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Biology and Fishery of Greenland Halibut at West Greenland

by

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ABSTRACT

This paper provides information on the fishery and biology of Greenland halibut in West Greenland waters. The biological aspects are discussed mainly in relation to the description of the lifecycle given by Jensen (1935) and Smidt (1969).

The fishery is in an increasing phase at West Greenland and the total catch of Greenland halibut by Greenland was about 9000 t in 1986. The main part of the catch is taken in the inshore area of NAFO Div. 1A and is concentrated primarily to limited localities in or near deep fiords. The gears used are gillnets and longlines. Size composition of the catches in 1986 and 1987 shows great difference between the most important areas.

Drift of Greenland halibut larvae is discussed on the basis of the knowledge of the distribution of pelagic larvae and young bottom stages and of the current pattern in the area. Although the main drift pattern seems to be from the 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. When growing up the Greenland halibut migrates to deeper water both in the fiords and on the continental slope in the Davis Strait. Mean length at age based on commercial samples indicates a linear growth pattern for the age groups involved. Differences in mean lengths at age were found between districts, but not between sexes. Tagging experiments show, that the stocks in the fiords may be considered as stationary as only two long distance migration have been recorded. Analysis of the ratio of males to females shows the proportion of females as generally being the highest. Some differences in sex ratio between the districts were seen. Very few Greenland halibut caught in the fiords have mature gonads. Based on these maturity observations, the non-migration of the stocks and the temperature conditions in the fiords, the authors propose, that most Greenland halibut in the fiords are stationary and do not develop mature gonads.

INTRODUCTION

Greenland halibut (Reinhardtius hippoglossoides Walb.) is widely distributed in the Northwest Atlantic. In the West Greenland area it is fairly common along the coast - especially in the deep fiords. It has been caught as far north as Smith Sound (78°N lat.) as reported by Smidt (1969). In the East Greenland fiords it is common as far north as Ammassalik.

SPECIAL SESSION ON DEEPWATER FISHES

Little is known about the life of Greenland halibut in West Greenland waters. Smidt (1969) made an extensive description of the knowledge of the biology of Greenland halibut there. Spawning seems to take place in spring in the deep water south of the submarine ridge between Greenland and Baffin Island at about 67°N lat. (Jensen, 1935 and Smidt, 1969). The larvae are spreadt by the currents along the west coast of Greenland and the northern part of the Davis Strait. The larvae seek the bottom on nursery grounds in the autumn, afterwards the young fish migrate to deeper water and into the fiords, where they grow up. When reaching maturity the fish are assumed to migrate to the Davis Strait to spawn and re-immigrate to the West Greenland fiords after spawning.

Since the description by Smidt (1969) little work has been done on Greenland halibut in West Greenland waters. However, in the later years there has been a growing interest of the resources of the Greenland halibut and investigations of the exploitation and biology of this fish species have been initiated.

This paper gives a description of the fishery of Greenland halibut at West Greenland and some of the research results in later years. Different biological topics are selected and discussed mainly in relation to the work done by Smidt (1969). A discussion of the lifecycle of Greenland halibut in the west Greenland area is presented.

THE FISHERY FOR GREENLAND HALIBUT

Trends in catches

The fishery for Greenland halibut is in an increasing phase at West Greenland and at the same time the structure of the fishery has changed toward a more directed fishery.

In Fig. 1 are shown annual catches of Greenland halibut in NAFO Subarea 1 from 1964 to 1986 as taken by Greenland and "other nations" respectively as reported to ICNAF/NAFO Stat. Bull. The catches by other nations fluctuate during the period showing two marked peaks. In 1975 catches peaked at 20.000 t mainly as a result of USSR catches in offshore areas in Div. 1C. In 1979 catches were 13.000 t taken mainly by the Federal Republic of Germany. However, the latter may be an overestimate of the actual catches (Horsted, 1980). Since 1980 the fishery by foreign nations has been negligible. The fishery by Greenland has increased stepwise from about 2.500 t in 1964 to about 9.000 t in 1986 with some fluctuations over the period.

The annual catches taken by Greenland since 1964 are broken down by divisions in Fig. 2 and Table 1. Since 1975 the catches have been taken mainly in Div. 1A, and from 1983 catches have increased relatively much in this division from 2.700 t to 6.500 t in 1986. As seen in Fig.3, the main part of landings in Div. 1A are received at Jakobshavn, Umanak, Ikerasak and Prøven.

The fishery for Greenland halibut presently extends further northwards in the area and preliminary data for 1987 indicate that catches in Umanak and Upernavik will increase further.

Catches of Greenland halibut in Division 1B-1F have varied at a level about 2.000 t since 1972. In the period 1974-78 catches in Div. 1B predominates, the fishery taking place in Amerdlog Fiord just south of

Holsteinsborg. This fishery decreased in 1980/81, and Division 1D has dominated since then with the whole catch taken in the Godthåb Fiord.

The Greenland fishery

Greenland halibut are mainly taken by gillnet and longline. Longline fishery from small boats has been the traditional fishery, but more recently gillnet have become popular. The fishing localities are often very restricted areas in the deepest and the innermost part of fiords, which often are icefiords.

In Jakobshavn, which is the most important place for the fishery, both a longline and a gillnet fishery take place. The fishing localities are the two icefiords Jakobshavn Icefiord and Torssukatak. Longline fishery is mainly carried out from dog sledges in winter when Jakobshavn Icefiord is covered by ice. Typically longlines with 100-200 hooks are used at depths of 200-800 m in the icefiord. Gillnet fishery is carried out in summer from small boats just outside Jakobshavn Icefiord and in Torssukatak. In 1986 the gillnet fishery accounted for about 80% of the total annual catch (further description of the fishery in Jakobshavn is given in Boje & Riget, 1987 and Nellemann, 1961). Gillnet and longline catches from 1987, which are believed to be typical for the more recent fishery, are shown in Fig. 4b and c. The two length distribution are very different. The gillnet catch covers a narrow length interval around 55-70 cm, whereas the longline catch covers a broad length interval from 50 cm to more than 100 cm. However, the two samples are from different localities; the longline is catch from the Icefiord (depths 200-800 m) and the gillnet is catch from outside the fiord (depths of 300 m).

In Umanak district the fishery is more scattered in the area between Nussuaq Peninsula and Svartenhuk Peninsula (Fig. 3) and is carried out with both longlines and gillnets. Gillnets were introduced newly in this area and be increasing. Both gears are used throughout the year, from dog sledges in winter and from small boats in summer. Catches from gillnet and longline fishery in Umanak in 1987 (Fig. 4d and e) have a much more uniform length distribution; both covering a broad length range and have common peaks at 70-79 cm. This might be explained by the fact that the fishing grounds are the same for the two types of fishery. Compared to the other gillnet catches presented the bigger size of fish in gillnet catches from Umanak, might be caused by gear selection as larger mesh size is used in gillnet in Umanak district.

Further north, in Upernavik district, only longline fishery takes place mainly from small boats. During the most recent years an attempt has been made to develop the longline fishery further in the area. Catch compositions are shown for the southern and the northern part of the district (Fig. 4f and g). The sample from the southern part of the district is distributed with a peak at 70-74 cm while the distribution of the sample from the northern part is more uniform with no distinct peaks.

In Godthåb Fiord only gillnets are used yearround from small boats when ice conditions allow sailing. The fishery takes place in the deep parts of the fiord, around 600 m of depth. The effort of the fishery changes within the year according to the prospects of other fisheries that are more economically attractive to the fishermen (i.e. cod-, scallop- or shrimp fishery). A gillnet catch is shown in Fig. 4a. The length distribution is very narrow, 50-80 cm, peaking at the length group 60-64 cm. The fishery in the fiord has showed great fluctuations during the

lateet decades, and according to information from fishermen in the area, mean size of fish has decreased during this period.

RECRUITMENT TO THE WEST GREENLAND AREA

The spawning area of Greenland halibut is south of the submarine ridge between Greenland and Baffin Island at about 67°N lat. (Jensen, 1935). Spawning occurs in spring in the deep warm water south of the ridge where temperatures are between 3° and 4°C at about 1000 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 be carried by currents to the West Greenland area, where they settle.

Distribution of pelagic larvae

Since Jensen (1935) and Smidt (1969) described the distribution of pelagic larvae in the Greenland area no new data have become avaible. Fig. 4 shows the distribution of pelagic larvae summarized from several expeditions, of which "NORWESTLANT" in 1963 is the most important. In the West Greenland area the densest occurrence is between 62°30´N and 66° 15´N lat. In the East Greenland-Iceland area and off the southernmost part of West Greenland the number of larvae are scarce only. However, it should be mentioned that pelagic larvae were caught in south West Greenland in the "Godthåb" expedition in 1928 (Jensen, 1935).

However, quantitative comparisons between the West Greenland and East Greenland areas are difficult because the average lenght 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) (same year and month) indicating different spawning time in the two areas. This implies that the reduction in numbers due to natural mortality has worked an a longer time in the East Greenland-Iceland area compared to the West Greenland area. Also compared to the main West Greenland area the catchability of larvae has presumably been lower in the East Greenland-Iceland area and in the southernmost West Greenland area due to a higher ability of gear avoidance of larger larvae.

Distribution of young bottom stages

The pelagic larvae chang to the bottom stage at a length of about 70 mm (Jensen 1935 Smidt 1969 and Riget & Boje 1987b). Knowledge of the distribution of young bottom stages derives mainly from shrimp research trawl surveys carried out by the Greenland Fisheries and Environment Research Institute during 1964-84 and from stratified-random bottom trawl surveys carried out by the Federal Republic of Germany since 1982.

An analysis of the distribution and abundance of the young Greenland halibut (Riget & Boje, 1987b) shows, that the main area of distribution is the offshore areas north of 68°N lat. and the Disko Bay (Fig.6). In the more southernly offshore area young Greenland halibut have only been found in small numbers but with the abundance increasing towards the north. However, high abundance is found in coastal areas in the southern part of West Greenland, e.g. near Holsteinsborg, south of Godthåb and to some extent inshore at Julianehåb district. This finding is somewhat in discrepancy with the relative scarcity of pelagic larvae in the samples from the southernmost part of West Greenland.

The current pattern

To understand the drift of Greenland halibut in the West Greenland area it is necessary to look at the hydrography and the current pattern in the area. The East Greenland current carries large amounts of cold, relatively fresh 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 side branch of the North Atlantic Current, Fig. 7. The two currents flow southward under intense mixing, rounds Cape Farewell and continues northward along the coast of West Greenland, now known as the West Greenland Current.

Due to the temperature/salinty characteristics and the action of the Coriolis force the East Greenland current component is situated nearest to the coast, Fig. 7.

