

Nursery grounds for the West Nordic Greenland halibut stock – where are they?

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Abstract

Greenland halibut in the Northwest Atlantic is composed of two management units reflecting the stock entities, namely the Canada-Greenland stock complex and the East Greenland/Iceland/Faroe Island stock (West Nordic stock). Major juvenile concentrations (nursery grounds) of the Canada-Greenland stock are located at the slope of Store Hellefisk Bank but similar concentrations of the West Nordic stock have not been located. Nursery grounds are traditionally believed to be located off East Greenland, since 0-group surveys show that eggs and larvae drift from spawning grounds west of Iceland towards East Greenland. An analysis of the combined data bases of Greenland halibut by-catch in research shrimp surveys from 1988 to 1999 in Icelandic and Greenland waters (4190 hauls, 637 thousand length records) was done in order to determine possible locations of nursery grounds for the West Nordic stock. At West Greenland, most catches are comprised of fish below 40 cm (juveniles) while at East Greenland and Iceland lengths ranges between 30 cm and 60 cm (immature adults). Length modes corresponding to age 1-3 years old, which dominates in West Greenland waters are virtually absent in East Greenland and Icelandic waters. The catch rates of juveniles in West Greenland are more than one order of magnitude higher than in East Greenland and Icelandic water. The analysis of Greenland halibut by-catches in shrimp surveys suggest that main nursery grounds for the West Nordic stock must be located outside East Greenland or Icelandic waters.

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Introduction

Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum) is widely distributed in the Northwest Atlantic from Smith Sound, between Greenland and Canada, southward throughout Baffin Bay and Davis Strait to the north-east coast of U.S.A. and eastward along East Greenland to Iceland and further to Faroe Islands (Bowering and Brodie 1995; ICES 2000; Smidt 1969). Although the species is an important fishing resource in the north-western Atlantic, considerable gaps still exist in knowledge on basic biological features. Thus, knowledge on stock structure, reproduction and recruitment is still sparse for the major stocks in the western Atlantic, e.g. Labrador Sea, Davis Strait, Denmark Strait and off Iceland. For Greenland halibut at East Greenland, Iceland and Faroe Islands (the West Nordic stock) there is presently little information available on young Greenland halibut and possible nursery grounds. The assessment of the stock as carried out by ICES is severely hampered by the lack of any recruitment indices (ICES 2000). Indices of recruitment of Greenland halibut are an obvious prerequisite for sound management advice. Predictions in the present assessments are based on recent average values and any failure in recruitment will first be detected in the fishery 5-8 years after (ICES 2000).

The prevailing view used in management of the stocks is that the north-western Atlantic consist of two major spawning stocks; the Canadian-Greenland stock complex and the West Nordic stock in East Greenland, Iceland and Faroe Islands (Anon. 1999; ICES 1999). For the West Nordic stock spawning probably occurs west of Iceland at depth around and below 1000 m (Magnusson 1977; Sigurdsson 1977). From there, eggs and larvae are carried either towards East Greenland by the Irminger Current/East Greenland Polar Current or northeastward along the northern Icelandic coast (Magnusson 1977; Sigurdsson 1980). A part of the larvae carried towards Greenland drift south to Cape Farewell and are then carried northwards by the West Greenland Current (Boje 1997; Jensen 1935; Smidt 1969). The Canadian-Greenland stock spawns in 800-2000 meters deep waters over an extended area from Davis Strait, south of 67°N (Jensen 1935; Smidt 1969) to south of Flemish Pass off Newfoundland (Junquera and Zamarro 1994). Eggs and larvae are dispersed along the western shore of Greenland by the West Greenland Current and along the Eastern Shore of Canada by the Canadian Polar Current (Templeman 1973). At a length of about 6-7 cm the larvae metamorphose to the bottom-stage upon settling on the banks at depth of about 200 m. (Jensen 1935; Riget and Boje 1988). Riget and Boje (1988) evaluated the occurrence of young Greenland halibut in West Greenland and location of possible nursery grounds. They concluded that high abundance of young fish at Lille- and Store Hellefisk Bank north of 68°N probably originated from the Canadian-Greenland stock while smaller concentrations in southwest Greenland coastal areas may have derived from the spawning stock west of Iceland, i.e. the West Nordic stock.

The present paper evaluates information on young Greenland halibut in Icelandic and Greenland waters based on research shrimp surveys from 1988 to 1999, in order to locate possible nursery grounds for the West Nordic stock. Information from West Greenland is included in the study for comparative purposes.

