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Rebuilding the Stock of Northeast Arctic Greenland Halibut (*Reinhardtius hippoglossoides*)

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Abstract

After the absence of 1989–1994 year classes of Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*) in regular surveys, an annual survey programme was initiated in 1996 to map juveniles in previously unsurveyed waters north and east of Svalbard. After rather stable juvenile indices in the first years, the recruitment indices have increased tenfold from 2001 to 2006. The increase in juvenile Northeast Arctic (NEA) Greenland halibut corresponded with an increase in spawning stock biomass. The swept area abundance estimates of spawning females (*i.e.*, females >60 cm), has nearly tripled since 1996 having achieved 29 000 t in recent years. This improvement occurred after years of strong regulations, introduced in 1992, by enforcing a moratorium on the targeted offshore fishery and strict bycatch regulations for the species. Regulations were introduced after a dramatic change in stock status for the NEA Greenland halibut during the 1980s. Females >75 cm contributed more to the stock's total egg production (TEP) in more recent years. The contribution from these larger females increased from 10% of the TEP estimate in 1996 to 21% in 2006. The results from the present study indicate that rebuilding Greenland halibut stocks takes time, and that at least 12–15 years with restrictions are needed to recover from the low levels observed in the Barents Sea in the beginning of the 1990s.

Key words: Arctic, Barents Sea, Greenland halibut, recruitment, spawning stock, stock recovery.

Introduction

The Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) is an arcto-boreal, deep-water flatfish. It is distributed both in the Atlantic and the Pacific Ocean (Bowering and Nedreaas, 2000). In the North Atlantic the species is distributed in cold water along the slope areas and the species appears to be subdivided into partially isolated populations (Knudsen *et al.*, 2007). However, Greenland halibut is regarded as one species throughout the Northern Hemisphere but due to their distributional separation and integrity the species is separated into different management units often referred to as stocks. The main management units of the north Atlantic are the Northwestern stock (Canada and West Greenland), West Nordic stock (East Greenland, Iceland, Faroe Island and Hatton Bank) and the Northeast Arctic stock (Eastern Norwegian Sea and Barents Sea).

The Northeast Arctic (NEA) Greenland halibut is found along the continental slope of Norway north of 61° N. The distribution area extends into the Arctic area north and east of Svalbard (Fig. 1). The main distribution area for adults is between Lofoten on the northern coast of Norway and Svalbard (*e.g.* Godø and Haug, 1989; Albert, 2002). Spawning locations are distributed along the continental slope in this area (Fedorov, 1971; Albert *et al.*, 2001; Albert, 2002).

Exploitation of Greenland halibut increased rapidly in the 1970s and 1980s, as a result of fisheries moving into new areas and deeper waters (*e.g.* Godø and Haug, 1989;

