Northwest Atlantic Fisheries Organization

Serial No. N5093 **NAFO SCR Doc. 05/14**

SCIENTIFIC COUNCIL MEETING – JUNE 2005

Survey for Greenland Halibut in the Northern Part of Baffin Bay, NAFO Division 1A, 2004

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Abstract

In 2001 Greenland conducted a bottom trawl survey in the southern part of Baffin Bay to 74°N, primarily aimed at Greenland halibut, which was found all over the area, except at shallow water. In 2004 the area between 73°N and 77°N was surveyed down to 1 500 m. Greenland halibut was also observed all over the northern part of the Baffin Bay and the trawlable biomass was estimated as 53 900 tons. Greenland halibut was the only species of commercial interest that was found in noticeable amounts. Canada conducted a similar survey in the Canadian part of Baffin Bay.

Introduction

In 1999 (Treble *et al*., 2000) and 2001 (Treble 2002; Jørgensen, 2002; Treble and Jørgensen, 2002) Canada and Greenland have conducted a number of surveys in the southern part of Baffin Bay. The surveys discovered densities of Greenland halibut of commercial interest. Based on a Canadian survey in 1999 a separate TAC on 4 000 tons was set for 2001 and 2002 for the Baffin Bay. In 2001 Greenland conducted a survey that covered the Greenland part of the Baffin Bay to 74°N. Based on this survey the TAC in the Baffin Bay was increased to 8 000 tons in 2003. Both from a scientific and a commercial point of view there has been great interest in surveying the northern part of the Baffin Bay in order to investigate the distribution of Greenland halibut. In 2004 Greenland conducted a bottom trawl survey that covered the area between 73°N and 77°N at depths down to 1 500 m. An identical survey was conducted by Canada in the Canadian part of the Baffin Bay immediately before the Greenland survey (Treble 2005).

Materials and Methods

The survey was conducted during 22 September - 7 October 2004.

Stratification

The survey covered the northern Baffin Bay (73°N-77°N) (NAFO Div. 1A) between the 3-nm line and the midline to Canada at depths down to 1 500 m. The survey area was stratified in 6 depth strata 0-201, 401-600, 601-800, 801-1 000, 1 001-1 200, 1 201-1 500-1 500 m. The depth stratification was based on maps from NOAA. The area of each stratum was measured using "MapInfo Version 7.0" (Table 1).

The survey was planned as a Stratified Random Bottom Trawl Survey with in total 100 hauls. Basically the number of hauls allocated to each stratum was proportional to the stratum area, but as the survey was aimed at Greenland halibut, the number of haul allocated to depth stratum 1-200 was reduced while the number of hauls allocated to

deeper strata was increased. The hauls were distributed according to (Kingsley *et al*., 2004) whom method combines the use of a minimum between-stations-distance rule (buffer zone) with a random allocation scheme.

Vessel and gear

The survey was conducted by the 722 GRT trawler *PAAMIUT*, using an *ALFREDO III* trawl with a mesh size on 140 mm and a 30-mm mesh-liner in the cod-end. The ground gear was of the rock hopper type. The trawl doors were Greenland Injector weighing 2 700 kg. Further information about trawl and gear is given in Jørgensen, 1998b. A Furuno net sonde mounted on the head rope measured net height. SCANMAR sensors measured the distance between the trawl doors. Wingspread, taken as the distance between the outer bobbins, was calculated as:

distance between outer bobbins = 10.122 + distance between trawl doors * 0.142

This relationship was estimated based on flume tank measurements of the trawl and rigging used in the survey (Jørgensen, 1998b).

Trawling procedure

Towing time was usually 30 min, but towing times down to 15 min were accepted. Average towing speed was 3.0 kn. Towing speed was estimated from the start and end positions of the haul, or in a few cases based on GPS observations (mean of records made every 5 min. during the haul). Trawling took place day and night.

Water temperature

Near-bottom temperatures were measured, by 0.1^{o}C, by a Seamon sensor mounted on a trawl door.

Further, temperature and salinity was measured in the entire water column by CTD at 25 stations.

Handling of the catch

After each haul the catch was sorted by species and weighed to nearest 0.1 kg and the number of specimens recorded. Most fish species were sexed and measured as total length (TL) to 1.0 cm below. Grenadiers were measured as pre anal fin length (AFL) to 0.5 cm below. In case of large catches sub-samples of the catch were measured. Sub-samples always comprised of at least 200 specimens.