Materials and Methods

The Greenland shrimp survey was carried out with the R/V "Paamiut", (722 GRT) in July – August in NAFO Subarea 1 and in September – October in ICES Div. XIVb using a 3000/20 meshes Skjervøy shrimp trawl with bobbins gear and a 20 mm (whole mesh) double-bag in the codend. The 20 mm mesh sizes used in the surveys will give a full selectivity on Greenland halibut from sizes of about 9 cm assuming a selection factor of 3.1 as found by Huse et al. (1999). Trawl doors were Greenland Perfect size 370*270 cm. Standard towing time was 60 minutes at a speed of approx. 2.5 knots. All hauls were carried out in daytime. The survey was a stratified-random trawl-survey covering depths 100- 600 m.

The total catch from each haul was sorted and weighed by species. All Greenland halibut were measured to the nearest cm below except in larger catches where subsamples were taken. Further information on the shrimp surveys is available in Carlsson et al. (2000).

The Icelandic shrimp surveys were carried out by R/V "Arni Fridriksson" (523 GRT) or R/V "Drofn" (185 GRT) in July-August 1988-99 using a 2800 mesh "Aegir" shrimp trawl with bobbins gear, 900 kg "Poly-Ice" trawl doors, and a 40 mm (whole mesh) double-bag in the codend. The 40 mm mesh sizes used in the surveys will give a full selectivity on Greenland halibut from sizes of about 15 cm assuming a selection factor of 3.1 as found by Huse et al. (1999). In total 153 fixed stations were towed at least 10 times of the 12 year study period, with additional 114 locations that have been surveyed less frequently. The majority of hauls were in the depth range of 200-600 m, covering the principal distribution of the offshore shrimp stock. Tow length was 4 nm in 1988-1990, 3 nm in 1991-1999 and 2 nm in 1999, with all hauls carried out within daylight hours towed at a speed of 2 knots. All Greenland halibut from each haul were counted and measured to the nearest cm, except in larger catches where subsamples were taken.

The difference in mesh size between the Greenland and Icelandic gear (20 mm versus 40 mm) is assumed to effect only Greenland halibut age 1, e.g. lesser than 15 cm. Trawl opening is considered roughly equal.

No valid age-length keys are available for small fish for the entire area. Hence, in order to analyse for specific age groups, a rough age separation of the young Greenland halibut were made based on the Petersen method, i.e. examination of the length frequencies. Age group 1 year was defined as fish less than 15 cm, age 2 as fish between 15 cm and 22 cm and age 3 as fish between 22 cm and 28 cm. After $\ln(x+1)$ -transformation of numbers ages 1-3 per hour trawling (NPUE), assuming normal distribution of $\ln(\text{NPUE})$, a three-way analysis of variance was performed on mean values by year and statistical squares (measuring $7.5^\circ \times 15^\circ$, i.e. approx. 45 nm^2) as follows:

$$\ln(\text{NPUE}) = \text{year} + \text{depth} + \text{division} + \text{error}$$

All analyses were performed by use of the statistical software SAS (SAS 1988) and StatSoft Inc. (2000).

Results

The two shrimp surveys analysed have a total geographical range from 8° W longitude to 60° W longitude and ranges in time from 1988 to 1999 (Table 1, Fig. 1). Data consist of 4,190 hauls and 637,000 length records of Greenland halibut. Most extensive effort has been directed into ICES Division Va and NAFO Divisions 1AB, while NAFO Divs. 1C-F and ICES Div. XIVb were less covered (Table 1). The limited coverage of the southern divisions is due to restrictions in time series and to smaller area of surveyed depth strata.

Catches of Greenland halibut in the entire area are within the length range 5 – 104 cm, covering age groups 0 to about 20. At West Greenland most catches consist of fish below 40 cm and clear modes below 30 cm indicate year-classes 1-3 (Fig. 2). At East Greenland and Iceland fish between 30 cm and 60 cm predominate, and modes representing year-classes are only indicative for East Greenland. In Iceland, fish smaller than 30 cm is virtually absent. High catch rates of the small sized Greenland halibut predominates in Div. 1AB, while in Divs. Va and XIV catch rate values are approximately 60 times lower (Table 1). The geographical distribution of the catch rates of various size-groups of young Greenland halibut are given in Fig. 3. Highest densities are seen for the well-known nursery grounds in West Greenland at Lille- and Store Hellefiske Bank and in Disko Bay. The discrepancy in catch rates between these areas and the remaining surveyed area is even more obvious for smaller sized Greenland

halibut (< 20cm) (bottom plot of Fig. 3). In order to exploit the East Greenland and Iceland areas further in detail, catch rates for Greenland halibut ages 1-3 was plotted by longitude as indicated on Fig. 4. Highest catch rates are found between 28°-36°W in the East Greenland area, while low NPUE values are recorded for the entire area north of Iceland.