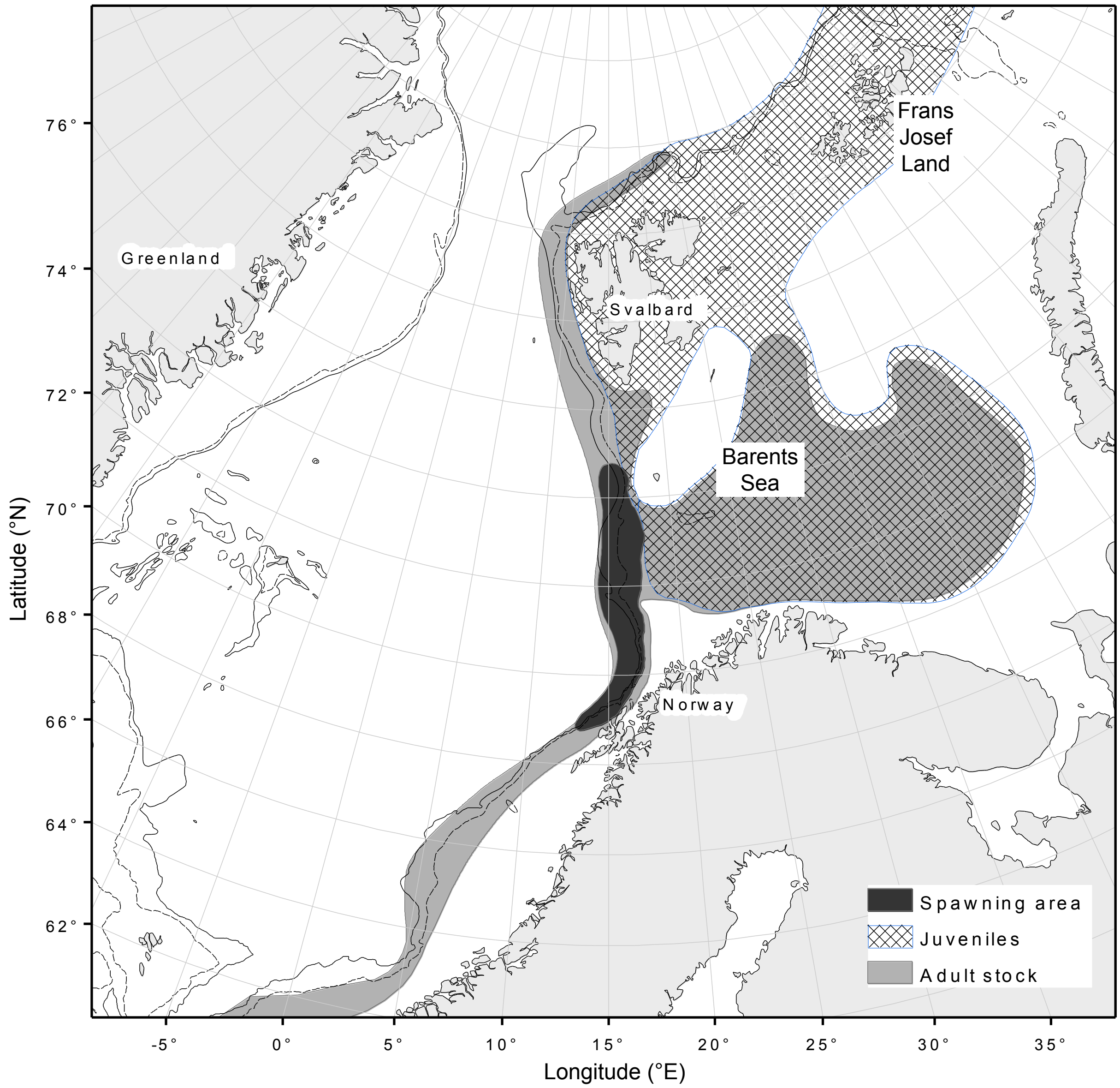

Fig. 1. Distribution of Northeast Arctic Greenland halibut. The most important adult area is along the slope from 600–900 m. The area north and east of Svalbard towards the Franz Josef Land is the most important juvenile area even though some juveniles are found in the central Barents Sea.

Bowering and Nedreaas, 2000; ICES, MS 2007). Godø and Haug (1989) review the fishery for NEA Greenland halibut. The majority of the catches were taken in ICES Division IIb and the landings increase sharply from about 10 000 t in the early 1960s and reached a maximum of over 90 000 t in 1970. Since then the total stock biomass of NEA Greenland halibut has decreased and the high fishing pressure and fishing mortality caused a decline in stock size in the late 1980s (ICES, MS 2007). Parallel to this, it was observed that year-class indices derived from regular 0-group and juvenile surveys dropped and that the spawning stock size reached historical low levels (Hylen and Nedreaas, 1995; Smirnov, 1995). A decrease in the commercial catch per unit of effort (CPUE) was observed until 1992 (ICES, MS 2007) when the total stock biomass estimate was the lowest observed in the time series (ICES, MS 2007). Consequently strong fishery regulations for Greenland halibut were introduced in 1992. Target trawl fishery was prohibited and trawl catches were limited to bycatch only. From 1992 to autumn 1994 bycatch in each haul was not to exceed 10% by weight and in the period from 1994 to 2004 the bycatch regulations have been executed with a varying allowable percentage onboard. From early 2004 the Norwegian Department of Fisheries decided that for Norwegian vessels in the NEEZ allowable bycatch at any time on board and by landing should not exceed 7%. In addition, the annual catch for each trawler was not allowed to exceed 4% of the sum of the vessels quota on cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*), and limited by a maximum annual catch of 40 t of Greenland halibut per vessel. Norwegian authorities also established an annual quota from 1992 of 2 500 t for the small coastal fleet as the only allowable targeted fishery because of historical rights. As a consequence of these strong regulations the catches dropped from 33 000 t in 1991 to below 8 600 t in 1992, and the mean catch in the period 1992–2006 was 14 000 t (ICES, MS 2007).

Six subsequent year-classes (1989–1994) of NEA Greenland halibut were almost absent from the routinely surveyed Barents Sea and Svalbard areas as 0–4 year olds (Hylen and Nedreaas, 1995; Albert *et al.*, 2001; Albert and Høines, 2003). These year-classes did however appear in the fishable stock in higher quantities than expected from the recruitment indices (ICES, MS 2007).

Albert *et al.* (2001) showed a change around 1990 in distribution of juveniles to areas beyond those covered by regular surveys, and Albert and Høines (2003) showed that the displaced distribution of the 1989–1994 year classes persisted up to age 7. Greenland halibut mainly recruits to the fishable stock at a size of *ca* 45 cm. Age readings are very uncertain but present knowledge supports that a fish of this length is 5–8 years old. This questioned the accepted knowledge of the distribution patterns of juveniles and suggested that regular surveys did not cover the distribution of young Greenland halibut. Earlier studies showed that juveniles (age group 0 and I) of Greenland halibut were found in the western Svalbard area (Hognestad 1969; Haug and Gulliksen, 1982; Godø and Haug, 1987; Haug *et al*., 1989). However, some Russian surveys (Borkin, 1983) and Norwegian shrimp surveys in the 1990s indicated that the areas north of Spitsbergen and eastwards to Franz Josef's Land were potential nursery areas. As a consequence of this, a new detailed annual survey programme was started in September 1996 aiming to map nursery grounds of NEA Greenland halibut and results from this survey state that this northeastern area is the most important nursery area for this stock.