Biomass and abundance estimates were obtained by applying the swept area method (estimated trawling speed * estimated bobbin spread*trawling time) taking the catchability coefficient as 1.0. All catches were standardized to 1 km^2 swept prior to further calculations

Otoliths for age determination of Greenland halibut (n = 208) were soaked in water and read in transparent light. Age distributions were estimated using age/length keys and survey length frequencies pooled in 3-cm groups.

Results and Discussion

In total 75 hauls of which 62 were successful were made, giving a mean coverage of the surveyed area on 1 701 km^2 per haul (Table 1). The number of tows was reduced compared to the 100 planned due to technical problems and long time spent on searching for trawlable bottom. Haul by haul information on catches of Greenland halibut, position, depth, temperature, etc. is given in Appendix 1.

In total 44 species or groups of species were recorded (Appendix 2).

The only species besides Greenland halibut that were caught in noticeable amounts were *Boreogadus saida, Actogadus glacialis* and *Raja hyperborea*. Otherwise a number of Liparidae and *Lycodes* spp. were relatively common (Appenidx 2).

Greenland halibut (*Reinhardtius hippoglossoides*)

Greenland halibut was caught in all hauls except six which were all <243 m (Fig. 1). The swept area biomass was estimated at 53 867.4 tons (S.E. 6 892.7). The highest density, 3.62 tons per km^2, was found at depth between 1 001-1 200 m (Table 2), while the largest biomass was found in depth stratum 601-800 m. Generally the densities were higher in most strata compared to the same depth strata in Div. 1CD.

The abundance was estimated at $77.948*10^6$ (S.E $9.325*10^6$) with the highest concentrations (3 282.6 specimens per km^2) at depth between 1 001-1 200 m and the highest abundance in depth stratum 601-800 (Table 3). The abundance per km^2 is comparable and at several depth strata higher than in Div. 1CD. It is noteworthy that the abundance per km^2 at depth between 401 and 600 m is about 10 times higher in Baffin Bay compared to Div 1C (no obs. from Div. 1D).

Estimated abundance by age is given in Table 4.

The length ranged from 15 cm to 84 cm. Generally the length distributions in the different depth strata were dominated by a single mode and fish size increased with depth (Fig. 2) The three deep strata 801-100, 101-1 200 and 1 201-1 500 m were dominated by a single mode around 48 cm. which is also seen in the deeper strata in Div 1D. The overall length distribution was dominated by two modes one at 30 cm mainly originating from the large 401-600 m dept stratum and one at 45 cm (Fig. 3)

The age ranged from 1 to 16 years. Generally the age increased by depth but the age composition in the depth strata >801 were dominated by a mode around age 7 (Fig. 4). The overall age distribution (weighted by stratum area) was dominated by the ages 3 to 7 with age 7 being slightly more dominant than the other (Fig. 5).

Mean weight and mean length at age was slightly lower compared to Div. 1CD. The survey in 1CD took place about one month later than the survey in Baffin Bay and further can the growth have been affected by the generally colder water temperatures in Baffin Bay. Mean weight - and length at age is given in Table 5.

Females seems to start maturing at age 9 but only 1 female showed maturation at stage 3 i.e. 1-2 mm eggs with a mixture of clear and turbid eggs Table 6. In Div. 1CD maturation starts at age 7 and 100% maturation was reached at age 11 (Jørgensen, 2005). It is hence doubtful if any spawning takes place in the Baffin Bay. The survey in an 1999 and 2001 as well as sampling from commercial gill net vessels, also showed little evidence for spawning in the area

Temperature

The bottom temperature ranged from -0.65 to 1.92°C and the mean temperature increased gradually from 0.11°C at depth stratum 1-200 m to 1.00°C at depth stratum 601-800 to decrease gradually to 0.13°C at depth stratum 1 201-1 500 m. (Table 7).

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Table 1. Area (sq. km) of depth strata and number of stations planned ( ) and conducted.

	Depth stratum (m)							
Lattituder.	0-200	201-400	401-600	601-800	801-1000	1001-1200	1201-1500	Sum
76-77	1545.5	2648.5	7006	2007	85			13292
75-76	3876	10149	12611	11133	603	288		38660
75-74	1328	5323	5119	11179	1901	1942	3509	30301
74-73	1348	5991	8468	6005	347	395	660	23214
Sum	8097.5	24111.5	33204	30324	2936	2625	4169	105467
%	7.677757	22.86165	31.48283	28.75212	2.783809	2.48893	3.952895	100
Stations.	4 (5)	6(18)	16(28)	20(29)	7(7)	4(5)	5(8)	62(100)

Table 2. Biomass (tons) of Greenland halibut by depth stratum, 2004.