The effects of depth, year and division on the catch rates of young fish (i.e. < 28 cm) were estimated by an ANOVA (Table 2). All effects contributes highly significant to the model ($P < 0.0001$). Effect of depth on catch rates varies from West Greenland to Iceland, as highest numbers changes continuously from 400 - 500 m depth in Div. 1AB, to 300 – 400 m depth in Icelandic waters (Fig. 5).

To explore whether abundance of the young year-classes in the present data are synchronised between East Greenland/Iceland and the southwestern Greenland, two-way ANOVA's (effects: depth, year) were performed on $\ln(\text{NPUE_age3})$ for each of the two NAFO divisions in southwest Greenland (Divs. 1EF) and east Greenland/Iceland (Divs. XIVb+Va). The depth standardised estimates by year from the ANOVA was plotted along with VPA estimates of stock numbers at age 5 from the most recent ICES working group assessment of Greenland halibut in Div. XIV+V (ICES 2000) (Fig. 6). The index values from the shrimp survey are only synchronised in the last three years and do not show the same trend as the VPA estimates. However, for the most recent period, 1997-98, all indices increases.

Discussion

The average annual yield from the Davis Strait Greenland halibut stock complex (SA 1) has been around 25 thousand tonnes in the last 10 years (Anon. 1999). In comparison, the average yield from the West Nordic stock has been 37 thousand tonnes in the last 10 years (ICES 1999). Although this fishery has not been sustainable, it suggests that the nursery areas of these two stocks should be of equivalent order of magnitude.

In the nursery area at West Greenland, juveniles are generally found in great numbers over the whole shelf, from the mouth of fjords to the edge of the continental shelf. The effort and aerial coverage in the shrimp surveys in East Greenland waters have been less than in West Greenland waters, partly because the topography in many places prevents bottom trawling. However, since most of the East Greenland continental shelf area has been surveyed in recent decades without finding great numbers of juveniles, it is unlikely that nursery grounds of such magnitude as to sustain the fisheries in the West Nordic stock are to be found in East Greenland waters. It is, however, notable that the size of potential area (i.e. within 300 – 500 m depths) for nursery grounds in East Greenland is about two times that of the corresponding area in West Greenland. A great northern area off Scoresbysund (Fig. 7) at 70° N latitude within the depth range 300-500m that was not covered in analysed shrimp surveys, has in been surveyed by a Japanese research vessel in the 1980'ies, but no small fish were caught (Jørgensen 1991). The observations from the Icelandic shrimp survey, as well as numerous other surveys, exclude Icelandic waters as being a significant settling and nursing grounds for Greenland halibut. Sigurdsson (1979) noted that "smallest bottom stage found in Icelandic waters was 21 cm long and 3 years, so it is unknown where the larvae seek the bottom and where the young fish live until 3 years old". Despite the present analysis of a long time series of Greenland and Icelandic shrimp surveys covering an extensive potential area of nursery grounds in the Northwest Atlantic, Sigurdsson's statement is still valid. Information from 0-group surveys have shown a drift of egg and larvae from Iceland with the Irminger Current and East Greenland Polar Current towards Cape Farewell and further northwards along West Greenland with the West Greenland Current (Jensen 1935, Boje 1977). However, the extent of this drift in regard to the major drift and settlement of larvae from this stock is unknown.

Although catch rates of young fish are low in the East Greenland/Iceland area, they might have been useful to reflect trends in recruitment to the West Nordic Greenland halibut stock. Trends in shrimp survey indices of 3 years old fish did however not match the VPA derived age 5 numbers of fish (Fig.

6). However, little contrast in the dataserries within the time span and poorly determined VPA estimates of age 5 numbers (recruits) in most recent years impedes the comparison.

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Table 1. Information on haul distribution and Greenland halibut caught in Icelandic and Greenland shrimp surveys 1988-1999.

Division	No hauls	year range	mean length	S.D.	ln(mean nos per tow hour)	S.D.	mean depth (m)
Va	1737	1988-99	47.2	7.2	2.18	1.03	369
XIV	346	1989, 1992-96	36.7	13.4	1.44	0.73	346
1F	90	1992-99	21.2	13.1	1.96	1.24	271
1E	77	1992-99	16.5	10.8	2.18	1.45	235
1D	133	1988, 1990-99	21.3	11.0	2.85	1.74	274
1C	228	1988-99	22.5	11.6	2.77	1.71	300
1B	850	1988-99	17.4	5.6	4.47	2.05	321
1A	729	1988-99	18.7	5.4	4.68	1.99	337

Table 2. Output of ANOVA of ln-transformed catch rates of Greenland halibut ages 1-3.

