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Analysis of data from a trawl survey in NAFO Division 0B

M. A. Treble
Fisheries and Oceans Canada, Freshwater Institute,
501 University Cres., Winnipeg, Manitoba, Canada R3T 2N6

Abstract

A stratified random otter trawl survey covering depths of 400 m to 1500 m and targeting Greenland halibut (*Reinhardtius hippoglossoides)* was conducted in NAFO Division 0B from September 23 to October 15, 2011. Survey coverage was 1 set per 750 km^2 with a minimum of two tows per stratum, this criteria was met in all strata with 84 of 90 planned tows completed. Greenland halibut were present in all tows with the greatest densities between 751 m and 1250 m. Total estimated biomass and abundance were 83,043 tons and $8.30x10^7$, respectively. Biomass has increased compared to previous years. Abundance was lower than in 2001 but higher than in 2000. Biomass and abundance were reduced at depths 1251-1500 and fewer fish <45 cm were present at depths 1001-1500 m in 2011 compared to 2000 and 2001. Lengths ranged from 6 cm to 92 cm with 30% <45 cm. The length distribution had a single mode at 51 cm, an increase in modal length compared to 2001 (45 cm) and 2000 (42 cm). The catch of other commercially important species was minimal and therefore these data were not included.

Introduction

A stratified random bottom trawl survey was conducted in the North West Atlantic Fisheries Organization (NAFO) Division 0B from September 23 to October 15, 2011. Prior to this surveys had been conducted in 1986 (Bowering 1987), 1990 (Chumakov and Soshin 1991), 2000 (Treble et al. 2001) and 2001 (Treble 2002).

The objectives of the 2011 survey were:

1. Collect the data required to establish age structure, estimate population abundance, biomass, and recruitment of Greenland halibut;
2. Collect the data required to establish age structure, estimate population abundance, biomass, and recruitment of shrimp;
3. Record numbers caught and collect length and weight data on all other commercial species caught, to allow calculation of abundance, biomass, and size structure of these species;
4. Record numbers and collect weight data on all non-commercial species caught, to allow calculation of abundance and biomass of these species;
5. Collect additional data and biological samples as desired and as time permits (e.g. lengths for by-catch, maturity information, coral samples, other special requests);
6. Collect temperature data at each fishing station.

Materials and Methods

Stratification and Set Selection

Table 1 lists the strata (401-1500 m) used for the survey in Div. 0B (Bowering 1987). This stratification scheme is also shown in Fig. 1. The total area between 401 and 1500 meters encompassed by the strata in Div. 0B is approximately 74,483 km^2. Portions of strata 4 (500 m to 750 m) were excluded due to rough bottom and sets were not allocated in a area that is under a shrimp fishing industry closure due to known concentrations of corals and sponges.

Set selection was based on a coverage level of approximately 1 set per 750 km^2. Sets were randomly selected from numbered units within each stratum using a buffered random design (Kingsley et al. 2004). If a set could not be fished due to bad bottom, ice, etc. then the tow was taken in an adjacent unit as close to the missed site within the stratum as feasible given the conditions. When this was not possible then the tow was re-located to an area of the stratum where there were "holes" in the set coverage and a unit location selected at random from those available in that area. Ninety sets were allocated proportionally to stratum size with a minimum of 2 sets per stratum. Table 2 gives the set distribution across depth strata.

Vessel and Gear

The survey was conducted in cooperation with the Greenland Institute of Natural Resources and the vessel was the M/Tr Pâmiut, a 722 GRT stern trawler measuring 53 m in length. An Alfredo III bottom otter trawl with rock hopper ground gear was used for the deep water survey. Mesh size was 140 mm with a 30 mm mesh liner in the cod end. Trawl doors were Injector International, measuring 7.5 m^2 and weighing 2800 kg. These doors replaced the Greenland Perfect doors (9.25 m^2 and 2420 kg) in 2004. The average net height was 20 cm higher with the new doors but the overall net performance was not significantly different (95% level) (Jørgensen personal communication). More information about the trawl and gear can be found in Jørgensen 1998. A Furuno based system mounted on the head rope measured net height and was used to determine bottom contact and the start/finish of each tow. Wingspread was directly measured using Scanmar sensors. In a few cases where wingspread was missing an average from adjacent tows at similar depths was used.

Oceanographic Sampling

A Seabird 19© CTD (conductivity, temperature and depth recorder) was mounted on the headrope and was used to determine temperature, depth and confirm the time spent on the bottom. In the few cases where there was no data from the CTD data from the Furuno trawl eye sensor was used.

Trawling Procedure

The targeted tow duration was 30 minutes, however, tows down to 15 minutes in length were considered acceptable. Average towing speed was 3.0 kn. Trawling took place throughout a 24 hr period in order to maximize the ships time and complete the necessary tows.

Biological Data Collection and Analysis

Numbers and total weight caught were recorded on a set by set basis for each species. Detailed sampling was carried out on Greenland halibut and shrimp. For other commercial species (e.g. redfish, grenadiers, skates) sexed length measurements were collected. Lengths were measured to the lowest 1 cm total length (0.5 cm pre anal fin length for grenadiers) using a standard meter board. Large catches of either Greenland halibut or shrimp were sub-sampled. Sub-samples of Greenland halibut were comprised of at least 200 fish. Adjustments were made during analysis to estimate total number caught in each case.

Greenland halibut sampling consisted of a visual assessment of maturity for all individuals based on maturity stages described in Riget and Boje 1989. For each sampled fish the whole weight was recorded at sea using an electronic

balance. Otoliths for age determination were collected, 10 per 1 cm length group per sex. However, research on age determination methods for Greenland halibut is on-going so the otolith samples were not analyzed.