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 Godthåb and Sukkertoppen, whereafter it turns west and joins the Labrador Current. The Irminger Current component has a relatively low intensity during the first half part of the year, and during this period it is found at the West Greenland fishing banks at a depth between 300-600 m. In August the intensity tends to increase and maximum inflow occurs during November-December in which period the current dominates the 100-500 m depth interval. In addition to the seasonal variation of the hydrographical parameters great interannual variations do occur, which is thoroughly described by Buch (1984) and Buch & Stein (1987).

Drift of larvae

When comparing the distribution of pelagic larvae as shown in Fig. 5 and the main area of young bottom stages in Fig. 6 with the current pattern in the area (Fig. 7) it seems reasonable to propose a drift of larvae from the assumed spawning area in the Davis Strait. However, according to the general current pattern, pelagic larvae from the Davis Strait area should 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 derived from the Davis Strait area.

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. 8). 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 (Sigurdsson & Magnusson, 1980, Vilhjalmsson & Magnusson 1982, 83, 84, 85). In some years 0-group Greenland halibut are quite numerous, but there are great variations in the yearly abundance. In view of the current pattern in the area it is quite possible that young Greenland halibut to some extent are carried by the East Greenland/Irminger Current to the southern West Greenland area. Such a larvae/young fish drift has been argumented for both haddock and cod (Buch & Hansen, 1986 and Hovgård & Messtorf, 1987).

SIZE DISTRIBUTION

Size distribution of Greenland halibut at different areas in West Greenland was derived from several catch data, where different gears have been used. Therefore, it is difficult to compare the length distributions obtained, but it would give a general impression of the migration pattern in the area.

The inshore area near Holsteinsborg and the inshore area south of Godthåb are two of the known nursery grounds for young Greenland halibut. Fig. 9a shows the length distribution from research shrimp trawlings in these areas (mesh size in the codend is 18 to 21 mm). There is a pronounced dominance of small sizes of Greenland halibut representing the youngest yearclasses (1 and 2 years old).

When growing up the Greenland halibut migrates to deeper water and into the fiords. This has been shown for several areas by Smidt (1969), see Fig. 9b. The biggest fishes are found in the innermost and deepest part of the fiords, where the commercial fishery takes place.

From the banks and the continental slope very few data are available. Fig. 9c,d,e shows three size distributions from different data sources. One is the stratified-random bottom trawl surveys in 1982 and 1984 carried out by the Federal Republic of Germany. These surveys included the West Greenland shelf outside the 3-mile base line and the continental slope down to 600 m depth extending from 67°N lat. southward to Cape Farewell. Mesh size in the codend was 30 mm. The dominant lengths in these surveys are from 15 to 40 cm (Fig. 9c). In July 1974 the Danish research vessel "Dana" trawled at depths between 700 and 1000 m on the continental slope at 64-67°N lat., 55-58°W long. The mesh size used was 80 mm. Fig. 9d shows the length distribution of the catches of Greenland halibut. The dominating length groups in these trawl catches are from 40 cm to 70 cm. The USSR research vessel "Artemida" in Oktober 1973 made a serie of trawl hauls along the southern slope of the Greenland-Canada ridge at 64°30´N lat. 58°30´W long. at depths from 620 m to 640 m (Konstantinov & Noskov, 1974). The length distribution from these trawlings can be seen in Fig. 9e, and the dominating length groups are 45 cm to 92 cm.

To be judged from the length distributions presented, there seems to be a migration from the nursery grounds to the deeper water in the fiords and also probably to the continental slope and the deeper parts of the Davis Strait.

MEAN LENGHT AT AGE

Age determination

From the West Greenland area age determination of Greenland halibut has been done previously by Smidt (1969), who also presented a growth curve. Of 1902 otoliths examined only 26% were characterized as readable (very few otoliths from fish older than 12 years could be read). In the last years age determination of Greenland halibut has been resumed from samples from the commercial fishery. The data presented here are based on samples from the commercial fishery in 1985 and 1986. Therefore only age groups occurring in the commercial fishery are covered.

Only the left otolith was used in age reading. The otoliths are placed in a solution of alcohol and glycerin and examined in transparent light under a microscope. Age determination of Greenland halibut is still in a stage of development and the results must therefore be regarded as preliminary.

Mean length at age

Mean length at age from four districts at West Greenland is shown in Fig. 10. Use of commercial samples may bias the curves due to minimum landing size and gear selection. Therefore the growth curves do not include the youngest age group. In Jakobshavn, Umanak and in Godthåb Fiord fish as small as 50 cm are landed while in Upernavik only fish bigger than about 60 cm are landed.

The mean length at age found in this study is generally smaller than that found by Smidt (1969) in a survey covering whole West Greenland. The mean length at the age of 10 years is 71 cm in the growth curve given by Smidt, while the mean length at the same age in the present study ranges between 58.7 cm and 65.0 cm.

Growth seems to be quite linear, at least until the highest ages are reached. Similar conclusions have been reached in Canadian Atlantic waters (Bowering, 1978) and in the coastal waters of western Spitzbergen (Haug & Gulliksen, 1982).

Mean length at age seems to be higher in Jakobshavn and Umanak than in Upernavik district and in Godthåb Fiord. In Canadian Atlantic waters there appears to be a general increase in average size at age from north to south (Bowering, 1978, 1983). This also seems to be the case in the West Greenland area, when comparing the curves from Upernavik, Umanak and Jakobshavn districts. However, the results from Godthåb Fiord with lower mean length at age do not fit into this pattern. The stock in Godthåb Fiord is in a poor state of condition as compared to other stocks at West Greenland (Smidt, 1969); this could be the reason for the observed lower mean length at age.

The mean length at age by sex for two samples from the commercial fishery in the Godthåb Fiord in 1986 is shown in Fig. 11. There seems to be no significant difference in growth rates between the two sexes. Bowering (1983) showed a difference in growth rate between the two sexes in Canadian waters, but the difference in mean size at age could not be seen before an age of 8-12 years. Although the data are sparse, they may indicate that the stocks in the Godthåb Fiord are composed of immature fish.

THE STOCKS IN THE FIORDS

Tagging experiments

In Table 2 are summarized the results of the tagging experiments in the West Greenland area. A total of 3515 Greenland halibut caught by longlines and a total of 909 caught by trawl have been tagged. The tagging has been done in the inshore area.

From the tagging experiments from longlines catches a total of 574 (16.3%) recaptures and from those of trawl catches a total of 28 (3.2%)

recaptures were reported by the end of 1986. The time spent in the sea from time of tagging to the time of recapture varies from less than 1 year to 16 years. About 88% of the recaptures were taken within the first three years after tagging.

With the exception of three specimens all recaptures of known location were made less than 50 miles from the tagging place. Two of the migrants were from a tagging experiment in Lichtenau Fiord in August 1954. One specimen was recaptured at Narssaq in June 1955 (a distance of about 60 miles) and the other was recaptured in June 1959 northwest of Iceland (66°30´N lat. 25°20´W long.), a distance of about 900 n. miles. The third migrant was tagged in September 1964 at the inner part of Godthåb Fiord (45 cm) and was recaptured in September 1980 by a German trawler west of Dohrn Bank (65°28´N lat. 30°20´W long.), a distance of about 900 n. miles.

Some considerations of a re-immigration of Greenland halibut to the fiords after spawning in the Davis Strait have been made by Smidt (1969) based on the tagging experiments in Jakobshavn 1935-36 and Lichtenau Fiord 1937-39. In these two experiment there was a rise in numbers of recaptures between year 3 and year 4 after the tagging (Table 2). This was interpreted as a return of fish from the spawning area. However, the numbers of recaptures in these years of the experiments are very small and no adjustment to variation in fishing effort has been made. Furthermore a the rather large tagging experiment which was carried out in Godthåb Fiord in 1968-71 and no rise in numbers of recaptures was seen between year 3 and year 4 (Table 2).

The spawning migration to the Davis Strait as proposed be Smidt (1969) and Jensen (1935) has never been confirmed by tagging experiments at West Greenland. This could be due to a lack of fishing effort in the Davis Strait. However, in 1975 there was a considerable fishery for Greenland halibut in the offshore area at West Greenland with USSR vessels catching 20.000 t in Div. 1C. This was only few years after the rather large tagging experiment in Godthåb Fiord and no recaptures have been reported from this fishery.

Ratio of males to females.

Previous investigations have shown that the ratio of males to females of Greenland halibut in the fiords at West Greenland is unequal, the proportion of females generally being the highest (Jensen, 1935 and Smidt, 1969). The predominance of females was observed only among fish longer than 60 cm; below this size the ratio was equal. From 60 cm to 90 cm the male frequencies decreased steadily from 50% to nil. No males longer than 90 cm have been reported at West Greenland, while females longer than 100 cm are not unusual.

These findings are confirmed by investigations in Godthåb Fiord (Div. 1D), Jakobshavn, Umanak and Upernavik districts (all Div. 1A) carried out by the Greenland Fisheries and Environment Research Institute in 1985-87 (Table 3 and Fig. 12): Generally, females are statistically more abundant from lengths at 55 cm (binomial test, $p<0.05$) and represents all fish at lengths above 85 cm. Within the different districts the length at which female dominance starts differs insignificantly, regarding both time of the year (month 1-6 vs. month 7-12) and choice of gear (gillnet vs. longline). When looking at female frequencies as total for each district there is an increase in lenght where ineqvality of sex frequencies first appears from Godthåb Fiord to

Umanak district. In Godthåb fiord the predominance of females begins at 50 cm, in Jakobshavn at 65 cm, in Umanak at 70 cm. Upernavik does not fit into this pattern, having a predominance of females from lengths of about 55 cm.

Length distributions of Greenland halibut males and females caught during surveys carried out by Canada (Bowering 1987, Atkinson et al. 1982) and USSR (Zilanov 1976, Chumakov et al. 1987, Konstantinov and Noskov 1974) in the Davis Strait in the period from August to December, generally show that no males above 80 cm are caught and that females predominate from lengths of about 68 cm. Furthermore the fraction of males in the length interval 60 - 80 cm constitutes a negligible part of the total number of males.

Smidt (1969) interpreted the ratio of males to females observed in West Greenland fiords as a consequence of a spawning migration of the males to the Davis Strait at an younger age than females. On the background of this he assumed that males and females become mature at a length of about 60 cm and of 70 - 80 cm, respectively.

Although the above mentioned surveys in the Davis Strait took place in the assumed prespawning period, males above 60 cm in length are not represented in such a proportion so as to explain the lack of these length groups in the fiords of West Greenland. Therefore if the male Greenland halibut from West Greenland have migrated to the Davis Strait, it must be assumed that they have gone to depths not covered either by surveys or commercial fishery.

Sexual maturity.