Effect	SS	df	MS	F	r ²
Model	11949.0	19	628.9	283.7	0.57
Year	848.9	11	77.2	34.8***	
Division	10255.8	7	1465.1	661.0***	
Depth	844.3	1	844.3	380.9***	
Error	9019.4	4069	2.2		

*** highly significant with $P < 0.0001$

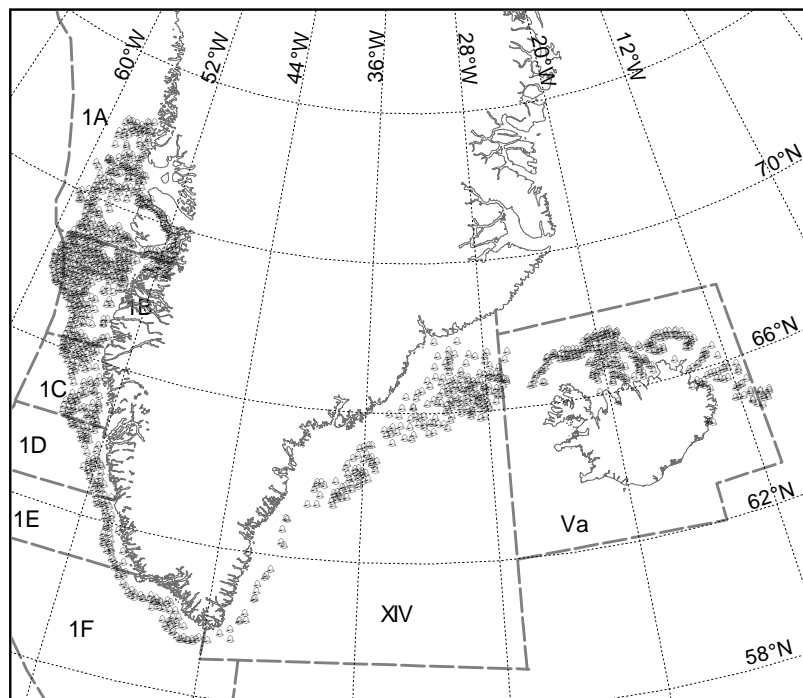


Fig. 1. Distribution of statistical squares surveyed by the Greenland and Icelandic shrimp surveys in 1988-99. NAFO and ICES divisions indicated.

