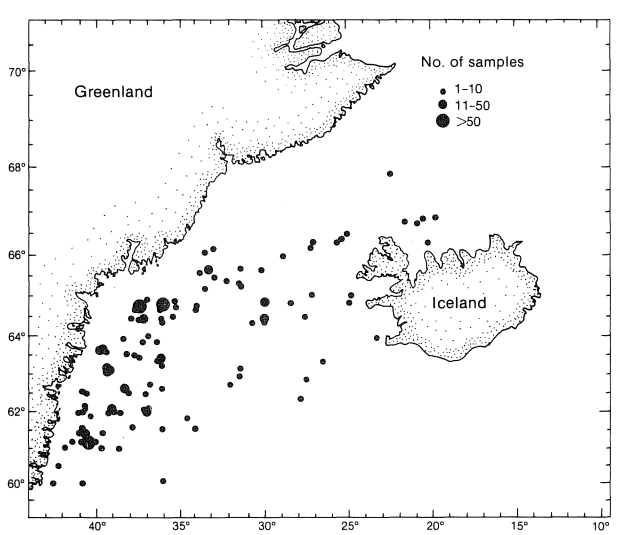

Fig. 3. Distribution and abundance of 0-group Greenland halibut from Icelandic 0-group surveys 1970–79 (from Sigurdsson and Magnusson, MS 1980). Surveys from 1982 to 1985 showing a similar pattern of distribution are reported by Vilhjalsson and Magnusson, MS 1982, MS 1983, MS 1984 and MS 1985.

1984 and MS 1985). The surveys have been carried out mainly in August, and mean lengths in the different years range between 51.8 mm and 67.6 mm. In some years the 0-group is quite numerous, but there are great variations in the yearly abundance.

Distribution of demersal young

The pelagic larvae change to the demersal stage at a length of about 70 mm (Jensen, 1935; Smidt, 1969). Riget and Boje (1988) described the distribution and abundance of the young in the West Greenland area based on catches in shrimp research trawl surveys carried out by the Greenland Fisheries Research Institute during 1964–87 and in stratified-random bottom trawl surveys carried out by the Federal Republic of Germany (FRG) during 1982–84. They especially focused their description on 0–2 year Greenland halibut. The main areas of distribution were found to be the offshore areas north of 68°N and the Disko Bay (Fig. 4). In the more southern offshore area, the young have been found only in small numbers, with abundance increasing towards the north, while considerable amounts are taken as by-catch in the shrimp fishery off West Green-

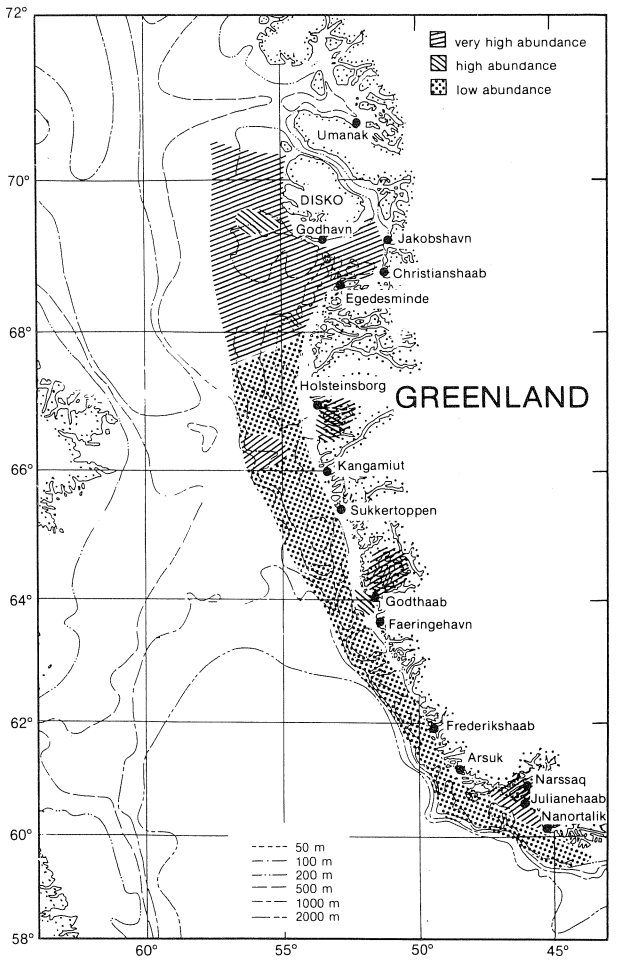

Fig. 4. Map showing relative abundance of young demersal stages of Greenland halibut observed over a wide range of years (from Riget and Boje, 1988; Smidt, 1969). No investigation has been made outside the shaded areas.

land (Riget *et al.*, MS 1988). High abundance is also found in coastal areas in the southern part of West Greenland, e.g. near Holsteinsborg, south of Godthaab and to some extent inshore in the Julianehaab district.