Observations on mature Greenland halibut from coastal and fiord areas of West Greenland are sparse. Smidt (1969) summarizes observations from the period 1908 to 1960, during which only 7 specimens of Greenland halibut with ripening sperm or eggs were observed (maturity stage V). The month of the observed maturity stage V varies from March to August. Moreover several spent females were observed in March in Godthåb Fiord, while several spent females in Julianehåb Fiord (Div. 1F) were observed in May.

Data from West Greenland on sexual maturity of Greenland halibut from 1960 until today are sparse due to a very restricted effort in this field. The only data available are from March 1987 sampled in Jakobshavn and Umanak districts by the Greenland Fisheries and Environment Research Institute.

Fig. 13 and Table 5 shows the proportions of maturity stages of males from Umanak and females from Jakobshavn and Umanak. Only 2 nearly ripening females (stage IV) were observed with lengths of 76 cm and 87 cm, while several males were observed with ripening sperm (stage IV/V).

For both sexes maturity generally increases with increasing length of the fish. For females maturity stage I seems to predominate in lengths up to 60-65 cm, stage II from 60-65 cm to 85-90 cm and stage III from 85-90 cm and up. No clear relationship between maturity and length of fish seems to occur for the stages IV and VI, the few observations taken into account. For males only distinction between maturity stage I (juvenile or immature) and stage IV/V (nearly or with ripening sperm) is made. As well as for females, there is a relationship between length and

stage of maturity. The proportion of males with ripening sperm increases from 0% in fish with length up to 55 cm, to a level round 15% at length 70-80 cm, and 50% for fish above 80 cm.

Smidt (1969) concluded from investigations of distribution of eggs and pelagic larvae and on adult fish in the fiords that spawning in fiords can only be negligible. The temperatures in the assumed spawning area in the Davis Strait are 3-4°C (Smidt, 1969 and Templemann, 1973) and in the spawning area for the Icelandic stock west of Iceland 4-5°C (Sigurdsson, 1979). It therefore seems, that Greenland halibut requires temperatures of 3-4°C to develop mature gonads. The bottom layers of the West Greenland fiords reaches their maximum temperatures in November-December due to inflow of warm Irminger water with maximum values around 3°C. The temperatures are quickly reduced again due to vertical convection of wintercooled surface water (pers. comm. E. Buch).

Smidt (1969) assumed that the variation of observations of stage V/VI within the time of the year was due to the presence of first time spawners and second time/older spawners. He also assumed that all the spent fish had re-immigrated into the fiords from the spawning area in the Davis Strait.

However, another interpretation of the observations could be that most females of Greenland halibut in the West Greenland fiords do not develop further than to maturity stage II and then possibly reabsorb their sexproducts during the summer, leaving only a minor part of the fish to develop into maturity stage V and later spawning. The work on the reproduction of Greenland halibut in the West Greenland area is in an initial phase and further work needs to be done.

CONCLUSION

The Greenland halibut fishery is in a developing phase, with rapidly increasing catches. It is carried out as a longline and/or a gillnet fishery mostly from small vessels. The fishery is concentrated mainly in or near deep fiords and is highly dependent on weather and ice conditions. The future extendtion of the fishery seems to be in the more northerly areas.

On the basis of investigations from 1930 to 1968 Smidt (1969) discussed the biology and pattern of distribution of Greenland halibut. He concluded that Greenland halibut in the fiords and coastal areas of West Greenland originate from a spawning area in the deeper waters of the Davis Strait south of the submarine ridge at 67° N lat. After young Greenland halibut reach the fiords, they are stationary while growing up until becoming mature. At that time the Greenland halibut migrate to the spawning grounds in the Davis Strait returning each postspawning period to the West Greenland fiords.

However, another interpretation of the lifecycle of Greenland halibut seems more reasonable in the light of more recent investigations.

Analyses of the distribution of young Greenland halibut show a rather large abundance in some of the coastal areas in the southern part of West Greenland and in the the main distribution area north of 68 N lat. as well. With the knowledge of the current pattern in the area in mind, it seems likely that there is some influx of Greenland halibut larvae to the West Greenland area from the East Greenland/Iceland area. The extent and importance of this influx is not known. Tagging experiments also

show at least some connection between southern West Greenland stocks and the East Greenland/Iceland stocks.

Difference in length frequency distributions indicates that when growing up a part of the Greenland halibut population seeks the deeper parts of the fiords at West Greenland (Smidt 1969, Boje & Riget 1987). Not much attention has been paid to Greenland halibut on the West Greenland continental slope, but the scarce data available indicate that a migration also may occur down the continental slope to the deeper part of the Davis Strait. The extent of such a migration is unknown partly due to a lack of a commercial fishery in the area. A slopeward migration pattern is found both in the Canadian area (Bowering, 1984) and in the Svalbard area (Godø & Haug, 1987).

The results of the tagging experiments do not support on a spawning migration out of the fiords to the Davis Strait. Nor is there convincing data of a re-immigration to the fiords after spawning. The only examples of long distance migration were two fish tagged in the southern West Greenland and recaptured in the East Greenland/Iceland area. However, the lack of recaptures outside the tagging places can to some extent be explained by the lack of commercial fishery for Greenland halibut outside the fiords.

The females dominance from lengths above 55 cm may indicate that males migrate to the Davis Strait at a smaller size (younger age) than female do. However, in surveys carried out in the Davis Strait males are not represented in such a proportion among the larger fish as one would have expected.

Few Greenland halibut caught in the fiords at West Greenland are found with ripening gonads. Therefore Greenland halibut does probably not spawn to a significant degree in the fiords at West Greenland.

It is not possible to conclude whether the stocks in the West Greenland fiords are stationary or if they migrate to the Davis Strait for spawning. However, in the authors' view the most simple interpretation of the existing data is, that the stocks in the West Greenland fiords may be regarded as mainly stationary and do not participating in the spawning in the Davis Strait.

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Table 1. Catch of Greenland halibut (in tons) by Greenland in Subarea 1, by year and Division (from NAFO Stat. Bull.).

	Divisions							
Year	1A	1B	1C	1D	1E	1F	NK	Total
1964	1259	172	82	1006	66	103	0	2688
1965	1416	893	136	413	54	133	0	3045
1966	1118	598	145	458	79	175	0	2573
1967	889	512	148	134	55	86	0	1834
1968	747	432	80	206	34	69	0	1568
1969	626	344	28	329	128	22	0	1477
1970	691	195	41	185	65	18	17	1212
1971	520	236	29	288	35	34	17	1159
1972	604	492	92	614	57	79	1012	2950
1973	1382	801	55	1013	254	150	0	3655
1974	1731	1115	123	735	251	99	0	4054
1975	1651	1057	198	384	86	60	0	3436
1976	2556	607	47	206	91	39	0	3546
1977	3821	1189	166	583	134	217	0	6110
1978	3795	1182	179	603	121	105	0	5985
1979	3036	1275	292	541	34	95	0	5273
1980	3448	622	331	718	131	105	0	5355
1981	3830	375	196	711	389	254	0	5755
1982	3167	330	61	815	386	638	0	5397
1983	2738	82	55	567	414	280	0	4136
1984	4010	423	109	963	511	459	34	6509
1985	5491	195	77	2138	284	770	0	8955
1986	6481	89	24	1180	565	362	4	8705

Table 2. Results of the tagging experiments of Greenland halibut in the West Greenland area.

Locality	Tagging year and month	Gear	Numbers tagged	Recaptures (numbers and %) in calendar years after tagging year: years 0	1	2	3	4	5	6	7	8	9	10	13	15	16	7	Total
Umanak district	1935,36	LL	106	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Div. 1A	July-August				1.9														1.9
	1960,62	LL	288	-	6	3	4	1	-	-	-	-	-	-	-	-	-	2	16
	August				2.1	1.0	1.4	0.4										0.7	5.6
	1978-81,83	LL	80	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	4
	Sept.-Oktober				2.5	2.5													5.0
		ST	37	-	-	-		-	-	-	-	-	-	-	-	-	-	-	0
																			0.0
Jakobshavn distr.	1935,36	LL	441	22	53	26	2	4	3	-	-	-	-	-	-	-	-	5	115
Div. 1A	Aug.-September			5.0	12.0	5.9	0.5	0.9	0.7									1.1	26.1
	1960	LL	47	1	4	4	1	1	-	-	-	-	-	-	-	-	-	-	11
	August			2.1	8.5	8.5	2.1	2.1											23.4
	1973,75	ST	269	2	-	3	1	-	-	-	-	-	-	-	-	-	-	-	6
	June-July			0.7		1.1	0.4												2.2
Godthåb Fiord	1935,36	LL	216	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Div. 1D	May-June																		0.0
	1955	LL	95	-	-	-	-	-	-	-	-	2	1	1	-	-	-	-	4
	May-Oktober											2.1	1.1	1.1					4.2
		ST	15	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
										6.7									6.7
	1959	LL	151	-	4	3	4	2	5	2	-	-	1	-	1	-	-	-	22
	Aug.-Oktober				2.7	2.0	2.7	1.3	3.3	1.3			0.7		0.7				14.6
		ST	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
																			0.0
	1964	ST	47	-	-	2	1	-	-	-	-	-	-	-	-	-	1	-	4
	September					4.2	2.1										2.1		8.5
	1968,69,70,71	LL	1637	38	108	84	60	27	12	5	1	-	-	-	-	-	-	-	335
	February-May			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
	1978	LL	5	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
	September					20.0													20.0
Ameralik Fiord	1964	LL	27	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	2
Div. 1D	Sept.-Oktober				3.7											3.7			7.4
		ST	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
																			0.0
	1978,79	LL	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Aug.-September																		0.0
Arsuk Fiord	1937	LL	194	1	-	-	2	1	-	-	-	-	-	-	-	-	-	-	4
Div. 1E	July			0.5			1.0	0.5											2.1
Tunugdliarfik Fiord	1937	LL	6	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Div. 1F	September				33.0														33.0
	1957,58,59	ST	154	1	4	1	-	1	3	-	-	-	-	-	-	-	-	-	10
	March-December			0.6	2.6	0.6		0.6	1.9										6.5
Lichtenau Fiord	1937,38,39	LL	128	1	20	12	1	3	-	-	-	1	-	-	-	-	-	-	38
Div. 1F	August-Sept.			0.8	15.6	9.5	0.8	2.3				0.8							29.7
	1952,54	LL	57	-	3	3	-	-	2	2	-	-	-	-	-	-	-	-	10
	August				5.3	5.3			3.5	3.5									17.5
	1984	LL	40	-	7	1	-	-	-	-	-	-	-	-	-	-	-	-	8
	Sept.-Oktober				17.5	2.5													20.0
Total for longline	experiments		3515	63	211	139	74	39	22	9	1	3	2	1	1	1	1	7	574
				1.8	6.0	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

LL = longline experiments
ST = shrimp trawl experiments
FT = fish trawl experiment

Table 3. Percentage of females in 5 cm groups in catches of Greenland halibut. Numbers of fish indicated in brackets.