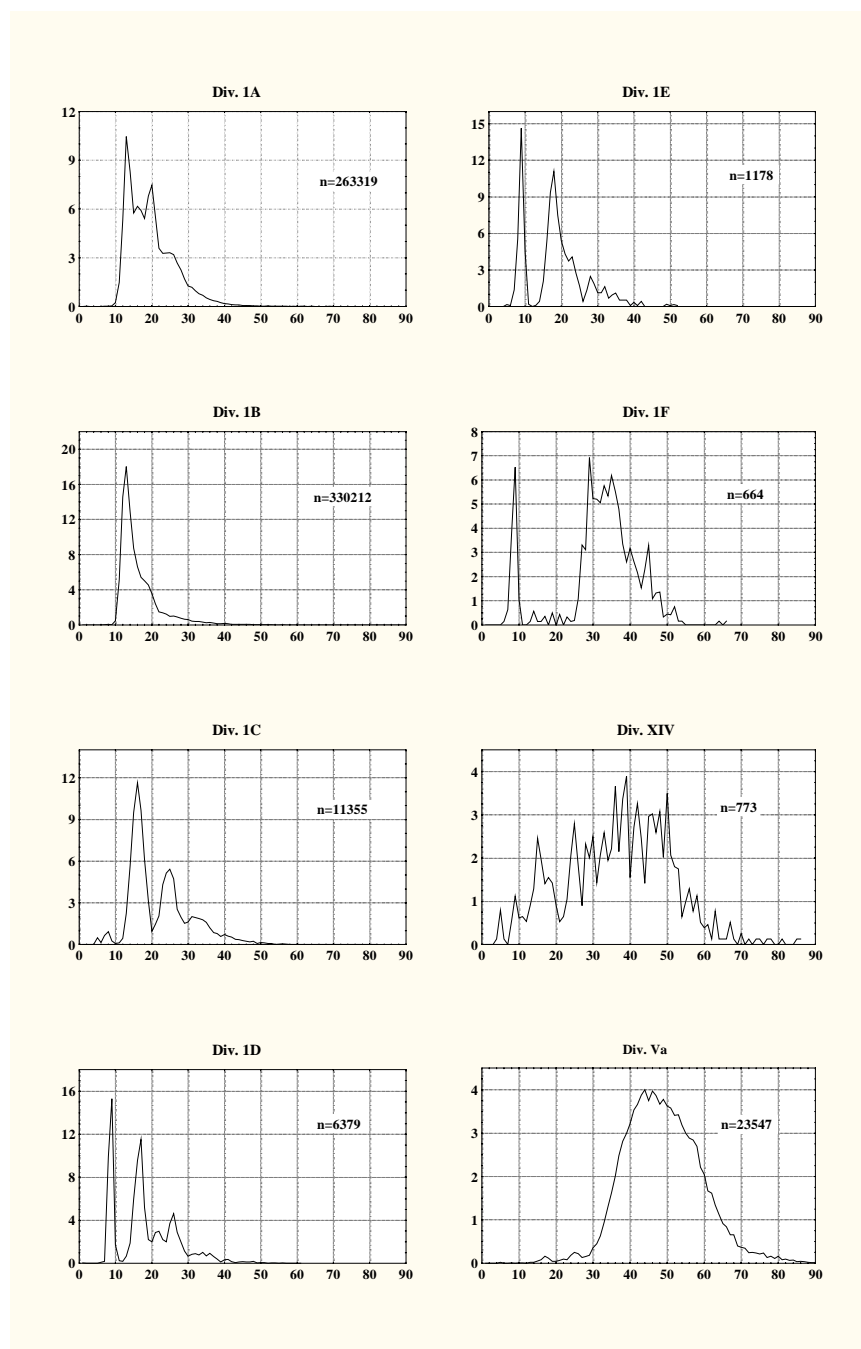
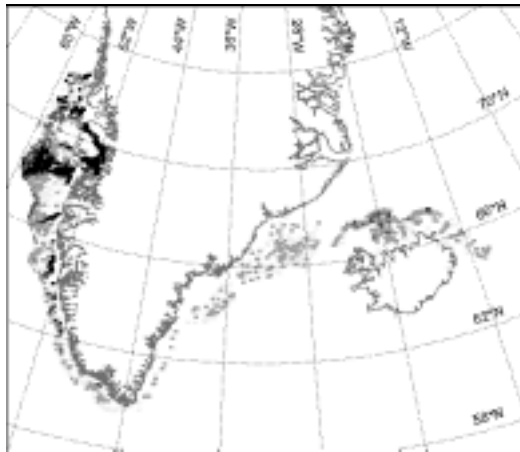
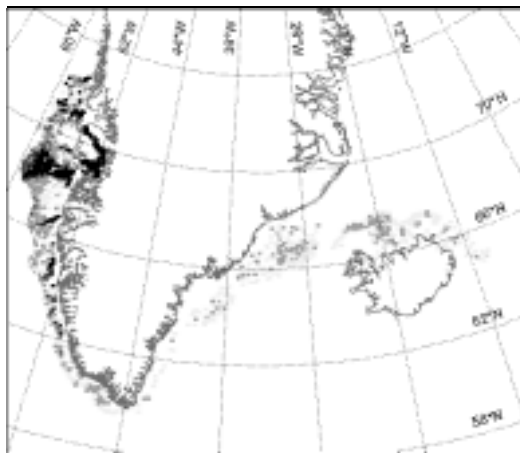


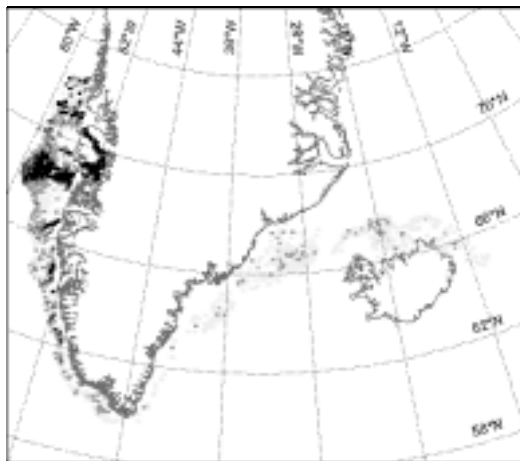
Fig. 2. Length distributions (percent) of Greenland halibut caught in shrimp surveys 1988-99 by Division.



Greenland halibut all sizes



Greenland halibut < 30 cm



Greenland halibut < 20 cm

Nos/haul hour

- 100 to 5,000
- 20 to 100
- 1 to 20
- 0

Fig. 3. Catch rates of Greenland halibut in Greenland and Icelandic shrimp survey 1988-99, given by size groups.

