REPORT MA 11-13

Agnes C. Gundersen, James Kennedy, Astrid K. Woll, Inge Fossen and Jesper Boje

Identification of Greenland halibut nursery grounds and spawning area in East Greenland: Implications for management of the West Nordic stock

Møreforsking MARIN
P.O. Box 5075, NO-6021 Ålesund, Norway
Tel. +47 7011 1600
NO 991 436 502

Title	Identification of Greenland halibut nursery grounds and spawning area in East Greenland: Implications for management of the West Nordic stock
Author(s)	Gundersen, A.C., Kennedy, J. Woll, A., Fossen, I. and Boje, J
Report no.	MA 11-13.
Pages	33
Project no.	54591
Project title	Blåkveite ved Grønland; utbredelse, biologi og seleksjon/ bidødelighet i trål
Source of funding	Norwegian Research Council.
Reference	170690, Nina Hedlund.
ISSN	0804-54380
Distribution	Open
Keywords	CPUE, longline, gillnet, maturity, nursery grounds, size distribution
Approved by	Director Roar Tobro
Approved date	08.11.11

Abstract
Spawning of Greenland halibut was found to occur in August based on data form a gillnet survey in 1995. About 10% of the matured females were spawning. The nursery grounds are currently unknown for the West Nordic stock of Greenland halibut (*Reinhardtius hippoglossoides*) and the entire stock is assumed to originate from a common spawning ground southwest of Iceland. Our data confirms spawning also in another area than previously described (Iceland). We present information on juvenile Greenland halibut which were caught in the fjords of East Greenland. The densities in Tasilaq area suggest that this area may be part of a nursery area for Greenland halibut in the West-Nordic management unit. However, the importance of this area to the stock is currently unknown. This has implications for the management of the West Nordic Greenland halibut as the management unit may comprise of several stocks, or perhaps a meta-population.

PREFACE

This study was funded by the Norwegian Research Council, project number 170690. The authors would like to thank the Greenland Homerule for providing fishing licence for the vessels and supporting the scientific work. Further thanks to the Norwegian Ministry of Fisheries for support. Thanks to the scientific staff at the Greenland Institute of Natural Resources as well as Møreforsking AS Marine Dept. Last but not least: thanks to the owners and crew of M/S Skarheim, M/S Kato, M/S Husøy, M/S Loran, M/S AudLill and M/S Fjellmøy for conducting the surveys.

Ålesund 7.11.2011

Agnes C. Gundersen
Head of Research/Senior Researcher/PhD

CONTENTS

SUMMARY

Adult Greenland halibut (*Reinhardtius hippoglossoides*) belonging to the West Nordic management unit are distributed throughout the continental slopes of East Greenland from Cape Farewell to Tasilaq area (66^{o}N), along the ridge between East Greenland and Iceland and along the north and east coast of Iceland. Greenland halibut also inhabit the waters around the Faroe Islands. The highest aggregations described so far are found just south of the Greenland-Iceland ridge (Hjörleifsson *et al.*, 2000). Since 2005 a small fishery has developed further north in the slope from Ridge between Iceland and Greenland and northwards towards Jan Mayan / Scorsbysund (Boje and Sünksen, 2008). The fishery has been carried out at about 68^{o}N. It may be questioned if the Greenland halibut distribution is continuous northwards along the continental slope along East Greenland.

During the surveys many running females were caught. These fish were mainly caught at Kap Bille Banke. During the gillnet survey in 1995, over 10 % of the fish assessed for maturity were found to be running. This indicates that Kap Bille Bank is a spawning area for Greenland halibut. The gillnet survey was carried out in three areas. However, it was only at Kap Bille Bank that running females were caught.

There is a lack of data on pre-recruitment variability for the West Nordic stock as the nursery grounds for this management unit have not been identified. Therefore it has not been possible to carry out pre-recruit surveys specifically targeting Greenland halibut.

For effective management of a fish stock it is essential to have knowledge on the spawning grounds and of the nursery grounds for the stock in question. The nursery grounds are currently unknown for the West Nordic stock of Greenland halibut and the entire stock is assumed to originate from a common spawning ground southwest of Iceland. From our results we can see that the structure of the West Nordic management unit is complicated and remains un-clear. Our results do demonstrate that the hypothesis that the unit originates from a single spawning area in Iceland is likely to be inaccurate. At present, the unit is below safe biological limits with reductions in the quotas recommended by ICES (ICES, 2010). This places extra emphasis on the need to increase the knowledge on the stock structure of this west-Nordic management unit.

1 INTRODUCTION

Greenland halibut (*Reinhardtius hippoglossoides*) is a deep water flatfish species with a distribution covering large areas of the Northern Atlantic and is mainly found at depths from 200 m to 2000 m. Despite it being the target of large international fishery, knowledge on many aspects of its life cycle is lacking. Greenland halibut distributed around East Greenland, Iceland and Faroe Island are managed as a single unit by ICES and is referred to as the West Nordic Stock (ICES 2010). This management unit has been assumed to originate from one common spawning ground southwest of Iceland (Magnússon, 1977). This assumption was, however, based on very few observations. Adult Greenland halibut belonging to the West Nordic management unit are found throughout the continental slopes of East Greenland from Cape Farewell to Tasilaq area (66^{o}N), along the ridge between East Greenland and Iceland and along the north and east coast of Iceland. Greenland halibut also inhabit the waters around the Faroe Islands. The highest aggregations described so far are found just south of the Greenland-Iceland ridge (Hjörleifsson *et al.*, 2000). Since 2005 a small fishery has developed further north in the slope from Irminger Ridge and northwards towards Jan Mayan / Scorsbysund (Boje and Sünksen, 2008)around 68^{o}Nand it may be questioned if the Greenland halibut distribution is continuous northwards along the continental slope along East Greenland.

Whether the West Nordic management unit consists of a single or several separate populations is unknown. Greenland halibut tagged in Iceland have been recaptured on the Norwegian coast and also in the Faroe Islands however, whereas none from Iceland have been recaptured in East Greenland despite there being an extensive fishery in the area (Sigurõsson, 1979; Godø and Haug, 1989; Boje, 2002). This wide distribution of adult fish and non-migration into East Greenland enforces the speculation that spawning may also occur in other areas of the distribution area of this management unit. Additional spawning grounds open the possibility that the West Nordic stock is comprised of more than one stock. This has implications within management as the individual stocks may differ in their productivity, and management of these as a single unit can lead to depletion of the less productive populations (Iles & Sinclair, 1982; Ruzzante *et al.*, 1999).

There is a lack of data on pre-recruitment variability for the West Nordic stock as the nursery grounds for this management unit have not been identified. Therefore it has not been possible to carry out pre-recruit surveys specifically targeting Greenland halibut. Further, in the assessment of the stock information about recruitment is lacking and the assessment model output do not show a trend in recruitment (*e.g.* ICES 2010).

0-group surveys in East Greenland/Irminger Sea were carried out by Iceland, beginning in 1970 and ceased in 1998. The targets for these surveys were cod and redfish. 0-group Greenland halibut were present but only in low numbers (pers. comm. E. Hjörleifsson, Marine Research Institute. Reykjavík, Iceland). On the East Greenland continental shelf, no areas have been found where juvenile Greenland halibut occurs in high enough numbers to constitute a nursery area similar to that seen in West Greenland (Boje & Hjörleifsson, 2000). From scientific surveys in the area only very few juveniles are reported (K. Sünksen pers. comm.). Within the literature there are only a few mentions of the whereabouts of newly settled Greenland halibut larvae in the East Greenland area. Tåning (1936) assumed that Greenland halibut larvae settle on the bottom in the East Greenland fjords. This was based on the account by Jensen (1935) who reports numerous small (down to 11 cm) juveniles, washed upon shores in South-west Greenland. Sigurđsson & Magnússon (1980) reported the presence of 0-group Greenland halibut in East Greenland and also report the presence of some in the waters of Iceland. They concluded that the dispersal of eggs and larvae towards Iceland is dependent on the ocean currents and will vary from year to year. However, significant concentrations of 0-group Greenland halibut have never been found in Icelandic waters. More recent research in East Greenland waters have shown the existence, although very limited in numbers, of Greenland halibut less than 20 cm further north along the East Greenland coast (between 61˚30 and 65˚00 N at depth mostly below 200 m) (Yatsu & Jørgensen, 1988).

For effective management of a fish stock, accurate knowledge on the reproduction and recruitment is essential. However this is strongly lacking with the West Nordic Greenland halibut stock and the lack of knowledge on the nursery grounds is a major hindrance in the estimation of potential recruitment. In an attempt to locate potential nursery grounds and possible indications of spawning, maturity and length distribution data were examined from exploratory longline and gillnet surveys carried out in East Greenland (a collaboration between Møreforsking and Greenland Institute of Natural Resources) between 1993 and 2000 and the implications for the management of this stock are considered.

