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Intermingling and Seasonal Migrations of Greenland Halibut Stock Components in the Northwest Atlantic Based on Tagging Studies

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Abstract

A study was carried out to clarify the stock discreteness and migration routes of Greenland halibut in the Northwest Atlantic and to describe the seasonal movements of several fjord populations.

From a total of 7244 Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum) tagged in Greenland waters between 1986 and 1998, 517 recaptures were recorded in the Northwest Atlantic area. Among halibut released in the Davis Strait, Baffin Bay, and the fjords of southwestern and eastern Greenland, a substantial portion migrated distances up to 2500 kilometres, primarily to the Denmark Strait between Greenland and Iceland, but also from the fjords of western Greenland to the Newfoundland coast. These recaptures were mainly larger specimen, indicating a prespawning migration. Estimating the age of recaptures based on length provided evidence that some Greenland halibut inhabiting the Davis Strait and the fjords of southwestern and eastern Greenland originate in the spawning grounds west of Iceland. The prevalent high mobility of Greenland halibut from Baffin Bay and the Davis Strait in these areas suggests that extensive feeding and prespawning migrations occur for these offshore halibut populations.

Greenland halibut in the fjords of northwestern Greenland appear to be resident and do not intermingle with other offshore or more southerly inshore populations. Some intermingling of populations was observed in the northwestern fjords and a seasonality in the recovery pattern indicates an aggregation of Greenland halibut in the inner part of fjords in the second half of the year, while the population was more dispersed during the first half of the year. The data suggests that such seasonal movement may be related to feeding behaviour.

Keywords: Greenland halibut, migrations, stock affinities, Northwest Atlantic, tags, seasonal movements

Introduction

Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), is widely distributed in the Northwest Atlantic. Their natural range covers an extensive geographical area—from Smith Sound, between Greenland and Canada, southward throughout Baffin Bay and the Davis Strait to the northeastern coast of the U.S.A. and eastward along eastern Greenland to Iceland (Bowering and Brodie 1995; Smidt 1969). Spawning grounds of Greenland halibut are believed to be located southwest of Iceland (Sigurdsson 1979) and in the deeper regions of the Davis Strait (Atkinson *et al.* 1982, Smidt 1969). The halibut populations off the eastern coast of Canada, in the Davis Strait, in the fjords of western Greenland, in the Denmark Strait, and in Icelandic waters are believed to be recruited from these spawning grounds (Sigurdsson 1979, Templeman 1973). Several investigations have been carried out to determine the interactions among different local populations of Greenland halibut in the Northwest Atlantic. These studies have considered and, in some cases, attempted to quantify meristic characteristics (Templeman 1970, Misra & Bowering 1984, Riget *et al.* 1992), genetic variability (Fairbairn 1981, Rasmussen et al. 1999, Riget *et* al. 1992, Vis et al. 1997), indicator parasites (Boje et al. 1997, Khan et al. 1982), and tagging data (Boje 1993, Bowering 1984, Riget & Boje 1989, Smidt 1969). The results of these investigations suggest that the entire halibut population between Greenland and Canada originates from a common spawning stock in the Davis Strait. There is some evidence that the populations between Greenland and Iceland originate from a stock with spawning grounds situated along the continental slopes west of Iceland. It was also observed that some halibut populations seem to maintain a degree of isolation without any prespawning migration from their original spawning areas; this is characteristic of the Greenland halibut population in the Gulf of St. Lawrence (Khan *et al.* 1982) as well as for the populations in the fjords of northwestern Greenland (Riget & Boje 1989). Spawning has been observed in the Gulf of St. Lawrence (Bowering 1980), while only a few ripe females have been sighted in the fjords of western Greenland (Riget and Boje 1989).

Previous tagging experiments in the fjords of western Greenland (Boje 1993, Riget & Boje 1989, Smidt 1969) suggest that halibut stocks in the southernmost fjords might be recruited from Icelandic spawning grounds. The Irminger Current and the East Greenland Polar Current carry eggs and larvae from these spawning grounds to eastern Greenland and probably as far as southwestern Greenland (Boje 1997. Sigurdsson 1979). In 1959 Smidt (1969) observed the recapture of Greenland halibut west of Iceland that had been tagged in Licthenau Fjord in southwestern Greenland in 1954. Riget and Boje (1989) reportedly observed a recapture of halibut west of Iceland in 1980 that had been tagged in Godthaab Fjord in 1964.

In the present study, tagging experiments in the fjords of eastern and western Greenland from 1986 to 1998 are evaluated in order to clarify the stock discreteness of Greenland halibut populations in the Northwest Atlantic and to describe seasonal migrations of halibut in inshore areas.