The current pattern

The East Greenland current carries large amounts of cold, relatively low salinity water as well as great quantities of polar ice southward along the east coast of Greenland. In the area between Greenland and Iceland the East Greenland Current meets the warm, saline Irminger Current which is a branch of the North Atlantic Current (Fig. 5). The two currents flow southward under intense mixing, round Cape Farewell and continues northward along the coast of West Greenland, now known as the West Greenland Current. Due to the temperature/salinity characteristics and the action of the Coriolis Force the East Greenland current component is located nearest to the coast.

The intensity of the two current components shows distinct seasonal variations (Buch, 1984). In the West Greenland area the East Greenland Current component increases in intensity during spring and attains its maximum intensity in late-June/early-July. Thereafter the flow decreases rapidly to almost nil in August. During the most intense period the East Greenland polar water dominates the 50–250 m depth interval and reaches as far north as the area between Godthaab and Sukkertoppen, whereafter it turns west and joins the Laboratory Current. The Irminger Current component has a relatively low intensity during the first 6 months of the year, and during this period it is found on the West Greenland fishing banks at depths between 300 and 600 m. In August the intensity tends to increase and maximum inflow occurs during November–December when the current dominates the 100–500 m depth interval. In addition to the seasonal variation of the hydrographic parameters, great interannual variations do occur (Buch, 1984).

Recruitment areas

The distribution of pelagic and demersal stages in the West Greenland area show somewhat of a contrast (Fig. 2, 3 and 4). In the offshore area, the main area of abundance of the demersal stage is found north of where the pelagic stage is densest. In the inshore area in the south, where demersal stage is found in high abundance in some places, only few pelagic larvae have generally been observed. The reason for these discrepancies may be found in the drift pattern of larvae.

In relation to the current pattern (Fig. 5), it seems reasonable to propose that the main drift of larvae to the West Greenland area originates from the assumed spawning area in the Davis Strait south of about 67° N. The main recruitment to the West Greenland area should therefore be from a spawning stock in the Davis Strait, as proposed by Jensen (1935). However, according to the general current pattern, pelagic larvae from the Davis Strait area would have difficulty in reaching the coast in the southernmost part of West Greenland, because the current here is dominated by the East Greenland/Irminger Current deriving from the East Greenland area. Therefore, the young Greenland halibut in coastal areas in southern West Greenland may not be from the Davis Strait area. It seems quite possible that the young to some extent are carried by the East Greenland/Irminger Current to the southern West Greenland area. Such a drift of larvae and young fish has been proposed for other species such as Atlantic halibut (Hansen and Hermann, 1953), haddock (Hovgård and Messtorff, MS 1987) and cod (Buch and Hansen, 1986).