2 MATERIAL AND METHODS

2.1 Surveys

Details of the surveys are summarised in Table 1. Survey descriptions are found in the respective survey reports (Fossen & Gundersen, 2000; Gundersen & Woll, 1996; 1997; Gundersen *et al*., 1996; 1998; Woll & Gundersen, 1997; Woll *et al.* 1998; 2000). The longline surveys were carried out using longline fishing gear which is commonly used for the commercial fishing of Greenland halibut with the exception of 1997 when a combination of normal and circle hooks were used (see Woll *et al.* (2001) for details). The fishing performance in East Greenland water is affected by rough bottom and strong currents and longlines are usually set along the continental slope to avoid gear loss. Longlines were set within predefined depth intervals; 400-600m, 600-800m, 800-1000m, 1000-1200m, 1200-1400m and deeper than 1400m. In some areas such as in the fjords, longlines were sometimes set down the slope. In such cases longlines were labelled when crossing the limits of the above mentioned depth intervals as observed from the echo transducer.

The Skarheim 1994 survey was carried out in five areas in the Fjords around 65˚N (Fig. 2.1). The Skarheim 1996 survey was carried out in three areas 60˚, 62˚ and 63˚N (Fig. 2.2). The areas at 63˚N covered only offshore areas whereas the areas at 60˚ and 62˚N covered both fjord and offshore areas. The 1997 and 2000 surveys were carried out in offshore areas (Fig. 2.2). In the longline surveys, each setting usually consisted of two magazine, giving a total of 2600-2800 hooks pr. setting. The catch per unit effort (CPUE) and number per unit effort (NPUE) was calculated for each station in the longline surveys as the weight of Greenland halibut (kg) caught per 1000 hooks and number caught per 1000 hooks respectively.

In 1995 two gillnet surveys were conducted. The gillnets used were monofilament with a mesh size of 100, 110 or 120 mm (half mesh size). These were carried out at three locations in East Greenland at depths between 500 and 1400 m (Fig. 2.2). These surveys were carried using the same gear and close together in time so the results for these surveys were combined.

A gillnet survey was carried out in 1998 in South-east and South-west Greenland (Fig 2.3) using fine meshed gillnets designed to catch Greenland halibut between 10 and 40 cm. One gillnet setting consisted of 6 nets which had a mesh size of 15, 19, 25, 33, 42 and 55 mm (half mesh). These nets were set in a line with increasing mesh size with a space of 1 m between nets. The number of Greenland halibut caught per setting was calculated for each station.

2.2 Sampling

The biological sampling varied slightly between years but in all surveys, all Greenland halibut caught were counted and measured for length (to the nearest 1.0 cm). The sex, total weight (nearest 10 g) and gonad weight (nearest 1.0 g) for a sub-sample of the catch at each station was taken. The numbers of fish caught and sampled during each survey is summarised in Table 2.1.

Table 2.1. Details of the survey in East Greenland showing the year, dates of the survey, vessel, Gear type (LL=longline, Gi=gillnet), Areas surveyed (see Fig. 2.1-2.3), the number of stations (St.), the depth range of the stations and the number of Greenland halibut measured/assessed during each survey for each parameter (L=length, W=weight, S=sex, M=maturity).

Year	Dates	Vessel	Gear	Area	St.	Depth (M)	Details collected			
							L	W	S	M
1994	3 Aug-20 Aug	Skarheim	LL	A-F	62	56-900	2231	537	548	469
1995	14 Aug-27 Aug	Kato	Gi	J and L	283	500-1340	7537	229	1580	260
1995	11 Aug-27 Aug	Husøy	Gi	J and K	175	570-1307	7670	326	2241	128
1996	25 Jul-12 Aug	Skarheim	LL	G-K	57	176-1518	7115	798	2882	1055
1997	19 Jul-27 Jul	Loran	LL	J	43	1157-1486	4253	857	2050	473
1998	12 Aug-30Aug	Audlill	Gi	N-U	71	88-588	787	441	693	693
2000	20 Aug-30 Aug	Fjellmøy	LL	J and M	43	380-1440	4917	667	1285	246

Gonadosomatic index (GSI) was calculated as a percentage of the total weight. A GSI of 1 % was chosen as a threshold value for maturity classification with a GSI >1% being classed as mature (adult) and fish with a GSI <1% classed as immature (juvenile). This limit is used previously by Burton (1999) for other species. Using GSI is a poor indicator of the ovary development stage in Greenland halibut. However, it can be used as a rough guide in assessing whether a group of fish (when caught at a similar time of the year), consist mostly of mature fish or fish which have not begun or are at an early stage of development (Simonsen & Gundersen, 2005). Thus, this labelling of fish as immature or mature does not claim whether the fish will spawn in the coming spawning season.

The gonads of females which contained hydrated oocytes were classed as running. They were not weighed due to loss of eggs giving an inaccurate weight. In 1998 gonad stage was assessed macroscopically with fish being classed as immature (ovaries small with no visible oocytes) or mature (oocytes > 1 mm and visible to the naked eye).

For males, the maturity stage was assessed macroscopically by personnel on board the vessel. These were classed as either immature (gonads are small with no milt present) or maturing (milt is present in the gonads) or running (milt is released under light pressure). The exception was 1994 where maturity stage was assessed using GSI with fish with a GSI <1% was classed as immature and greater than >1% was classed as mature (Burton, 1999). The percentage of male and female Greenland halibut which were considered mature were calculated for 5 cm length groups for comparison between the offshore and fjord areas for each survey.

2.3 Statistics

For comparison of the mean size between fjords and offshore areas, the results from the 1996 survey areas were compared using ANOVA in the following combinations; 1996 survey area G with I and 1996 survey area H with J in order to exclude effects of latitude on size. The mean size in 1994 (Fjord) was compared with the mean size from 1997 (offshore) and 2000 (offshore) using ANOVA.

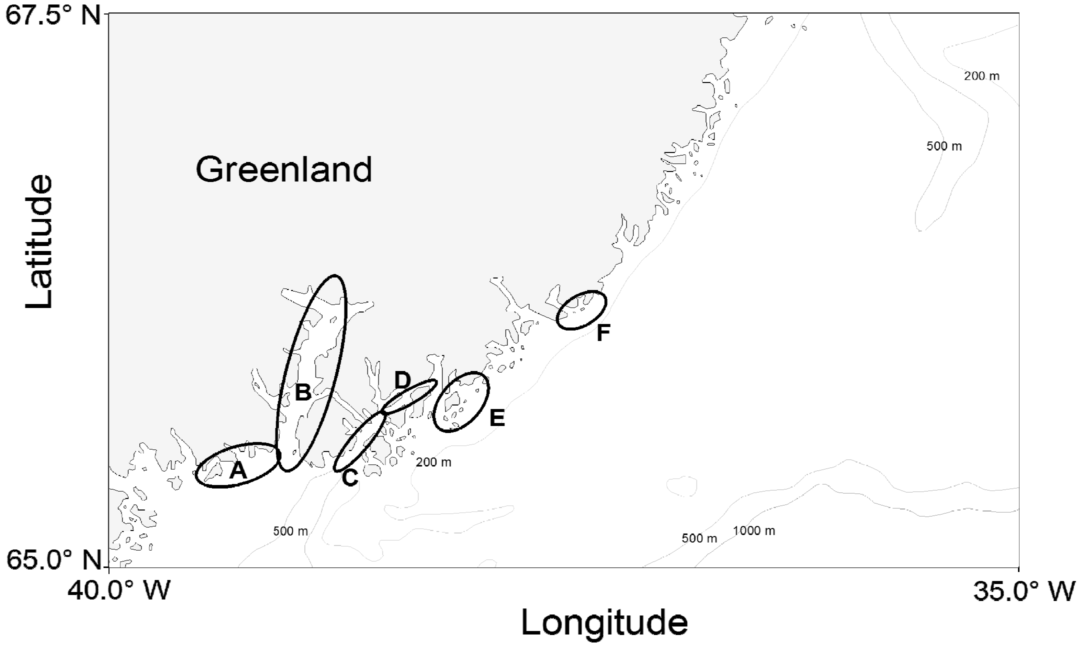

Figure 2.1. Areas surveyed during the 1994 longline survey in East Greenland.