Materials and Methods

Greenland halibut from four areas around Greenland were tagged between 1986 and 1998. The tagging was carried out in the fjords of eastern Greenland at Ammassalik in September 1990, in the fjords of southwestern Greenland from Cape Farewell to Godthaab Fjord in January 1987-1988, in the fjords of northwestern Greenland from Disko Bay to Upernavik during July-August 1986-1998, and off western Greenland from the Davis Strait to Baffin Bay during May-August 1991-1993 (Table 1, Figure 1). Research vessels employed with longlines caught all fish sampled for tagging. Squid, capelin, and mackerel were used as bait. The fishing depth was generally between 400 and 900 meters. The fishing time for line settings was approximately six hours.

A landing net was placed under each fish from the time it left the water until the fish was onboard the ship in order to avoid damage by the hook due to gravity when the specimen was removed from the water. The hook was removed with extreme care and only fish hooked in the mouth region were selected since injuries to the mouth are usually minor and nonfatal. The condition of the fish was judged visually, mainly by examining the colour of the gills, to ensure that the hook did not result in internal injuries. The length of the fish was measured to the nearest full centimetre (total length) and only fish with a length above 35 cm were selected for tagging. Each fish was tagged in the musculature with a yellow T-bar tag just below the dorsal fin-ray near the head. Immediately after tagging, the fish was released by putting it directly into the sea without the use of any mechanical devices.

In order to analyse for seasonal movements among ‘resident’ recaptures (i.e., fish caught less than 100 km from the release site) of northwestern Greenland, the fjords were stratified into five rectangles of equal area, and positioned in an east-west direction. A random walk model (Skellam 1951) was applied to the distribution of all releases (n= 4319) pooled for the entire period, 1986-1998, for all five areas assuming equal probability that the fish would migrate either east or west, or remain in the area (p=0.33). The model operated on a time unit of three months thereby allowing each fish to move from only one rectangle to the next rectangle within a quarter of a year. The model was extended to cover a total of eight years, which was the maximum period of time recorded for a release at sea. The random walk distribution was compared to the true recapture distribution by means of a Chi-square test. The true recapture distribution was corrected for fishing effort using the frequency of recaptures per unit landing in a statistical square (smallest statistical unit to assign landings), where landings were monthly averages for the period 1993-1997. Landings were used instead of effort as effort data were not available for the inshore fishery. However, landings for the inshore areas of western Greenland were found to correlate with fishing effort (Anon. 1998).

Fishermen seldom provide length at recapture and, if provided, the length is often not reliable, e.g., the length given at recapture may be smaller than release length. In order to analyse the effect of fish size on the distance migrated, a linear growth pattern with an annual growth rate of 5 cm was assumed (Boje and Jørgensen 1991) based on the initial recorded length at release.

In order to determine if the distance migrated was size dependent, a step-wise ANOVA was performed for the three effects: tagging area, a log-transformed migration distance, and the interaction of both effects on estimated length at recapture. Step-wise regressions were performed, adding the combined effect of the two variables, to examine if size and distance were correlated. F-tests were used to evaluate the two models. Differences in recapture length between resident fish and long-distance migrants were tested by a posteriori mean range test for pairwise comparisons (Tukey's Studentized Range Test, SAS 1988).

Since the probability of tag recovery was dependent on the commercial fishery and, consequently, on the return of tags by fishermen, informative posters announcing the purposes of the tagging experiments were displayed in publicly accessible places and a reward of DKK 100 (approximately US $14) was offered for each tag returned with information on catch position, gear used, and the date of catch.

Migration distances reported here are given in metric kilometres (1 km = 0.540 nautical mile). All estimated migration distances are straight-line distances between the release site and the recovery site. Analyses in this study were carried out by use of a spreadsheet (Excel) and SAS statistical software (SAS 1988).

Results

A total of 7244 Greenland halibut were tagged in studies from 1986-1998. By the end of 1998, 517 recaptures (i.e., 7.1% of halibut released during the period of study) were reported (Table 1). The majority of records were recorded within two years after tagging, but some recoveries were reported as late as eight years after tagging. In general, Greenland halibut tagged in the fjords of northwestern Greenland tended to be resident while Greenland halibut from the three other tagging sites were more migratory.