Stratum(m)	Area	Hauls	Mean sq km	Biomass	SE
001-200	8097.5	4	0	0.0	0.0
201-400	24111.5	6	0.0375	904.8	429.2
401-600	33204.0	16	0.3157	10482.4	1607.7
601-800	30324.0	20	0.6399	19404.0	3457.1
801-1000	2936.0	7	1.4272	4190.2	534.0
1001-1200	2625.0	4	3.6231	9510.7	4505.6
1201-1500	4169.0	5	2.2488	9375.4	3493.3
All			0.5108	53867.4	6892.7

Table 3. Abundance of Greenland halibut by depth stratum, 2004.

Stratum(m)	Area	Hauls	Mean sq km	Abundances	SE
001-200	8097.5	4	0.0	0	0
201-400	24111.5	6	80.7	1944844	1039258
401-600	33204.0	16	783.7	26021463	5307380
601-800	30324.0	20	965.3	29271462	5940380
801-1000	2936.0	7	1513.0	4442215	591967.4
1001-1200	2625.0	4	3282.6	8616777	3847595
1201-1500	4169.0	5	1835.3	7651292	2696735
All			739.1	77948053	9325409

Table 4. Estimated abundance by age of Greenland halibut.

1	251564
2	4970004
3	13649838
4	12337551
5	12836298
6	10468719
7	14812521
8	6023319
9	1705798
10	358734
11	249044
12	94894
13	41057
14	50591
15	63428
16	34693
	77948052

Table 5. Mean weight and mean length-at-age of Greenland halibut.

Age	Weight	S.E.	Length	S.E.	N
4	0.427	0.020	37.2	0.6	10
5	0.574	0.020	40.8	0.4	39
6	0.777	0.025	44.8	0.4	30
7	1.121	0.036	49.3	0.4	47
8	1.475	0.038	54.3	0.4	35
9	1.794	0.045	58.1	0.5	23
10	2.128	0.123	60.6	1.0	7
11	2.747	0.118	66.3	0.7	7
12	3.100	0.376	67.7	2.8	3
13	3.428	0.148	71.5	0.5	2
14	3.803	0.113	72.0	2.0	2
15	6.098	0.828	81.0	3.0	2
16	5.785	.	81.0	.	1

Table 6. Maturity-at-age in percent, females, 1 immature, 2-3 maturing.

Age	Maturity			n
	1	2	3	
4	100	0	0	8
5	100	0	0	17
6	100	0	0	9
7	100	0	0	27
8	100	0	0	22
9	94.1	5.9	0	17
10	83.3	16.7	0	6
11	71.4	28.6	0	7
12	66.7	33.3	0	3
13	100	0	0	2
14	0	100	0	2
15	50	0	50	2
16	0	100	0	1

Table 7. Mean temperature, S.E and number of observations by depth stratum.

Depth Stratum	Temp °C	S.E	n
1-200	0.11	0.23	10
201-400	0.70	0.33	7
401-600	0.79	0.22	17
601-800	1.00	0.07	23
801-1000	0.59	0.09	7
1001-1200	0.38	0.11	5
1201-1500	0.13	0.09	6