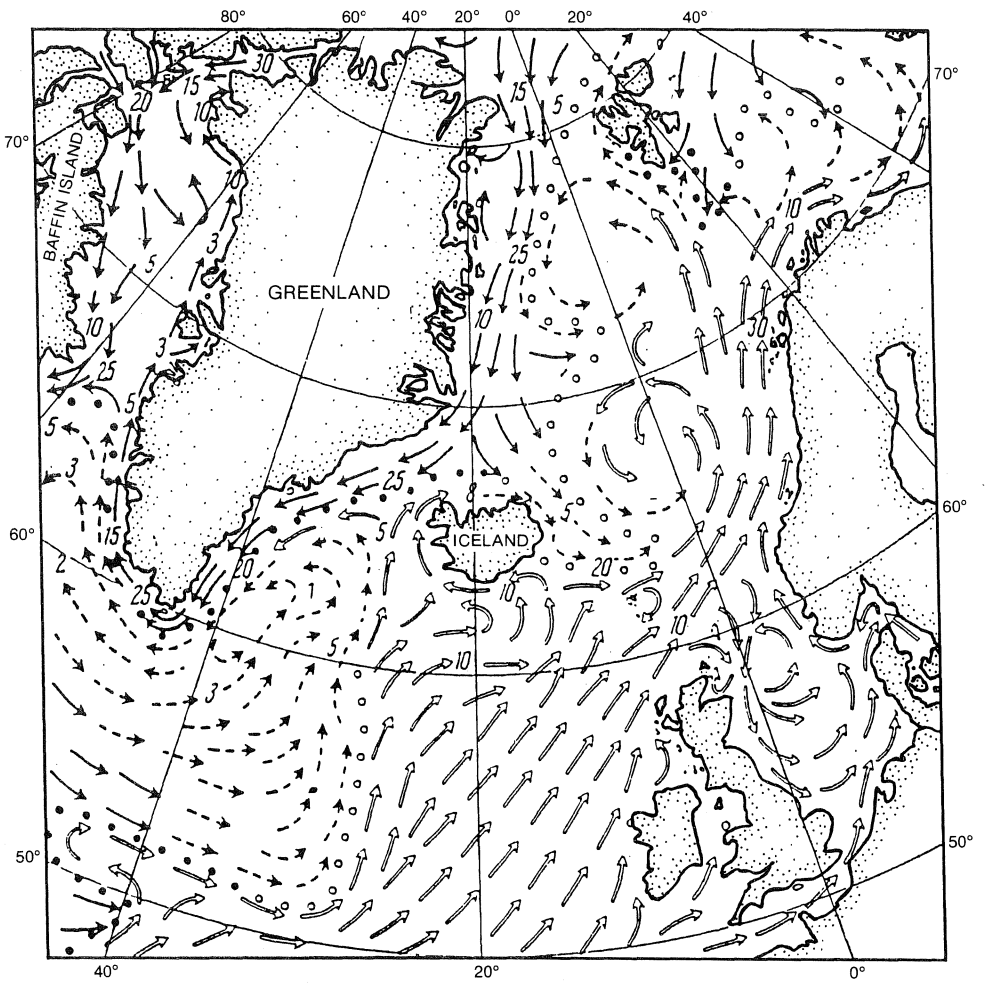

Fig. 5. Surface currents in the northern part of the Atlantic Ocean (⟹ Atlantic water, ⟶ Polar water, - - -→ Mixed water, •••ooo Polar front). The number represent the current speed in centimeters per second.

Relationship Between the Stock in the Fjords and the Stock in the Davis Strait Area

Size distributions

The length distributions of Greenland halibut taken from the inshore and offshore waters off West Greenland, are shown in Fig. 6A-H.

Longline catches from outer and inner inshore areas in Umanak and Jakobshavn in NAFO Div. 1A are shown in Fig. 6A-B. Localities named "outer" and Disko Bay are at depths of 200-400 m, while localities named "inner" and Icefjord are at depths 400-800 m. The length distributions show distinctly different modes, the inner areas peaking at the largest size.

Samples taken in shrimp trawls carried out along an inshore/offshore and depth gradient show similar patterns as for the longline catches, with the inner and deepest parts of the fjords having modes with highest size (Fig. 6C-E).

Data along an east-west gradient from the banks down the continental slope are few. However, data from some trawl surveys conducted during the last decade are shown in Fig. 6F-H. One set is from stratified-random bottom trawl surveys in 1982 and 1984 carried out by the FRG off the West Greenland shelf, from a 3-mile base line and the continental slope down to a depth of 600 m and extending from 67° N southward to Cape Farewell. The codend mesh size was 30 mm. Greenland halibut from these surveys ranged from 7 to 104 cm in length with a dominance of fish from 20 to 40 cm(Fig. 6F).

In July 1974 the Danish research vessel *Dana* trawled at depths of 700-1,000 m on the continental slope at 64-67° N, 55-58° W. The mesh size used was 80 mm. The dominant length groups in these trawl catches were from 40 to 70 cm (Fig. 6G).

In October 1973, the USSR research vessel *Artemida* made a series of trawls along the southern slope of the Greenland-Canada ridge at 64° 30'N, 58° 30'W at