Prevailing migratory patterns

An overview of release and recovery sites from the studies is presented in Table 2. Seventy percent of Greenland halibut recovered from releases in the fjords of eastern Greenland, Ammasalik, were recovered near the release site, while the remaining 30% were recorded by the fishery located west of Iceland in the Denmark Strait and one specimen migrated as far as the Faroe Islands. Greenland halibut recovered from releases in the fjords of southwestern Greenland (55 specimen) were mostly recaptured at the release site (approximately 80%), while the remaining 20% were captured in the Denmark Strait. The majority of releases from the most comprehensive tagging experiments in the fjords of northwestern Greenland were recaptured at the tagging site (approximately 90%), this observed fidelity was most pronounced in the northern areas of the fjord system at Uummannaq and Upernavik. However, some intermingling between halibut populations from Ilulissat and Torsukatteq appeared to occur (8-16%); limited intermingling was also noted between the populations of Ilulissat and Uummannaq (1-4%). No releases from the fjords of northwestern Greenland were recaptured outside the fjord system comprised of Disko Bay, Uummannaq, and Upernavik. Of the halibut released in the offshore areas of western Greenland, i.e., Davis Strait and Baffin Bay, about 67% were recovered in the Davis Strait, while the remaining 33% were recaptured in the inshore fjord of northwestern Greenland (Torsukatteq) and offshore as far as the Denmark Strait (eastern Greenland) and Newfoundland (Flemish Pass).

Long-distance migrants

Several specimen were recovered at substantial distances from the release sites. Greenland halibut tagged in the Godthaab Fjord and recaptured in the Denmark Strait migrated an average of approximately 1100 kilometres, while fish released in the Godthaab Fjord and the Davis Strait and recaptured off Newfoundland migrated an average of 1800 kilometres. A schematic overview of release origin for long-distance recoveries in selected offshore areas is shown in Figure 2. A single recapture north of the Faroe Islands originated from Ammassalik in eastern Greenland. All recaptures in the Denmark Strait originated from inshore areas of eastern and southern Greenland or from offshore areas of western Greenland; comprising about 20% of the recaptures from these tagging sites. The percent recaptured increased from 13% in western Greenland to 26% in eastern Greenland. Recaptures off Newfoundland originated from releases in the Davis Strait and Godthaab Fjord, contributing 10% and 2%, respectively. Two recaptures (i.e., 10%) from Baffin Bay were recorded in the inshore northern fjord of Disko Bay (Torsukatteq).

A cumulative distribution of estimated migration distance for each main release area (see Figure 3) revealed that Greenland halibut from the offshore area of western Greenland were the more frequent long-distance migrants. For all migration distances, recaptures from offshore western Greenland were the most significant when measured as percent of total recaptures in an area. About 30% of recaptures of Greenland halibut from eastern Greenland fjords migrated 400 kilometres or more. Approximately 20% of halibut from the fjords of southwestern Greenland migrated 1000 kilometres or more.

Effect of fish length

In order to determine whether tagging site, distance migrated, or the two effects combined correlated with estimated recapture length, a step-wise regression revealed that a 'full' model (including all three effects) fit the data significantly better than a 'reduced' model (without the combined effect) ($F_{1,\ 513}$=8.57, p<0.01). The ANOVA showed that fish length and distance migrated correlated significantly only for halibut from the fjords of northwestern Greenland and the offshore area of western Greenland. A box plot of distance migrated by length at recapture, as shown in Figure 4, indicates that distance migrated sharply increased for specimen ≥80 cm, only for halibut from the fjords of southwestern Greenland. A clear trend was not detected for halibut from the offshore area of western Greenland or from the fjords of eastern Greenland, but fish ≥55 cm generally migrated longer distances than smaller fish. A weak trend of greater length at recapture for longer distances migrated was noted for halibut from the fjords of eastern Greenland. It was apparent that all size groups are mainly resident for the fjords of northwestern Greenland. A slightly higher migration activity was seen for the largest size group. A comparison of the estimated length at recapture of resident fish with long-distance migrants for each of the tagging sites that contributed to recoveries in the Denmark Strait showed that resident Greenland halibut in the fjords of southwestern Greenland were significantly smaller than the corresponding non-resident recoveries in the Denmark Strait (Table 3).

Inshore seasonal migration

Recapture data from the fjords of northwestern Greenland were examined to determine whether recapture location is seasonally dependent, i.e., seasonal movements compared the actual recapture distribution with a random dispersal for the same dataset of releases. A distribution of the recaptures was categorised by stratifying the fjords into five rectangles of equal area, ranging from the mouth of the fjord to the innerpart of the fjord. A Chi-square test on the actual recapture distribution compared with the random-walk distribution proved significant (Chi-square: 4.93E+12, df=134, p<0.0001), indicating that Greenland halibut do not migrate randomly in the fjord system but tend to aggregate at specific localities at certain times. Pooling the data by winter (1^{st} and 2^{nd} quarters) and summer (3^{rd} and 4^{th} quarters) and weighting the distribution within each quarter equally also resulted in significantly different distributions between the true data and the random-walk data (p<0.001). The pooled data, shown by quarters (Figure 5), demonstrate that Greenland halibut are rather dispersed in winter (1^{st} and 2^{nd} quarters), but concentrate in the inner parts of the fjords in summer (3^{rd} and 4^{th} quarters). An explanation for the steep gradient between the 1^{st} and 4^{th} quarters may be due to the commercial fisheries, which are virtually dormant between November and February. Data points for the 1^{st} and 4^{th} quarters mainly represent February-March and October, respectively.