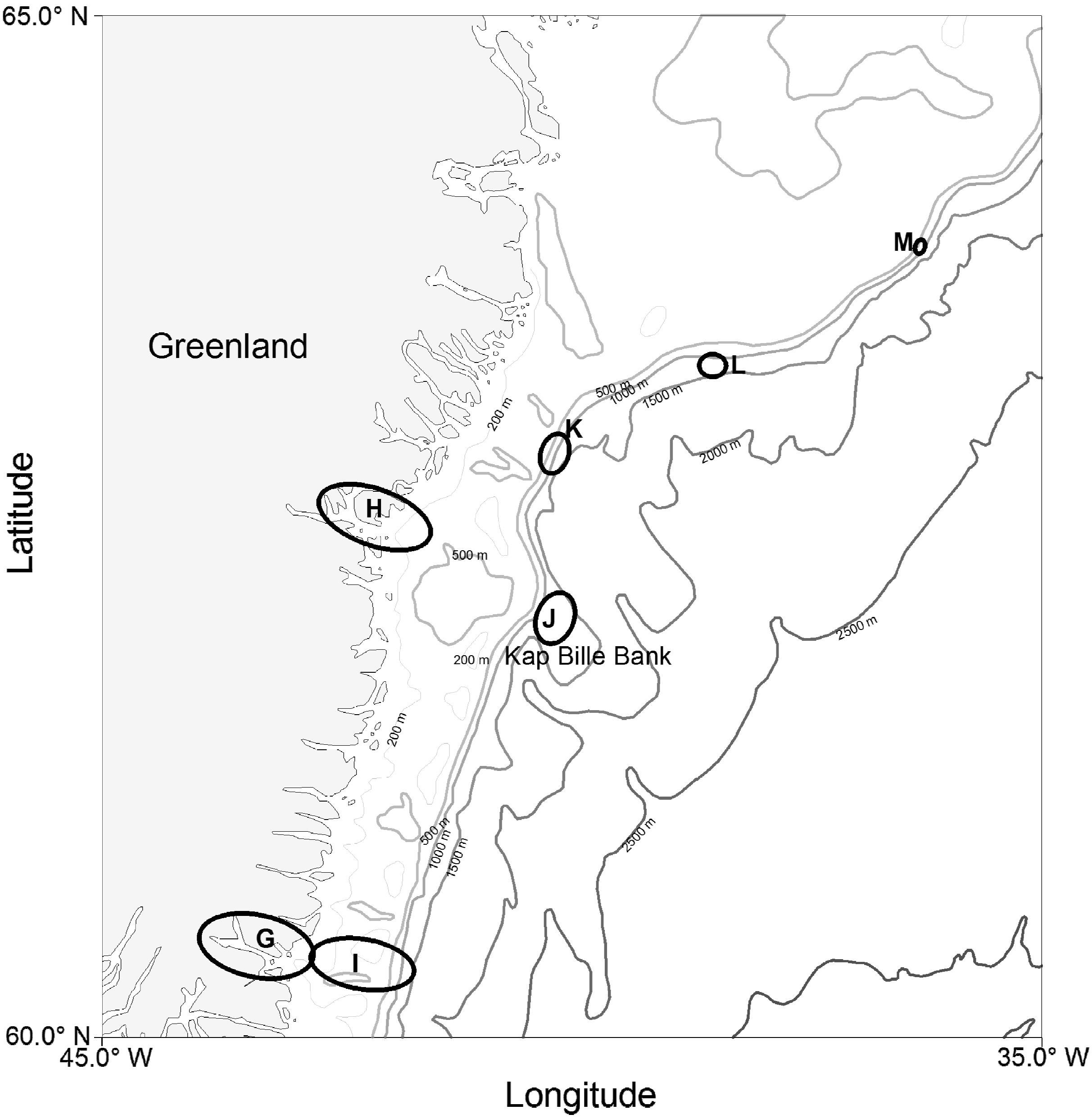

Figure 2.2. Areas surveyed in East Greenland during the 1996 fjord (A and B), 1996 offshore (C-E), 1997 (D) and 2000 (D and G) longline surveys and the 1995 gillnet surveys (D-F).

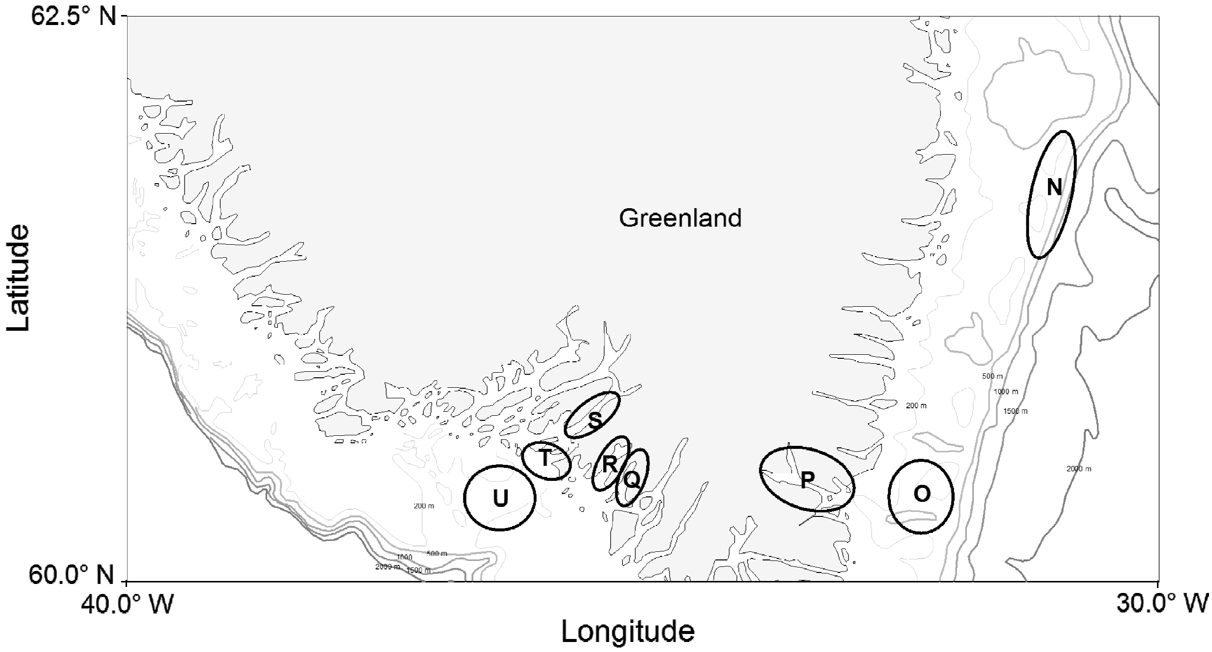

Figure 2.3. Areas surveyed during the 1998 juvenile gillnet survey. Settings consisted of nets with meshsize 15, 19, 25, 33, 42 and 55 mm (half mesh).

3 RESULTS

3.1 Size distribution

There was a significant difference in the mean length between Greenland halibut caught in the fjord and the offshore area (ANOVA; $p<0.0001$) (Fig. 3.1) with smaller fish in the fjords. The smallest fish caught within the fjords using longlines was 24 cm but this gear caught very few fish below 30 cm. The use of fine meshed gillnets caught fish from 15 to 65 cm with a peak in the distribution around 35 to 40 cm and the average size at each station increasing with depth (Linear regression; $p<0.0001$) (Fig. 3.2).

The average size of fish caught using commercial gillnets was significantly different between mesh sizes (ANOVA; $p<0.001$) with the average size of the fish caught for the 100, 110 and 120 mm mesh being 75, 79 and 82 cm respectively. Combination of the three gillnets types gave an average length of 75 cm (Fig 3.1).

3.2 Maturity

The majority of the fish caught within the fjords were immature (Tab. 2.1) and the percentage of fish which were mature in a specific length group was higher in the offshore area than those caught in the fjord areas (Fig. 3.3 and 3.4). This was true for both males and females.

Sixty-three running females were caught during the gillnet surveys in 1995. During the longline survey in 2000 one running female and two running males were caught (Tab. 2.1). Total length of the spawning females was between 61 and 109 cm and the two running males were 65 and 68 cm. There was a roughly even distribution of spawning females across size classes (Fig. 3.5). The spawning fish were caught at depths between 1000 and 1300 m. All of the spawning fish from the gillnet surveys were caught in area J with none being caught in area K or L (Fig. 2.2). It must be noted that 417 of the 458 stations were in area D (Fig. 2.2). All of the running fish caught in the 2000 survey were caught at area J between 1250 and 1300 m (Fig. 2.2).

3.3 Number per unit effort

The NPUE of Greenland halibut differed between fjords and offshore areas (Fig 3.6), and also between fjords (Tab. 2.2). The majority of the high catches of Greenland halibut occurred between 1100 and 1400 m. The NPUE at stations in the Fjords, in shallower water, were generally much lower than in the offshore area. However, there were some higher catches at several stations in the fjords in 1994, these are in area B (Fig. 2.1).

