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Northwest Atlantic Fisheries Organization

Serial No. N5142 **NAFO SCR Doc. 05/56**

SCIENTIFIC COUNCIL MEETING – JUNE 2002

Analysis of Data from the 2004 Trawl Surveys in NAFO Division 0A

M. A. Treble

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

Abstract

Two stratified random otter trawl surveys covering depths of 400 m to 1500 m and targeting Greenland halibut (*Reinhardtius hippoglossoides)* were conducted in NAFO Division 0A (Baffin Bay). The first was conducted in northern Div. 0A from September 4 to 12 in an area that had not been previously surveyed. The second, from October 14 to 24, 2004 covered previously surveyed strata in southern Div. 0A. In northern Div. 0A there were 43 valid tows in a survey area covering 54 204 sq km. In southern Div. 0A 58 stations were successfully completed and the survey area was 44 484 sq km. Greenland halibut were distributed throughout the surveyed area and were present in all but one tow taken at 340 m in northern Div. 0A. This was the only haul that we were able to complete in depths <500 m during the northern survey. Biomass and abundance in northern Div 0A was estimated to be 45,877 tons (S.E. 9,406) and 4.85 x 10^7 (S.E. 9.0 x 10^6), respectively. Densities declined with depth from 0.97 t/sq km to 0.5 t/sq km. The estimate of biomass for southern Div. 0A was 86,176 (S.E. 12 502) with abundance of 1.11 x 10^8 (S.E. 1.7 x 10^7). Densities were highest (2.0 to 3.3 t/sq km) within the 751 to 1 000 m depth strata. Overall strata, mean densities were lower in northern Div. 0A (0.8 t/sq km) than in southern Div. 0A (1.9 t/sq km). While the overall abundance in southern Div. 0A is relatively unchanged from previous surveys a decline in abundance/sq. km was observed for the 1 001-1 250 m depths from a high of 4 579 per sq. km to 3 319 per sq km. The overall length distribution for southern Div. 0A in 2004 ranged from 12 cm to 96 cm with a mode of 45 cm and 57% were less than 45 cm. The distribution for northern Div. 0A ranged from 12 cm to 81 cm with two modes, one at 33 and a larger one at 48 cm. Age distribution was estimated for northern Div. 0A using an age length key from a small (n = 80) subset of samples from three different age structures. Scale ages using a polarized transmitted light source ranged from 1 to 31 years with multiple modes, a small one at 10 years, followed by a larger one at 16 years. Otolith section ages ranged from 1 to 23 years with a mode at age 11. Whole left otolith ages ranged from 1 to 20 years with a mode at age 12.

Introduction

Two stratified random survey's were carried out in the North West Atlantic Fisheries Organization (NAFO) Div. 0A (Baffin Bay) from September 4 to 12 and from October 14 to 24, 2004. This was a collaborative effort between Fisheries and Oceans Canada, the Nunavut Wildlife Management Board, Baffin Fisheries Coalition, Government of Nunavut, Nunavut Tungavik Inc., Indian and Northern Affairs Canada, and the Greenland Institute of Natural Resources. The Greenlandic research vessel Paamiut was used to carry out the surveys. The science crew was comprised of six Canadians and one scientist from Greenland. The first survey covered the northern portion of Div. 0A (72°N to 76°N) and the second survey covered the southern part of Div. 0A which had been previously surveyed in 1999 (Treble *et al*., 2000), and 2001 (Treble, 2002). The objectives were:

1. Collect the data required to establish age structure, estimate population abundance, biomass, and recruitment of Greenland halibut;
2. 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;

3. Record numbers and collect weight data on all non-commercial species caught, to allow calculation of abundance and biomass of these species;
4. 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);
5. Collect oceanographic data at each fishing station.

A comparison of survey results between Subarea 0 and Subarea 1 was made easier through the use of the same vessel, fishing gear and crew (Jørgensen. 2005).

Materials and Methods

Stratification and Set Selection

Table 1 and 2 list the strata (401-1 500 m) used for the surveys in Div. 0A. These stratification schemes are also shown in Fig. 1 and Fig. 2. The total area between 401 m and 1500 m encompassed by the strata in southern Div. 0A (to 72^{o}N) is 49 834 km^2 (14 529 nm^2) and in northern Div. 0A it is 77 634 km^2 (22 634 nm^2). Survey coverage was intended to be approximately 1 set per 750 km^2 (220 nm^2) for both the southern and northern survey areas with a minimum of 2 sets per stratum. Sets were allocated proportionally to stratum size. This coverage was similar to that used in the 1999 and 2001 surveys. A total of 90 sets for each trip were randomly selected from numbered units within each stratum, along with an additional 2 sets per stratum to be used as alternate fishing stations as necessary.