After the strong regulations were implemented, information about the development of the adult Greenland halibut stock was needed. A new survey along the slope between Norway and Spitsbergen was started and the stock has been monitored annually since 1994. The survey results have been reported to ICES and are used in the tuning series for the assessment of this stock (ICES, MS 2007).

The present study uses the two new surveys targeting NEA Greenland halibut to analyse the development and rebuilding of spawning stock size after the regulations introduced in 1992. Further it addresses how spawning stock size development coincides with changes in juvenile abundance.

Materials and Methods

Estimates of juvenile abundance were obtained from surveys targeting juvenile Greenland halibut in the waters north and east of Svalbard that have been conducted annually in late August-mid September since 1996. The survey was designed based on previous sporadic reports of Greenland halibut north and east of Svalbard (Borkin, 1983). When designing the juvenile survey the area was divided into seven sub areas (Fig. 2), and each of these sub areas was divided into three depth strata, 100–300 m, 300–500 m, and >500 m. The surveys have been conducted with close collaboration between Norway and Russia.

The trawlers used were all equipped with the same type of trawl that is used by the IMR's research vessels in the Barents Sea; a Campelen 1800 standard shrimp trawl equipped with rockhopper gear and 22 mm stretched meshes in the trawl bag (Engås and Godø, 1989). The trawls were operated with 40 min sweeps and strapping according to Engås and Ona (1991) to stabilize trawl geometry and performance. The standard trawling time was 30 min at 3 knots. The trawls were equipped with Scanmar sensors, which measured the distance between the doors, the trawl's vertical opening and contact with the bottom. The trawls were also equipped with a calibrated temperature recorder from Scanmar. From 2000 both Norwegian and Russian vessels were equipped with a CTD-probe providing improved coverage of the hydrographical conditions in the survey area.

The adult Greenland halibut survey covering the slope area between 68° N (Røst) and 80° N (northwest edge of Svalbard), which is the main distribution area for adult Greenland halibut, has been conducted annually in August since 1994, using hired factory trawlers. Several trawlers have been used but gear, technical equipment and survey design have been the same each year. The survey vessels used Alfredo 5 commercial bottom trawls equipped with rockhopper gear, and with 60 mm stretched mesh inner lining in the codend. The sweeps

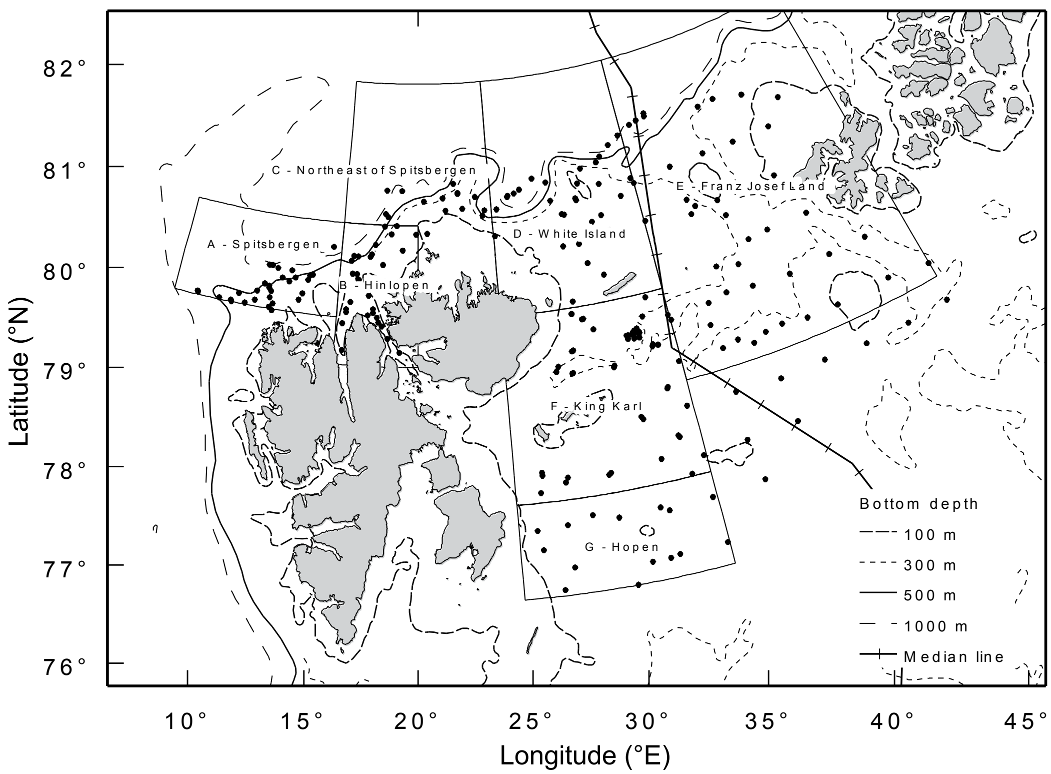

Fig. 2. Strata used in the juvenile survey for Greenland halibut. Black dots represent trawl stations covered in a typical year (2001). Median line is the borderline between the Russian EEZ and the fishery protection zone around Svalbard.