The highest catch of Greenland halibut with the fine-meshed gillnets occurred in area R (Fig. 3.7) in South-west Greenland with an average catch of 1.4 Greenland halibut per net (43 individuals).

Table 3.1. The number of Greenland halibut caught in each maturity stage during each survey (I=Immature, M=mature, R=running). Only females where both maturity stage as well as gonad weight information was recorded are included in the material.

		Females				Males			
Survey	Area	I	M	R	Total N	I	M	R	Total N
1994	Fjord	351	28	0	379	85	14	0	99
1995	Offshore	39	425	63	592	1	58	0	59
1996	Fjord	109	19	0	158	54	9	0	63
1996	Offshore	72	367	0	439	45	350	0	395
1997	Offshore	2	119	1	122	51	299	0	351
1998	Fjord/offshore	290	0	0	290	402	1	0	403
2000	Offshore	8	149	1	159	2	84	2	87

Table 3.2. The NPUE (number caught per unit effort) for longline surveys in East Greenland. Fj/off = whether the survey was in a fjord or offshore, N = number of fish caught in the area, AvN = average NPUE (number per 1000 hooks) of al stations from that area Max = NPUE (number per 1000 hooks) of the station with the highest catch, Min = NPUE (number per 1000 hooks) of the station with the lowest catch (excluding zero catches), AvW = average CPUE (kg per 1000 hooks), n_0 = the number of stations with zero catch, Stations = total number of stations in the area. For areas see to Fig. 2.1 for 1994 and Fig. 2.2, 2.3, for 1996, 1997 and 2000.

Year	Area	Location	N	AvN	Max	Min	Av W	n0	T
1994	A	Fjord	31	1	4	1	1,8	6	12
	B	Fjord	217	11	27	1	20	0	7
	C	Fjord	188	4	24	1	8	6	19
	D	Fjord	2	0,1	1	1	8	7	8
	E	Fjord	1755	52	135	11	140	2	12
	F	Fjord	47	4	8	1	6	0	4
1996	G	Fjord	163	5	14	0,36	8	1	11
	H	Fjord	79	3	9	0,36	7	4	11
	I	Offshore	5996	20	35	14	117	1	14
	J	Offshore	713	78	148	4	387	1	18
	K	Offshore	164	22	36	12	158	0	3
1997	J	Offshore	4254	31	61	2	156	0	39
2000	J	Offshore	4877	75	107	35	462	0	34
	M	Offshore	172	10	23	2	47	0	9

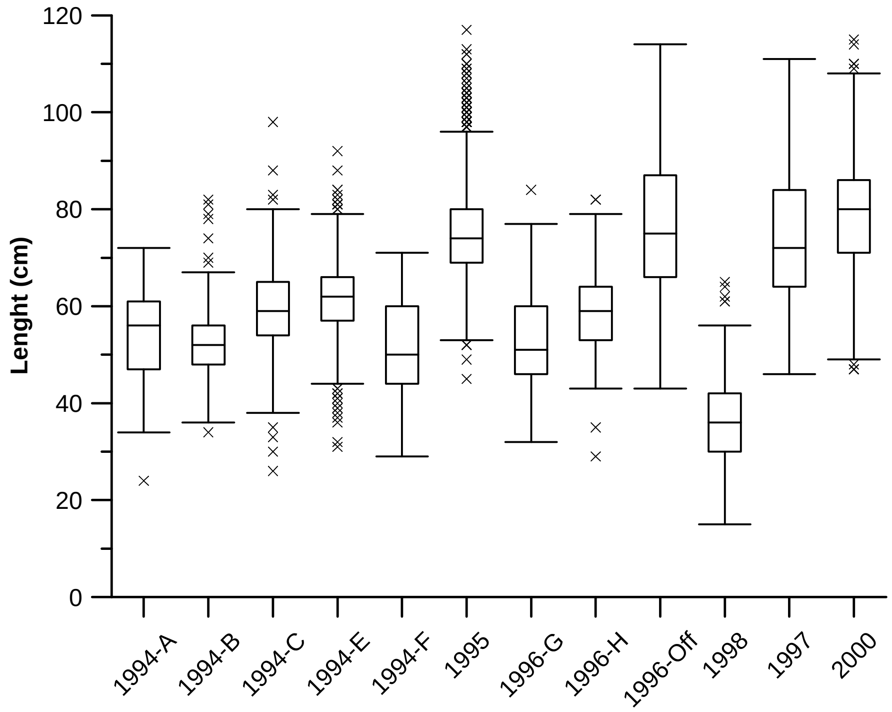

Figure 3.1. Size distribution of Greenland halibut caught during surveys (indicated by the year in which they were carried out) in the waters of East Greenland. 1994 a-f represents the areas from the 1994 survey. 1996-G and 1996-H represent the fjords surveyed during the 1996 survey at 60˚N, 62˚N (respectively) and 1996-Off represents the three combined offshore areas (I, J and K) surveyed during 1996. Crosses indicate outliers.

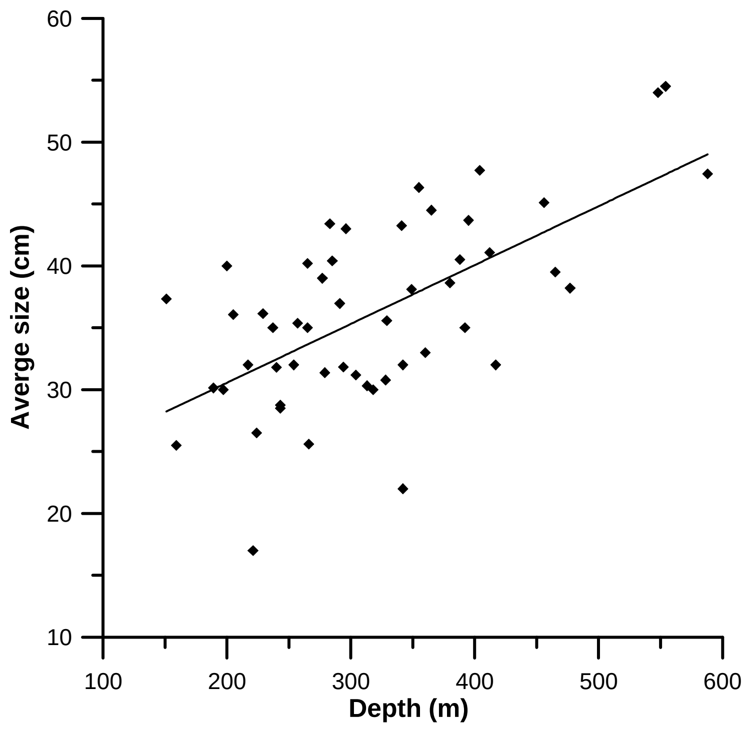

Figure 3.2. Average size of Greenland halibut at each station caught using fine meshed gillnets versus depth. Linear regression line shown.