Various species from the catch were collected or had tissue samples taken for use by other researchers within DFO.

Biomass and Abundance Indices

The swept area method was used in the estimation of biomass and abundance for Greenland halibut: Swept area (km^2) = (wingspread (m) x haul-length)/1,000,000. The haul-length used in the sweptarea calculations was estimated from the start and end positions of the tow. Abundance and biomass were calculated for each set and standardized to 1 km^2:

Abundance (n/km^2)=catch (n)/sweptarea (km^2)
Biomass ($tons/km^2$)=catch (kgs)/swept area (km^2)/1000.

Mean and standard error for abundance and biomass were calculated for each depth strata. An estimate of total abundance and biomass was then calculated for each depth strata (mean x area surveyed within each depth strata (km^2)) as well as over all depths. Standard error values were also calculated for the overall total.

Abundance at length was calculated for each depth strata (standardized to km^2 and weighted by tow), and a total abundance at each length (weighted by the area within each depth strata) was calculated (mean number/ km^2 x area surveyed within each depth strata (km^2)). The sum across all lengths and depth categories was calculated and compared to the overall abundance value determined above to confirm the results.

Results and Discussion

Prior to 2011 Division 0B had been surveyed only twice using M/Tr Pâmiut; 2000 (Treble et al. 2001) and 2001 (Treble 2002) and once using the RV Gadus Atlantica (Bowering 1987).

The stratified area within Division 0B covers 74,483 km^2 and the area was fully surveyed in 2011 with a minimum of two tows completed in all strata. Of the 90 stations planned, 84 were completed successfully (Table 2) with stations missed primarily due to bad bottom. In comparison there were problems completing the 2001 survey (36 of 76 planned tows completed) but only 2 shallow strata (24 and 25) were incomplete (i.e. <2 tows) resulting in a reduction of the area surveyed (62,207 km^2). The 2000 survey was completed although at a slightly reduced level of coverage (1 set per 1030 km^2 compared to 750 km^2 in 2011). The current coverage matches levels applied to DFO surveys of Div. 0A since 2004 and the Greenland Institute of Natural Resources surveys in 1CD.

Appendix 1 contains set by set information on stratum, swept area, mean depth, near bottom temperature and catch for Greenland halibut.

In 2011 bottom temperatures ranged from a high of 4.5 ^oC to a low of 2.9 ^oC (Table 3, Fig. 2). The majority of tows (85%) had temperatures greater than or equal to 1.5 ^oC. Mean temperatures by depth stratum ranged from 2.9 ^oC for the 401-500 m depth stratum to 3.8 ^oC for the 751-1250 m depth strata (Table 3). Bottom temperatures were greater in all depth strata in 2011 compared to 2000 and 2001.

Detailed analysis of species other than Greenland halibut were not done due to their low level of catch.

Greenland Halibut

Greenland halibut were present in all tows in 2011. The catch was comprised of 63% males, 36% females and 1% sex unknown. The number of fish caught varied from 3-353 and catch weight from 3-381 kg (Appendix 1).

The 2011 estimate of biomass in the surveyed area is 83,043 t (S.E. 5,685) (Table 4). This compares to 68,917 t in 2001 and 57,438 t in 2000 (Table 4 and Figure 3). Biomass estimates have increased at depths <1251 m and have

decreased slightly at depths 1251-1500 m. Distribution of biomass for years 2000, 2001 and 2011 are shown in Figure 2).

Mean biomass per tow or density in 2011 was 1.11 t/km^2 and is similar to 2001 but higher than 2000 (Table 4). Density was approximately 2.5 t/km^2 between 751 m and 1250 m. Between 1251 m and 1500 m mean biomass has decreased to 1.7 t/km^2 in 2011 from 2.0 t/km^2 and 2.4 t/km^2, in 2001 and 2000, respectively.

Abundance in 2011 is estimated at 8.30 x 10^7 (S.E. 5.8 x 10^6), lower than in 2001 (8.6 x 10^7) and higher than seen in 2000 (7.7 x 10^7). The highest levels occurred between 501 and 1000 m (Table 5). Abundance has increased or remained the same at depths 401-1000 and decreased at depths 1001-1500.

Mean abundance per tow was 1115 per km^2, a decrease over 2001 (1381 per km^2) and similar to 2000 (1039 per km^2) (Table 5).

Length frequency distributions by depth strata for 2001 and 2011 are given in Figure 6. There is a broad size distribution of lengths at depths below 750 m. At depths 501-750 m the modes were both 45 cm while the modal lengths tended to be greater by as much as 6 cm in three of the four other depth strata in 2011 compared to 2000 (Figure 6). The number of fish <45 cm decreased in 2011 compared to 2001 at depths 1001-1500 m, while the number of fish >45 cm increased at depths 751-1000 m.

Overall lengths in 2011 ranged from 6 cm to 92 cm with a mode at 51 cm, this compares to modal lengths of 45 cm in 2001 and 42 cm in 2000 (Table 6, Figure 7). 30% of fish were <45 cm in 2011 compared to 47% in 2001 and 57% in 2000 (Table 6).

Bowering and Parsons (1986) found a catchability effect for young Greenland halibut between day and evening tows. Due to time constraints and for reasons of economy the survey of 0B consisted of tows taken throughout the day and night. The length frequency distribution (Figure 7) shows very few fish below 24.5 cm therefore, a mix of day and evening hauls is unlikely to have a significant effect on the overall estimation of abundance and biomass.