		Length 40-44		45-49		50-54		55-59		60-64		65-69		70-74		75-79		80-84		>85	
Godthåb Fiord																					
July	1986[1]			37	(19)	61	(294)	57	(199)	71	(79)	79	(24)	67	(6)			100	(1)		
Jan-April	1987[1]			0	(2)	51	(231)	55	(562)	54	(197)	63	(70)	89	(19)	100	(6)	100	(2)		
January	1987[2]	33	(6)	57	(23)	49	(119)	62	(233)	71	(84)	74	(34)	94	(17)	100	(4)	100	(4)	100	(3)
Total		33	(6)	45	(44)	55	(644)	57	(994)	62	(365)	69	(128)	88	(41)	100	(10)	100	(7)	100	(3)
Jakobshavn district																					
Sept-Oct	1985[2]	100	(1)	50	(8)	55	(69)	53	(158)	46	(214)	71	(150)	70	(54)	94	(18)	100	(7)	100	(2)
March	1986[1]					50	(10)	54	(157)	59	(233)	70	(249)	67	(220)	82	(109)	93	(69)	100	(175)
March	1986[2]	33	(3)	33	(6)	52	(21)	67	(43)	79	(24)	62	(37)	73	(30)	41	(22)	95	(20)	100	(60)
March	1987[1]	50	(2)	13	(8)	32	(53)	37	(366)	48	(751)	57	(551)	63	(296)	80	(158)	91	(57)	100	(27)
March	1987[2]					67	(3)	50	(6)	85	(20)	80	(15)	56	(39)	92	(36)	95	(38)	100	(243)
Total		50	(6)	32	(22)	47	(156)	48	(732)	51	(1342)	63	(1002)	65	(639)	80	(343)	93	(191)	100	(505)
Umanak district																					
September	1985[2]	100	(2)	50	(8)	42	(24)	48	(27)	70	(40)	61	(38)	88	(26)	96	(26)	100	(9)	100	(13)
July-Aug	1986[1]					33	(6)	58	(38)	44	(194)	50	(408)	66	(385)	78	(212)	88	(101)	100	(52)
March	1987[1]									35	(17)	39	(85)	55	(162)	77	(131)	92	(83)	100	(75)
March	1987[2]					50	(2)	0	(2)	56	(9)	39	(18)	51	(35)	80	(15)	85	(13)	100	(15)
Total		100	(2)	50	(8)	41	(32)	52	(67)	48	(260)	49	(549)	63	(608)	79	(384)	90	(206)	100	(155)
Upernavik district South																					
July-Aug	1986[2]					40	(5)	76	(25)	63	(209)	58	(534)	71	(641)	92	(741)	98	(484)	100	(390)
Upernavik district North																					
July-Aug	1986[2]							77	(52)	70	(269)	74	(383)	86	(193)	97	(109)	100	(105)	100	(140)
TOTAL		50	(14)	42	(74)	53	(838)	52	(1840)	56	(2440)	61	(2622)	68	(2094)	87	(1587)	94	(993)	100	(1193)

1) from gillnet catches 2) from longline catches

*p<0.05 **p<0.01 (one tailed binomial test)

Table 4. Descriptive stages of maturity used for visual analyses of Greenland halibut gonads (modified after Walsh & Bowering, 1981).

stage	description
females	
I	Juvenile or immature; ovary very small, eggs not visible to naked eye.
II	Maturing (A): eggs becoming visible to the naked eye, all eggs opaque.
III	Maturing (B): eggs 1-2 mm in diameter, mixture of opaque and clear eggs with less than half of eggs clear.
IV	Maturing (C): eggs 3-4 mm in diameter, mixture of opaque and clear eggs with more than half off eggs clear. 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 in appearence, wall is thick and tough, some residual clear or opaque eggs are seen.
males	
I	Juvenile or immature. Testes very small and mostly clear.
IV	Maturing: testes big and white, the ripe condition.
V	Running stage: sperm is running.

Table 5. Maturity stages of Greenland halibut from Jakobshavn and Umanak, March 1987. Percentages for each length group are indicated in brackets.

	Stages of maturity									
	females, Jakobshavn			females, Umanak					males, Umanak	
Length (cm)	I	II	III	I	II	III	IV	VI	I	IV/V
50-54	3(100)									
55-59	19 (83)	4 (17)							1(100)	
60-64	23 (70)	8 (24)	2 (6)	6 (60)	4 (40)				27 (96)	1 (4)
65-69	6 (17)	28 (80)	1 (3)	14 (37)	24 (63)				112 (97)	4 (3)
70-74	5 (11)	38 (83)	3 (6)	8 (17)	38 (81)	1 (2)			166 (81)	38 (19)
75-79	2 (4)	39 (83)	6 (13)	7 (12)	40 (70)	9 (16)	1(2)		69 (85)	12 (15)
80-84		31 (74)	11 (26)	1 (2)	32 (59)	21 (39)			11 (61)	7 (39)
85-89	2 (7)	19 (61)	10 (32)		21 (54)	17 (44)	1(2)			1(100)
90-94		12 (55)	10 (45)		10 (31)	20 (63)		2(6)		
95-99	2 (17)	6 (50)	4 (33)		5 (26)	14 (74)				
100-104		6 (55)	5 (45)			4(100)				
>104	1 (17)	5 (83)				5(100)				
Total	62 (20)	192 (61)	57 (19)	36 (12)	174 (57)	91 (29)	2(1)	2(1)	386 (86)	63 (14)

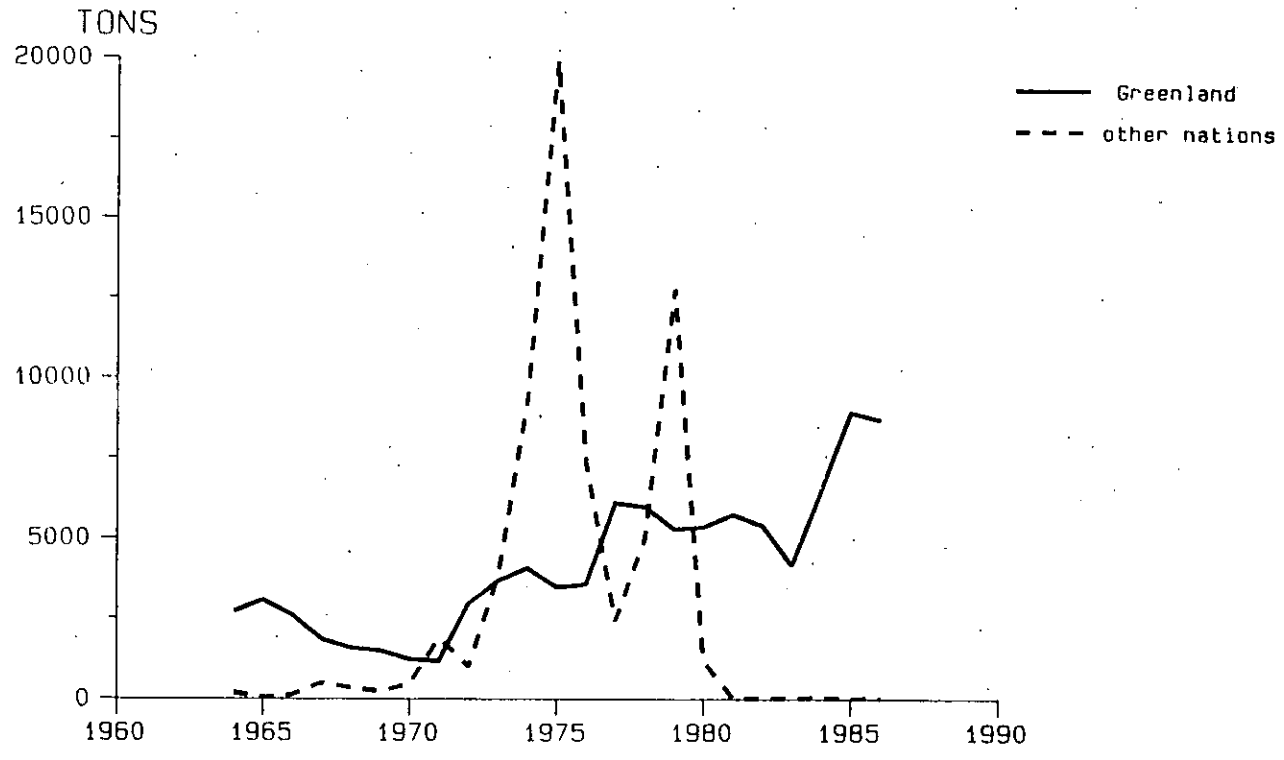


Fig. 1. Annual catches of Greenland halibut in Subarea 1, 1964-86 (from NAFO Stat. Bull.).

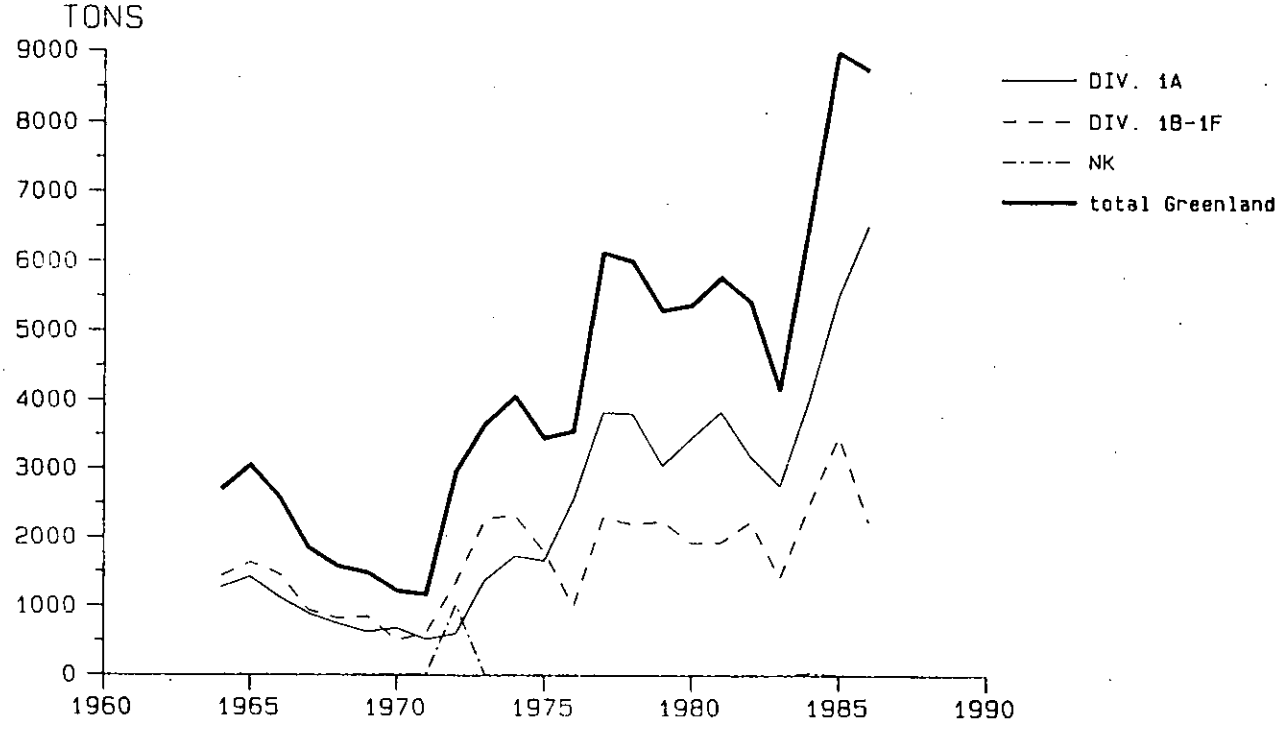


Fig. 2. Annual catches of Greenland halibut by Greenland in Subarea 1 by Division (from NAFO Stat. Bull.).