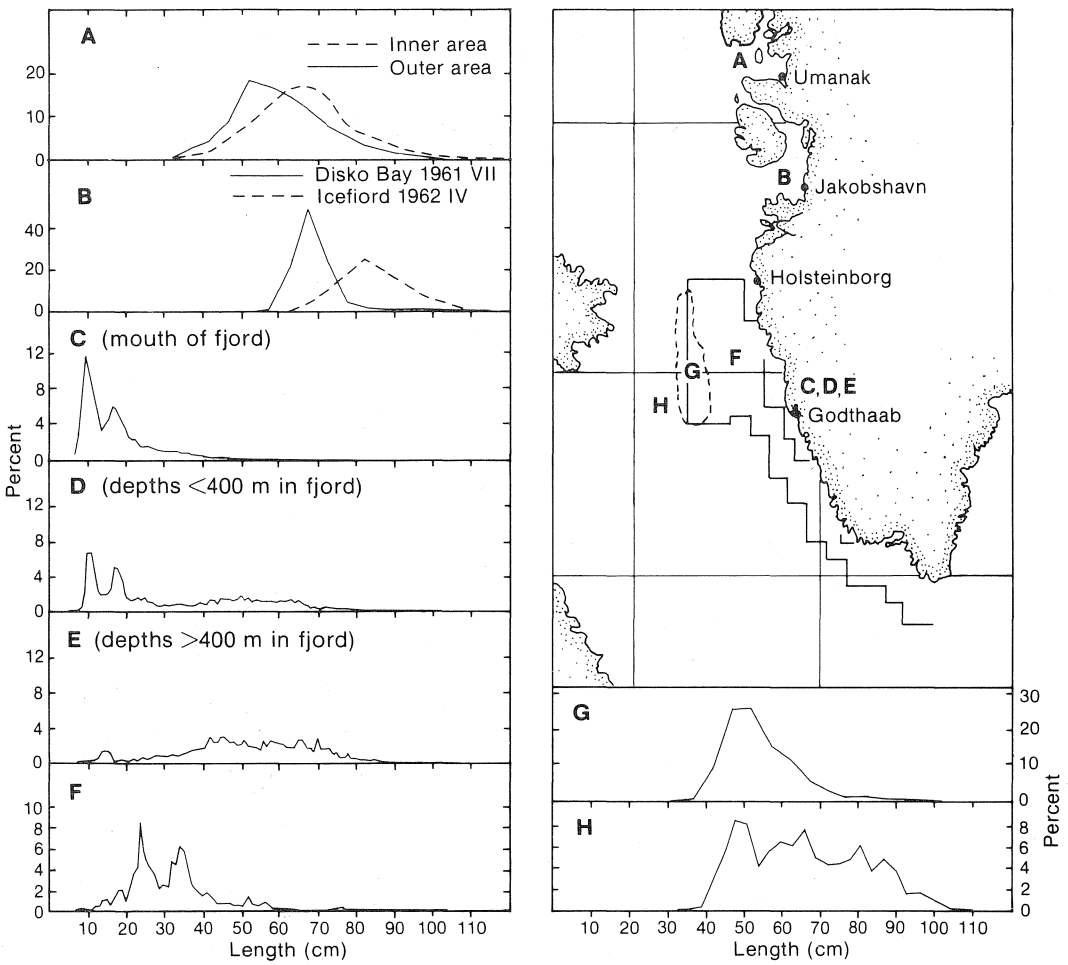

Fig. 6. Length distributions of Greenland halibut from various sources and different locations. (**A**) Longline catches from Umanak district (modified from Smidt, 1969); (**B**) Longline catches from Jakobshavn district (modified from Smidt, 1969); (**C**)-(**E**) shrimp research trawl catches from Godthaab Fjord (from Riget and Boje, 1988); (**F**) German bottom trawl survey catches (from Riget and Boje, 1988); (**G**) Danish research bottom trawl catches (R/V *Dana*, 1974); (**H**) USSR research bottom trawl catches (from Konstantinov and Noskov, MS 1974).

depths from 620 to 640 m (Konstantinov and Noskov, MS 1974). The dominant length groups were 45 to 92 cm (Fig. 6H).

A Japanese-Greenland joint-venture offshore stratified-random bottom survey was carried out in July/August 1987, covering Subarea 1 south of 70° N at depths from 0 to 1,000 m (Yamada *et al.*, MS 1988). The codend mesh size was 30 mm. In the northern areas (Div. 1ABC) fish lengths mainly ranged between 20 to 60 cm, while in the southern areas (Div. 1DEF) the length ranged mostly between 40 and 60 cm, both at the depth interval 600–1,000 m.

In summary, the average size generally seems to increase with increasing depth. This represents an increase from the banks in an inshore direction as well as in an offshore direction, and also in a southward direction offshore (as indicated by the Japanese-Greenland survey). This pattern could be attributed to a migration during early growth and when they reach the banks, the young demersal stages migrate gradually to deeper water. This migration seems to take place both towards the fjords and down the continental slope. In the fjords they grow up to a considerable size and constitute the main resource of the commercial fishery in West Greenland. The migration down the continental slope is presumably a move towards the spawning area in the Davis Strait south of 67° N.

Tagging experiments

Smidt (1969) summarized results of the tagging experiments carried out in West Greenland waters and recently Riget and Boje (MS 1987) reported on a tagging experiment carried out during 1969–70 in the Godthaab Fjord (Div. 1D). Table 1 shows an update of the tagging experiments carried out at West Greenland. A total of 3,515 Greenland halibut were caught by longlines and a total of 909 caught by trawl have been

TABLE 1. Recaptures of Greenland halibut at West Greenland from tagging experiments at various locations during 1935-81 (LL = longline, ST = shrimp trawls, FT = fish trawls).