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Table 1. Division 0B strata and area (Bowering, 1987).

Stratum	Area (km^2)	Units	Depth	# sets planned
3	8972.88	748	401-500	8
4	16021.53	1335	501-750	18
5	7100.1	592	751-1000	11
6	6774.25	564	1001-1250	9
7	5628.63	469	1251-1500	7
10	5371.38	448	401-500	6
11	7926.73	661	501-750	10
12	3234.49	270	751-1000	5
13	1176.49	98	1001-1250	2
24	4970.07	414	401-500	5
25	7305.9	609	501-750	9
Total	74482.45			90

Table 2. Area by depth strata for NAFO Division 0B with the number of hauls planned ( ) and conducted for surveys in 2000, 2001 and 2011.

Depth Stratum (m)	401-500	501-750	751-1000	1001-1250	1251-1500	Total
Area (sq. nm)	5631	9112	3013	2318	1641	21715
Area (sq. km)	19314	31254	10335	7951	5629	74483
Hauls in 2000	(19) 18	(31) 20	(10) 12	(9) 9	(6) 5	(75) 64
2001	(19) 9	(32) 8	(10) 8	(9) 7	(6) 4	(76) 36
2011	(19) 18	(37) 32	(16) 16	(11) 11	(7) 7	(90) 84

Table 3. Mean temperature, S.E. and number of observations for NAFO Division 0B by depth stratum.

Year	Depth Stratum (m) 401-500	501-750	751-1000	1001-1250	1251-1500
2000	2.1 (0.20)	2.5 (0.15)	3.5 (0.04)	3.5 (0.03)	3.2 (0.02)
2001	2.6 (0.24)	2.9 (0.15)	3.7 (0.04)	3.5 (0.03)	3.4 (0.00)
2011	2.9 (0.34)	2.9 (0.21)	4.0 (0.03)	3.8 (0.02)	3.7 (0.02)

Table 4. Biomass estimates for Greenland halibut by depth stratum for NAFO Division 0B.

Year	Stratum (m)	Survey Area (km^2)	No. Sets	Mean Biomass (t/ km^2)	Biomass (tons)	SE
2000	401-500	19314	18	0.1398	2701.4	359.4
	501-750	31254	20	0.3558	11119.7	1915.2
	751-1000	10335	12	1.3077	13515.0	1826.7
	1001-1250	7951	8	2.0700	16455.2	5178.0
	1251-1500	5629	6	2.4243	13646.2	3618.0
	Overall	*74483*	*64*	*0.7712*	*57437.5*	*6858.3*
2001	401-500	14344	9	0.2153	3088.4	630.0
	501-750	23948	8	0.7443	17824.8	5003.8
	751-1000	10335	8	1.5881	16413.3	2655.5
	1001-1250	7951	8	2.5244	20071.3	2870.2
	1251-1500	5629	3	2.0465	11519.6	1348.6
	Overall	*62207*	*36*	*1.1079*	*68917.4*	*6522.5*
2011	401-500	19314	17	0.3217	6213.7	848.8
	501-750	31254	33	0.6775	21176.0	3929.7
	751-1000	10335	16	2.5709	26570.1	3024.8
	1001-1250	7951	11	2.4699	19638.5	2593.1
	1251-1500	5629	7	1.6779	9445.1	535.9
	Overall	*74483*	*84*	*1.1149*	*83043.4*	*5685.4*

Table 5. Abundance estimates of Greenland halibut by depth stratum for NAFO Division 0B.

Year	Stratum (m)	Survey Area (km^2)	No. Sets	Mean Abundance (km^2)	Abundance (000's)	SE
2000	401-500	19314	18	466.20	9.0E+06	2.0E+06
	501-750	31254	20	579.17	1.81E+07	2.6E+06
	751-1000	10335	12	1655.32	1.71E+07	2.9E+06
	1001-1250	7951	8	2381.64	1.89E+07	6.5E+06
	1251-1500	5629	6	2526.86	1.4E+07	4.7E+06
	Overall	*74483*	*64*	*1038.81*	*7.737E+07*	*9.2E+06*
2001	401-500	14344	9	485.20	6.96E+06	1.2E+06
	501-750	23948	8	1082.20	2.59E+07	7.1E+06
	751-1000	10335	8	1907.50	1.97E+07	3.2E+06
	1001-1250	7951	8	2726.40	2.17E+07	3.3E+06
	1251-1500	5629	3	2064.10	1.16E+07	1.4E+06
	Overall	*62207*	*36*	*1380.66*	*8.589E+07*	*8.7E+06*
2011	401-500	19314	17	454.77	8.8E+06	1.7E+06
	501-750	31254	33	789.74	2.5E+07	4.1E+06
	751-1000	10335	16	2388.70	2.5E+07	2.8E+06
	1001-1250	7951	11	2151.08	1.7E+07	2.5E+06
	1251-1500	5629	7	1378.32	7.8E+06	4.4E+05
	Overall	*74483*	*84*	*1114.55*	*8.301E+07*	*5.8E+06*

Table 6. Estimated length distribution (3cm groups) in total numbers (000's) and weight (tons) for the Greenland halibut population in NAFO Division 0B.