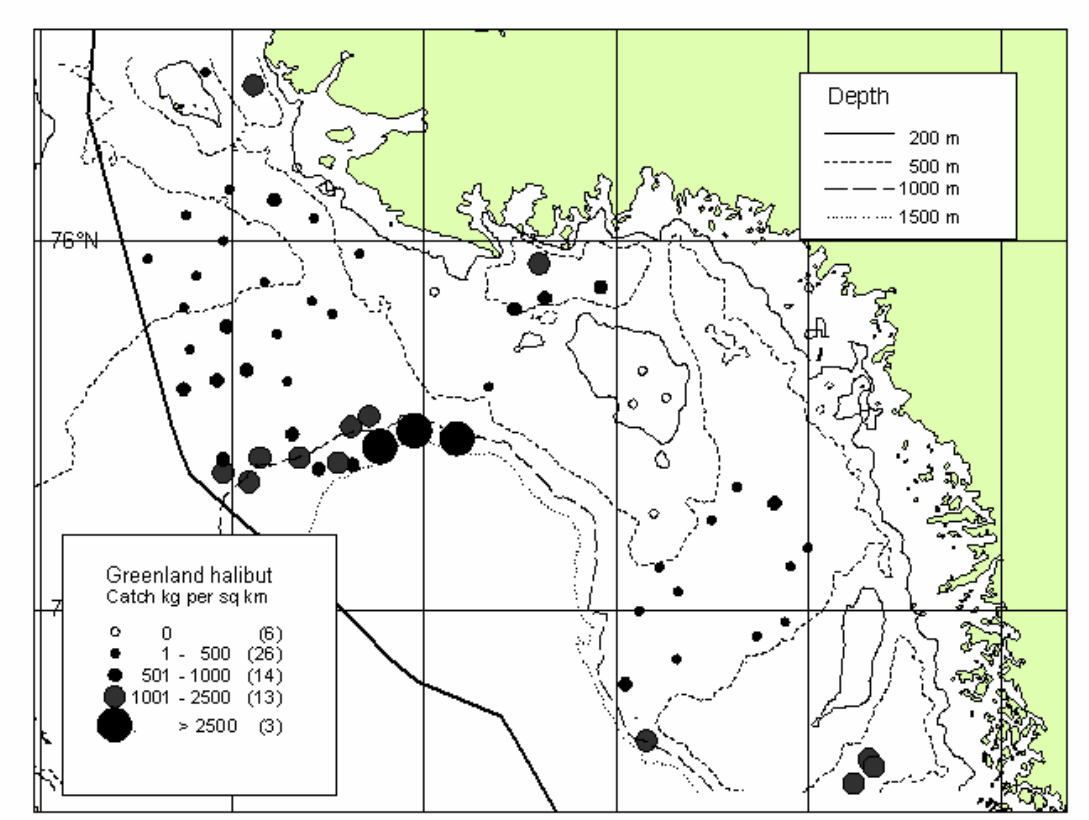

Fig. 1. Distribution of catches of Greenland halibut in 2004 in kg km^{-2}

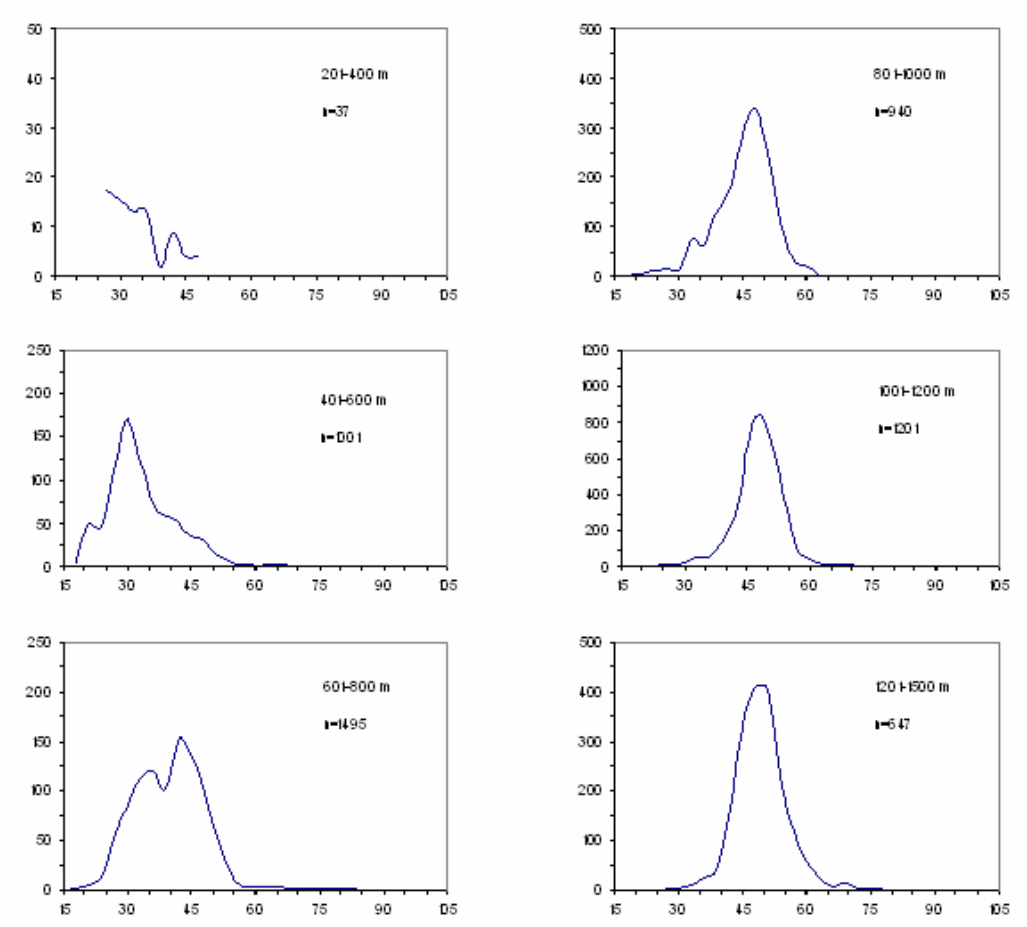

Fig. 2. Length distribution in numbers/km^2 of Greenland