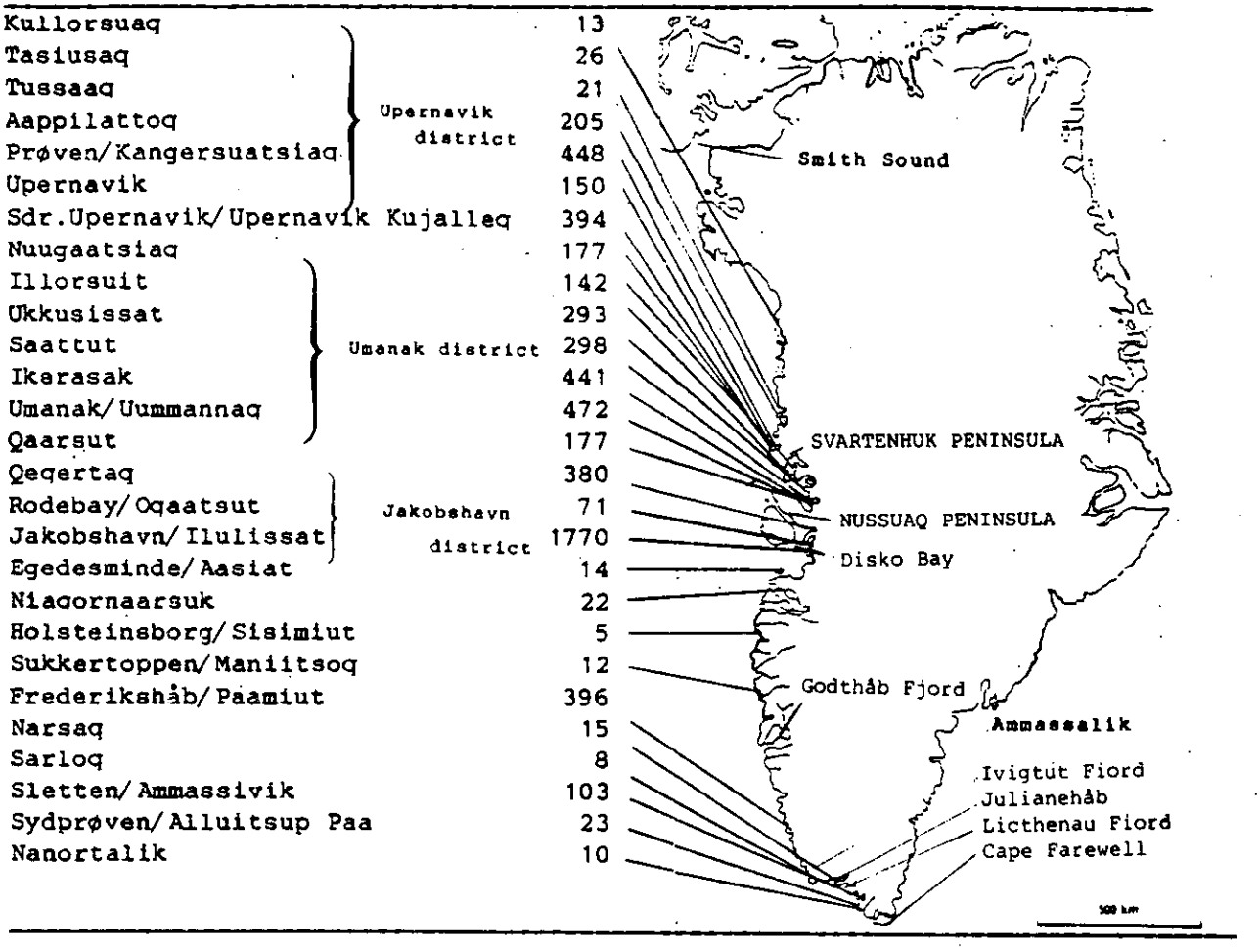


Fig. 3. 1986 landings of Greenland halibut in West Greenland (in tons). Landings to private fishery plants are not included. Provisional data (Statistics from the Greenland Home Rule, KTU).

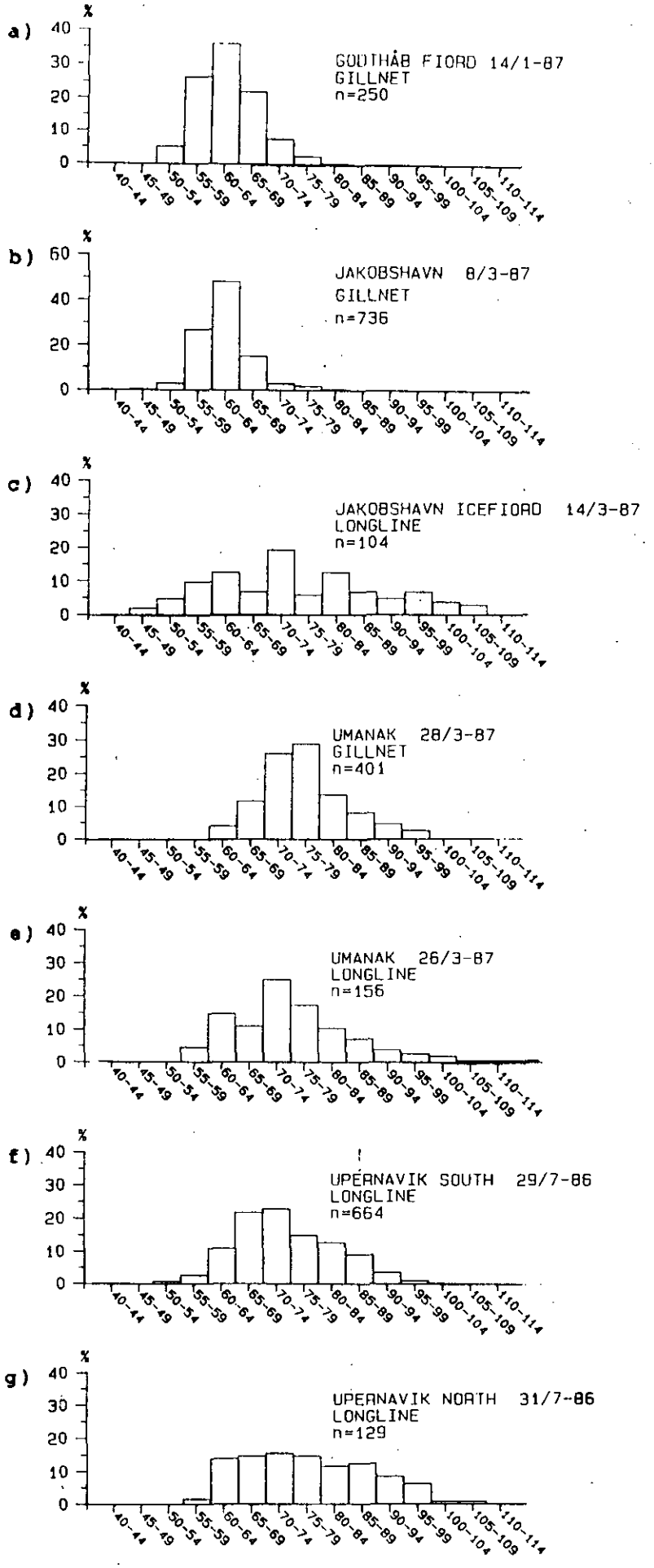


Fig. 4. Length distributions of Greenland halibut from the commercial fishery in different areas.

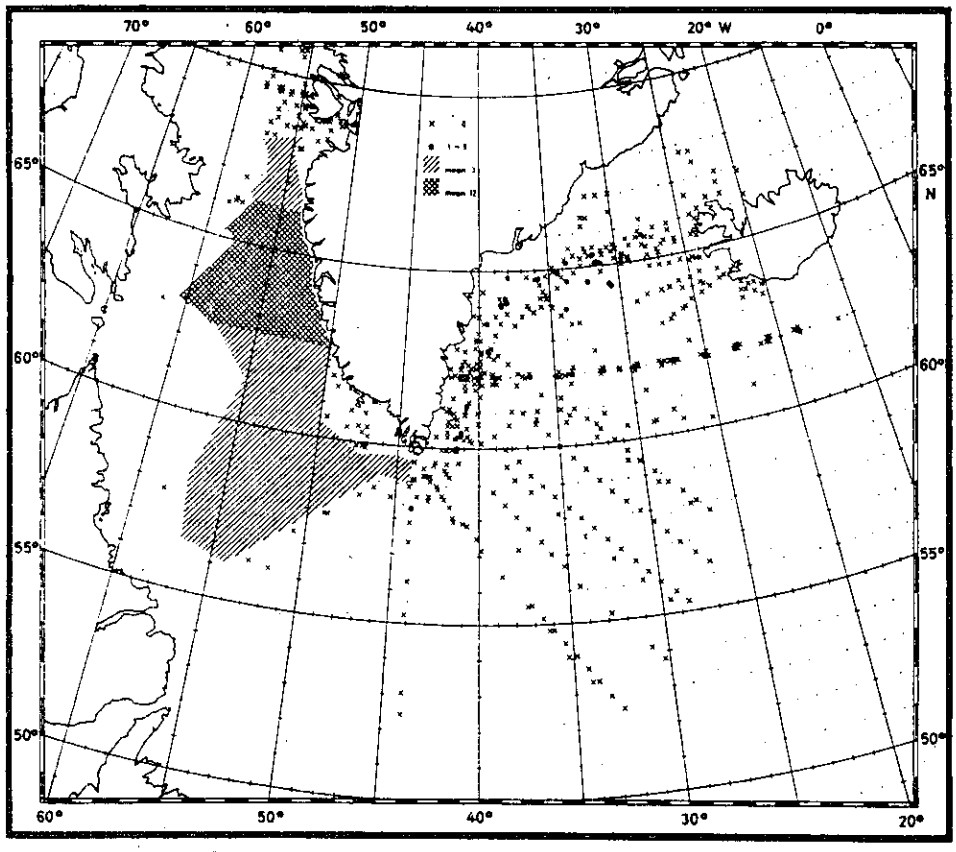


Fig. 5. Distribution of pelagic larvae, all data from West Greenland waters from 1908 to 1964 and from East Greenland-Iceland waters from 1925 to 1964. West Greenland waters : hatched area indicates frequent occurrence (cross-hatched area : 12 larvae per 30 minutes haul, diagonal-hatched areas : 3 larvae per 30 minutes haul). East Greenland-Iceland area : black circles indicate stations with few larvae (never more than 5 per 30 minutes haul). Outside the hatched area the stations with no larvae are shown as crosses. (from Smidt, 1969)