Discussion

The high percentage of long-distance recoveries indicates that Greenland halibut is a highly migratory species that can cover distances of nearly 2000 kilometres over a two-year period. The majority of migrations recorded in the present tagging study support the current understanding of stock relationships among halibut populations noted by other researchers; however, cases of single recoveries suggest some links between different halibut populations. This is the case for the single recovery recorded off Newfoundland that was released in Godthaab Fjord two years earlier, as it is believed that Greenland halibut from the fjords of southwestern Greenland could originate from the Icelandic spawning stock (Smidt 1969, Riget et al. 1989, Boje 1993). Releases from Baffin Bay also exhibited a notable recovery pattern, with single recoveries in the northwestern Greenland fjord of Torsukatteq and in the Denmark Strait, which for the latter is a migration distance of about 2500 kilometres. One Greenland halibut released in eastern Greenland at Ammassalik was recaptured north of the Faroe Islands four years after release. This recovery provides evidence for a link between the Greenland halibut population in the Northwest Atlantic and the population in the Northeast Atlantic or at least suggests that some intermingling of halibut populations occurs in the Atlantic Ocean. Previous studies on genetic differentiation have suggested that Greenland halibut in the North Atlantic are rather homogenous (Riget et al.

1992, Vis et al. 1997). Conventional tagging experiments in Iceland (Sigurdsson 1981) revealed 12% of recoveries at long distances east of the release sites (Norway) and as far away as the Barents Sea, suggesting a movement pattern of adults from the Northwest Atlantic to the Northeast Atlantic.

The recoveries in the Denmark Strait comprise 13% to 26% of recoveries in the geographical range from the Davis Strait and the Godthaab Fjord to the fjords of eastern Greenland (Table 2, Figure 2). In general, this implies that an increased portion of the population in the fjords of eastern Greenland originate from the Icelandic spawning stock in the Denmark Strait and west of Iceland. Previous tagging studies confirm this finding (Smidt 1969, Boje 1993) with recaptures off western Iceland released in the Godthaab and Licthenau fjords in southern Greenland. As the mean size of recaptures in the fjords is typically smaller than the mean size of recaptures in the Denmark Strait (Table 3), long-distance migrations to the Denmark Strait are presumed to involve only mature fish. This data provides further evidence for a spawning migration. Genetic studies and studies using parasites as natural tags (Boje et al. 1997, Riget et al. 1992) have shown that Greenland halibut in the fjords of southwestern Greenland differ considerably from the offshore fish belonging to the Davis Strait stock. Riget and Boje (1988) hypothesised that young Greenland halibut in the southernmost coastal areas of western Greenland do not originate from the same spawning grounds as those in the northern part of western Greenland. Larvae distribution studies provide additional information on a link between the populations of southwestern Greenland and those of the Denmark Strait. Magnusson (1977) and later data from Icelandic 0-group surveys 1970-1997 (E.Hjörleifsson, pers. comm.) have identified larvae in a continuous belt from the Icelandic spawning grounds eastward along the continental slope of eastern Greenland and southward to Cape Farewell. Based on investigations on pelagic Greenland halibut eggs and larvae in the western and southeastern Greenland areas, Smidt (1969) and Boje (1997) distinguished between two groups of larvae with different growth patterns. This could arise by the intermingling of larvae originating from two different spawning areas, namely the spawning complex in the Davis Strait and the stock west of Iceland, suggesting that both Greenland halibut eggs and larvae are transported by the East Greenland Current from the Denmark Strait to the southernmost areas of western Greenland, a phenomenon that was shown earlier for cod eggs and larvae (Buch et al. 1994, Tåning 1937). A hypothetical life cycle of the Denmark Strait population could therefore include recruitment of larvae and juvenile fish to the eastern and southwestern regions of Greenland by means of the Irminger Current, later followed by a movement of reproductive adults back to the Denmark Strait.