halibut (3 cm groups) by depth stratum Note different scales on y-axis.

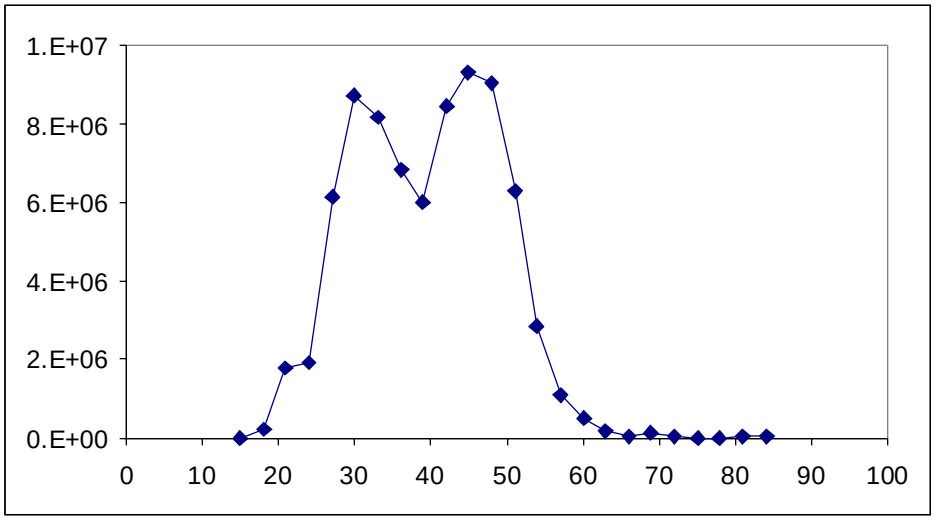

Fig. 3. Over all length distribution of Greenland halibut in numbers (weighted by stratum area).