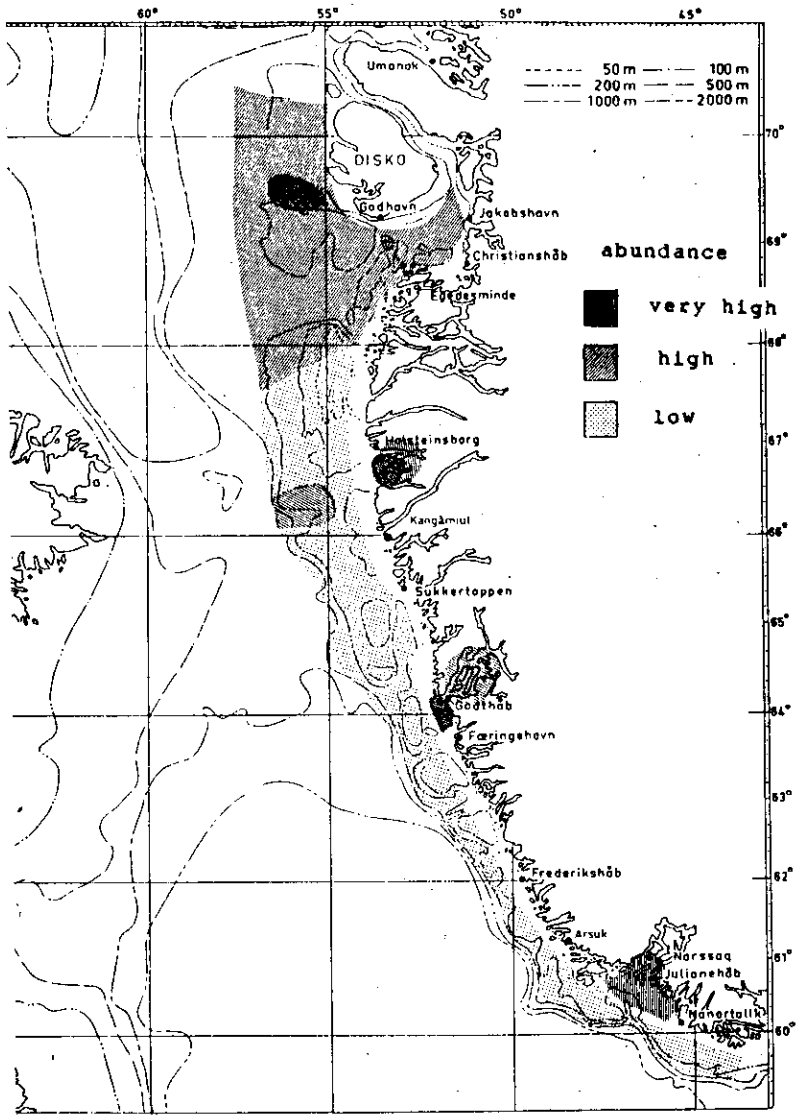


Fig. 6. Map of the relative abundance of young bottom stages of Greenland halibut based on the informations in Riget & Boje, 1987b and Smidt, 1969. Data covers a wide range of years and should only be taken as a rough indication of the distribution pattern. Outside the hatched area no investigation has been made.

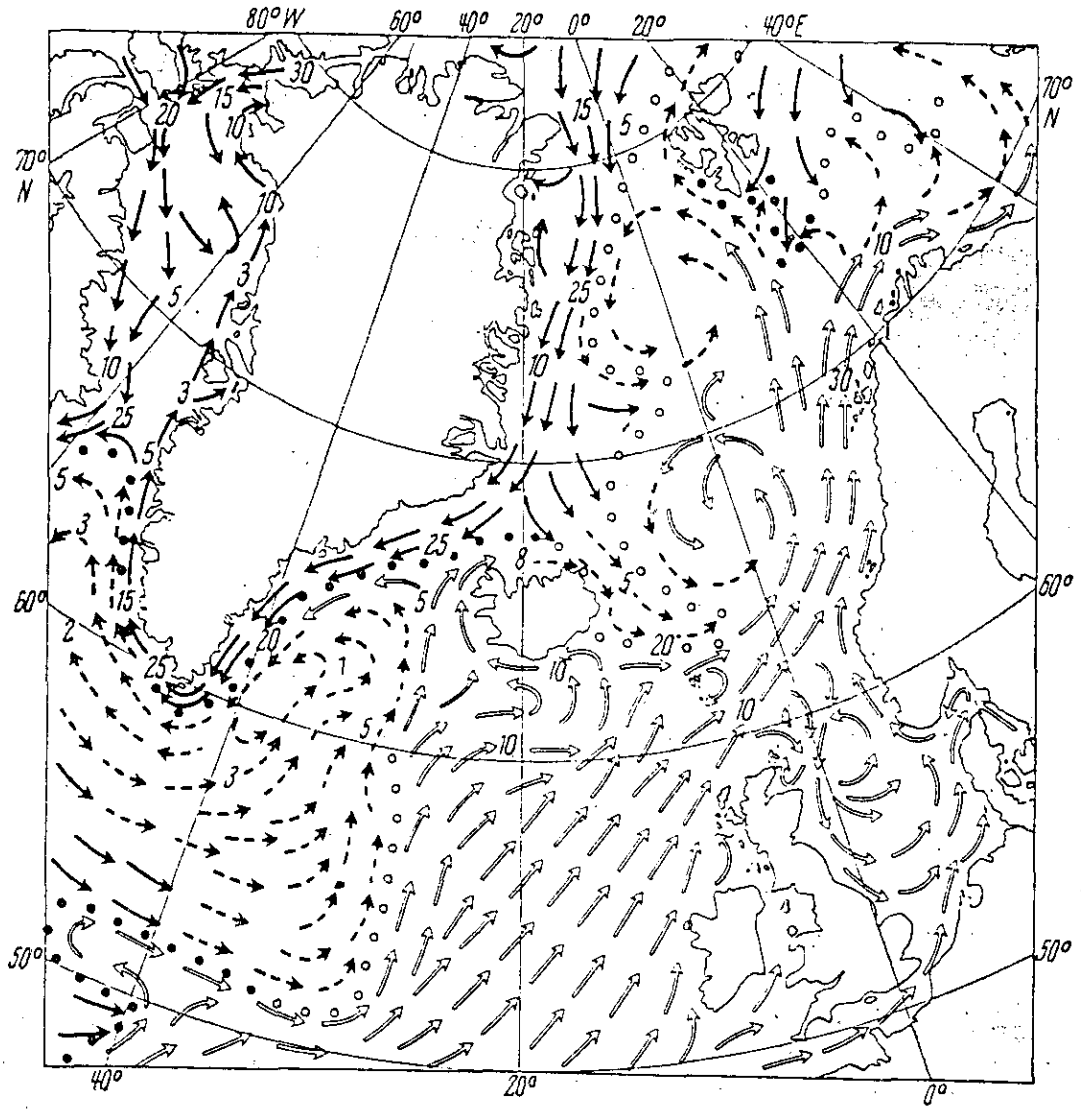


Fig. 7. Surfacecurrents in the northern p rt of the Atlantic Ocean.

⟹ Atlantic water
⟶ Polar water
⟶ Mixed water
• • • ○ ○ ○ Polar front

The numbers represents the current speed in cm/s.

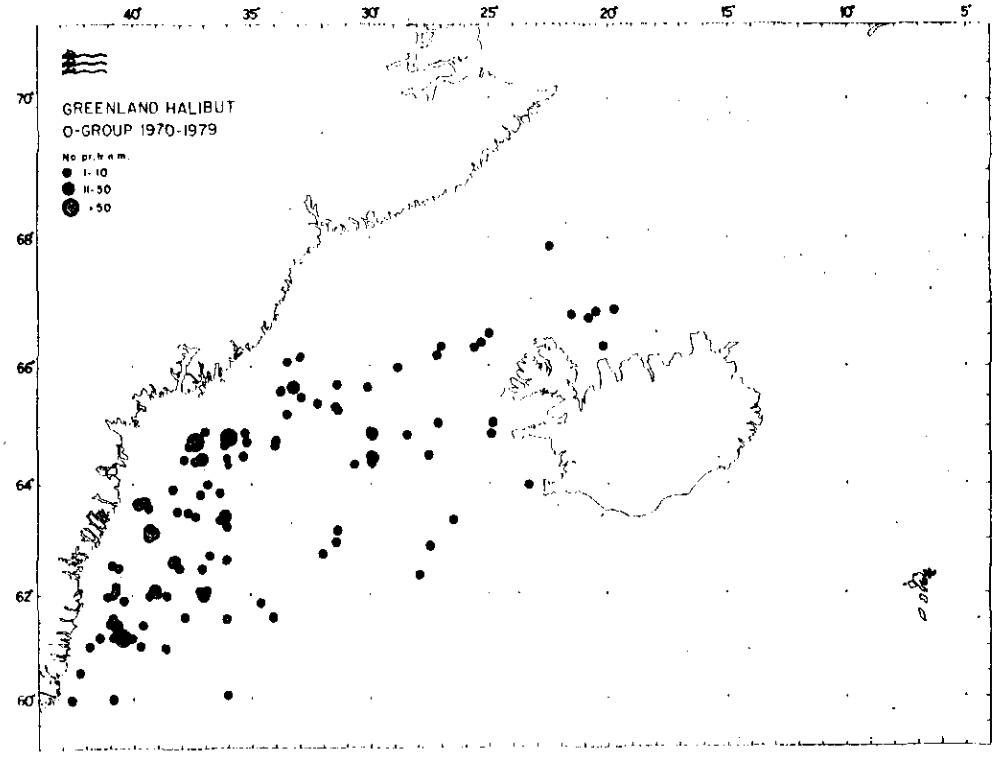
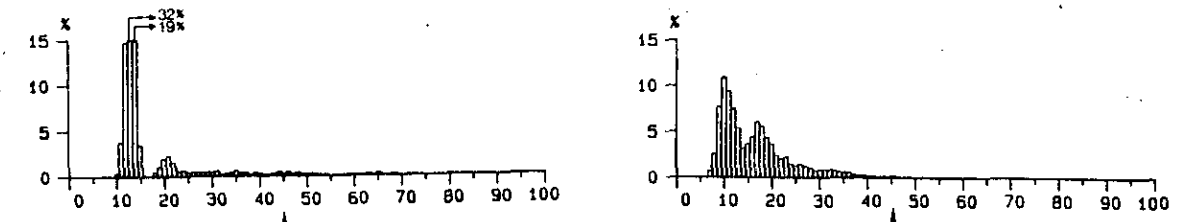
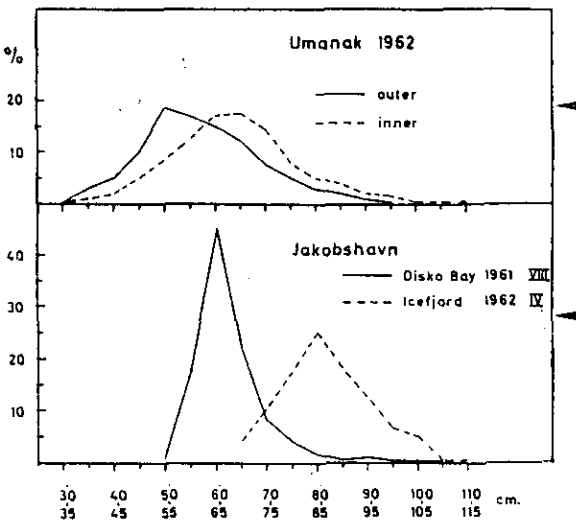