Vessel and Gear

The survey was conducted by the MV *Paamiut*, 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 survey. Mesh size was 140 mm with a 30 mm mesh liner in the cod end. Trawl doors were Greenland Injector weighing 2700 kg. Jørgensen (1998) contains more information about the trawl and gear. 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. 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 (m) x 0.142. This relationship was based on flume tank measurements of the trawl and rigging (Jørgensen, 1998).

Oceanographic Sampling

A Seamon© temperature sensor (sensitive to within ±0.1^{o}C) was mounted on one of the trawl doors and provided bottom temperature data for most sets. In the few cases where there was no data from the trawl door sensor the temperature sensor on the trawl eye was used.

A Seabird 19© conductivity, temperature and depth instrument equipped with a fluormeter was deployed at 4-5 stations along three transects in Baffin Bay, two during the September trip and one during the October trip. Readings were taken to the bottom or within the top approx. 600 m of the water column.

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 knots. The towing speed used in the calculations for abundance and biomass was estimated from the start and end positions of the tow, or in a few cases from GPS observations (mean of records made every 5 minutes during the tow). 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, as outlined below. For other commercial species (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). A standard meter board was used during the Div. 0A surveys. Three large catches of Greenland halibut were sub-sampled during the southern Div. 0A survey, none during the northern survey. Adjustments were made during analysis to estimate total number caught in each case.

Greenland halibut was the targeted species and was therefore sampled in more detail. Maturity was assessed visually 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. Scales were also collected from a small subset of fish during the northern Div. 0A survey.

Research on age determination methods for Greenland halibut is still on-going so the otolith samples were not analyzed. However, a subset of the samples (n = 80) were used in an age structure comparison study (Treble *et al*., 2005) and were used here as an age-length key, applied to length data from the northern Div. 0A survey to provide an estimate of age distributions for that area.

Various species from the catch were collected or had tissue samples taken for use by other researchers within DFO, the University of Manitoba and the University of Dalhousie.

Biomass and Abundance Indices

The swept area method was used in the estimation of biomass and abundance: Swept area = wingspread (m) x trawl time (min) x trawl speed (kn/hr) x $1.852/6x10^4$. Abundance and biomass were calculated for each set and standardized to 1 sq km:

Abundance (no./sq. km) = catch (no.)/swept area (sq km)
Biomass (tons/sq km) = catch (kgs)/swept area (sq km)/1 000.

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

Abundance at length was calculated for each strata (standardized to km^2 and weighted by tow), and a total abundance at each length (weighted by the strata area), was calculated (mean number/sq km. x stratum area surveyed (sq km)). The sum across all lengths and strata was calculated and compared to the overall abundance value determined above to ensure they were equal.

Results and Discussion

Near bottom temperatures throughout the surveyed area in Div. 0A varied from 1.5 ^oC to 0.1^oC in 2004 (Table 3, Fig. 3). The majority of tows (79.2%) had temperatures less than or equal to 1.0^oC (Fig. 1). In southern Div. 0A, mean bottom temperatures were similar across all years for depths below 500 m and showed a declining trend with depth. Mean temperatures for northern Div. 0A were lower across all depths compared to southern Div. 0A, declining from 0.9^oC at 501-750 m to 0.1^oC at 1251-1500 m (Table 3). Results from the three oceanographic sections can be found in Treble and Van Hardenberg (2005).

The stratified areas within Div. 0A are shown in Fig. 1 and 2 (Tables 1 and 2). In southern Div. 0A 58 of 90 planned stations were successfully completed (Table 4) and the actual survey area was 44 484 sq km (Table 6). Stratum numbers that were missed were 34, 53, 54, 56, and 57. Three were in depths 401-500 and 2 in depths 501-750. Two stratum had only 1 tow, 33 and 52. In northern Div. 0A we did 47 of 90 stations with 43 valid tows (Table 5). The following stratum were missed: 89, 62, 84, 86, 88, 90, 67, 82, 87, 83, 71, and 75. One was in depths 301-400, 5 in depths 401-500, 3 in depths 501-750 m, 1 in depths 750-1 000 m, and 2 in depths 1 001-1 250 m. Two strata had only 1 tow, 85 and 83. The actual area surveyed in northern Div. 0A was 54 204 sq km (Table 6).

Catches of most species other than Greenland halibut were small in number and so detailed analysis of these species has not been done. In total 31 species or groups of species were caught during the northern Div. 0A survey (Appendix 1). During the southern Div. 0A survey 40 species were caught (Appendix 2). This compares to 49 species in the 1999 and 2001 surveys.