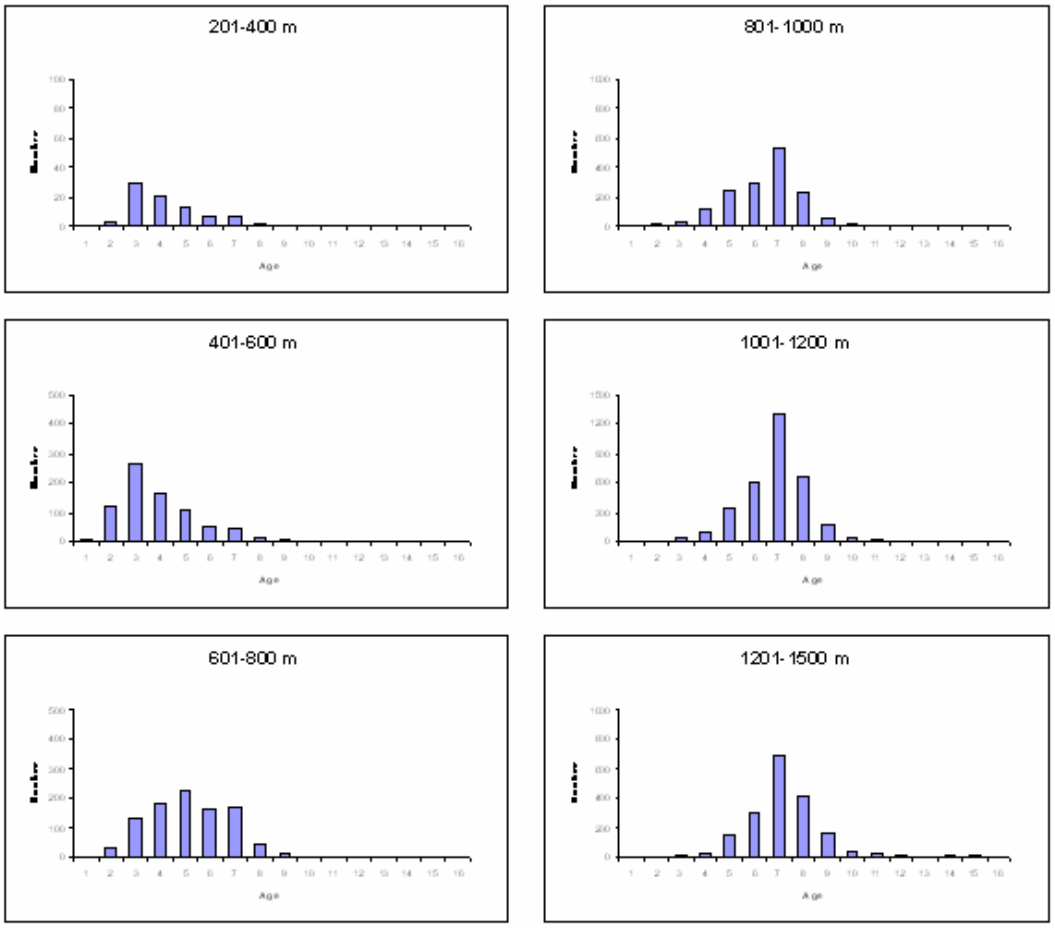

Fig. 4. Age distribution (number km^{-2}) by depth stratum Note different scales on y-axis.

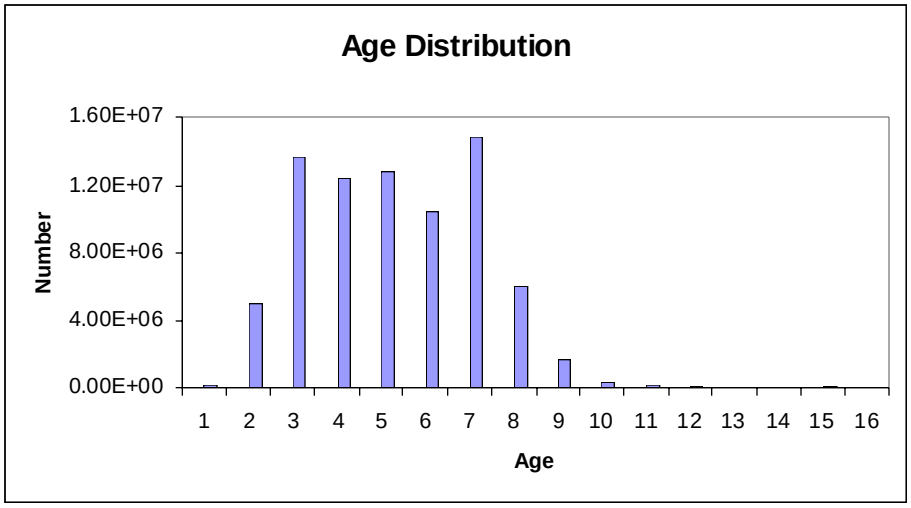

Fig. 5. Over all age distribution of Greenland halibut in numbers.

Appendix 1. Catch weight and - numbers (not standardised to kg/km^2) of Greenland halibut by haul. Depth in m, swept area in km^2 and bottom temperature in °C. 13 hauls have been excluded as invalid.