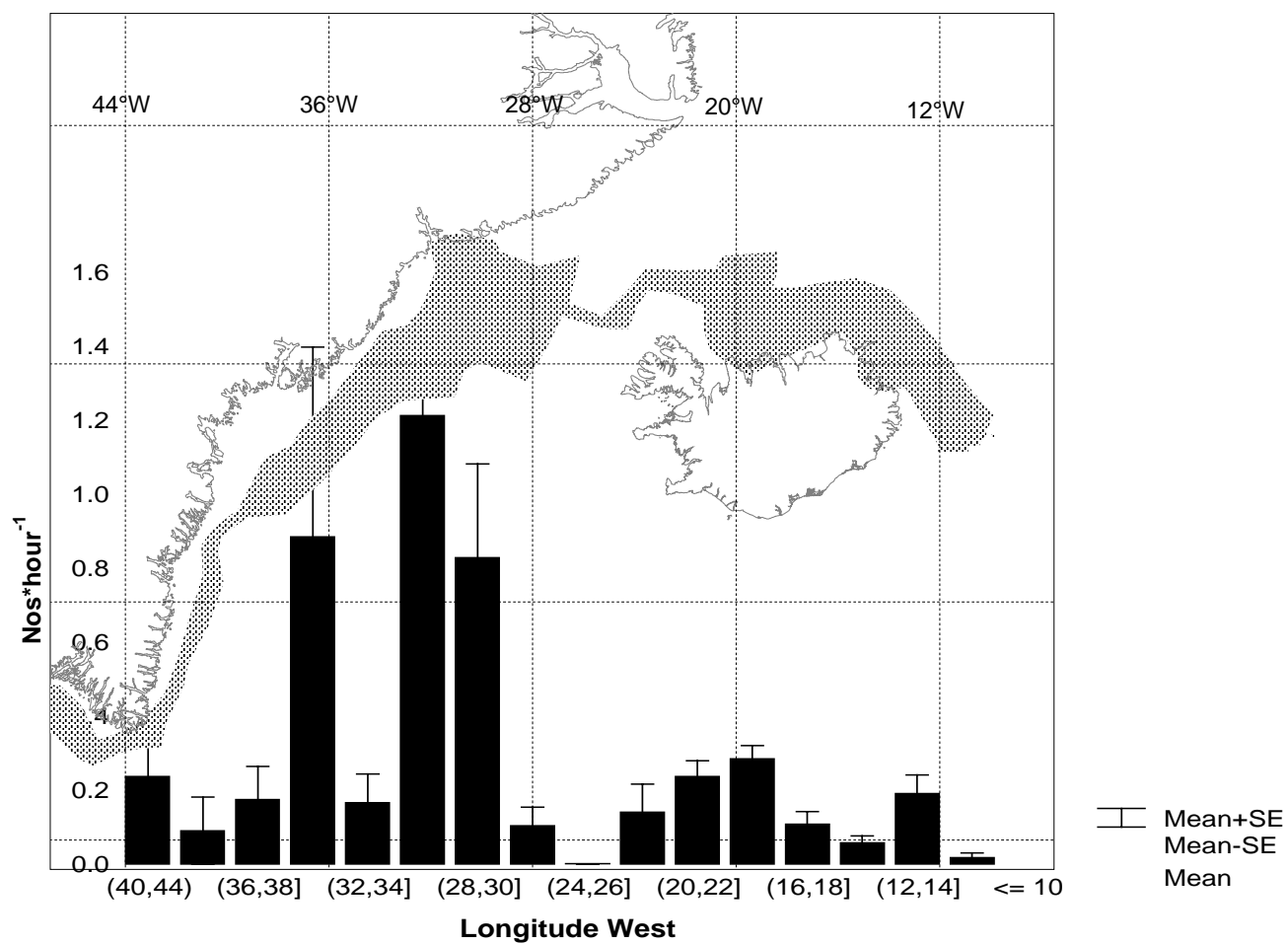


Fig. 4. Catch rates of Greenland halibut ages 1-3 (< 28 cm) along longitude. Surveyed area shown dotted on map.