Greenland Halibut

Greenland halibut were distributed throughout the survey area and were present in all but one tow taken at 340 m in northern Div. 0A. This was the only haul that we were able to complete in depths <500 m during the northern survey (Fig. 4 and 5 and Table 5). In northern Div. 0A catches varied from 10.85 kg (n = 10, 1 214 m) to 627 kg (n = 537 914 m) (Table 5). In southern Div. 0A catches varied from 8.95 kg (n = 6, 1 337 m) to 839 kg (n = 590, 1 286 m) (Table 5).

Total biomass and abundance for the 1999 and 2001 surveys in southern Div. 0A had to be recalculated due to a revision in the strata area (Table 6). The revised estimate for 1999 is 68 760 tons (S.E. 18 263) and for 2001 it is 81 002 tons (S.E. 20 871). The 2004 estimate of biomass for this area is 86 176 (S.E. 12 502). Densities were highest (2.0 to 3.3 t/sq km) within the 751 to 1 000 m depth strata (Table 6). The 1999 and 2004 surveys had similar survey area. In 2001 eight strata were missed (Treble, 2002) but only one stratum was likely to contain substantial biomass (stratum 61, 1 251-1 500 contained 11 339 tons in 1999).

New area was surveyed in northern Div. 0A in 2004 and biomass was estimated to be 45 877 tons (S.E. 9 406). (Table 6). The 501-1 000 m depth strata contained 74% of the total survey area and the largest biomass. Densities declined with depth from 0.97 t/sq km to 0.5 t/sq km (Table 6)). Overall strata mean densities were lower in northern Div. 0A (0.8 t/sq km) than in southern Div. 0A (1.9 t/sq km) (Table 6).

Abundance in southern Div. 0A in 1999 and 2001 was re-calculated at 1.189×10^8 (S.E. 3.2×10^7) and 1.187×10^8 (S.E. 3.3×10^7 (Table 7)). Abundance from the 2004 survey is estimated at 1.11×10^8 (S.E. 1.7×10^7) with mean abundance per sq km varying between 2 977 and 3 319 across three depth strata 501 to 1250 m (Table 7). While the overall abundance is relatively unchanged from 1999 to 2004 a decline in abundance/sq. km is observed for the 1 001-1 250 m depths from a high of 4 579 per sq. km to 3 319 per sq km.

Abundance in the new area surveyed in northern Div. 0A for 2004 was estimated at 4.85×10^7 (S.E. 9.0×10^6) with the highest concentration at 1 423 per sq. km. in depth strata 500-750 m and declining to approx. 300 per sq. km at 1 000 m to 1 500 m (Table 7).

Length frequency distribution by depth strata for southern Div. 0A and northern Div. 0A are given in Fig. 6. The number of fish at larger length classes increases with depth in southern Div. 0A but not in the north. In southern Div. 0A depth strata 401-500 m had two modes one at 15 cm and the highest mode at 27 cm. The mode increased to 39 cm for the next two depth strata 501-750 m and 751-1000 m and was 51 cm in 1250-1500 m depth strata. In northern Div. 0A the length distribution for depths 501-750 is bi-modal with peaks at 30 cm and 48 cm. The mode for depths 751-1 000 is also 48 cm and increased to 51 cm for the two deepest strata 1 001-1 250 m and 1 250-1 500 m.

The overall length distribution adjusted for survey area for southern Div. 0A in 2004 ranged from 12 cm to 96 cm with a slightly greater mode of 45 cm compared to 42 cm for the 2001 survey and 39 cm for the 1999 survey (Table 8 and Fig. 7). Note that the 1999 total abundance by length class does not match the overall abundance calculated for 1999 shown in Table 7 but it is reasonably close. The 1999 length frequency data were in a different format so the standard SAS© programs used for biomass, abundance and length frequency calculations for the other years could not be used. Instead the Excel© spreadsheet program was used and so the difference observed could be due to rounding differences between the two programs or errors in performing the Excel calculations. The distribution for northern Div. 0A ranged from 12 cm to 81 cm with two modes, one at 33 and a larger one at 48 cm (Table 8 and Fig. 7).
The percentage of fish <45 cm has decreased in southern Division 0A to 57.0% compared to 68.1% in the 2001 survey and 77.2% in the 1999 survey (Table 9). In comparison, Div. 0B in 2001 had 46.8% of the catch <45 cm. If we consider that growth is slower for Greenland halibut from this area (Treble et al. 2005) the observed trend in abundance at length may be partially attributed to continued growth in the abundant 1995 year class (see Jorgensen

2005, Fig. 3 for an offshore recruitment index). In contrast the percentage of fish =<35cm was lowest in 2001 at 15.7% increasing to 21.1% in 2004 (Table 9). This trend may be reflecting the sharp drop in offshore recruitment observed in 1996 and 1997 which was followed by slightly better recruitment in 1999 and 2000. In northern Div. 0A the percentage of fish <45 cm was 36%.