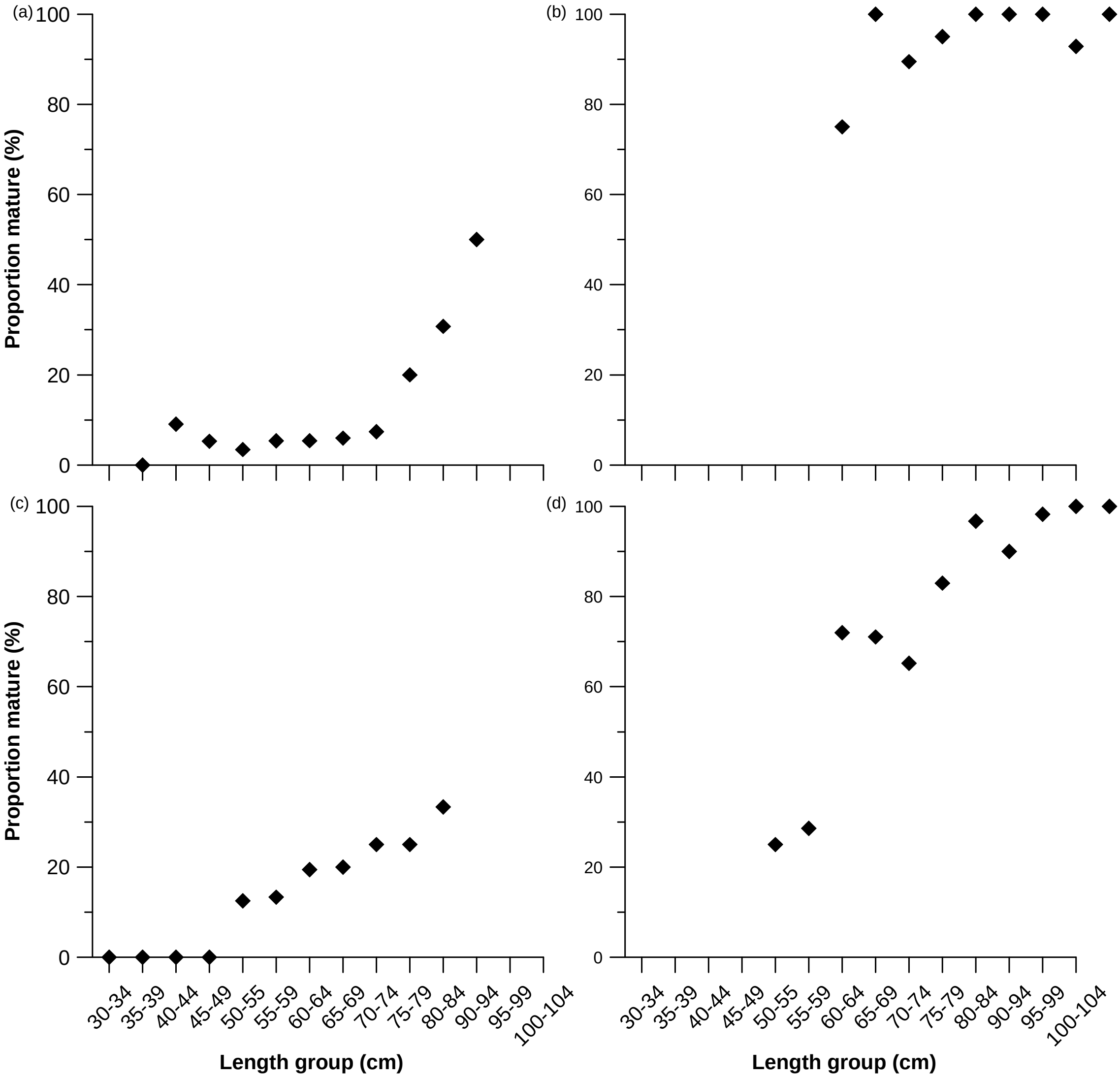

Figure 3.3. Percentage of female Greenland halibut which were mature in different length groups caught in (a) 1994 (fjords) (b) 1997 (offshore) (c) 1996 (fjords) and (d) 1996 (offshore).

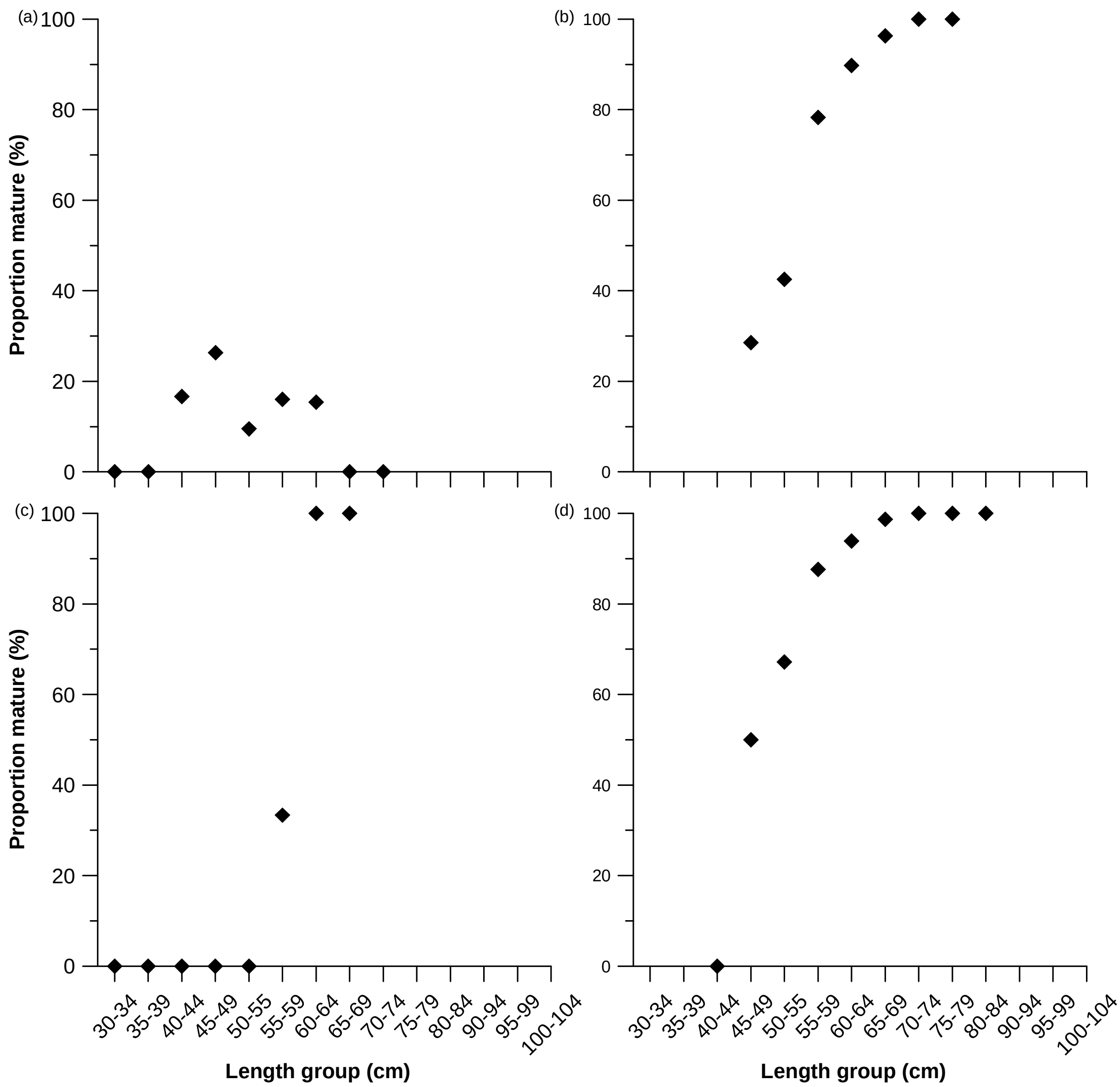

Figure 3.4. Percentage of male Greenland halibut which were mature in different length groups caught in (a) 1994 (fjords) (b) 1997 (offshore) (c) 1996 (fjords) and (d) 1996 (offshore).

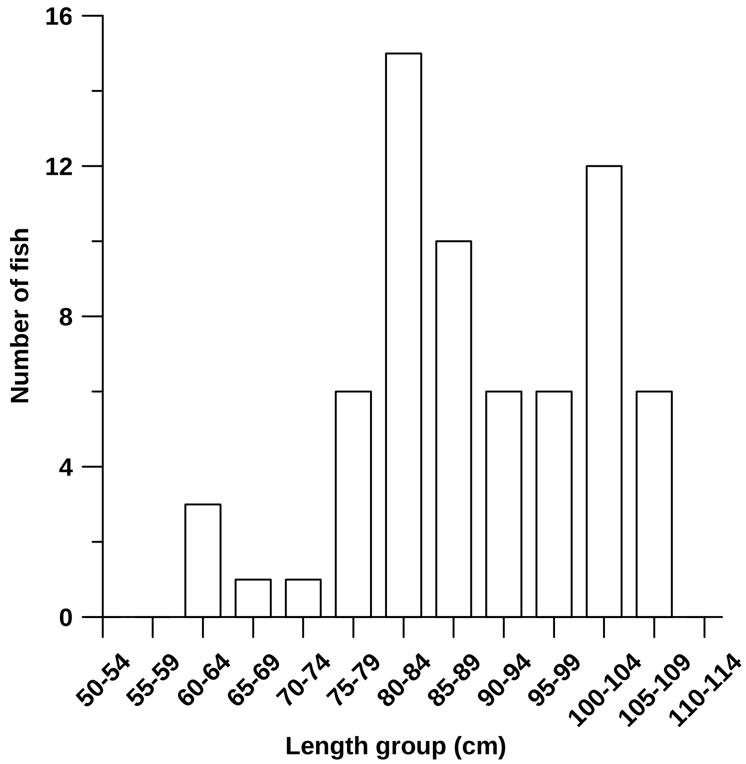

Figure 3.5. The number of running Greenland halibut in different length groups caught during surveys in East Greenland.