The resident behaviour of Greenland halibut tagged in the fjords of northwestern Greenland is quite remarkable. Only a few fish have undergone large-scale migrations of 100 to 500 km while the majority has remained within 50 km of the release sites, even during release periods up to eight years in duration. Releases from the fjords of northwestern Greenland have never been reported outside these fjord areas. The residency should of course be seen in the light of almost no fishing activity in Baffin Bay, the offshore area adjacent to the Uummannaq and Upernavik fjord areas, inhibiting recoveries of any offshore migrants in this area. However, an assumed spawning migration to the Davis Strait complex is not plausible, as a considerable fishery has developed in this area since the late 1980s (Anon. 1998). It is therefore consistent with the general assumption that Greenland halibut in the fjords of northwestern Greenland are recruited from the Davis Strait spawning stock (Anon. 1998, Riget et al. 1989, Smidt 1969) and that adults thereafter remain resident in the fjords without undertaking any significant spawning migrations. Some spawners and spent specimen have been observed in the fjords (Smidt 1969, Nielsen and Boje 1995, Riget et al. 1989) showing that spawning may occur in the fjords, at least sporadically. Low bottom temperatures in the fjords probably inhibit the maturation process (Jensen 1935, Templeman 1973).

The seasonality apparent in local migrations for populations in the fjords of northwestern Greenland (Figure 5) are presumed to correlate with feeding behaviour. However, no information is available on seasonality among prey organisms for Greenland halibut in the fjords, but seasonal patterns for primary production are expected to affect other levels in the food chain including Greenland halibut.

Most recoveries from offshore areas of western Greenland were recorded within the offshore area but at a substantial distance from the release sites, with no distinct patterns in orientation of movement. The low number of recoveries from this area precludes further analysis. Such large-scale movements could be associated with spawning migrations as suggested by Bowering (1984), who observed a northward migration of Greenland halibut tagged at Newfoundland and Labrador to the proposed spawning area in the Davis Strait. Jørgensen (1997) also found indications of movements based on a survey series taken over six years, which he interpreted as seasonal movements between feeding areas and spawning grounds in the eastern part of the Davis Strait. However, the spawning grounds for the Davis Strait Greenland halibut populations have never been definitively determined. Apart from observations of eggs and larvae, the spawning location is based on two records of ripe fish (Jensen 1935, Smidt 1969). Flemish Pass was proposed as a spawning area based on observations of several ripe fish by Junquera and Zamarro (1994). Based on this information and additional data from ichthyoplankton surveys from western and southern Greenland, Boje (1997) hypothesised spawning to extend more or less continuously along the continental slope from the Davis Strait southward to Flemish Pass. The wide migrations of Greenland halibut as observed in present study, i.e., from the Davis Strait to Newfoundland, lends support to such a view.

References.

Anon. (1998). Northwest Atlantic Fisheries Organization. Scientific Council Reports, 1997. 274 pp.

Atkinson,D.B., W.R.Bowering, D.G.Parsons, Sv.Aa.Horsted and J.P.Minet. (1982). A review of the biology and fisheries for roundnose grenadier, Greenland halibut and northern shrimp in Davis Strait. NAFO Sci. Coun. Studies, 3:7-27.

Boje,J. (1990). On recaptures of Greenland halibut in icelandic waters from tagging experiments in West Greenland fjords. NAFO SCR Doc. 90/37, Ser. No. N1754.

Boje,J. and O.A.Jørgensen. (1990). On the relevance of a combined assessment of Greenland halibut in NAFO Sub-areas 0,1,2 and Divisions 3KL. NAFO SCR Doc. 90/35, Ser.No. N1735.

Boje,J. & O.A.Jørgensen (1991). Growth of Greenland halibut in the Northwest Atlantic. ICES C.M. 1991/G:40, 12 pp. (in prep. for Fisheries Research).

Boje, J., F.Riget & M.Køie (1997). Helminth parasites as biological tags in population studies of Greenland halibut (*Reinhardtius hippoglossoides*, (Walbaum)), in the north-west Atlantic. ICES Journal of Marine Science, 54:886-895.

Bowering,W.R. (1980). Fecundity of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), from southern Labrador and southeastern Gulf of St. Lawrence. J. Northw. Atl. Fish. Sci., 1:39-43.

- (1984). Migrations of Greenland halibut, *Reinhardtius hippoglossoides*, in the Northwest Atlantic from tagging in the Labrador-Newfoundland region. J. Northw. Atl. Fish. Sci. Vol. 5:85-91.

Fairbairn,D.J. (1981). Biochemical genetic analysis of population differentiation in Greenland halibut (*Reinhardtius hippoglossoides*) from the Northwest Atlantic, Gulf of St. Lawrence, and Bering Strait. Can. J. Fish. Aquat. Sci., 38:669-677.