Estimates of length-at-age (Fig. 8) and age distribution (Fig. 9) have been prepared for northern Div. 0A only and are based on a limited collection of samples (n = 80) examined in an age methods comparison study (Treble *et al*., 2005). Although it is based on a small number of samples it gives an initial idea as to the age distribution for this area. Scale ages ranged from 1 to 31 years with multiple modes, a small one at 10 years, followed by a larger one at 16 years. Otolith section ages ranged from 1 to 23 years with a mode at age 11. Whole left otolith age ranged from 1 to 20 years with a mode at age 12.

Acknowledgements

This work could not have been conducted without the financial support provided by Fisheries and Oceans Canada, the Nunavut Wildlife Management Board, Baffin Fisheries Coalition, Government of Nunavut, Indian and Northern Affairs Canada and Nunavut Tungavik Inc. Technical support was provided by staff from Fisheries and Oceans Central and Arctic Region and the Greenland Institute of Natural Resources science staff and ships crew. Michael Rosing provided training and assistance with the new database system and Ole Jørgensen generously provided revised SAS programs to facilitate data analysis.

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Table 1. Stratification scheme for Southern Div. 0A. Errors made in the original calculation of area within these strata were corrected in 2004. Both the original value and the corrected value are given. A conversion factor of 3.430 was used to calculate square kilometres from square nautical miles.

Stratum	Original Sq. N Miles	Corrected Sq. N Miles	Units	Corrected Sq. Km.	Depth Range (m)
First roughed out by hand in 1986 and corrected in May 2004					
024	457	281	90	963.8	401-500
025	1780	1527	510	5237.6	501-750
030	1099	1004	330	3443.7	751-1000
031	496	832	280	2853.8	1001-1250
032	301	391	130	1341.1	1251-1500
033	184	305	100	1046.2	501-750
034	75	156	50	535.1	401-500
	4,392	**4,496**		**15,421**	
First done in March 1999 and corrected in May 2004					
040	1671	1296	480	4445.3	1251-1500
041	698	546	200	1872.8	1001-1250
042	577	443	160	1519.5	751-1000
043	609	472	170	1619.0	501-750
044	375	289	110	991.3	401-500
045	348	268	100	919.2	501-750
046	370	281	110	963.8	751-1000
047	883	686	250	2353.0	1001-1250
048	843	653	240	2240.0	1251-1500
049	712	547	200	1876.2	1251-1500
050	650	491	190	1684.1	1001-1250
051	574	437	160	1499.0	751-1000
052	635	477	180	1636.1	501-750
053	276	214	80	734.0	401-500
054	852	649	240	2226.1	501-750
055	334	253	100	867.8	401-500
056	200	125	60	428.8	401-500
057	652	416	190	1426.9	501-750
058	350	220	100	754.6	501-750
059	600	377	170	1293.1	751-1000
060	671	422	190	1447.5	1001-1250
061	730	471	210	1615.5	1251-1500
	13,610	**10,033**		**34,413**	
TOTAL		**14,529**		**49,834**	

Table 2. Stratification scheme for Northern Div. 0A, developed in 2004. A conversion factor of 3.430 was used to calculate square kilometres from square nautical miles.

Stratum	Sq. N Miles	Units	Sq. Km	Depth Range (m)
062	114	40	391.0	401-500
063	569	190	1951.7	501-750
064	1586	530	5440.0	751-1000
065	683	230	2342.7	1001-1250
066	576	190	1975.7	1251-1500
067	674	220	2311.8	501-750
068	1051	350	3604.9	751-1000
069	1602	540	5494.9	751-1000
070	507	170	1739.0	751-1000
071	81	30	277.8	1001-1250
072	1274	420	4369.8	1001-1250
073	421	140	1444.0	1251-1500
	9,138		**31,343**	
074	1429	520	4901.5	751-1000
07 5	53	20	181.8	1001-1250
076	999	360	3426.6	751-1000
077	898	330	3080.1	751-1000
078	732	270	2510.8	1001-1250
079	401	150	1375.4	1250-1500
080	1033	380	3543.2	501-750
081	1224	450	4198.3	501-750
082	968	350	3320.2	501-750
083	583	210	1999.7	751-1000
084	320	120	1097.6	401-500
085	822	300	2819.5	301-400
086	302	110	1035.9	401-500
087	494	180	1694.4	501-750
088	348	130	1193.6	401-500
089	1234	450	4232.6	301-400
090	838	310	2874.3	401-500
091	818	300	2805.7	501-750
	13,496		**46,291**	
TOTAL	**22,634**		**77,634**	

Table 3. Mean temperature and S.E. in () by depth stratum for NAFO Div. 0A, 2004.