Length Class (3 cm)	2000	2001	2011
0			
3			
6	202.164	67.965	17.433
9	46.653	103.906	
12	513.184		1824.725
15	839.756	22.414	816.183
18	2177.146	199.255	620.797
21	855.307	612.353	633.493
24	1430.696	1358.497	664.370
27	1648.410	1060.367	707.726
30	1866.125	1865.648	894.384
33	2954.698	3243.666	1608.425
36	4805.272	4692.739	2321.563
39	10170.381	9967.780	4822.473
42	14680.183	16973.462	9641.443
45	13747.121	20021.648	16529.356
48	8724.134	12414.917	16907.868
51	4556.455	6401.508	12176.685
54	2425.963	2847.439	6184.427
57	1337.390	1887.003	2964.766
60	559.838	944.613	1579.341
63	373.225	506.754	869.389
66	171.061	252.271	477.853
69	108.857	177.178	268.238
72	108.857	152.722	119.126
75	124.408	17.553	134.525
78	77.755	25.107	50.099
81	62.204	23.765	55.432
84	62.204	11.981	27.971
87		11.981	28.542
90	15.551		71.922
93			
96		22.513	
99			
Total	74645.000	85887.003	83018.555
Total <45 cm	42189.976	40168.051	24573.015
% <45 cm	56.521	46.768	29.599
% <35 cm	16.792	9.936	9.380

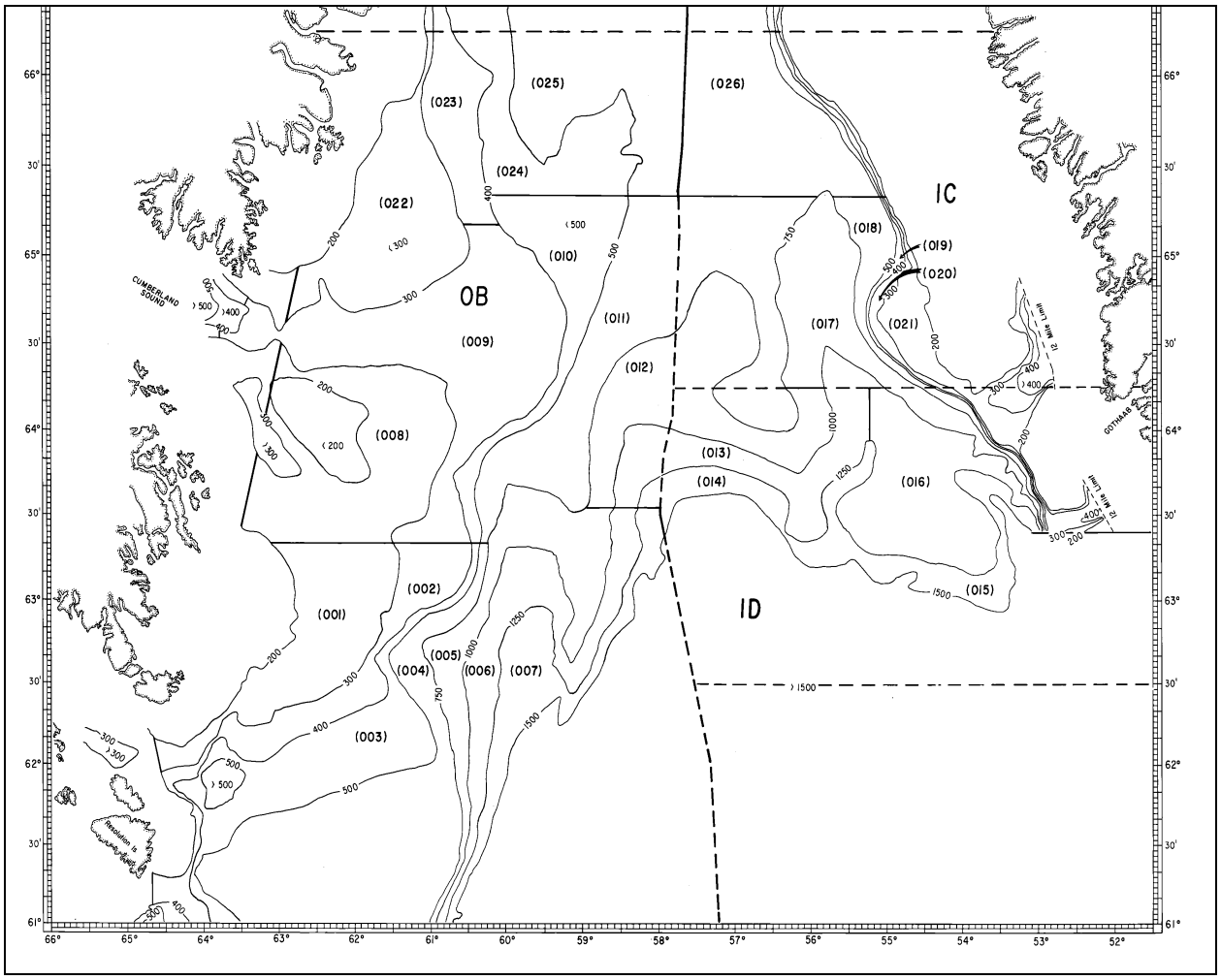

Figure 1. Stratification scheme for NAFO Division 0B.