Month and year	Gear	No. tagged	Calendar years after tagging year															Total
			0	1	2	3	4	5	6	7	8	9	10	13	15	16	?	
Umanak district — Div. 1A (numbers and %)																		
Jul-Aug	LL	106	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2
1935-36			—	1.9	—	—	—	—	—	—	—	—	—	—	—	—	—	1.9
Aug	LL	288	—	6	3	4	1	—	—	—	—	—	—	—	—	—	2	16
1960-62			—	2.1	1.0	1.4	0.4	—	—	—	—	—	—	—	—	—	0.7	5.6
Sep-Oct	LL	71	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	4
1978-81			—	2.8	2.8	—	—	—	—	—	—	—	—	—	—	—	—	5.6
	ST	37	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0
Jakobshavn district — Div. 1A (numbers and %)																		
Aug-Sep	LL	441	22	53	26	2	4	3	—	—	—	—	—	—	—	—	5	115
1935-36			5.0	12.0	5.9	0.5	0.9	0.7	—	—	—	—	—	—	—	—	1.1	26.1
Aug	LL	47	1	4	4	1	1	—	—	—	—	—	—	—	—	—	—	11
1960			2.1	8.5	8.5	2.1	2.1	—	—	—	—	—	—	—	—	—	—	23.4
Jun-Jul	ST	269	2	—	3	1	—	—	—	—	—	—	—	—	—	—	—	6
1973, 1975			0.7	—	1.1	0.4	—	—	—	—	—	—	—	—	—	—	—	2.2
Godthaab Fjord — Div. 1D (numbers and %)																		
May-Jun	LL	216	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
1935-36			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0
May-Oct	LL	95	—	—	—	—	—	—	—	—	2	1	1	—	—	—	—	4
1955			—	—	—	—	—	—	—	—	2.1	1.1	1.1	—	—	—	—	4.2
	ST	15	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
			—	—	—	—	—	—	6.7	—	—	—	—	—	—	—	—	6.7
Aug-Oct	LL	151	—	4	3	4	2	5	2	—	—	1	—	1	—	—	—	22
1959			—	2.7	2.0	2.7	1.3	3.3	1.3	—	—	0.7	—	0.7	—	—	—	14.6
	ST	23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0
Sep	ST	47	—	—	2	1	—	—	—	—	—	—	—	—	—	1	—	4
1964			—	—	4.2	2.1	—	—	—	—	—	—	—	—	—	2.1	—	8.5
Feb-May	LL	1,637	38	108	84	60	27	12	5	1	—	—	—	—	—	—	—	335
1968-71			2.3	6.6	5.1	3.7	1.7	0.7	0.3	0.1	—	—	—	—	—	—	—	20.5
	ST	276	1	2	1	—	—	—	—	—	—	—	—	—	—	—	—	4
			0.4	0.7	0.4	—	—	—	—	—	—	—	—	—	—	—	—	1.5
	FT	33	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	3
			—	3.0	—	3.0	3.0	—	—	—	—	—	—	—	—	—	—	9.1
Sep	LL	5	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
1978			—	—	—	20.0	—	—	—	—	—	—	—	—	—	—	—	20.0
Ameralik Fjord — Div. 1D (numbers and %)																		
Sep-Oct	LL	27	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	2
1964			—	3.7	—	—	—	—	—	—	—	—	—	—	3.7	—	—	7.4
	ST	55	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0
Aug-Sep	LL	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
1978-79			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0
Arsuk Fjord — Div. 1E (numbers and %)																		
Jul	LL	194	1	—	—	2	1	—	—	—	—	—	—	—	—	—	—	4
1937			0.5	—	—	1.0	0.5	—	—	—	—	—	—	—	—	—	—	2.1
Tunugdliarfik Fjord — Div. 1F (numbers and %)																		
Sep	LL	6	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2
1937			—	33.0	—	—	—	—	—	—	—	—	—	—	—	—	—	33.0
Mar-Dec	ST	154	1	4	1	—	1	3	—	—	—	—	—	—	—	—	—	10
1957-59			0.6	2.6	0.6	—	0.6	1.9	—	—	—	—	—	—	—	—	—	6.5
Lichtenau Fjord — Div. 1F (numbers and %)																		
Aug-Sep	LL	128	1	20	12	1	3	—	—	—	1	—	—	—	—	—	—	38
1937-39			0.8	15.6	9.5	0.8	2.3	—	—	—	0.8	—	—	—	—	—	—	29.7
Aug	LL	57	—	3	3	—	—	2	2	—	—	—	—	—	—	—	—	10
1952, 1954			—	5.3	5.3	—	—	3.5	3.5	—	—	—	—	—	—	—	—	17.5
Total for long-line experiments		3,475	63	204	138	74	39	22	9	1	3	2	1	1	1	1	7	566
			1.8	5.9	4.0	2.1	1.1	0.6	0.3	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.2	16.3
Total for trawl experiments		909	4	7	7	3	2	3	1	—	—	—	—	—	—	1	—	28
			0.5	0.8	0.8	0.3	0.2	0.3	0.1	—	—	—	—	—	—	0.1	—	3.2

tagged using both Petersen discs and yellow T-bar tags.

From longline catches a total of 574 (16.3%) recaptures and from trawl catches a total of 28 (3.2%) recaptures, were reported by the end of 1986. The time spent at sea varied from less than 1 year to 16 years. About 88% of the recaptures were taken within the first 3 years after tagging.

With the exception of two specimens all recaptures of known location were made near the tagging site. One of the migrants was tagged in Lichtenau Fjord in August 1954 and recaptured in June 1959 northwest of Iceland (66° 30'N, 25° 20'W), a distance of about 800 nautical miles. The second migrant was tagged in September 1964 in the inner part of Godthaab Fjord and was recaptured in September 1980 by a FRG trawler west of Dohrn Bank (65° 28'N, 30° 20'W), a distance of about 900 nautical miles. Long-distance migrations of Greenland halibut have also been observed from other tagging experiments in the North Atlantic (Bowering, 1984; Sigurdsson, 1979, 1981; Nizovtsev, 1974).

Length distribution of the tagged fish in the two most comprehensive tagging experiments are shown together with the length distribution in the successive years of recapture (length of fish at the time of tagging) in Fig. 7. In both experiments many of the large fish and probably mature fish (males above 60 cm and females above 80 cm) were recaptured in the tagging area 6 years after being tagged.

On the basis of the tagging experiments in Jakobshavn 1935-36 and Lichtenau Fjord 1937-39, in which there was a more than average decrease in numbers of recaptures between year 2 and 3 after tagging followed by an increase between 3 and 4 (Table 1), Smidt (1969) suggested that Greenland halibut migrated to the spawning grounds in the Davis Strait after year 2 and returned to the tagging area at year 3. However, the numbers of recaptures in these years of the experiment were extremely small and no adjustment to variation in fishing effort had been made.