Jørgensen, O.A. (1997). Movement patterns of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), at West Greenland, as inferred from trawl survey distribution and size data. Journal of Northwest Atlantic Fishery Science, Vol. 21:23-37.

Khan,R.A., M.Dawe, R.Bowering, and R.K.Misra (1982). Blood protozoa as an aid for separating stocks of Greenland halibut (*Reinhardtius hippoglossoides*) in the Northwest Atlantic. Can. J. Fish. Aquat. Sci., 39:1317-1322.

Misra,R.K. and W.R.Bowering (1984). Stock delineation of Greenland halibut in the Northwest Atlantic using a recently developed multivariate statistical analysis based on meristic characters. North Amer. J. Fish. Manag., 4:390-398.

Riget,F. and J.Boje (1988). Distribution and abundance of young Greenland halibut (*Reinhardtius hippoglossoides*) in West Greenland waters.

- (1989). Fishery and some biological aspects of Greenland halibut (*Reinhardtius hippoglossoides*) in West Greenland waters. NAFO Sci. Coun. Studies, 13:41-52.

Riget,F., J.Boje and V.Simonsen (1992). Analysis of meristic characters and genetic differentiation in Greenland halibut (*Reinhardtius hippoglossoides*) in the Northwest Atlantic. J.Northw. Atl. Fish. Sci., Vol. 12:7-14.
SAS Institute Inc. 1988. SAS User's Guide: Statistics, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 956 pp

Sigurdsson,A. (1979). The Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)), at Iceland. Hafrannsóknir, 16, 31p.

Skellam, J. G. (1951). Random dispersal in theoretical populations. Biometrika Vol. 38 (p.196-218).

Smidt,E.L.B. (1969). The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), biology and exploitation in Greenland waters. Medd. Danm. Fisk.- Havunders. 6(4):79-148.

Templeman,W. (1970). Vertebral and other meristic characters of Greenland halibut, *Reinhardtius hippoglossoides*, from the Northwest Atlantic. J. Fish. res. Bd. Can., 27:1549-1562.

Templeman,W. (1973). Distribution and abundance of Greenland halibut (*Reinhardtius hip-poglossoides* (Walbaum)), in the Northwest Atlantic. ICNAF Res. Bull., 10:83-98.

Tåning,Å.V. (1937). Some features in the migration of cod. J. Cons. Perm. int. Explor. Mer., 12: 1-35.

Table 1. Overview of taggings and recaptures.

Data on tagging experiments							Information on recaptures											
							Calendar years after release											
Site	Year	Month	Location	NAFO/ ICES Area	Length range	Nos Released	0	1	2	3	4	5	6	7	8	Un-known	Total nos	% of released
East Greenland Fjords	1990	September	Ammassalik	XIVb	40-74	183		6	3	3	9	1		1			23	12.6
Southwest Greenland Fjords	1988	January	Cape Farewell	1F	35-91	120	4	1	2	1			1				9	7.5
	1987	January	Godthaab Fjord	1D	34-110	839	14	20	9	1		1		1			46	5.5
Northwest Greenland Fjords	1986	August	Ilulissat	1A	33-95	43		1	1		1						3	7.0
	1987	August	Ilulissat	1A	30-90	154	1	2	4	5	2			1			15	9.7
	1993	August	Ilulissat	1A	26-96	34											0	
	1994	August	Ilulissat	1A	34-68	71	4	2	1								7	9.9
	1986	August	Torsukattaq	1A	31-85	272	1	6	5		3	2			1		18	6.6
	1987	August	Torsukattaq	1A	38-100	384	8	21	8	10	2					3	52	13.5
	1993	August	Torsukattaq	1A	48-82	88	7	10	7								24	27.3
	1994	July	Torsukattaq	1A	36-92	144	4	14			1						19	13.2
	1996	August	Torsukattaq	1A	49-76	31	1	1									2	6.1
	1997	July	Torsukattaq	1A	44-93	264	3	15									18	6.8
	1987	August	Uummannaq	1A	36-98	244	2	7	3	8	3	3		1			27	11.1
	1993	August	Uummannaq	1A	39-87	136	3	12	6	1	2						24	17.6
	1994	August	Uummannaq	1A	42-84	49	1	2	1	1							5	10.2
	1995	August	Uummannaq	1A	41-83	363	4	25	16	4							49	14.0
	1996	August	Uummannaq	1A	39-79	574	2	21	10								33	5.7
	1998	July	Uummannaq	1A	40-80	454	13										13	2.9
	1989	August	Upernavik	1A	35-107	634	2	26	15	14	9	8	2	1			77	12.1
	1990	August	Upernavik	1A	39-106	41											0	
	1994	July	Upernavik	1A	46-92	162	4	12	5								21	13.0
	1995	July	Upernavik	1A	38-88	177	2	6	2	1							11	6.2
West Greenland Offshore	1991	August	Davis Strait	1D	42-109	682	5		1	2	1			1			10	1.5
	1992	May	Davis Strait	1D	36-101	385	3	1	2			1					7	1.8
	1993	August	Baffin Bay	1A	43-92	716		1			1	2					4	0.6
Totals					26-110	7244	88	212	101	51	34	18	3	6	1	3	517	7.1