NAFO Division 0A	Depth Stratum (m) 301-400	401-500	501-750	751-1000	1001-1250	1251-1500
South-1999		1.6 (0.50)	1.4 (0.16)	1.0 (0.03)	0.6 (0.05)	0.1 (0.04)
2001		0.7 (0.10)	1.5 (0.22)	0.9 (0.07)	0.7 (0.05)	0.2 (0.05)
2004		1.3 (0.21)	1.5 (0.25)	1.0 (0.05)	0.6 (0.05)	0.1 (0.04)
North-2004	0.3	.	0.9 (0.04)	0.6 (0.04)	0.2 (0.04)	0.1 (0.06)

Table 4. Area by depth strata for NAFO Division 0A with the number of hauls planned for the 2004 survey ( ) and conducted/ successful. A conversion factor of 3.430 was used to calculate square kilometres from square nautical miles.

NAFO Division	Depth Stratum (m)	301-400	401-500	501-750	751-1000	1001-1250	1251-1500	Total
0A-South	Area (sq. nm) previous		1717	5410	3220	3398	4257	18002
	Area (sq. nm) corrected		1318	4334	2542	2977	3358	14529
	Area (sq. km) corrected		4521	14866	8719	10211	11518	49835
	Hauls		(12) 5/5	(27) 13/13	(16) 12/12	(15) 11/11	(20) 17/17	(90) 58/58
0A-North	Area (sq. nm)	2056	1922	5780	8655	2823	1398	22634
	Area (sq. km)	7052	6592	19825	29687	9683	4795	77634
	Hauls	(8) 2/1	(11) 0	(20) 8/7	(32) 22/20	(13) 9/9	(6) 6/6	(90) 47/43
Overall (SA0)	Area (sq. nm)	2056	3240	10114	11197	5800	4756	37163
	Area (sq. km)	7052	11113	34691	38406	19894	16313	127469
	Hauls	(8) 2/1	(23) 5/5	(57) 21/20	(48) 34/32	(28) 20/20	(26) 23/23	(180) 105/101

Table 5. Catch weight and numbers (not standardised to kg/km^2) of Greenland halibut, by haul for NAFO Div. 0A, 2004. Depth in m, swept area in km^2 and bottom temperature.