An alternative possibility is that of a migration from the West Greenland fjords without returning. This has not been confirmed by a recapture in the Davis Strait area, probably due to a lack of fishing effort in the Davis Strait. Even though in the offshore area along the West Greenland coast a considerable fishery for other species takes place, no recaptures have been reported. The other possibility is that the stocks in the fjords are stationary. This has been indicated by the constant rate of recapture within all length groups at the place of tagging, and is especially indicated by the recaptures, 2-4 years after tagging at Godthaab.

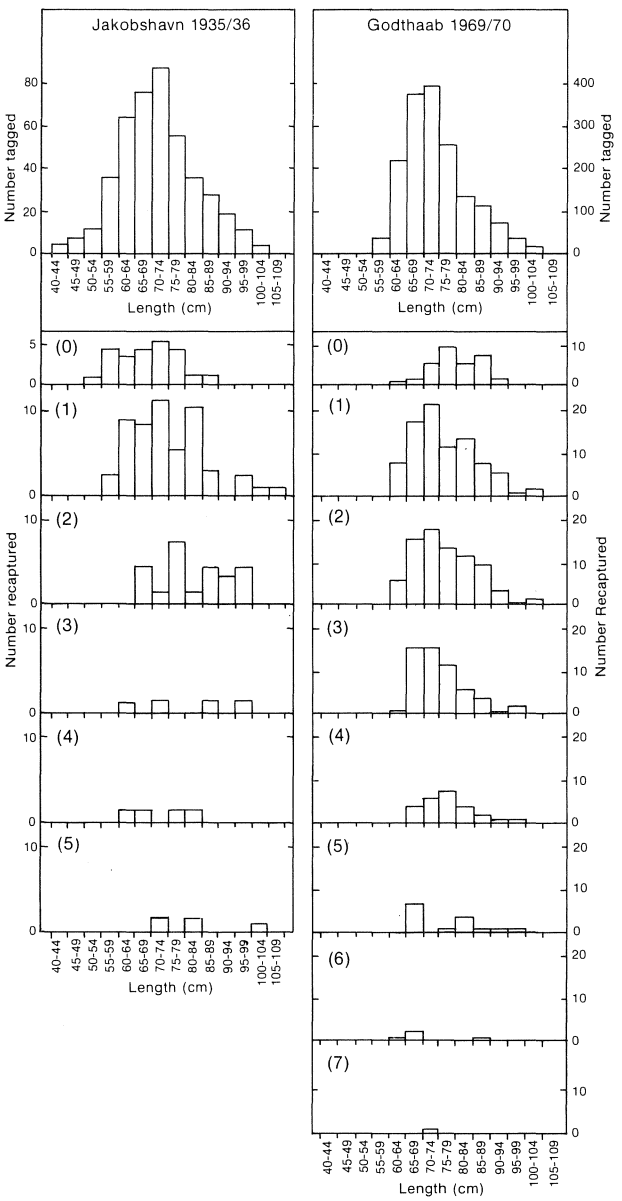

Fig. 7. Length distributions of Greenland halibut in tagging experiments at Jakobshavn (1935-36) and Godthaab Fjord (1969/70) and length distributions of recaptures in subsequent years. (Year of recapture after tagging is shown in parentheses.)

Ratio of males to females

Previous investigations have shown that the ratio of males to females in the fjords at West Greenland is unequal, females generally being more abundant (Jensen, 1935; Smidt, 1969). Predominance of females was observed among fish larger than 60 cm, below which the ratio was equal. From 60 to 90 cm the male frequencies decreased steadily from 50% to nil. No males larger than 90 cm have been reported at West

TABLE 2. Percentage of females (5 cm groups) in catches of Greenland halibut during investigations by the Greenland Fisheries Research Institute in 1985-87. (Numbers of fish indicated in parentheses.)

Location	Length																			
	40-44		45-49		50-54		55-59		60-64		65-69		70-74		75-79		80-84		>85	
Godthaab Fjord (Div. 1D)	33	(6)	45	(44)	55	(644)**	57	(994)**	62	(365)**	69	(128)**	88	(41)**	100	(10)**	100	(7)**	100	(3)
Jakobshavn district (Div. 1A)	50	(6)	32	(22)	47	(156)	48	(732)*	51	(1,342)	63	(1,002)**	65	(639)**	80	(343)**	93	(191)**	100	(505)**
Umanak district (Div. 1A)	100	(2)	50	(8)	41	(32)	52	(67)	48	(260)	49	(549)	63	(608)**	79	(384)**	80	(206)**	100	(155)**
Upernavik district (Div. 1A)					40	(5)	77	(77)**	67	(478)**	65	(917)**	74	(834)*	93	(850)**	98	(589)**	100	(530)**
Total	50	(14)	42	(74)	53	(838)	52	(1,840)*	56	(2,440)**	61	(2,622)**	68	(2,094)**	87	(1,547)**	94	(993)**	100	(1,193)**

*P<0.05; **P<0.01 (one-tailed binomial test).

Greenland, while females larger than 100 cm have not been uncommon.