							Grl. halibut	
St. No	Day	Month	Depth	S. Area	Duration	Temp.	Number	Weight
3	23	9	680.5	0.0885	30	1.2	23	14.6
5	23	9	716.0	0.0835	30	1.2	25	19.0
7	24	9	756.5	0.0838	30	1.5	121	52.9
8	24	9	787.0	0.0417	15	1.5	172	98.2
9	24	9	585.5	0.0857	30	1.6	137	56.5
10	24	9	501.0	0.0820	30	1.6	193	50.8
11	24	9	243.5	0.0519	15	1.3	0	0.0
12	24	9	456.5	0.0796	30	1.3	48	13.2
13	25	9	677.5	0.0907	30	0.1	34	17.8
14	25	9	653.5	0.0816	30	0.0	100	51.4
15	25	9	153.5	0.0643	30	-0.5	0	0.0
16	25	9	861.5	0.0933	31	0.6	161	137.0
17	25	9	359.5	0.0698	30	0.6	4	1.9
20	26	9	562.5	0.0334	18	-0.4	12	7.3
21	26	9	427.0	0.0764	26	-0.2	18	10.8
22	26	9	384.5	0.0752	30	-0.2	21	8.6
23	26	9	391.0	0.0819	30	0.0	9	4.9
24	26	9	384.5	0.0801	29	-0.1	3	1.9
25	26	9	443.5	0.0463	19	-0.3	18	8.3
26	27	9	494.5	0.0668	32	-0.4	15	11.4
27	27	9	533.5	0.0616	24	-0.4	8	3.0
28	27	9	564.5	0.0833	30	-0.4	28	16.4
30	27	9	592.5	0.0678	26	1.1	32	14.2
31	27	9	589.5	0.0866	30	1.3	123	59.6
32	28	9	629.0	0.0826	30	1.0	61	39.1
33	28	9	724.5	0.0874	30	0.9	70	51.1
34	28	9	709.5	0.0900	30	0.9	64	55.9
35	28	9	663.0	0.0919	30	1.0	92	63.1
36	28	9	632.5	0.0581	20	0.9	35	27.7
38	28	9	867.0	0.0955	30	0.7	91	80.2
39	29	9	1072.5	0.0976	30	0.1	199	239.2
40	29	9	1291.5	0.0414	15	0.0	35	39.3
41	29	9	1418.5	0.0769	28	-0.1	65	69.5
42	29	9	961.5	0.0883	30	0.3	130	144.7
43	29	9	917.5	0.0859	30	0.5	57	58.3
44	29	9	955.5	0.0871	30	0.6	150	156.3
45	29	9	1069.0	0.0951	30	0.2	138	168.7
47	30	9	1315.5	0.0890	30	0.2	90	101.2
48	30	9	846.5	0.0841	30	0.4	157	137.3
49	30	9	785.0	0.0924	30	0.7	145	104.4
50	30	9	1299.5	0.0437	30	0.1	100	134.1
51	30	9	1216.5	0.0853	30	0.6	357	442.4

Appendix 1. (Cont'd)

							Grl. halibut	
St. No	Day	Month	Depth	S. Area	Duration	Temp.	Number	Weight
52	30	9	1081.0	0.0916	30	0.5	702	800.7
53	1	10	484.5	0.0863	30	1.0	81	31.4
56	2	10	103.5	0.0606	30	-0.5	0	0.0
57	2	10	150.5	0.0353	16	0.2	0	0.0
59	2	10	161.0	0.0653	31	0.4	0	0.0
60	3	10	664.5	0.0803	30	1.6	38	20.0
61	3	10	762.0	0.0929	30	1.2	62	56.2
62	3	10	506.0	0.0900	30	1.7	144	33.0
63	3	10	241.5	0.0685	30	1.5	0	0.0
64	3	10	567.0	0.0699	26	1.8	60	25.4
65	4	10	732.0	0.3695	30	0.9	23	15.8
66	4	10	772.5	0.0843	30	0.8	25	31.0
67	4	10	706.0	0.0957	30	1.0	122	85.0
68	4	10	656.5	0.0846	30	1.0	43	29.1
69	5	10	543.0	0.0849	30	1.5	31	22.9
70	5	10	578.0	0.0812	30	1.3	53	31.9
72	6	10	1008.5	0.0818	30	0.8	162	125.2
73	7	10	771.5	0.0772	30	1.2	105	77.5
74	7	10	779.5	0.0895	30	1.1	135	100.6
75	7	10	841.5	0.0886	30	1.1	194	171.9

Appendix 2. List of species and groups of species recorded in Div. 1C-D in 2004 with observedmaximum catch weight (kg), maximum number, minimum and maximum depth(m), minimum and maximum bottom temperature (°C) and most northern observation, respectively (Weight < 50 g given as 0.0 kg).