Area	Trip	Set No.	Month	Day	Mean Depth (m)	Sweptarea (sq. km)	Stratum	Temp (°C)	Start T (UTC)	Greenland halibut Number	Kg
North 0A	6	1	9	4	1345	0.090254	1500	0.10	9:10	78	117.80
North 0A	6	2	9	4	914	0.09024	1000	0.70	12:04	537	627.35
North 0A	6	3	9	4	710	0.042599	750	0.80	16:13	50	45.80
North 0A	6	4	9	4	1289	0.089796	1500	-0.03	21:38	31	44.80
North 0A	6	5	9	5	1166	0.098193	1250	0.03	0:05	36	56.90
North 0A	6	6	9	5	1179.5	0.091461	1250	0.05	2:41	34	51.25
North 0A	6	7	9	5	1374.5	0.093808	1500	-0.04	9:08	12	27.60
North 0A	6	8	9	5	1214	0.095598	1250	0.15	13:15	10	16.15
North 0A	6	9	9	5	863	0.08594	1000	0.72	18:30	77	73.60
North 0A	6	10	9	5	818.5	0.048198	1000	0.73	22:25	76	73.00
North 0A	6	12	9	6	940	0.148733	1000	0.96	9:05	132	74.13
North 0A	6	14	9	6	959	0.05122	1000	0.49	14:01	9	10.85
North 0A	6	15	9	6	960	0.09031	1000	0.51	16:34	40	42.20
North 0A	6	16	9	6	933.5	0.096867	1000	0.55	21:22	79	77.55
North 0A	6	17	9	6	957.5	0.087978	1000	0.70	23:55	180	163.00
North 0A	6	18	9	7	915.5	0.103749	1000	0.70	9:42	36	31.06
North 0A	6	19	9	7	848	0.03653	1000	0.59	13:08	26	25.90
North 0A	6	20	9	7	683	0.081461	750	0.97	16:56	42	40.40
North 0A	6	21	9	7	661.5	0.091474	750	0.88	19:12	119	58.80
North 0A	6	22	9	7	690.5	0.042736	750	0.79	23:16	44	42.70
North 0A	6	23	9	8	620.5	0.063436	750	0.73	1:48	50	33.20
North 0A	6	24	9	8	340.5	0.062706	400	0.26	6:32	0	
North 0A	6	26	9	8	664.5	0.086095	750	0.99	17:56	273	154.05
North 0A	6	27	9	8	657.5	0.089833	750	1.03	21:03	178	108.55
North 0A	6	29	9	9	1042.5	0.048561	1250	0.37	0:17	17	24.00
North 0A	6	30	9	9	868.5	0.089048	1000	0.60	15:56	48	65.80
North 0A	6	31	9	9	783	0.088335	1000	0.59	19:35	42	40.04
North 0A	6	32	9	9	787.5	0.088159	1000	0.81	22:03	55	53.00
North 0A	6	33	9	10	818.5	0.079825	1000	0.40	1:13	33	31.71
North 0A	6	34	9	10	874.5	0.334841	1000	0.51	6:23	26	28.70
North 0A	6	35	9	10	886.5	0.087797	1000	0.54	8:01	26	23.05
North 0A	6	36	9	10	907	0.049199	1000	0.24	10:30	13	23.05
North 0A	6	37	9	10	960	0.050168	1000	0.44	12:56	27	28.70
North 0A	6	38	9	10	967	0.097173	1000	0.52	15:48	98	87.60
North 0A	6	39	9	10	876	0.084281	1000	0.72	20:16	75	70.05
North 0A	6	40	9	11	1085	0.096143	1250	0.40		69	92.45
North 0A	6	41	9	11	1138	0.096586	1250	0.23	4:27	20	30.78
North 0A	6	42	9	11	1078.5	0.091848	1250	0.32	10:33	33	47.20
North 0A	6	43	9	11	1345	0.089954	1500	0.04	14:15	22	30.25
North 0A	6	44	9	11	1269	0.096699	1500	0.16	17:20	13	20.05
North 0A	6	45	9	12	1173.5	0.085596	1250	0.24	9:08	15	29.59
North 0A	6	46	9	12	1218	0.088436	1250	0.28	11:52	17	36.75
North 0A	6	47	9	12	1265.5	0.091294	1500	0.32	14:46	20	36.05
South 0A	8	1	10	14	1299.5	0.088801	1500	0.17	10:19	179	271.90
South 0A	8	2	10	14	728	0.097399	750	0.98	16:15	108	67.50
South 0A	8	3	10	14	1286	0.077935	1500	0.22	19:08	590	839.35
South 0A	8	4	10	15	638.5	0.082826	750	1.12	0:43	64	34.80
South 0A	8	5	10	15	838.5	0.069305	1000	1.05	3:03	77	41.15