These findings were confirmed by investigations in Godthaab Fjords (Div. 1D), Jakobshavn, Umanak and Upernavik districts (all in Div. 1A) carried out by the Greenland Fisheries Research Institute in 1985-87 (Table 2). Generally, females were statistically more abundant at lengths >55 cm (one-tailed binomial test, $p<0.05$) while they represented all fish at lengths above 85 cm. Geographically, the inequality of sex frequencies first appeared when proceeding from Godthaab Fjord to Umanak district and this in turn was related to the length of the females. In Godthaab Fjord the predominance of females began at 50 cm, in Jakobshavn at 65 cm, in Umanak at 70 cm. Upernavik, however, differed by having a predominance of females from about 55 cm.

Length distributions in the Davis Strait, obtained from bottom trawl surveys carried out by Canada (Bowering, MS 1987; Atkinson *et al.*, 1982) and USSR (Zilanov, MS 1976; Chumakov *et al.*, MS 1987; Konstantinov and Noskov, MS 1974) in the period August-December, generally showed males predominating in the size groups 40-65 cm and females predominating from lengths of about 65 cm. Catch data from a Faroese longliner, which carried out a fishery in Subarea 0 in June-October 1987, showed modal lengths of about 80 cm during the entire period with females constituting about 90% by number (Bowering, DFO, Newfoundland, pers. comm.).

Smidt (1969) interpreted the observed sex ratio at West Greenland fjords as a consequence of a spawning migration of the males to the Davis Strait at a younger age than females assuming that males and females become mature at a length of about 60 cm and 70-80 cm, respectively. However, when the different gears used are taken into account, it becomes apparent that the sex ratio in the West Greenland fjords and in the Davis Strait are very similar. The absence of males larger than 70-80 cm at West Greenland can be related to other causes such as higher natural mortality, as stated by Ernst and Borrmann, (MS 1987), and found among other flatfish (Pitt, 1975). Therefore, the absence of larger males in the West Greenland fjords cannot be exclusively attributed to the spawning migration assumed by Smidt (1969).

Sexual maturity

Observations on mature Greenland halibut from coastal and fjord areas of West Greenland are sparse. Smidt (1969) summarizes observations from the period 1908-60, during which 2 specimens with ripening sperm or eggs, 7 specimens with ripe sperm or eggs and 29 spent specimens were observed. Time of these observations varied from March to August. Since then, the only data available are from March and August 1987, and March 1988, sampled in Jabokshavn and Umanak districts in Div. 1A (Boje and Riget, MS 1988). The stages of maturity were judged visually on the basis of the description given in Table 3. Table 4 presents the occurrence of maturity stages of male and female by length.

Generally very few were observed in ripe or running condition (Stage IV and V). Among 3,630 females examined only 9 specimens, all in March, were recorded in ripe/running condition. In contrast, ripe/running males were more common with 49 observations among 1,488 males examined, again all in March. Ripe/running females occurred from lengths of 75 cm, while males occurred from lengths of 60 cm.

The spent stage (VI) has only been observed in March, but it has shown a great variability within the localities. The majority of the observed females were in Umanak in 1988. The lack of observations of males is presumably related to difficulties in the visual classification of this stage, where spent males might be included in the immature or early maturing stages.

The present recordings are generally in agreement with the observations summarized by Smidt (1969) in that very few ripe or running females have been recorded. However, the greater numbers of ripe or running males in the March samples might suggest that local spawning takes place. This agrument is supported by the records of spent females. It is known for yellowtail flounder and probably other flatfish with

TABLE 3. Descriptive stages of maturity used for visual analyses of Greenland halibut gonads (modified after Walsh and Bowering, 1981).

Maturity stage	Physiological stage of gonads
	Females
I	Juvenile or immature: ovary very small, eggs not visible to naked eye.
II	Maturing (A): eggs becoming visible to the naked eye.
III	Maturing (B): eggs 1-2 mm in diameter.
IV	Maturing (C): eggs 2-4 mm in diameter. The category includes the ripe condition where contents are almost liquid with translucent eggs.
V	Running stage (partly spent): some eggs extruded but several thousand clear eggs remaining.
VI	Spent stage: ovary appears reddish purple, wall is thick and tough, some residual clear or opaque eggs are seen.
	Males
I	Juvenile or immature: testes mostly clear and very small having a length of less than 1/4 of the abdominal cavity.
II	Maturing (A): testes opaque having a length between 1/4 and 1/2 of the abdominal cavity.
III	Maturing (B): testes opaque having a length between 1/2 and 3/4 of the abdominal cavity.
IV	Maturing (C): testes big and white in appearance having a length between 3/4 and 1/1 of the abdominal cavity. The category includes the ripe condition.
V	Running stage: sperm is running.

pelagic and bathypelagic eggs, that female gonad development from Stage III to Stage IV (hydration) only last about 24 hr (J. Zammaro, Instituto de Investigaciones Marinas, Vigo, pers. comm.), while male gonad development is continuous. Therefore, Stage IV and V of females are not expected to be recorded in the same numbers as the corresponding stages of males. This is supported by the present observations, where all female stages except IV and V have been recorded in some samples. The observations of ripe and running males are in accordance with the expected gonad development.

In summary, the present observations of ripe/running males and spent females indicate that some spawning occurs in the West Greenland fjords, although this spawning might be sporadic in time and place as suggested by the variation of the different stages between years and localities.