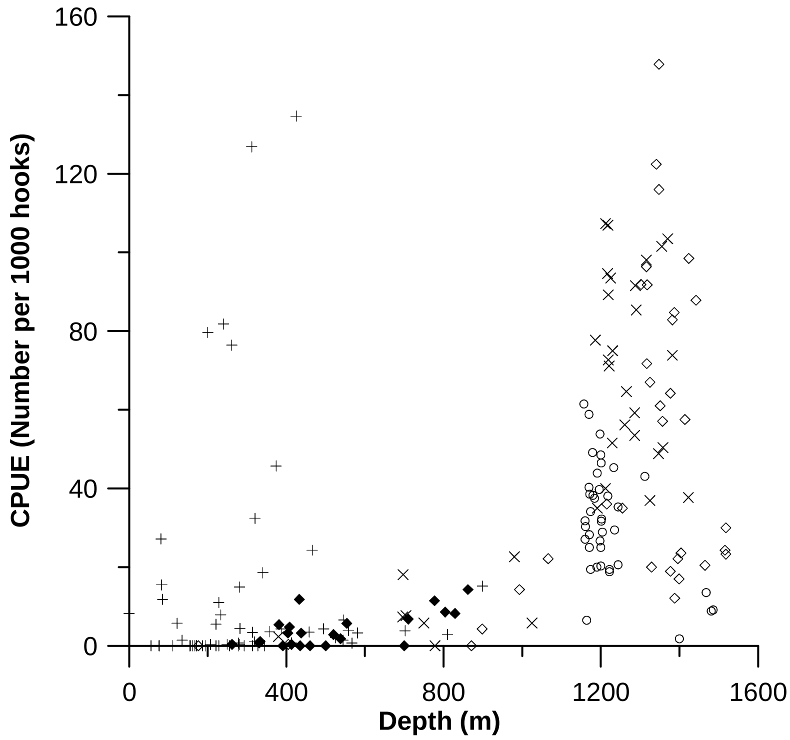

Figure 3.6. The number caught per unit effort (NPUE) (number per 1000 hooks) versus depth for Greenland halibut at each station during 4 longline surveys in East Greenland; 1994 (fjords) (+), 1996 (offshore) (◊), 1996 fjord (♦) 1997 (Offshore) (o) and 2000 (offshore) (x).

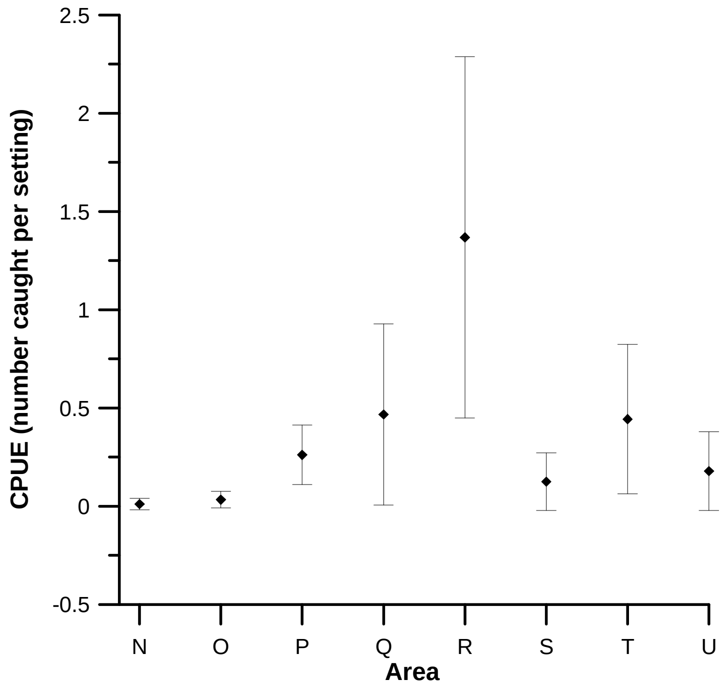

Figure 3.7. Average catch per net (NPN) of Greenland halibut with fine meshed gillnets in different areas of Greenland. Areas correspond with Figure 2.3. Error bars show 95% confidence intervals.

4 DISCUSSION

This study addresses two aspects important for management considerations of Greenland halibut in East Greenland and also for the West-Nordic management unit for which Greenland halibut in East Greenland are a part. We attempt to do this using data collected during exploratory surveys in East Greenland i.e. data which were collected without the specific aims stated in this study. The data is thus not ideal due to use of different gears and that the surveys are limited to only one season in each year. The selectivity of the different gears used differ greatly and rely on different principles for the capture of fish with the most selective being the gillnets where the median size of the fish caught will only differ slightly between different underlying populations.

Physical evidence of the nursery grounds of Greenland halibut in the waters of Green land is an important piece of information that has been lacking. As a result of this, there is no data on pre-recruitment variability as dedicated Greenland halibut pre-recruit surveys have never taken place. This is a major hindrance when attempting to forecast stock size and productivity in a stock assessment. In the assessment of the model output do not show a trend in recruitment (*e.g.* ICES 2010). From the results presented in the current study we find that young fish are present around the coastal area of Greenland. The fjords of East Greenland do resemble nursery grounds having a population composition of fish with a total length down to 26 cm. There are several indications that lead us to our conclusion;

1) The mean size of Greenland halibut differed between the Fjords and offshore area, and Greenland halibut as small as 15 cm were caught within the fjords of southern Greenland.
2) The majority of fish caught within the fjord were immature and also the maturity ogive shows that the percentage of fish mature in different length classes is much lower within the fjord, than in the offshore area.
3) The numbers of females above 80 cm or males above 65 cm caught within the fjord was very low, above these sizes almost 100 % of the fish are generally mature (Morgan *et al.*, 2003).
4) The NPUE of immature Greenland halibut in one area (area E in 1994) in East Greenland was as high the NPUE of immature fish in the offshore area.

Several studies have attempted to locate the nursery areas in East Greenland. A number of surveys using shrimp or fine meshed bottom trawls on the outer banks of East Greenland did not report any catches of young Greenland halibut (Sigurđsson & Magnússon, 1980). An analysis of the by-catch of Greenland halibut in shrimp trawl surveys was analysed by Boje & Hjörleifsson (2000) in order to evaluate potential areas which could be nursery grounds for Juvenile Greenland halibut. They concluded there was nowhere on the East Greenland continental shelf in which Greenland halibut occurred in significant numbers to constitute a nursery area similar to that seen in West Greenland. However, it must be noted that the shrimp surveys are not carried out within the fjords. Sigurđsson & Magnússon (1980) did report catches of 1 year old Greenland halibut in Northern Iceland in 1980, but concluded that this was a rare occurrence and influenced by the strength of the ocean currents. Sigurđsson & Magnússon (1980) also mentioned that that the highest concentration of 0-group Greenland halibut are caught off Tasilaq, this is close to the area where the highest concentrations of juveniles were found in the present study.

Drift models have showed that eggs spawned in Iceland are likely to drift towards East Greenland, ending up in the shelf area (Ådlandsvik, 2000; Stenberg, 2007). Sigurđsson & Magnússon (1980) also believed that the main drift of Greenland halibut larvae would be to East Greenland. Therefore the concentration of immature Greenland halibut found in area E during the 1994 survey may originate from Greenland halibut spawning in Icelandic waters. Due to the concentration of juveniles we would consider this to constitute a nursery area, however its importance, in terms of contribution to the adult population, in comparison to other areas around East Greenland is unknown. Stenberg (2007) found that some of the eggs would drift along the coast of East Greenland resulting in a continuous distribution as far away as South-west Greenland. So there are likely to be other areas along the coast of East Greenland which would give comparable catches of immature Greenland halibut as to that caught in the 1994 survey. Further surveys around the coast of East Greenland are thus required to get the full picture, however, this presents practicality issues due to the presence and variability in the amount of ice within the fjords; in 1998, several areas in which surveys were planned could not take place for this reason.

The fine meshed gillnets caught Greenland halibut as small as 15 cm. Catches were, however, low with the highest catch per net being only 1.4 individuals. The low catches of Greenland halibut are most likely to be the result of very low catch efficiency of the nets. These nets were tested during 1999 in areas in west Greenland known to have high concentrations of Greenland halibut, however, the catches from the nets were very low (Boje, 2000). It is therefore difficult to assess the numbers of juveniles present in the areas sampled. However, the nets do confirm the presence of juveniles and that there are likely to be higher numbers in the stations fished in South-west Greenland compared to those in East Greenland.

Drift models show that eggs spawned in East Greenland will drift round to South-west Greenland (Stenberg, 2007). Juvenile Greenland halibut were present in East Greenland, so there is potential for a continuous band of juveniles around the entire coast of East Greenland, stretching round to the South-west. At the start of the band the juveniles will probably consist exclusively of juveniles which originate from the Icelandic spawning. As one moves southwards along the coast it is likely that there will be a decrease in numbers; as predicted by egg drift models (Stenberg, 2007), followed by an increase as one approaches South-east Greenland. In this area, there is probably a mixture of juveniles of both East Greenland and Icelandic origin, with an increasing proportion being of East Greenland origin as they move around the coast and approaches South-west Greenland. As one moves north along the coast of West Greenland, it is likely that the proportion of Juveniles of East Greenland origin decreases and juveniles which were spawned in West Greenland will begin to dominate.