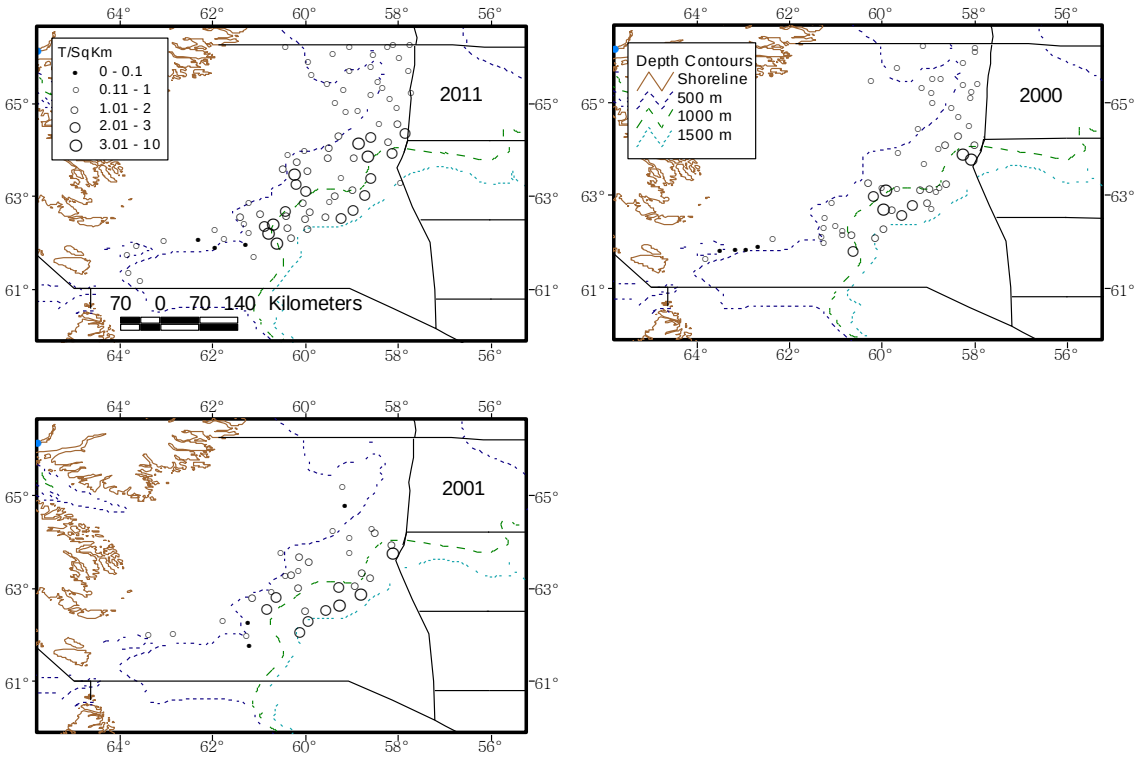

Figure 2. Distribution of Greenland halibut biomass (kg/km^2) in Division 0B 2000, 2001 and 2011.

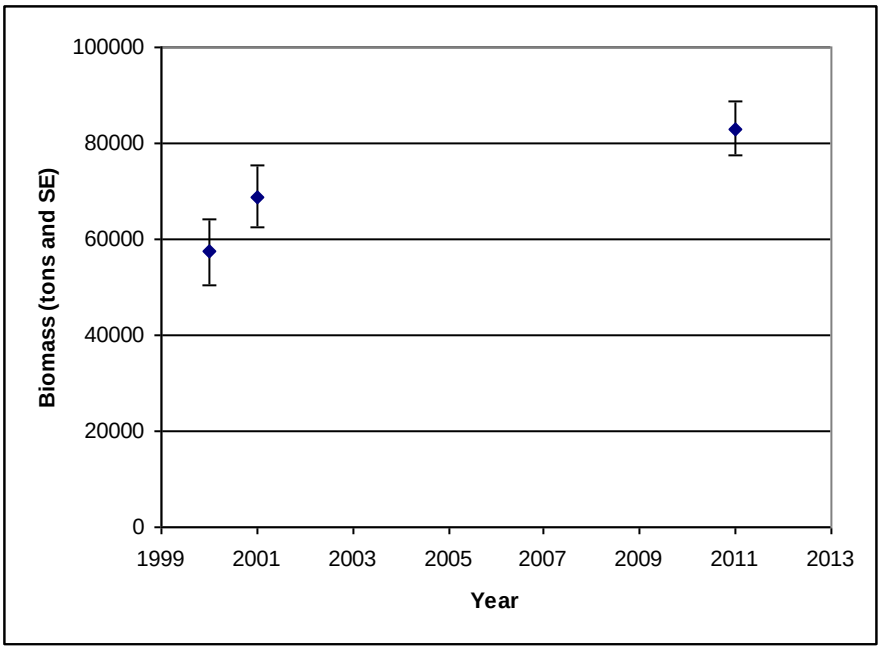

Figure 3. Biomass estimates for Greenland halibut in Division 0B.