Obs	species		maxwgt	maxno	mindepth	maxdepth	mintemp	maxtemp	maxpos
1	Alepocephalus	agassizzi	0.2	1	1299.5	1299.5	0.1	0.1	74.886
2	Arctogadus	glacialis	14.9	273	153.5	1008.5	-0.5	1.8	76.838
3	Artediellus	atlanticus	0.2	6	153.5	732.0	-0.5	1.9	76.910
4	Bathylagus	euryops	0.0	1	578.0	961.5	0.3	1.6	75.050
5	Bathypolypus	arcticus	0.1	1	562.5	653.5	-0.4	0.0	76.275
6	Benthosema	glaciale	0.0	1	1081.0	1081.0	0.5	0.5	74.929
7	Boreogadus	saida	29.8	2752	103.5	1183.0	-0.7	1.9	76.910
8	Careproctus	micropus	0.0	1	867.0	1418.5	-0.1	0.7	74.952
9	Careproctus	reinhardti	0.9	20	443.5	861.5	-0.4	1.8	76.838
10	Cirroteuthis	mulleri	16.8	63	501.0	1418.5	-0.1	1.6	75.874
11	Cottunculus	microps	2.8	24	350.0	1315.5	-0.4	1.9	76.275
12	Cyclothone	microdon	0.0	7	484.5	1400.5	0.0	1.7	75.688
13	Cylopteroptis	macalpini	0.0	1	663.0	663.0	1.0	1.0	75.300
14	Eumicrotremus	derjungini	0.0	1	117.0	153.5	-0.5	-0.2	76.395
15	Eumicrotremus	spinosus	0.1	1	153.5	161.0	-0.5	0.4	76.395
16	Gymnocanthus	tricuspis	0.1	1	103.5	161.0	-0.7	-0.5	76.819
17	Icelus	bicornis	0.0	2	153.5	170.5	-0.5	-0.4	76.852
18	Icelus	spatula	0.0	2	161.0	241.5	-0.7	1.5	76.852
19	Leptagonus	decagonus	0.1	4	150.5	861.5	-0.4	1.3	76.910
20	Leptoclinus	maculatus	0.0	2	241.5	772.5	0.8	1.5	74.525
21	Liparis	fabricii	0.9	28	150.5	1418.5	-0.4	1.8	76.910
22	Liparis	gibbus	0.7	1	103.5	653.5	-0.5	0.0	76.852
23	Liparis	tunicatus	0.2	1	456.5	456.5	1.3	1.3	75.928
24	Lycodes	adolfi	0.1	8	1400.5	1418.5	-0.1	0.1	74.788
25	Lycodes	eudipleurostictus	1.3	11	384.5	955.5	-0.4	1.8	76.119
26	Lycodes	luetkeny	0.1	1	443.5	443.5	-0.3	-0.3	75.637
27	Lycodes	macallister	1.3	10	562.5	677.5	-0.4	0.1	76.275
28	Lycodes	mirabilis	0.0	1	1069.0	1069.0	0.2	0.2	74.696
29	Lycodes	paamiuti	0.1	1	785.0	1072.5	0.1	0.7	75.050
30	Lycodes	pallidus	0.1	1	443.5	653.5	-0.4	0.0	76.218
31	Lycodes	reticulatus	2.6	6	170.5	456.5	-0.4	1.3	76.910
32	Lycodes	seminudus	1.2	11	427.0	1400.5	-0.4	1.6	76.275
33	Macrourus	berglax	4.8	11	564.5	1299.5	-0.4	1.6	75.604
34	Myoxocephalus	scorpius	2.3	9	153.5	153.5	-0.5	-0.5	76.395
35	Onogadus	ensis	7.3	19	685.5	1418.5	-0.1	1.2	75.197
36	Paraliparis	bathybius	0.7	13	1069.0	1418.5	-0.1	0.5	74.929
37	Raja	hyperborea	49.8	28	350.0	1418.5	-0.4	1.9	76.218
38	Raja	radiata	3.5	11	243.5	685.5	-0.4	1.9	76.275
39	Reinhardtius	hippoglossoides	800.7	702	350.0	1418.5	-0.4	1.9	76.910
40	Rhodichtlys	regina	0.1	2	1299.5	1418.5	-0.1	0.1	74.886
41	Rossia	macrosoma	0.0	1	350.0	350.0	1.9	1.9	75.069
42	Sebastes	mentella	0.2	1	589.5	589.5	1.3	1.3	75.535
43	Triglops	nybelini	1.4	87	150.5	841.5	-0.4	1.9	76.910
44	Triglops	pingeli	0.1	2	103.5	153.5	-0.5	-0.5	76.395