The average size of Greenland halibut increased with depth during the gillnet surveys therefore smaller, younger individuals are likely to be found at shallower depths than that fished during the survey. This points to a gradual movement of Greenland halibut to deeper water as they grow, a well-known dynamic for Greenland halibut (i.e. Jørgensen, 1997).

This distribution of the young immature Greenland halibut close to the shore and in the fjords in East and South-west Greenland is in contrast to the distribution in West Greenland. In West Greenland young Greenland halibut are found in dense concentrations at depths of about 200 m on the continental shelf (Riget *et al.*, 1988). In East Greenland there are large areas of a suitable depth range for young Greenland halibut, however, concentration of Greenland halibut in this area is very low (Boje & Hjörleifsson, 2000). It is likely that this area is unsuitable for other reasons such as temperature, bottom type, prey availability or predators.

During the surveys many running females were caught. These fish were mainly caught at Kap Bille Banke. During the gillnet survey in 1995, over 10 % of the fish assessed for maturity were found to be running. This indicates that Kap Bille Bank is a spawning area for Greenland halibut. The gillnet survey was carried out in three areas, however, it was only in Kap Bille Bank that running females were caught. The majority of the stations from this survey were in this area, however there were over 1000 fish caught in the other two areas. With running fish accounting for about 10 % of the fish caught, we consider 1000 fish to be sufficient size that can be used to assess the likelihood of spawning occurring in these areas. As no running fish were caught in these areas it is likely that these areas do not constitute spawning grounds at this time of year.

It is a question why spawning in this area has not been discovered previously, when a major commercial fishery occurs in this area. This is probably due to the main gear used in the fishery, namely longlines and bottom trawl, being unsuitable for catching running females as several longline surveys were carried out in the spawning area during the present study and only one running female was caught. The reason for the low catch in trawls is due to trawls selecting for fish mainly between 40 and 60 cm (Nedreaas *et al.*, 1996; Huse *et al.*, 1999), fish at this size are mainly immature females and males. Mature fish are mostly longer than 70-80 cm. Longlines rely on feeding motivation and so the low catch of running females is believed to be due to a low motivation for feeding. Of all the spawning females caught, the ovary contained only hydrated oocytes; i.e. no non-hydrated oocytes, this indicates that Greenland halibut spawn only a single batch, a conclusion supported by Stene *et al.* (1999). This means that the individuals are in running condition for only a very short period, compared to batch spawners, thus their probably of capture when in running condition is lower.
The running fish in East Greenland were exclusively caught at depths between 1000 and 1300 m, this is different to the Greenland halibut in the Barents Sea where they spawn at depths between 600 and 900 metres (Godø & Haug, 1989). The prevailing oceanographic conditions are probably more important factors for spawning areas as opposed to the depth.

The Greenland halibut maturity cycle has been well described over the last decade *e.g.*for the Davis Straid (Gundersen *et al*., 2010) and the Barents Sea (Kennedy *et al.,* 2011). However, the ovary cycle for the Greenland halibut population in East Greenland remains undescribed. However, it is clear from the present study that a small proportion of the population do spawn in the summer and a previous study has shown that there are many individuals which are close to spawning in March (Kennedy *et al*., 2009). A lack of clearly defined spawning season or fish being caught outside what is considered to be the main spawning season has been reported for several stocks of Greenland halibut (Junquera & Zamarro, 1994; Rideout *et al.*, 1999; Albert *et al.*, 2001) and is hypothesised to be due to a lack of synchronicity in the timing of oogenesis (Rideout *et al.*, 1999). In the Barents Sea and in the Davis Strait there is a large range in the development stages within a month for Greenland halibut. As a result of this large range, individual fish will reach full maturity at different times resulting in a prolonged spawning season (Gundersen *et al.*, 2010; Kennedy *et al.*, 2011). In combination with the spread of development stages and the rate of development it can be deduced that the individuals which were most advanced in development would be ready to spawn around August, with more fish progressivly being ready to spawn through to approximately May the following year (Kennedy *et al.*, 2011). This leads us to believe that these spawning fish caught in the present study represent the early part of an prolonged spawning season for the East Greenland population with increasing numbers coming to spawn through the year.

The surveys which caught running females were carried out only during the summer which is thought to be only the beginning of the spawning season, therefore it is difficult to estimate the importance of this area as a spawning ground. Further surveys later in the year are thus essential to get a better estimate of the size of the area that constitutes the spawning grounds and also the number of fish which spawn in the area.

This spawning of Greenland halibut in East Greenland waters raises questions on the definition of West Nordic management unit. This unit is partly based on the assumption that Greenland halibut in all areas originate from a common spawning ground southwest of Iceland. This assumption was based on few observations (Magnússon, 1977). The presence of the spawning area in East Greenland along with observations of late maturing females in the Faroe Islands (L. H. Ofstad, Faroe Islands Fisheries Laboratory, unpublished data), and Hatton Bank (I. Fossen. Pers. Com.) indicate that this is unlikely to be true. A tagging experiment carried out in Iceland between 1971 and 1978 resulted in no Greenland halibut recaptured in East Greenland despite there being a major fishery in this area between 1971 and 1975 (Sigurđsson, 1979). These observations make the disentangling of the West Nordic stock difficult, together with the fact that the nursery grounds of the Icelandic component may be present in East Greenland and possibly overlap with the nursery grounds of fish spawning in East Greenland. Questionsone must ask are

- If there is an overlap in nursery areas?
- Do the juveniles recruit exclusively to their natal populations?
- Will they recruit to the closest population?

Knutsen *et al.* (2007) showed evidence that the drift of eggs and larvae with the ocean currents mediates gene flow between populations of Greenland halibut, supporting the theory that juveniles will recruit to non-natal populations. It has also been shown that fish tagged at likely nursery areas in South-west and East Greenland have been re-captured in Icelandic waters. However, these fish may have been returning to their natal population. These were, however, only a very small fraction of the recaptures with the majority being recaptured in the release area (Boje, 2002; Smidt, 1969).

From our results we can see that the structure of the West Nordic management unit is complicated and remains un-clear. Our results do demonstrate that the hypothesis that the unit originates from a single spawning area in Iceland is likely to be inaccurate. At present, the unit is below safe biological limits with reductions in the quotas recommended by ICES (ICES, 2010). This places extra emphasis on the need to increase the knowledge on the stock structure of this west-Nordic management unit.

The fishing effort and catches are not evenly spread over the management unit (ICES, 2010) and if there are indeed several isolated or semi-isolated populations within the West Nordic stock unit, then the productivity of these are likely to differ. The failure to recognize separate subunits within a management unit can lead to local depletion of the less productive units (Iles & Sinclair, 1982; Ruzzante *et al.*, 1999), lead to the abandonment of spawning grounds (Smedbol & Wroblewski, 2002), and rebuilding of the stock complex could be impeded (Iles & Sinclair, 1982). Due to the prevailing egg and larval drift pattern it is likely that there is some connection between the units within the stock complex (Knutsen *et al.*, 2007; Stenberg, 2007) and they may form a meta-population rather than discrete stocks (Smedbol & Wroblewski, 2002). Local depletions may likely occur as long distance migration between areas is not a common behaviour for Greenland halibut (Boje, 2002). Further work to attempt to understand the stock structure of this West Nordic unit is thus considered essential for effective management of this unit.

5 REFERENCES

Albert, O.T., Nilssen, E.M., Stene, A., Gundersen, A.C., Nedreaas, K.H. 2001. Maturity classes and spawning behaviour of Greenland halibut (Reinhardtius hippoglossoides). Fisheries Research, 51: 217-228.

Ådlandsvik, B. 2000. Modelling transport of eggs and larvae of Greenland halibut in East-Greenland waters. In Greenland halibut in East Greenland waters – Recruitment studies and mapping of nursery grounds., p. 49. Ed. by A. K. WOLL. TemaNord Fiskeri, Copenhagen, Denmark.

Boje, J. 2000. Validation of small-meshed gillnets for juvenile Greenland halibut. In Greenland halibut in East Greenland waters – Recruitment studies and mapping of nursery grounds., p. 99. Ed. by A. K. Woll. TemaNord Fiskeri, Copenhagen, Denmark.

Boje, J. 2002. Intermingling and seasonal migrations of Greenland halibut (*Reinhardtius hippoglossoides*) populations determined from tagging studies. Fishery Bulletin, 100: 414-422.

Boje, J., Hjörleifsson, E. 2000. Nursery grounds for the West Nordic Greenland halibut stock – where are they? ICES CM 2000/N:03.