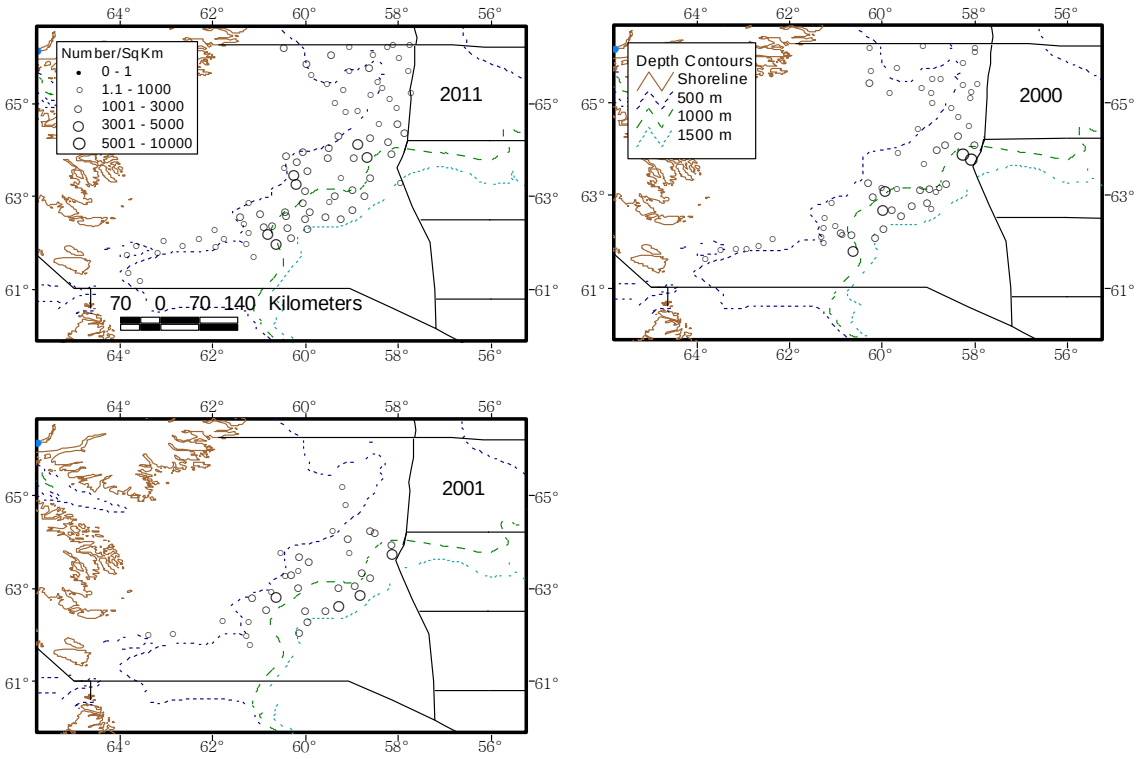

Figure 4. Distribution of Greenland halibut abundance (number/km^2) in Division 0B 2000, 2001 and 2011

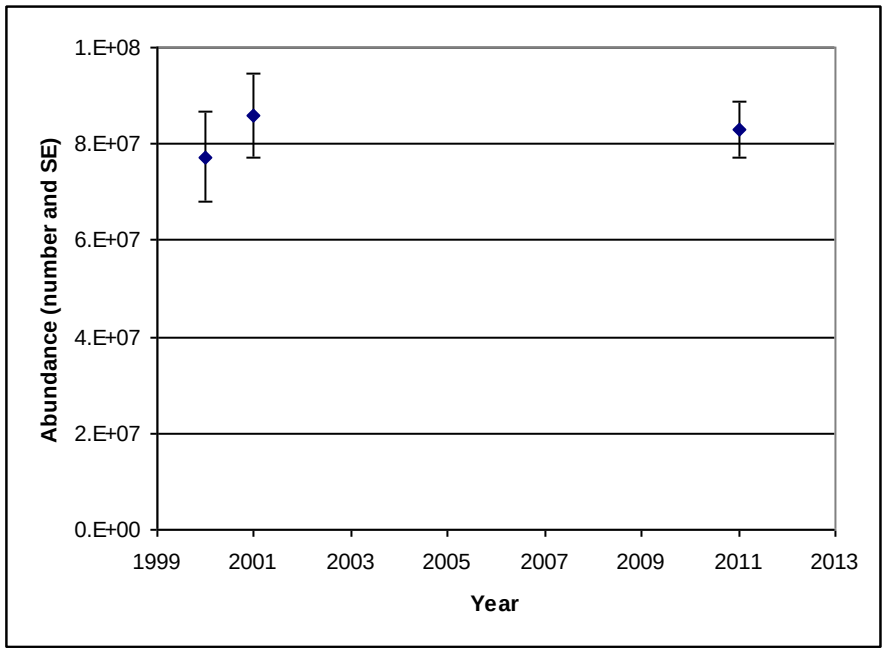

Figure 5. Abundance estimates for Greenland halibut in Division 0B.