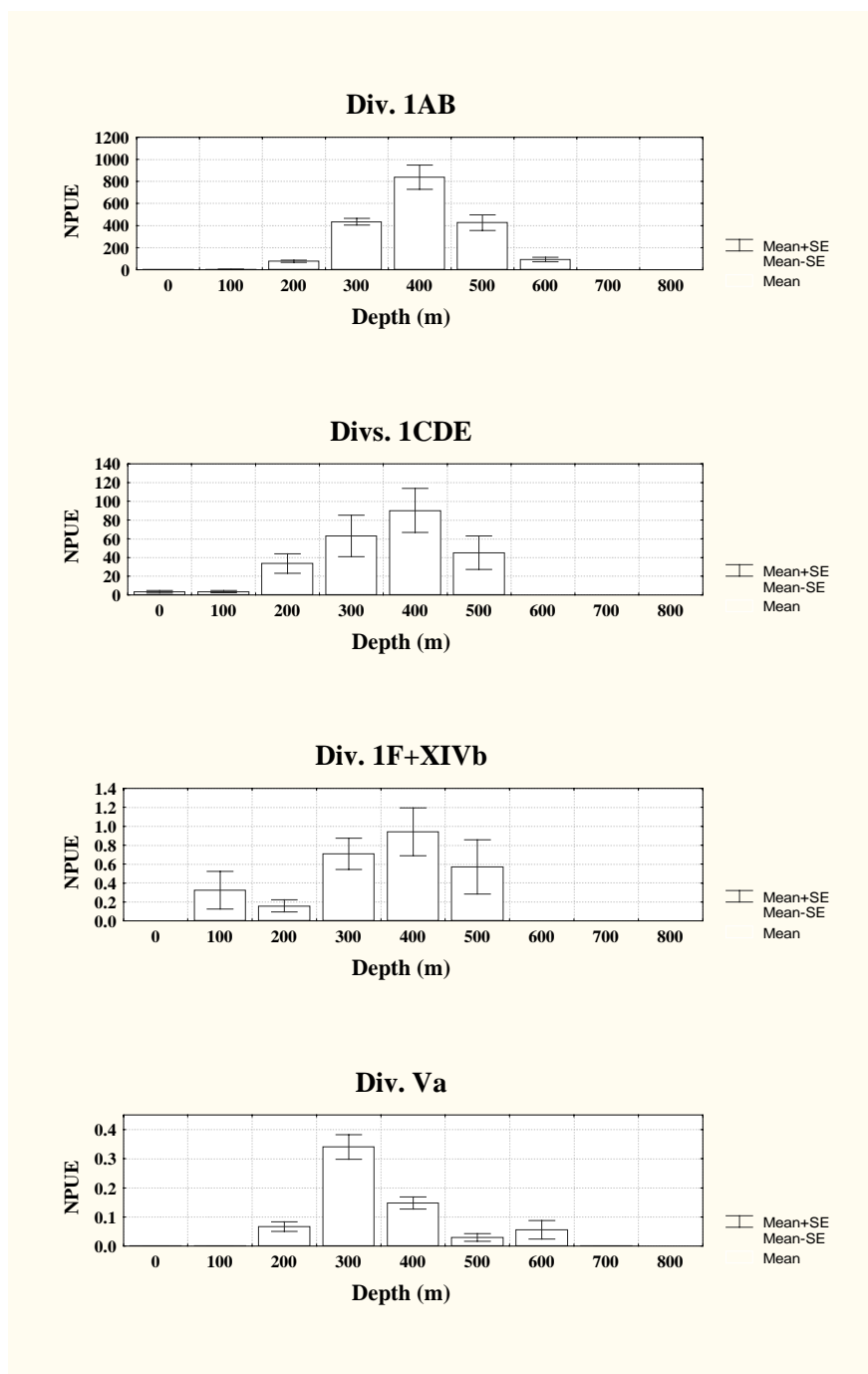


Fig. 5. Depth distribution of numbers (per trawl hour) of young Greenland halibut for main areas in the study.