Conclusion

Jensen (1935) and Smidt (1969) described the biology and distribution pattern at West Greenland and concluded that Greenland halibut in the fjords and coastal areas of West Greenland originated from a spawning area in the deeper waters of the Davis Strait south of the submarine ridge at 67° N. After the young reach the fjords, they have been described to stay there

TABLE 4. Distribution of maturity stages of Greenland halibut (males and females) in Jakobshavn and Umanak districts from March 1987 to March 1988. See Table 3 for description of maturity stages. Values indicate percentages of numbers within each length group for each sample.

Males

	Jakobshavn district											Umanak district										
Length (cm)	March 1987			Aug 1987			Mar 1988					Mar 1987			Aug 1987				Mar 1988				
	I	II/III	IV/V	I	II	III	I	II	III	IV		I	II/III	IV/V	I	II	III	IV	I	II	III	IV	V
30-39	100			100			100								100								
40-49	100			100			100								100								
50-59	100			97	3		100					50			95	5			100				
60-69	98		2	84	11	5	90	6	2	2		93	2	5	91	5	3	1	93	1	1	3	1
70-79	92	6	3	50	35	15	50	50				80	7	13	43	11	13	33	73	7	7	8	5
80-89	100			25	75		50	50				100						100	33		33	33	
No. of fish	192			698			106					158			201				133				

Females

	Jakobshavn district												Umanak district											
	Mar 1987				Aug 1987			Mar 1988					Mar 1987					Aug 1987			Mar 1988					
	I	II	III	IV	I	II	III	I	II	IV	V	VI	I	II	III	IV	V	I	II	III	I	II	III	IV	V	VI
30-39					100													100								
40-49					100													100								
50-59	100				100			100										100			50	50				
60-69	43	52	5		93	7		74	26				42	58				97	3		82	18				
70-79	10	80	10		58	38	4	4	96				15	74	10	1		75	20	5	2	95		1	2	
80-89	3	68	30		18	68	14		100				3	55	48	1		35	52	13		89		1	10	
90-99	6	53	38	3		96	4		99	1				31	65		4	10	46	44		73	2	2	23	
100-109		50	50			100			97		3				100				50	50		36	3		61	
110-119			100						50		50				100					100		50			50	
No. of fish	311				1,487			358					305					776			394					

until they mature, then migrate to spawning grounds in the Davis Strait and return to the West Greenland fjords at each postspawning period.

The results presented in this study suggest that a major revision of the interpretation of the life cycle of Greenland halibut in the West Greenland area should be considered.

Recruitment

The distribution pattern of pelagic larvae, young demersal stages and adult stages at West Greenland indicate that the main recruitment occur from a spawning area in the deeper parts of the Davis Strait. The eggs and larvae drift northward to West Greenland as proposed by Jensen (1935). However, in view of the ocean current patterns, it seems likely that the stocks in the southernmost fjords of West Greenland can be recruited from the spawning grounds west of Iceland. This is supported by the large number of young found in some of the coastal areas in Southwest Greenland and the pelagic 0-group larvae found along the shelf region of Southeast Greenland.

Migration of immature fish

Difference in length frequency distributions in the inshore area of West Greenland has been interpreted as being a result of migration to deeper parts of the fjords as they grow (Smidt, 1969; Boje and Riget, MS 1987). Not much attention has been paid to Greenland halibut on the West Greenland continental slope, but the limited data available indicate that a stepwise migration also may occur down the continental slope to the deeper part of the Davis Strait. The extent of such a migration is unkown, partly due to a lack of a commercial fishery in the area, but the migration could be quite considerable.

Spawning migration

Results of tagging experiments do not support the hypothesis of a spawning migration out of the fjords to the Davis Strait. The only examples of long distance migration were two specimens tagged in the southern West Greenland and recaptured in the East Greenland/Iceland area. However, the lack of recaptures outside the tagging areas can, to some extent, be explained by the lack of commercial fishery for Greenland halibut outside the fjords. There are also no convincing data to suggest migration back to the fjords after spawning. The most convincing interpretation of the recaptures of fish several years later, which probably were mature at the time of tagging, is that the stocks remained in the fjords without migrating.

The sex ratios in the West Greenland fjords have been interpreted by Smidt (1969) as the males migrating to the Davis Strait area at a smaller size than females. However, in the present comparisons of the sex ratios by length, these two areas seem to be similar and therefore do not support the occurrence of a spawning migration to the Davis Strait.

In the interpretation of observations of maturity, the progression of females gonads from the last maturing stage into the ripe stage could be assumed to occur very fast and hence ripe females are not expected to be encountered often. The male process, however, is protracted and the advanced stages are encountered more often. Since males were found in both ripe and running condition and females were found in spent stage in the fjords of West Greenland, it is now suggested that spawning does occur there, although it might be sporadically.

In summary there seem to be no convincing data to support the occurrence of a spawning migration from the West Greenland fjords and the most simple interpretation of data is that the stocks in the West Greenland fjords may be regarded as mainly stationary and do not participate in the spawning in the Davis Strait.

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