were 160–170 m long, and the trawl opening was 3–4 m high (no strapping was used to maintain these parameters). The trawl doors were of type Injector with an area of 9.9 m^2, weighing 2700 kg. The gear was towed at 3–4 knots, along the slope as a rule in a northerly direction, while the tow time varied from ½–1 hr depending on depth. The trawls were equipped with Scanmar trawl monitoring equipment which measured the distance between the doors, the trawl's vertical opening and contact with the bottom. The trawls were also equipped with a calibrated temperature recorder from Scanmar. Sampling stations along the slope were set on transects covering depths from about 450–1300 m. In total, *ca* 190 stations were sampled each year. The survey area was divided into four sub areas (Fig. 3), and each of these sub areas was divided into four depth strata, 400–500 m, 500–700 m, 700–1000 m, and 1000–1500 m.

Abundance estimates were obtained using swept area method on the two described survey series for total stock, female stock (>60 cm) and juveniles. Length based abundance estimates were estimated using the method of Jakobsen *et al.* (1997), for the four sub areas along the slope between the Barents Sea and the Norwegian Sea which define the area covering most of the spawning stock biomass, and for seven sub-areas defining the nursery grounds. The density of fish at station *s* of length *l* per nautical mile², $P_{s,l}$, is estimated by:

$$P_{s,l} = f_{s,l} / a_{s,l}$$

where $f_{s,l}$ is the estimated frequency of fish, and $a_{s,l}$ is the swept area given by:

$$a_{s,l} = d_s EW_l / 1852$$

where d_s is towed distance (in nautical miles) and EW_l is the length dependent effective swept width.

For Greenland halibut, there is no available estimate of the length dependent effective swept width, so it was set to 80 m in the slope area and 25 m in the nursery area, independent of fish length and trawl depth. Different swept width is used due to the use of different trawls in the two areas.

Point observations for fish density based on length *l* was summed up in 5 cm length groups denoted by $p_{s,l}$.

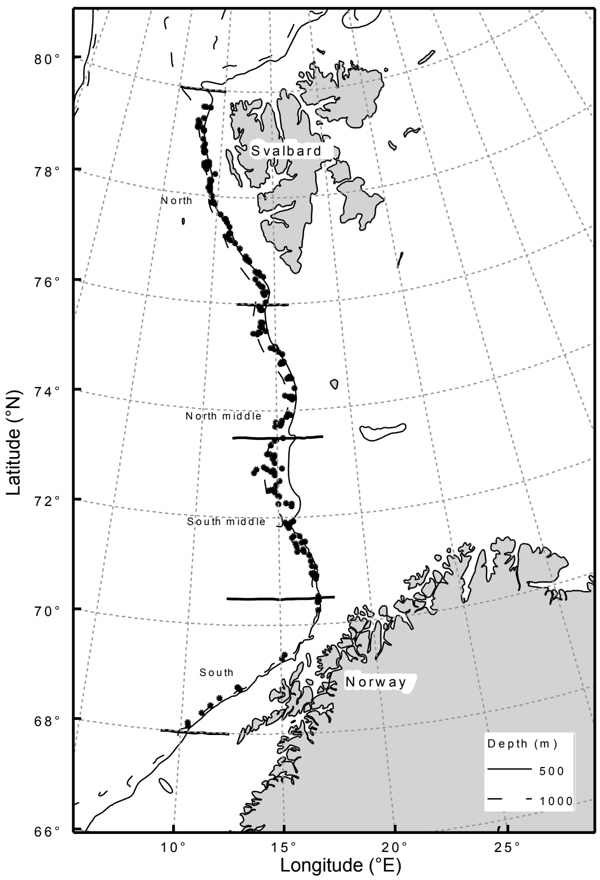

Fig. 3. Strata used in the survey covering the main adult stock. Black dots are fixed trawl stations covered.

Stratified abundance indices, $L_{p,l}$, for strata p and length group l are generated using:

$$L_{p,l} = \frac{A_p}{S_p} \sum P_{s,l}$$

where A_p area (in nautical mile^2) of stratum p, and S_p is the number of stations in stratum p.

For each sub area, the total number of fish in each 5 cm length group was estimated by summing over all strata in the sub area, and finally, the total index for each length class is the sum of the values for all sub areas.