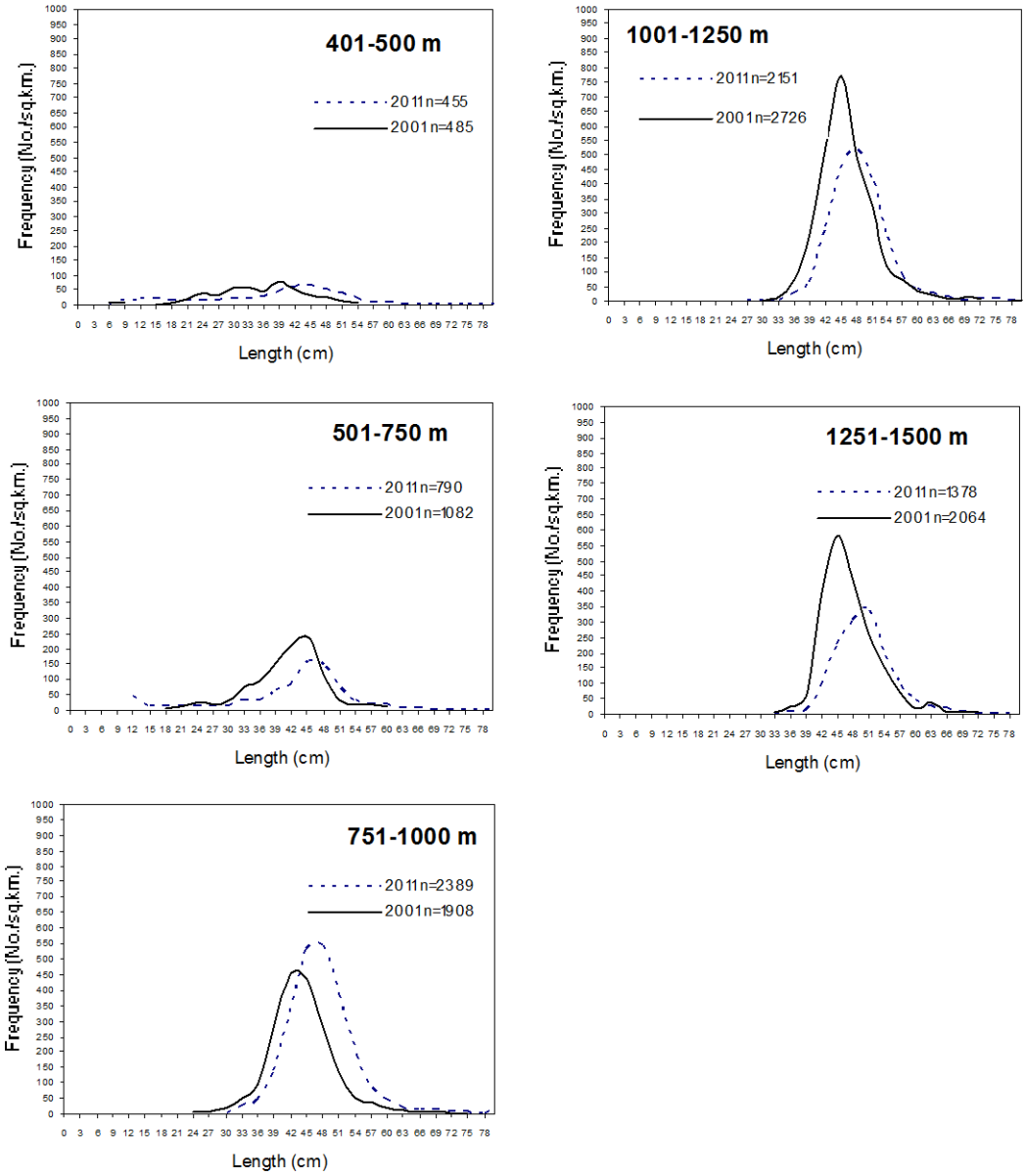

Figure 6. Length distribution (3cm groups) for Greenland halibut in Div. 0B, standardized to numbers/km^2 for the 2001 and 2011 survey's. Sample sizes (n) used in the calculation are also given.

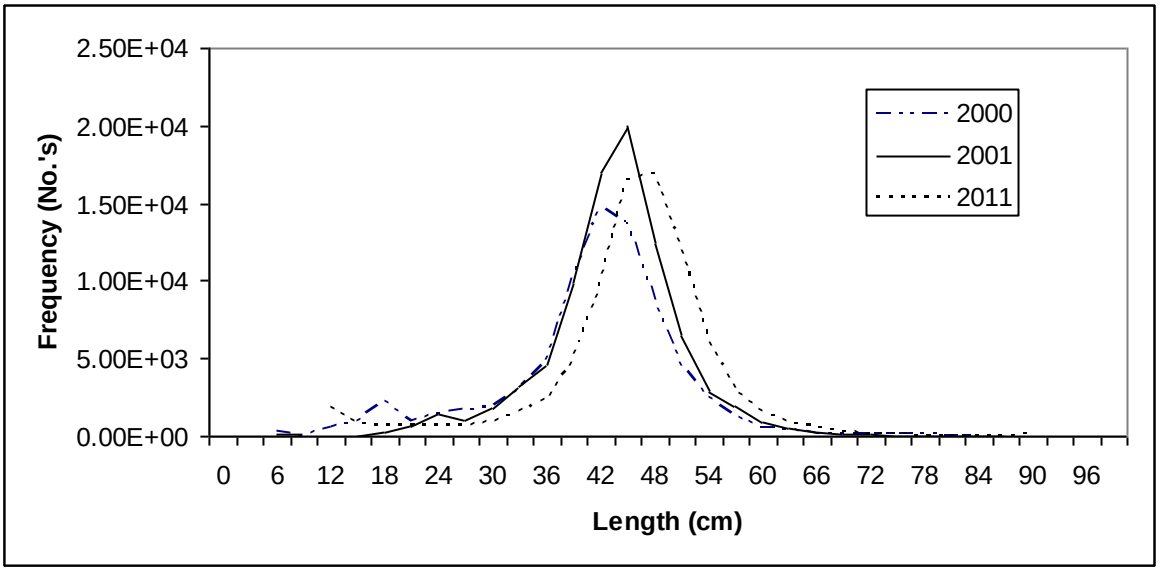

Figure 7. Estimated abundance at length for the Greenland halibut population in NAFO Division 0B in 2000.

Appendix 1. Catch weight and numbers (not standardized to kg/km^2) for Greenland halibut by set, for the 2011 survey of Division 0B.