Boje, J. , Sünksen, K. 2008. The fishery for Greenland halibut in ICES Div. XIVb in 2007. Working Document no. 11 presented at the ICES Expert Group: Northwestern Working group April – May 2008.

Burton, M. P. M. 1999. Notes on potential errors in estimating spawning stock biomass: Determining the effects of non-participatory adults for some groundfish species. Journal of Northwest Atlantic Fishery Science, 25: 205-213.

Fossen, I. og Gundersen, A. C., 2000: Ressursundersøkelse ved Kap Bille Banke og Heimlandsryggen, Øst-Grønland, august 2000. Møreforsking Ålesund (Rapport Å0018)

Gundersen A. C. og A. Woll, 1996: Forvaltningsrelaterte undersøkelser på blåkveite i ICES-område XIVb. (Rapport Å9608).

Gundersen, A.C. & A.K. Woll. 1997. Linesurvey ved Øst-Grønland, sommeren 1996. Forvaltningsrelaterte undersøkelser på blåkveite. Møreforskingsrapport nr. Å9702, 89p.

Gundersen, A.C., A.K. Woll, & J. Boje. 1998. Linesurvey ved Øst-Grønland, sommeren 1997.

Gundersen, A.C., A.K. Woll & T. Johansen. 1996. Forsøksfiske etter blåkveite ved Sydøst-Grønland. Garnundersøkelser sommeren 1995. Rapport nr. Å9606, Møreforsking Ålesund.

Gundersen, A.C., Stenberg, C., Fossen, I., Lyberth, B., Boje, J., Jørgensen, O.A. 2010. Sexual maturity cycle and spawning of Greenland halibut Reinhardtius hippoglossoides in the Davis Strait. Journal of Fish Biology, 77: 211–226.

Godø, O.R., Haug, T. 1989. A review of the natural history, fisheries, and management of the Greenland halibut (*Reinhardtius hippoglossoides*) in the eastern Norwegian and Barents Seas. Conseil international pour l'exploration de la mer, 46: 62-75.

Hjörleifsson, E., Boje, J., Woll, A.K., Gundersen, A.C. 2000. The West-Nordic stock of Greenland halibut. A review. In Greenland halibut in East Greenland waters – Recruitment studies and mapping of nursery grounds., p. 167. Ed. by A. K. WOLL. TemaNord Fiskeri, Copenhagen, Denmark.

Huse, I., Gundersen, A.C., Nedreaas, K.H. 1999. Relative selectivity of Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum) by trawls, longlines and gillnets. Fisheries Research, 44: 75-93.

ICES 2010. Report of the North-Western Working Group (NWWG), 27 April - 4 May 2010, ICES Headquarters, Copenhagen. ICES CM 2010 /ACOM:07. 751 pp.

Iles, T.D., Sinclair, M. 1982. Atlantic herring: Stock discreteness and abundance. Science, 215: 627-633.
Jensen, A.S. 1935. The Greenland halibut (*Reinhardtius hippoglossoides* (Walb.)) its development and migrations. D. Kgl. Danske Vidensk. Selsk. Skrifter, Naturv. og Math. Afd., 9: 1-36.
Junquera, S., Zamarro, J. 1994. Sexual maturity and spawning of Greenland halibut (*Reinhardtius hippoglossoides*) from Flemish Pass area. NAFO Science Council Studies, 20: 47-52.
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, 21: 23-37.
Kennedy, J., Gundersen, A.C., Høines, Å., Kjesbu, O.S. 2011. Greenland halibut (*Reinhardtius hippoglossoides*) spawn annually but successive cohorts of oocytes develop over two years, complicating correct assessment of maturity. Canadian Journal of Fisheries and Aquatic Sciences, 68: 201-209.
Knutsen, H., Jorde, P.E., Albert, O.T., Hoelzel, A.R. and Stenseth, N.C. 2007. Population genetic structure in the North Atlantic Greenland halibut (*Reinhardtius hippoglossoides*): influenced by oceanic current systems? Canadian Journal of Fisheries and Aquatic Sciences, 64: 857-866.
Magnússon, J.V. 1977. Notes on the eggs and larvae of Greenland halibut at Iceland. ICES C.M. 1977/F:47: 6 pp.
Morgan, M.J., Bowering, W.R., Gundersen, A.C., Høines, Å., Morin, B., Smirnov, O., Hjörleifsson, E. 2003. A comparison of the maturation of Greenland halibut (*Reinhardtius hippoglossoides*) from populations throughout the North Atlantic. Journal of Northwest Atlantic Fishery Science, 31: 99-112.
Nedreaas, K., Soldal, A.V., Bjordal, Å. 1996. Performance and biological implications of a multi-gear fishery for Greenland halibut (*Reinhardtius hippoglossoides*). Journal of Northwest Atlantic Fishery Science, 19: 59-72.
Rideout, R., Maddock, D.M., Burton, M.P. 1999. Oogenesis and the spawning pattern in Greenland halibut from the North-west Atlantic. Journal of Fish Biology, 54: 196-207.
Riget, F., Boje, J., Lehmann, K. 1988. By-catches of Greenland halibut and Redfish in the shrimp fishery at West-Greenland. NAFO SCR Doc., 88/12: 15.
Ruzzante, D.E., Taggart, C.T., Cook, D. 1999. A review of the evidence for genetic structure of cod (Gadus morhua) populations in the NW Atlantic and population affinities of larval cod off Newfoundland and the Gulf of St. Lawrence. Fisheries Research, 43: 79-97.
Sigurŏsson, A. 1979. Migrations of Greenland halibut *Reinhardtius hippoglossoides* (Walb.) from Iceland to Norway. Rit Fiskideildar, 6: 3-6.
Sigurŏsson, A., Magnússon, J. V. 1980. On the nursery grounds of the Greenland halibut spawning in Icelandic waters. ICES CM 1980, G:45: 1-8.
Simonsen, C.S., Gundersen, A.C. 2005. Ovary development in Greenland halibut *Reinhardtius hippoglossoides* in west Greenland waters. Journal of Fish Biology, 67: 1299-1317.
Smedbol, R.K., Wroblewski, J.S. 2002. Metapopulation theory and northern cod population structure: interdependency of subpopulations in recovery of a groundfish population. Fisheries Research, 55: 161-174.
Smidt, E.L.B. 1969. The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), biology, and exploitation in Greenland waters. meddelelser fra Danmarks Fiskeri- og Havundersøgelser, 6: 79-148.
Stenberg, C. 2007. Recruitment processes in West Greenland waters - With special focus on Greenland halibut (*Reinhardtius hippoglossoides*, W.). Department of Biology, University of Bergen, Bergen. Ph.D. Thesis: 136 pp.

Stene, A., Gundersen, A.C., Albert, O.T., Nedreaas, K.H. and Solemdal, P. 1999. Early development of Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*). Journal of Northwest Atlantic Fishery Science, 25: 171-177.

Tåning, A.V. 1936. On the eggs and young stages of the halbut. Meddelelser fra kommissionen for Danmarks Fiskeri og Havunder, Bind X No. 4: 20.

Woll A.K. & A.C. Gundersen. 1997. Kartlegging av fjorder og kontinnetalsokkel ved Sydøst-Grønland. Topografi, hydrografi og fiskeressurser. Møreforskingsrapport nr. Å9719, 66p.

Woll, A., J. Boie, A. C. Gundersen & G. Liaklev, 1998: Blåkveite ved Øst-Grønland. Effekt av krok- og agnseleksjon i blåkveitefiske. Møreforskning Ålesund (Rapport Å9813).

Woll, A.K., Boje, J., Holst, R., Gundersen, A.C. 2001. Catch rates and hook and bait selectivity in longline fishery for Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum) at East Greenland. Fisheries Research, 51: 237-246.

Woll, A.K., Boje, J. Hjørleifsson, E. & Gundersen, A.C. (Editors). 2000. Greenland halibut in East Greenland waters. Recruitment studies and mapping of nursery grounds. Tema Nord 2000: 585, 165p.

Yatsu, A., Jørgensen, O.A. 1988. Distribution and size composition of Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), from a bottom trawl survey off East Greenland in 1987. ICES CM 1988, G:62: 1-7.

MØREFORSKING

HØGSKOLEN I ÅLESUND

MØREFORSKING MARIN
Postboks 5075, NO-6021 Ålesund

Telefon +47 70 11 16 00
Telefax +47 70 11 16 01

epost@mfaa.no
www.moreforsk.no

HØGSKOLEN I ÅLESUND
Serviceboks 17, NO-6025 Ålesund

Besøksadresse: Larsgårdveien 2
Telefon +47 70 16 12 00

postmottak@hials.no
www.hias.no