Spawning stock estimates on females only (>60 cm) are based on the results of a series of 12 monthly surveys conducted throughout 1997 of Gundersen *et al.* (MS 2003) who estimated L_{50} = 59 cm for females in the slope areas west of the Barents Sea. Of course some females larger than 60 cm will be immature and similarly some females smaller than 60 cm will be mature. This means that a cut off size of 60 cm will exclude some females from the estimates, but this was used as a basis for the annual spawning stock abundance estimates. From a management perspective it is relevant to study egg production of the entire stock rather than examining production of individual females. Population fecundity is defined as the potential total egg production (TEP) of the stock (Serebryakov *et al.*, 1992). TEP is based on individual estimates of potential fecundity of a female and raised to the population level using estimates of spawning stock size, and mean length. The basis for the TEP estimates was the swept area estimates of females by 1 cm length groups from the slope area.

A factor for converting stock biomass to total egg production (TEP) was made using the following relationship between fecundity F and length L (in cm) obtained for 1996–1998, where $F = 0.0004320L^{4.259}$ (Gundersen *et al.*, 2000) combined with estimates of spawning stock in numbers.

Results

In 1996, a survey programme started to map juveniles in previously unsurveyed waters north and east of Svalbard. New nursery grounds were discovered in the waters north and east of Svalbard. Annual variability in juvenile abundance estimates was observed. The overall trend is, however, that after rather stable estimates in the first years, the recruitment indices have increased, in particular tenfold from 2001 to 2005–2006.

In the assessment of NEA Greenland halibut the spawning stock is regarded as mature females only (ICES, MS 2007). The rationale for this is that it is assumed that there are always enough mature males to fertilize the eggs and the best estimator of spawning stock thus is the amount of mature females. Not withstanding, recent analyses of potential male limitation have been explored in Atlantic cod and other species (Trippel, 2003). Consequently all analyses on spawning stock in this paper are undertaken on females only. In the first two years of the survey, distinguishing individuals by sex was unclear, thus only total abundance of Greenland halibut was available for those years. From 1996 the data were separated by gender. The total estimate was relatively stable and varied around a mean of 64 million individuals. The swept area estimates of females showed the same trend as the total estimate in the same period, and varied around a mean of 33 million individuals throughout the period from 1996 to 2006 (Table 1, Fig. 4). In the same period the abundance estimates of females >60 cm showed a significant increase (Linear regression; p <0.05, Fig. 4).

TABLE 1. Swept area estimates of the number of Greenland halibut along the continental slope of the northeast Atlantic Ocean. Length is midpoint in 5 cm length groups. The fish were not separated by sex in 1994 and 1995. Numbers are in thousands.

Length group	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
27.5								6	40	16	9	11	
32.5			14	46		35	69	99	340	265	317	726	566
37.5			238	607	424	322	372	919	1 460	1 982	2 058	2 843	3 400
42.5			4 353	3 641	2 613	2 027	1 968	3 245	3 347	4 077	3 294	4 678	4 837
47.5			12 217	8 515	8 241	9 284	4 577	6 750	7 099	6 579	5 557	4 633	5 552
52.5			9 377	6 377	7 480	13 181	7 174	9 111	9 441	8 883	9 331	3 547	5 032
57.5			3 731	3 125	3 124	5 811	4 856	6 049	6 307	7 428	6 012	3 334	4 380
62.5			1 994	2 359	2 475	3 432	3 217	3 374	3 829	4 601	4 570	3 509	3 406
67.5			1 482	1 666	1 668	3 248	2 394	3 015	2 750	4 185	3 433	2 949	3 101
72.5			579	778	778	1 432	1 138	1 200	1 241	1 764	1 863	1 385	1 653
77.5			187	295	262	618	437	493	483	814	641	557	638
82.5			55	101	128	242	155	163	198	268	328	238	342
87.5			3	33		56	4	57	37	64	72	55	104
92.5				2	2		10	12	6	10		45	21
97.5				17					2			6	3
102.5									4				9
Total females			34 230	27 560	27 195	39 686	26 371	34 492	36 585	40 933	37 482	28 516	33 045
Females >60 cm			4 300	5 249	5 313	9 027	7 355	8 314	8 550	11 704	10 906	8 744	9 276
Total Gr. Halibut	56 996	65 023	69 743	62 765	62 564	69 804	55 092	66 394	69 729	75 323	68 583	54 435	60 347

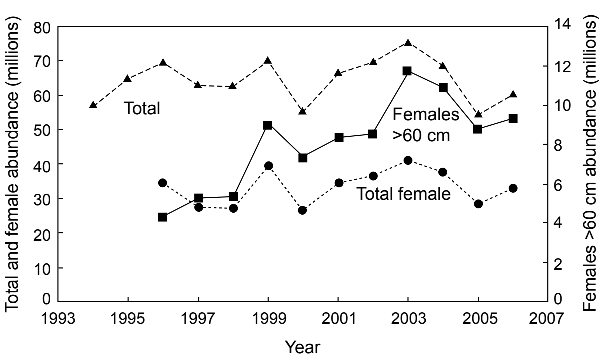

Fig. 4. Swept area abundance estimate (in numbers) of Greenland halibut from the slope area. Total abundance, total females, and females >60 cm.