								Greenland halibut	
Set	Month	Day	Mean Depth (m)	Net Damage	Swept Area (km^2)	Depth Stratum (m)	Temperature (^{o}C)	Weight (kg)	Number
1	9	23	871	1	0.07408	1000	4.02	175.950	142
2	9	23	767	1	0.07304	1000	3.94	169.900	184
3	9	23	696	1	0.07519	750	4.06	36.750	41
4	9	23	663	5			3.41		
5	9	23	680	1	0.06934	750	3.19	54.600	63
6	9	24	636	1	0.06569	750	3.26	40.700	50
7	9	24		5					
8	9	24	753	1	0.07243	1000	4.01	40.550	48
9	9	24	847	1	0.06766	1000	3.92	185.450	161
10	9	24	760	1	0.07416	1000	4.00	239.850	250
11	9	24	968	1	0.07475	1000	4.08	98.100	86
12	9	24	1112	1	0.07732	1250	3.84	164.850	150
13	9	24	952	1	0.07161	1000	3.90	255.400	229
14	9	25	748	1	0.07785	750	4.08	118.300	118
15	9	25	1062	1	0.07025	1250	3.73	380.600	353
16	9	25	1482	1	0.05414	1500	3.58	87.850	82
17	9	25	1077	1	0.07336	1250	3.87	151.140	139
18	9	25	913	1	0.07404	1000	3.93	138.600	123
19	9	25	938	1	0.07336	1000	3.96	104.650	90
20	9	26	1104	1	0.07150	1250	3.82	193.700	157
21	9	26	1136	1	0.07500	1250	3.77	188.600	153
22	9	26	1234	1	0.06901	1250	3.88	183.600	171
23	9	26	1458	1	0.07326	1500		135.796	97
24	9	26	1360	1	0.06799	1500	3.73	93.100	78
25	9	26	1360	1	0.07050	1500	3.67	139.200	118
26	9	27	1134	1	0.07150	1250	3.90	86.400	75
27	9	27	1332	1	0.06905	1500	3.67	124.250	106
28	9	27	1439	1	0.07311	1500	3.64	132.350	98
29	9	27	1131	1	0.07040	1250	3.84	126.750	94
30	9	27	913	1	0.06648	1000	4.09	243.350	195
31	9	27	773	1	0.06874	1000	3.64	165.570	166
32	9	27	759	1	0.06919	1000	3.78	348.300	333
33	9	27	934	1	0.06528	1000	4.08	276.850	238
34	9	28	554	5			4.03		
35	9	28	560	1	0.06208	750	4.30	14.300	6
36	9	28	482	1	0.04053	500	4.45	4.400	4
37	9	28	488	1	0.04722	500	4.51	5.160	4
38	9	28	592	1	0.04226	750	4.41	8.300	8
39	9	29	586	1	0.06559	750	4.44	32.700	30
112	10	9	516	1	0.06823	750	4.25	28.100	27
113	10	9	534	5			4.52		
114	10	9	535	1	0.06751	750	4.52	7.746	7
115	10	9	465	1	0.07615	500	4.27	43.199	45
116	10	9	442	5			4.48		
117	10	9	441	1	0.06617	500	4.35	5.750	4
118	10	9	431	1	0.06826	500	3.90	19.000	18
119	10	9	472	1	0.06745	500	3.99	7.834	7
120	10	10	516	1	0.06602	750	4.18	3.214	3

121	10	10	523	1	0.06139	750	4.02	6.000	6
122	10	10	1272	1	0.07818	1500	3.71	102.850	87
123	10	10	489	5			4.21		
124	10	10	480	1	0.07080	500	4.40	24.750	20
125	10	10	444	1	0.04950	500	3.78	19.100	18
126	10	10	580	1	0.07374	750	3.63	114.900	84
127	10	10	521	1	0.06893	750	4.04	64.200	46
128	10	11	819	1	0.07320	1000	4.08	119.700	124
129	10	11	1079	1	0.07162	1250	3.90	190.660	163
130	10	11	1224	1	0.07313	1250	3.79	128.480	104
131	10	11	1130	1	0.07826	1250	3.82	175.850	157
132	10	11	871	1	0.06643	1000	4.02	192.250	209
133	10	11	689	1	0.07143	750	3.53	278.950	282
134	10	11	832	1	0.08008	1000	4.12	147.900	119
135	10	11	500	5			3.31		
136	10	11	502	1	0.06348	750		64.200	62
137	10	12	630	1	0.06848	750	3.48	77.518	81
138	10	12	428	1	0.06517	500		50.361	71
139	10	12	508	1	0.07587	750		73.600	85
140	10	12	652	1	0.07507	750	3.75	102.300	110
141	10	12	536	1	0.07704	750	3.37	82.210	87
142	10	12	501	1	0.06780	750	2.32	70.650	78
143	10	13	509	3			1.92		
144	10	13	494	1	0.06781	500	2.94	33.350	33
145	10	13	468	1	0.07941	500	1.63	30.900	42
146	10	13	446	1	0.06901	500	1.69	25.600	40
147	10	13	452	1	0.06928	500	1.52	21.885	26
148	10	13	458	5			1.50		
149	10	14	483	1	0.07129	500	1.39	23.200	37
150	10	14	507	1	0.06994	750	1.40	35.350	85
151	10	14	504	3			1.41		
152	10	14	505	1	0.04723	750	1.43	5.200	9
153	10	14	538	1	0.06742	750	1.59	23.450	21
154	10	14	496	1	0.06900	500	1.46	21.800	34
155	10	14	467	1	0.06509	500	1.40	9.550	20
156	10	14	457	5			1.49		
157	10	14	504	1	0.07022	750	1.37	13.184	46
158	10	14	556	1	0.06746	750	1.44	38.250	137
159	10	15	428	1	0.07448	500	1.25	25.222	112
160	10	15	658	1	0.05069	750	1.45	33.950	57
161	10	15	669	1	0.06943	750	1.43	17.255	36
162	10	15	550	5			1.42		
163	10	15	518	1	0.05015	750	1.48	11.724	17
164	10	15	625	5			1.90		
165	10	15	640	1	0.05565	750	1.86	32.400	28
166	10	15	619	1	0.06988	750	1.92	8.650	20
167	10	15	553	1	0.06773	750	2.29	17.700	21
168	10	15	558	1	0.05792	750	1.96	19.350	24
169	10	15	588	1	0.07136	750	2.11	13.800	19