South 0A	8	6	10	15	1019.5	0.088086	1250	0.83	6:13	246	212.40
South 0A	8	7	10	15	1313	0.088144	1500	0.27	8:42	24	28.10
South 0A	8	8	10	16	808	0.07801	1000	0.95	16:24	59	34.80
South 0A	8	9	10	16	1162.5	0.096693	1250	0.48	19:05	504	524.95
South 0A	8	10	10	16	672	0.048945	750	1.05	23:04	70	38.30
South 0A	8	11	10	17	881	0.095116	1000	1.02	0:45	75	48.95
South 0A	8	12	10	17	949	0.078967	1000	0.90	3:05	88	55.77
South 0A	8	13	10	17	1075	0.079265	1250	0.54	5:39	681	609.75
South 0A	8	14	10	17	1102.5	0.103802	1250	0.50	7:49	196	184.90
South 0A	8	15	10	17	1295	0.088622	1500	0.20	9:54	205	301.80
South 0A	8	16	10	17	439	0.067535	500	0.75	13:02	38	20.20
South 0A	8	17	10	17	1337	0.095845	1500	0.21	17:33	6	8.95
South 0A	8	18	10	17	1145	0.091407	1250	0.43	19:32	171	186.40
South 0A	8	19	10	18	1276	0.09008	1500	0.00	6:11	168	170.70
South 0A	8	20	10	18	656	0.070524	750	0.70	11:27	317	135.00
South 0A	8	21	10	18	1410.5	0.095083	1500	-0.30	16:05	23	31.15
South 0A	8	22	10	19	1296.5	0.08614	1500	0.00	4:19	43	47.45
South 0A	8	23	10	19	1351.5	0.086501	1500	-0.20	15:47	20	20.60
South 0A	8	24	10	20	1117.5	0.104749	1250	0.50	16:47	277	241.40
South 0A	8	25	10	20	957.5	0.078113	1000	0.70	6:54	216	135.10
South 0A	8	26	10	20	1100.5	0.086709	1250	0.30	10:58	325	308.05
South 0A	8	27	10	20	618	0.084485	750	0.80	13:45	670	277.00
South 0A	8	28	10	20	992.5	0.069167	1000	0.70	16:33	988.29	593.51
South 0A	8	29	10	20	1351	0.099809	1500	0.00	18:50	47	51.45
South 0A	8	30	10	20	445.5	0.080742	500	1.10	23:19	118	43.00
South 0A	8	31	10	21	447	0.043675	500	1.10	1:19	190	44.35
South 0A	8	32	10	21	546	0.089314	750	1.29	3:04	215	65.80
South 0A	8	33	10	21	681.5	0.096871	750	1.19	5:51	72	33.05
South 0A	8	34	10	21	845.5	0.083512	1000	1.11	7:39	121	77.00
South 0A	8	35	10	21	977	0.098583	1000	1.00	10:06	512.05	388.47
South 0A	8	36	10	21	1075	0.086958	1250	0.70	12:48	301	308.88
South 0A	8	37	10	21	1096	0.096382	1250	0.70	14:28	227	208.40
South 0A	8	38	10	21	1359.5	0.098562	1500	0.33	16:43	96	145.50
South 0A	8	39	10	21	1498.5	0.088032	1500	-0.12	19:03	13	18.30
South 0A	8	40	10	21	1437.5	0.091355	1500	-0.01	22:47	7	14.45
South 0A	8	41	10	22	1359.5	0.1025	1500	0.22	1:45	12	26.70
South 0A	8	42	10	22	697	0.077583	750	4.15	7:24	953.72	572.85
South 0A	8	43	10	22	1302	0.088093	1500	0.34	10:38	51	46.20
South 0A	8	44	10	22	1295	0.058254	1500	0.11	15:11	7	13.75
South 0A	8	45	10	22	1105.5	0.087208	1250	0.47	18:15	148	173.30
South 0A	8	46	10	22	1289	0.089978	1500	0.19	21:21	51	66.10
South 0A	8	47	10	23	1098.5	0.09881	1250	0.79	0:17	222	266.90
South 0A	8	48	10	23	870	0.08908	1000	0.92	3:10	247	255.50
South 0A	8	49	10	23	871	0.086416	1000	0.96	5:36	266	248.95
South 0A	8	50	10	23	911.5	0.088233	1000	1.08	9:49	173	113.80
South 0A	8	51	10	23	688	0.083949	750	1.40	12:32	119	64.65
South 0A	8	52	10	23	510	0.084652	750	1.68	16:18	242	83.60
South 0A	8	53	10	23	459	0.086026	500	1.67	18:12	223	89.85
South 0A	8	54	10	23	448.5	0.086347	500	1.87	21:21	43	15.80
South 0A	8	55	10	24	700	0.089989	750	1.40	1:11	92	49.90
South 0A	8	56	10	24	750.5	0.085423	1000	1.37	2:57	62	25.80
South 0A	8	57	10	24	723	0.085234	750	1.40	6:48	119	74.10
South 0A	8	58	10	24	563.5	0.061653	750	2.29	10:30	51	31.35

Table 6. Biomass estimates (tons) of Greenland halibut by depth stratum for NAFO Div. 0A.

Year/Section	Stratum (m)	Survey Area (sq. km)	No. Sets	Mean Biomass (t/sq. km)	Biomass (tons)	SE
1999	401-500	2919	8	0.3914	1142.6	431.2
0A-South	501-750	11213	18	0.8232	9230.7	2825.8
	751-1000	8719	12	1.5764	13744.3	2559.2
	1001-1250	10211	12	2.9763	30391.4	7857.9
	1251-1500	11518	15	1.2373	14251.4	4588.4
	Overall	44580	65	1.5424	68760.4	18262.5
2001	401-500	429	2	0.3621	155.3	153.5
0A-South	501-750	11213	18	1.8865	21153.1	5107.0
	751-1000	8719	7	3.3261	29000.3	7665.9
	1001-1250	10211	7	2.5958	26505.5	7075.2
	1251-1500	9903	14	0.4228	4187.4	869.4
	Overall	40475	48	2.0013	81001.6	20871.1
2004	401-500	2823	5	0.6149	1735.9	504.2
0A-South	501-750	11213	13	1.4800	16595.5	6040.8
	751-1000	8719	12	2.0645	18000.8	5948.9
	1001-1250	10211	11	3.2376	33058.8	5589.9
	1251-1500	11518	17	1.4573	16785.4	7273.9
	Overall	44484	58	1.9372	86176.4	12501.6
2004	301-400	0	1	0.0000	0.0	0.00
0A-North	401-500	0	0	.	.	.
	501-750	12499	7	0.9620	12024.1	2174.1
	751-1000	27687	20	0.9737	26959.3	9091.1
	1001-1250	9223	9	0.4843	4466.4	682.6
	1251-1500	4795	6	0.5061	2426.9	789.8
	Overall	54204	43	0.8464	45876.8	9405.6

Table 7. Abundance estimates (000's) of Greenland halibut by depth stratum for NAFO Div. 0A.