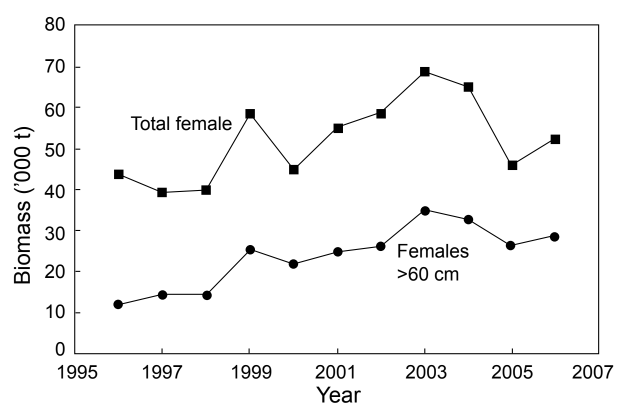

Fig. 5. Swept area estimates (biomass) of Greenland halibut, total female and female >60 cm, on the slope between Norway and Svalbard.

The biomass estimate of females from the slope area showed a slightly increasing trend over time ($p = 0.09$), but only females >60 cm showed a significant increase ($p < 0.05$, Fig. 5). There was no time trend in the mean weight of females throughout the period, thus the increase in biomass was caused by an increase in abundance (numbers).

The abundance estimates obtained from the survey north and east of Svalbard (the juvenile area) were relatively stable from 1996 to 2001 with a mean of 54 million individuals (Table 2). After 2001, the abundance estimates showed a dramatic increase in most years varying annually between 47 and 850 million individuals. The length modes showed that an approximation for I-group was fish of length 10–19 cm and II-group 19-27 cm as illustrated by the length distribution of juvenile Greenland haibut in 2002–2006 (Fig. 6). The length groups corresponding to I-group fish showed the same trend as

TABLE 2. Swept area estimates of the number of juvenile Greenland halibut in the area north and east of Spitsbergen. Length is midpoint in 5 cm length groups. Numbers in thousands.

Length group	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
7.5	0	14	0	0	0	0	451	0	5 376	95	2 190
12.5	8 512	5 679	835	1 363	7 936	14 711	61 322	17 009	16 262	202 417	118 008
17.5	13 000	2 117	8 610	1 236	4 660	15 229	16 982	9 375	27 007	77 275	226 685
22.5	11 444	15 040	20 600	15 927	8 557	21 845	21 998	13 860	52 888	15 384	393 058
27.5	8 098	12 504	6 703	7 943	4 916	6 088	12 942	2 097	34 616	30 259	79 985
32.5	4 103	17 088	18 333	8 572	6 132	4 597	8 761	2 466	14 817	44 682	13 787
37.5	1 647	7 504	5 616	4 759	2 325	2 152	2 849	2 011	6 974	20 451	15 505
42.5	1 320	3 510	2 810	2 123	1 536	979	1 836	442	3 175	2 958	4 735
47.5	1 715	164	527	497	444	649	326	237	1 655	568	1 493
Total	49 837	63 606	64 036	42 421	36 506	66 250	127 016	47 496	157 394	393 995	853 255
10–19 cm	21 511	7 796	9 446	2 600	12 596	29 940	78 303	26 385	43 269	279 692	344 693

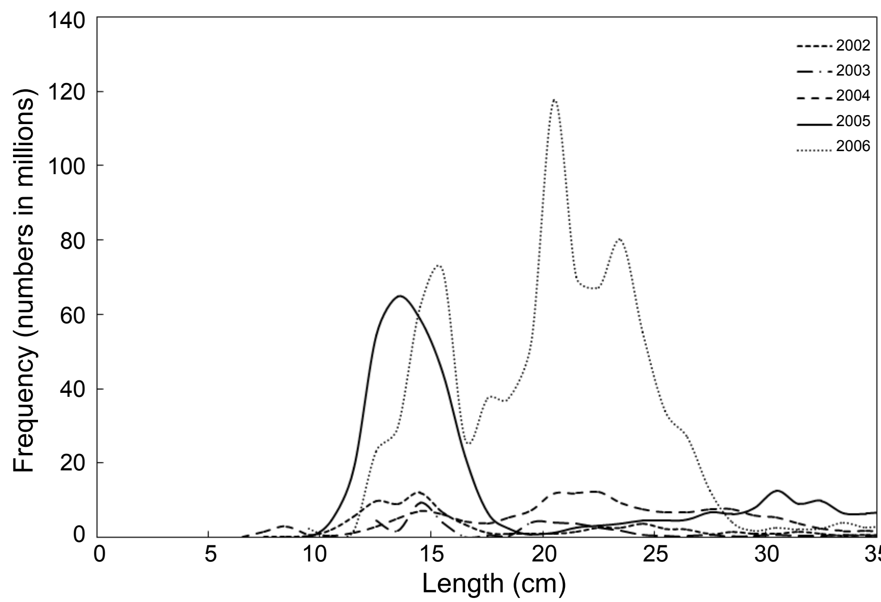

Fig. 6. Length distribution of Greenland halibut from the juvenile surveys in 2002–2006 illustrating length modes. Peak between 10–19 cm is I-group.

the total estimate throughout the period with a relatively stable situation before 2001 and a dramatic increase in the period afterwards (Table 2, Fig. 7). The swept area estimate of I-group abundance increased from a mean of 14 million in the period before 2001 to 345 million individuals in 2006. The trend is clear even if the abundance estimates were low for 2003 and 2004 and in the same level as the period before 2001.