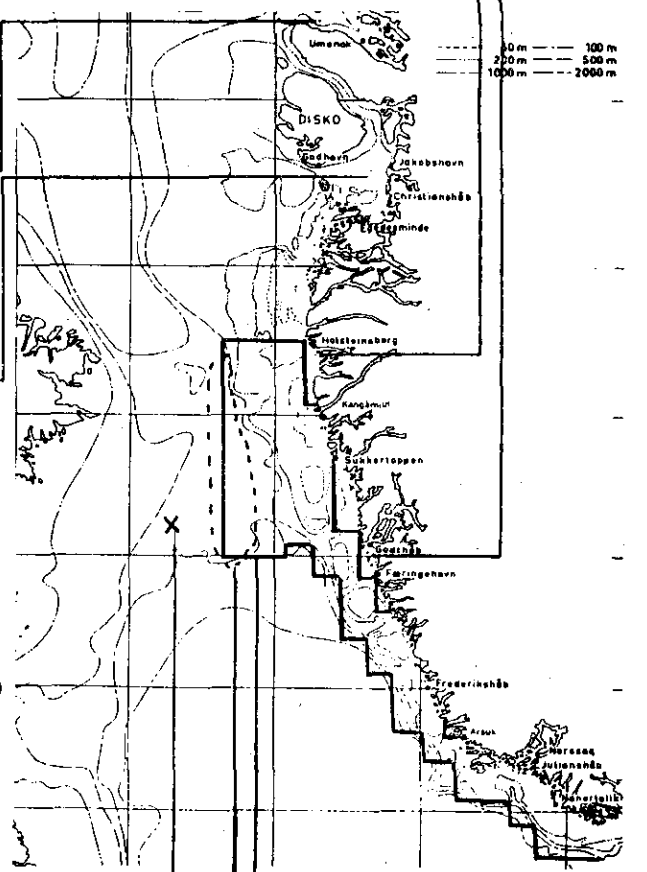
Fig. 8. Distribution and abundance of 0-group Greenland halibut from Icelandic 0-group surveys 1970-79. (from Sigurdsson & Magnusson, 1980). Surveys from 1982-85 have showed a similar pattern of distribution (Vilhjalmsson & Magnusson, 1982,83,84,85).

a) research shrimp trawlings (from Riget & Boje, 1987b)

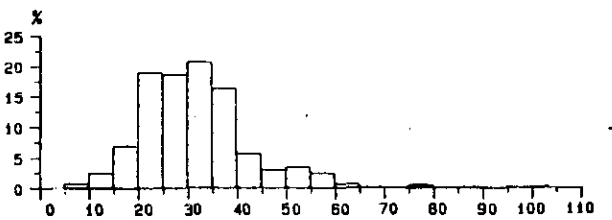


b) long line catches (from Smidt, 1969)

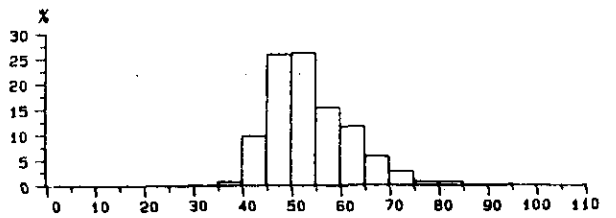




c) German bottom trawl surveys (from Riget & Boje, 1987b)



d) research trawlings, "Dana" 1974



e) research trawlings (from Konstantinov & Noskov, 1974)

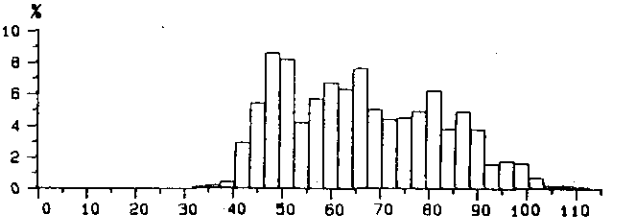
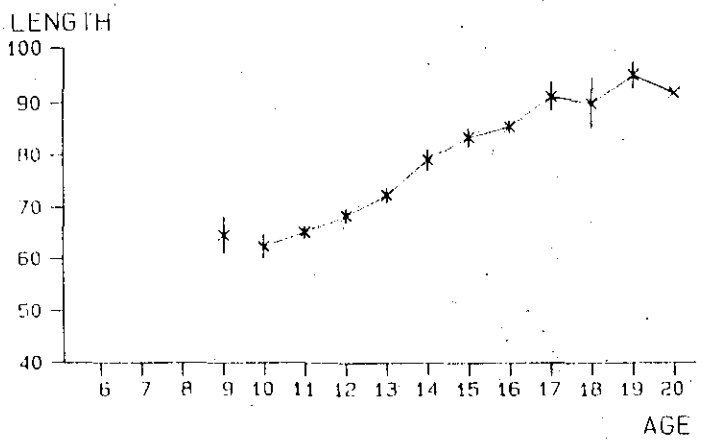
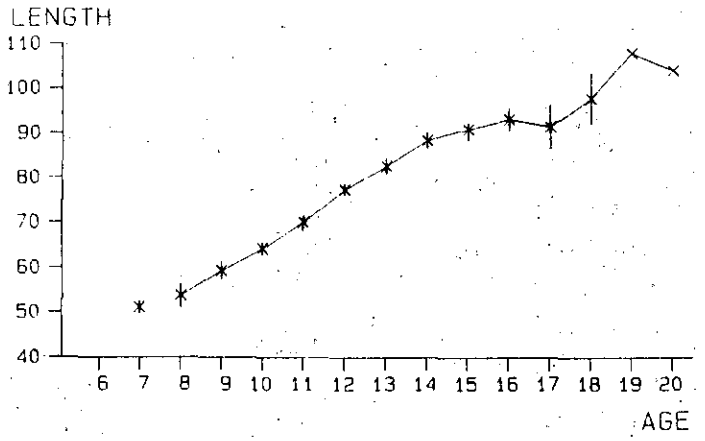


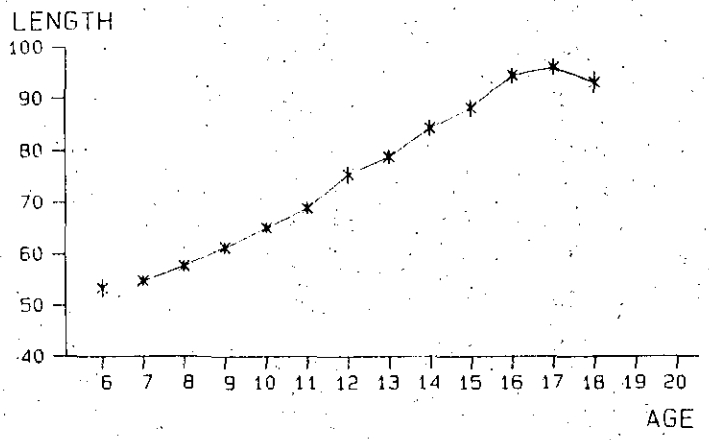
Fig. 9. Size distributions of Greenland halibut at different places at West Greenland (see text).