Table 2. Overview of recapture area by release site (in numbers).

Recapture area: **Release site:**	**Faroe Islands**	**Denmark Strait**	**Ammassalik**	**Qaqortoq**	**Nuuk**	**New-foundland**	**Davis Strait**	**Ilulissat**	**Torsukatteq**	**Upernavik**	**Uummannaq**	**Totals**
Ammassalik	1	6	16									23
Qaqortoq		2		7								9
Nuuk		6			39	1						46
West Greenland offshore		3				2	14		2			21
Ilulissat								23	2		1	26
Torsukatteq								18	95			113
Uummannaq								1			152	153
Upernavik									1	105	2	108
Total	1	17	16	7	39	3	14	42	100	105	155	499*

* only 499 fish of 517 fish total recaptured had reliable information on recapture position.

Table 3. Results of Tukey's Studentized Range Test on difference in mean length at recapture between tagging sites and Denmark Strait.

Release site	Difference between means for Denmark Strait and release site (cm)	
Godthaab Fjord	11.67	*
Cape Farewell	22.29	*
Ammassalik	2.94	
Baffin Bay	0.00	
Davis Strait	-5.65	

* Significance at the 5% level

Fig 1. Map of release sites (hatched areas) and names of localities mentioned in the text.

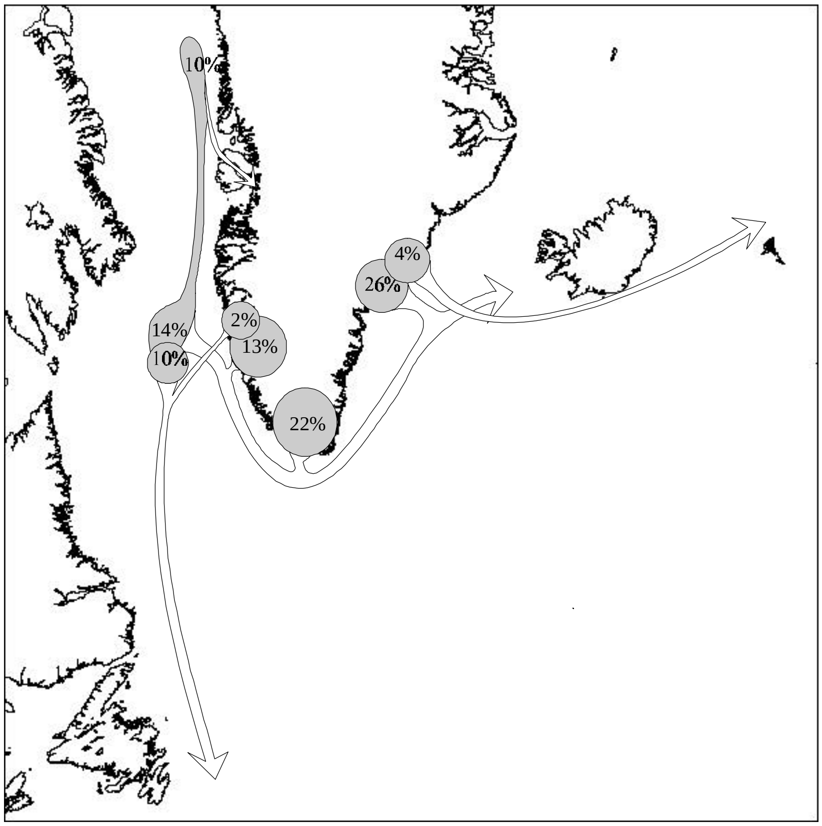

Fig. 2. Migration pattern among long distance migrants. Percent of recaptured fish from different tagging sites in Greenland, that were caught at fishing grounds in northwestern Greenland fjords (Torssukateq), off Newfoundland, west of Iceland and north of Faroe Islands.