The relationship between the estimated spawning stock (females >60 cm) at the slope area and the estimated recruitment (I-group the year after) showed low recruitment when spawning stock was below 20 000 t (Fig. 8). The highest values were associated with a spawning stock above 25 000 t.

Total egg production (TEP) estimated from the spawning stock showed a linear increase during the entire time period (Fig. 9). The relative contribution to the total estimate from the different length groups varied between years and in all years the main contribution came from females of 65–75 cm. Females >75 cm contributed

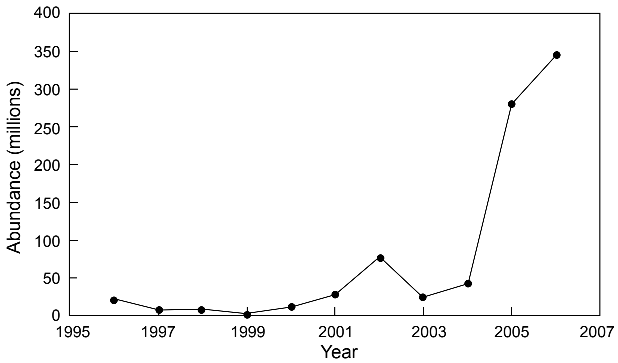

Fig. 7. Swept area abundance estimate of juvenile Greenland halibut in the Svalbard area. Abundance of fish of size 10–19 cm, approximately corresponding to I-group fish.

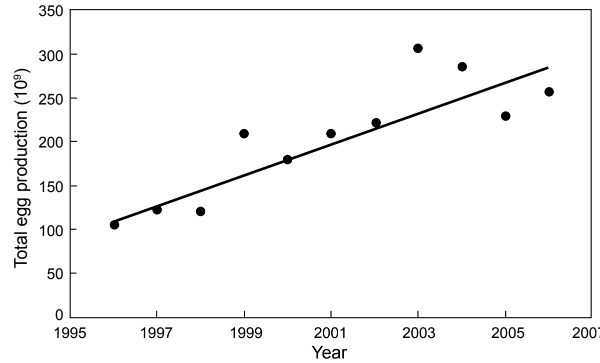

Fig. 9. Total egg production from the Greenland halibut spawning stock along the slope area (main part of the adult stock). Fitted regression line (y = -3480+1.749x, p <0.001).

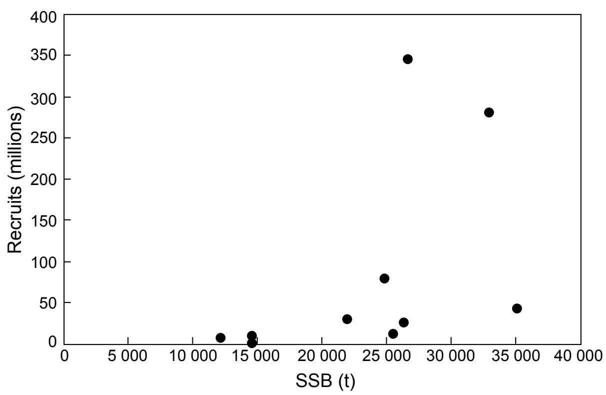

Fig. 8. Spawning stock (females >60 cm) and recruits of Greenland halibut as approximately I-group (length group 10–19 cm).

more to the total estimate in more recent years. The contribution from these larger females increased from 10% of the TEP estimate in 1996 to 21% in 2006.

Discussion

The geographical location of the nursery area north and east of Svalbard implies that ice extent may affect annual survey coverage. Even if the overall objective of the survey is to cover the same geographical area and depth strata with a specific number of stations each year survey operations have to adjust to the actual ice coverage. In 2003 ice extent was extreme, and the Barents Sea ice extent was the fifth largest since 1967 (Sorteberg and Kvingedal, 2006) and the waters north of Svalbard were completely covered by ice and trawling was impossible. The low abundance estimate of juveniles obtained in 2003 was directly affected by low survey coverage. This also explains the absence of the 2002 year class in 2003 which actually was considered to be quite strong and should have appeared as I-group in high quantities in 2003 if the survey distribution area had been accessible. It is also evident that the 2003 year class is very weak. Despite the low coverage one would have expected 0-group fish to be present in 2003 especially since trawling was possible in the Hinlopen area and the King Karl Land area where newly settled juveniles are commonly found. However, in 2003 juveniles <10 cm were totally missing in the catches. The weakness of the 2003 year class was confirmed by its rarity in the survey catches in 2004 and 2005.