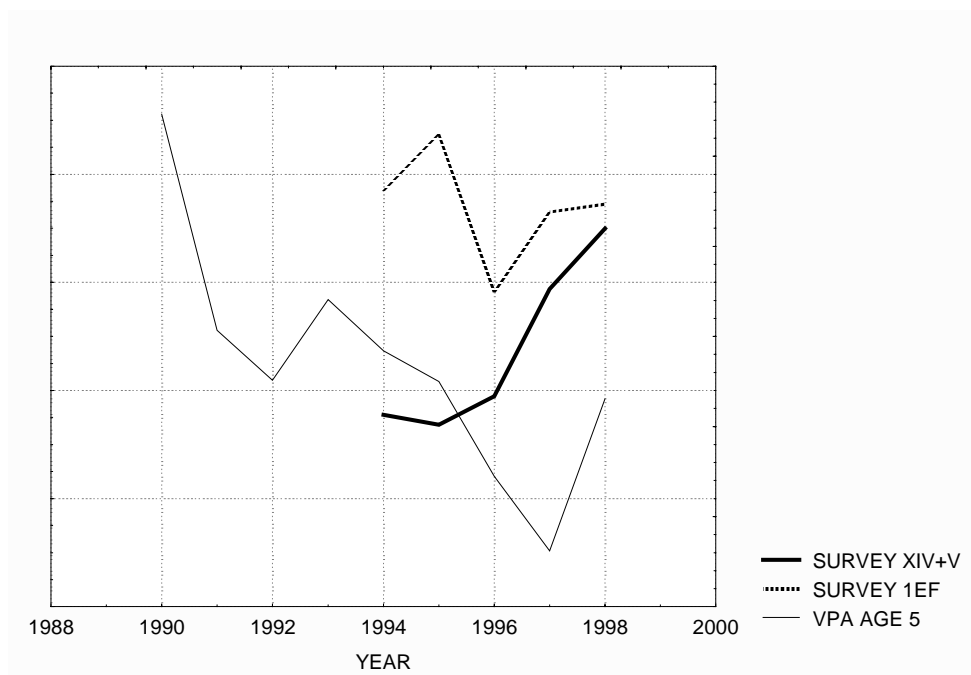


Fig. 6. Year-class indices for the West Nordic stock. Age 3 estimates of NPUE from shrimp surveys (shifted 2 years forward) derived from an ANOVA for Div. XIV+V and Div. 1EF separately, and plot of VPA estimates of age 5 numbers from NWWG 2000 (ICES 2000).

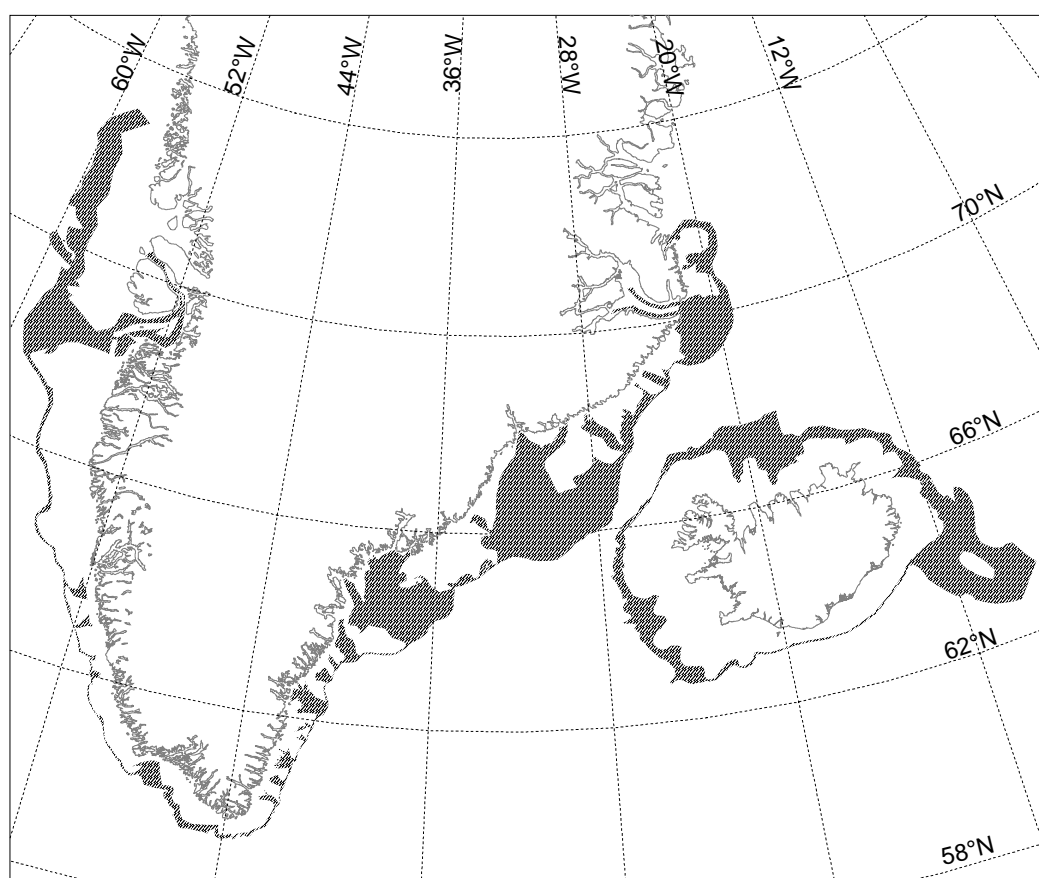


Fig. 7. Distribution of depth stratum 300-500 m (indicated hatched).