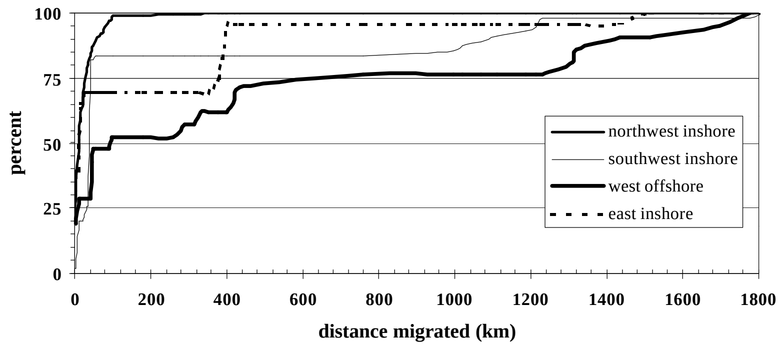

Fig. 3. Cumulative distribution of migrated distance of releases from four main areas.

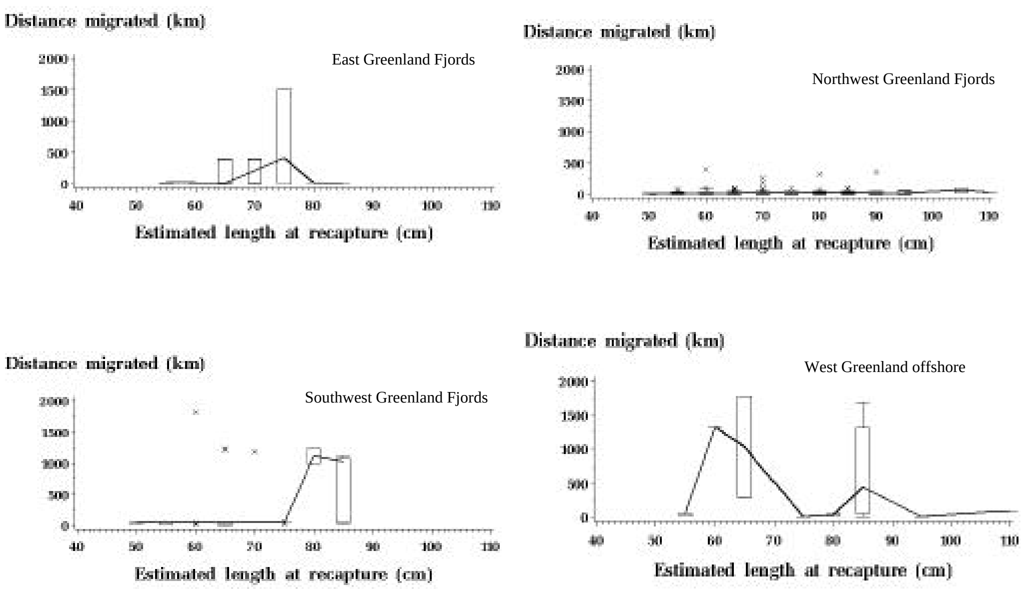

Fig. 4. Box plots of migration distance distributed by length at recapture estimated from tagging length and years of release for each of the four main tagging sites.

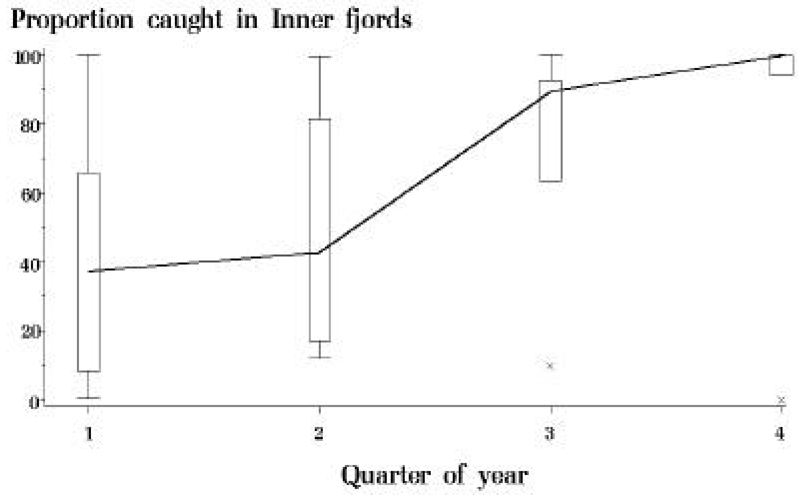

Fig. 5. Box plot of proportion Greenland halibut recaptured in inner part of fjords relative to recaptures in entire fjord system shown by season as revealed by pooled tagging – recapture data.