The recruitment index obtained for 2004, *i.e.* I-group fish, was unexpectedly low. Unlike 2003, in this year survey coverage was unaffected by ice. Even if Greenland halibut were broadly distributed in 2004, the number caught was in general low throughout the survey area. This verifies the indications from 2003 that this year class is extremely poor and is the main explanation for the low recruitment index in 2004. An interesting aspect in 2004, however, was a high abundance of newly settled juveniles in the catches. Keeping in mind that the newly settled juveniles have a low catchability to the gear used in the survey, this gave us a signal about high abundance in the years to come. The I-group estimate (based on length curves – see Fig. 6) in 2005 was extremely high compared to any of the previous years, as was the II-group estimate in 2006.

In 1993 sorting grids were introduced in the shrimp fishery in the Barents Sea and the waters around Svalbard (Albert and Høines, 2003). Grids are assumed to sort out Greenland halibut <20 cm, corresponding to 0 and I-group. This may have improved survival of the youngest age groups and contributed to the increase in juvenile abundance during the investigated period. However, the major increase in juvenile abundance seems to be after 2000, indicating that the potential positive effects of an increased spawning stock biomass probably overrides the effect of the introduced sorting grid as the increased recruitment occurs much later than the expected effect of the sorting grids.

In some years, halibut recruitment estimates may be driven by one or a few large hauls. A typical example of this was 1996 in Hinlopen where one extreme haul made up the majority of the Greenland halibut caught in this area. When including it in the abundance estimates, the Hinlopen area became the second most important area with about 30% of the total abundance. Excluding this haul from the abundance estimate diminished the importance of the Hinlopen area such that it was associated with the lowest abundance. The contribution to the total juvenile index from the Hinlopen area is normally of minor importance. The problem of large hauls is not easily addressed, but there are some arguments for excluding extremely rich catches from the analyses (Pennington, 1983, 1996). The Greenland halibut distribution is patchy implying that some areas have large concentrations of fish. It is neither right nor wrong to include or exclude such hauls from the analyses and we have therefore decided that these hauls should be included.

The increase in spawning stock biomass was observed after years of strong fishery regulations introduced in 1992. The number of spawning females has increased, but as important is that females have been allowed to grow older and enter the spawning stock. It is likely that this is a result of the control of fishing pressure. It is also important that more juveniles have been allowed to recruit to the spawning stock. One should keep in mind that the increased spawning stock biomass may be partly explained by immigration from other geographical areas but this has not been documented so far. Also changes in hydrographical conditions (*e.g.* water temperature) may contribute to fish gathering in smaller regions with favourable conditions and this could lead to estimates of higher abundance for larger areas. Tagging experiments conducted on this species throughout the North Atlantic have given no indications on mass movements between geographical areas (Sorokin, 1967; Sigurdsson, 1981; Godø and Haug, 1987; and personal unpublished data). Further, the general trend has been that temperatures have increased in the entire area over the time period (Stiansen and Filin, 2007), and this is not in favour of a coldwater species like Greenland halibut. Thus, increased abundance is not likely to be explained by immigration or aggregation due to hydrographical conditions, but is more likely to be a result of a recovering stock.

To contribute to a higher possibility for good recruitment it seems necessary to keep the spawning stock above a level of 20 000–25 000 t. The total spawning stock was below this level in each of the years 1992 to 2000 (ICES, MS 2007). The estimated spawning stock from the slope area may be comparable with the total spawning stock from the assessment since most of the distribution area of the mature Greenland halibut is covered by the survey in the slope area.

Discovery of the Greenland halibut nursery grounds was vital in the process of understanding the life history of this species and this knowledge assisted in the process of rebuilding the Greenland halibut stock in the Northeast Arctic. The increase in recruitment of this stock over the investigated period is supported by data from annual surveys that in some years had differing area coverage due to sea ice. However, despite this shortcoming, increased abundance of Greenland halibut over the time period was clearly evident. The increase in abundance co-occurred with an increased number of older females in the stock. This means that spawning females have accumulated in the stock over years, increasing the potential egg production. Greenland halibut are described to be determinate spawners (Gundersen *et al.*, MS 2003; Junquera *et al.*, 2003). Females often have a curved fecundity – length relationship implying they produce more eggs as they grow older (*e.g.* Simpson, 1951; Hodder, 1963; Kjesbu *et al.*, 1998; Gundersen *et al.*, 1999). The estimate of TEP has increased more than the increase in spawning stock. This underlines the importance of allowing females to grow old and should be taken into consideration in managing the stock. Further, it is evident that rebuilding Greenland halibut takes time and that at least 12–15 years with management restrictions were needed for the stock to recover from the low levels observed in the Barents Sea in the beginning of the 1990s.

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