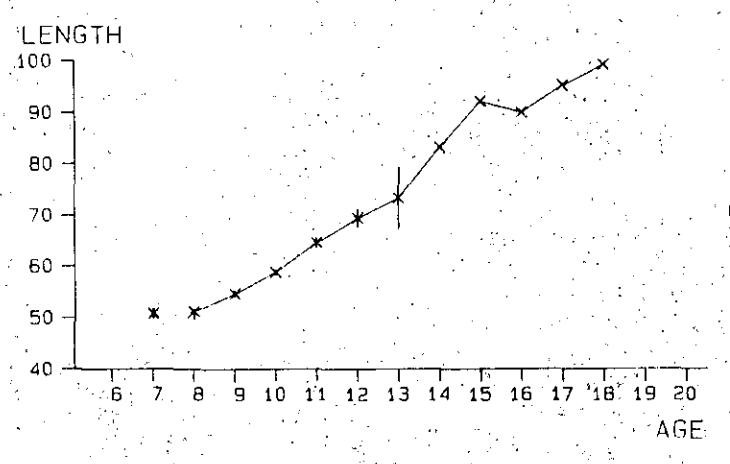
Upernavik district



Umanak district

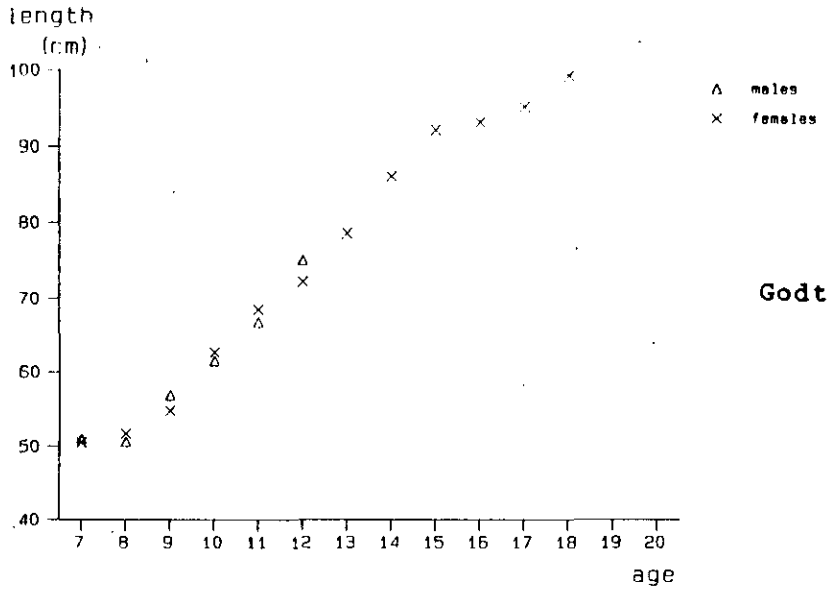


Jakobshavn district

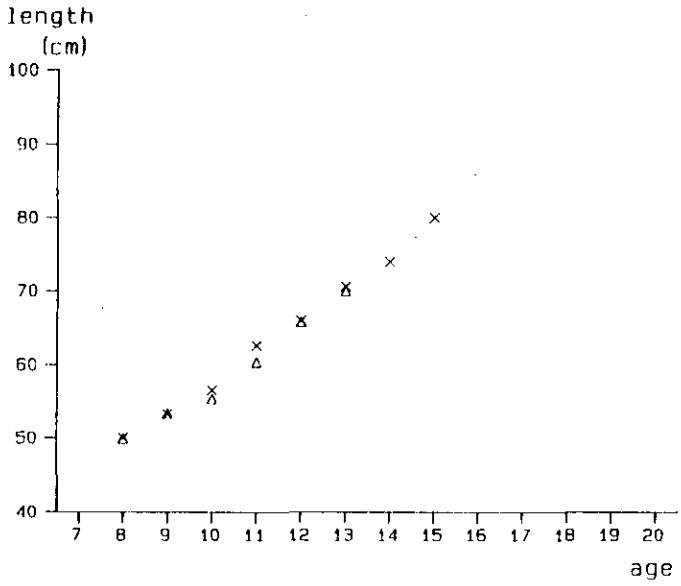


Godthåb Fiord

Fig. 10. Mean length at age from commercial catches in four districts at West Greenland. Vertical lines represent mean ± 2 X S.E.



Godthåb Fiord, March 1986



Godthåb Fiord, July 1986

Fig. 11. Mean length at age by sex for commercial catches in the Godthåb Fiord.

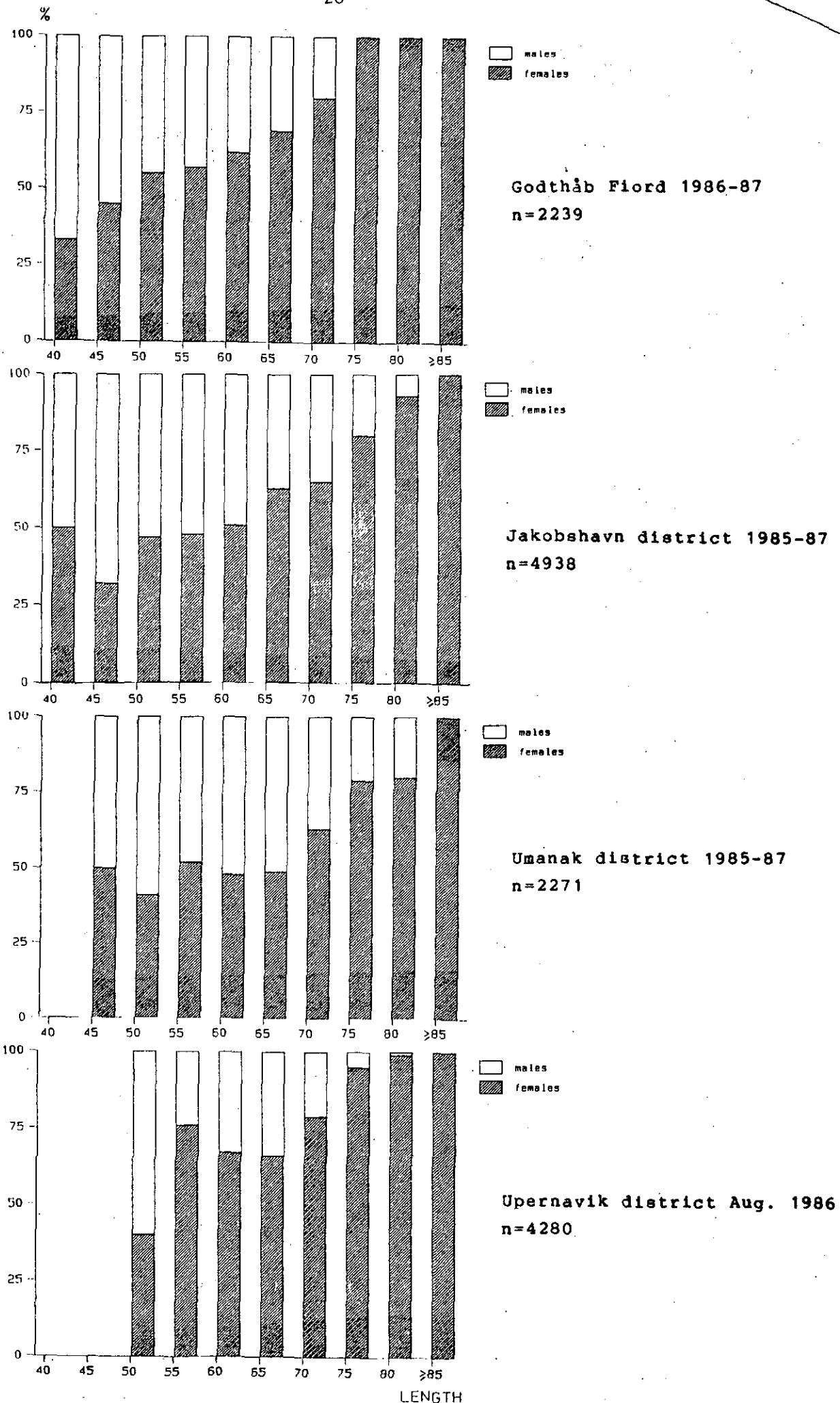


Fig. 12. Ratio of males to females of Greenland halibut.

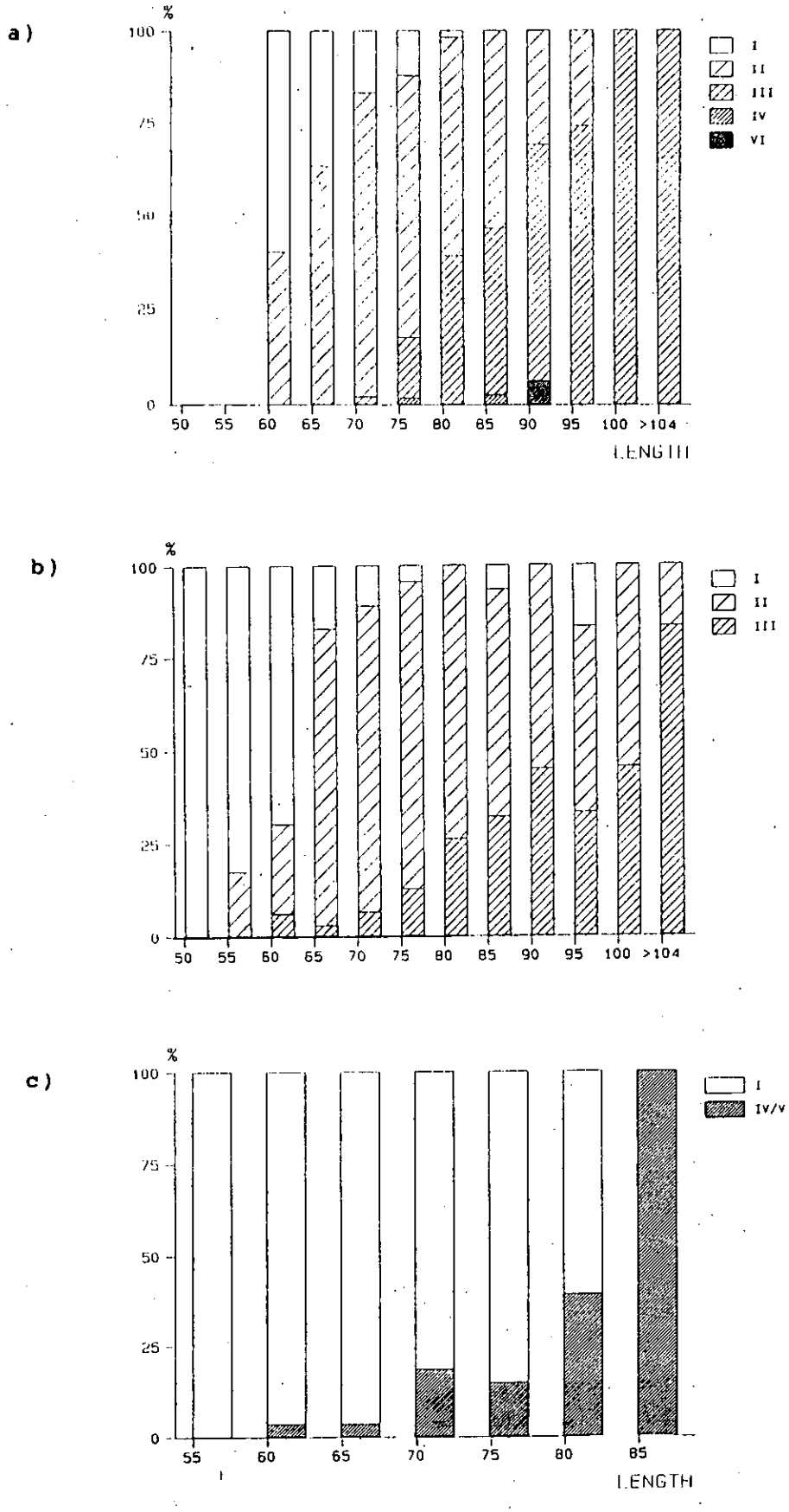


Fig. 13. Stages of sexual maturity of Greenland halibut, 5 cm groups. Maturity staying after Walsh & Bowering (1981) (see Table 4). For males in length group 85 cm only 1 fish is represented.

a) females, Umanak district, March 1987.
b) females, Jakobshavn district, March 1987.