Year/Section	Stratum (m)	Survey Area (sq. km)	No. Sets	Mean Abundance (sq. km)	Abundance	SE
1999	401-500	2919	8	1229.90	3.6E+06	1.3E+06
0A-South	501-750	11213	18	2327.80	2.61E+07	8.5E+06
	751-1000	8719	12	3482.70	3.04E+07	5.5E+06
	1001-1250	10211	12	4579.40	4.68E+07	1.3E+07
	1251-1500	11518	15	1045.40	1.2E+07	3.6E+06
	Overall	44580	65	2666.22	1.189E+08	3.2E+07
2001	401-500	429	2	553.60	2.4E+05	2.3E+05
0A-South	501-750	11213	18	3840.20	4.31E+07	1.0E+07
	751-1000	8719	7	4100.60	3.58E+07	9.9E+06
	1001-1250	10211	7	3456.60	3.53E+07	1.1E+07
	1251-1500	9903	14	439.60	4.4E+06	8.4E+05
	Overall	40475	48	2932.65	1.187E+08	3.3E+07
2004	401-500	2823	5	1892.90	5.34E+06	2.0E+06
0A-South	501-750	11213	13	2977.10	3.34E+07	1.1E+07
	751-1000	8719	12	3000.40	2.62E+07	9.5E+06
	1001-1250	10211	11	3319.00	3.39E+07	6.2E+06
	1251-1500	11518	17	1066.10	1.23E+07	5.1E+06
	Overall	44484	58	2496.53	1.11E+08	1.7E+07
2004	301-400	0	1	0.00	0.00E+00	0.0E+00
0A-North	401-500	0	0	.	.	.
	501-750	12499	7	1422.90	1.78E+07	4.2E+06
	751-1000	27687	20	948.80	2.63E+07	7.8E+06
	1001-1250	9223	9	316.10	2.92E+06	5.6E+05
	1251-1500	4795	6	322.60	1.55E+06	5.4E+05
	Overall	54204	43	895.08	4.85E+07	9.0E+06

Table 8. Length distribution (3 cm groups) estimated total number (000's) for Greenland halibut from NAFO Div. 0A (weighted by survey area).

Length Class (3cm)	Div. 0A South 1999	2001	2004	Div. 0A North 2004
0				
3				
6	73.240			
9	26.119	7.370		
12	61.248	16.925	25.854	27.595
15	21.036	192.867	722.746	0.000
18	322.593	181.545	443.925	28.148
21	639.739	766.476	1408.294	134.179
24	2902.035	2130.242	1881.047	415.786
27	8512.532	2464.872	5011.075	1685.961
30	12473.322	4327.508	5605.143	2696.234
33	15944.903	8561.021	8367.771	***2807.353***
36	16947.771	16223.824	10617.731	2382.807
39	***17014.003***	22102.681	13436.041	2556.338
42	14621.133	***23835.554***	15697.215	4727.469
45	10750.969	17459.631	***15979.390***	7958.063
48	6443.782	10695.541	13845.141	***9516.253***
51	4122.988	5219.180	9238.186	6810.913
54	2247.477	2096.945	4329.138	3469.205
57	1250.561	1189.117	2095.964	1589.423
60	704.208	592.811	976.217	734.081
63	471.663	255.268	532.397	365.444
66	242.111	140.190	317.073	288.196
69	117.638	131.897	141.182	70.236
72	127.133	40.866	126.200	187.243
75	9.577	23.947	69.875	37.749
78	18.739		45.719	8.855
81	9.427		42.088	19.178
84	0.000	28.336	17.519	
87	0.000		33.085	
90	0.000		14.255	
93	9.290		10.644	
96			6.874	
99		14.516		
Total	116085.240	118699.128	111037.788	48516.709

Table 9. Percentage of Greenland halibut less than 45 cm and less than or equal to 35 cm for the surveys in Div.0A, 2001 and 2004.

	South 0A 1999	South 0A 2001	South 0A 2004	North 0A 2004
Percent =<35 cm	35.3	15.7	21.1	16.1
Percent <45 cm	77.2	68.1	57.0	36.0

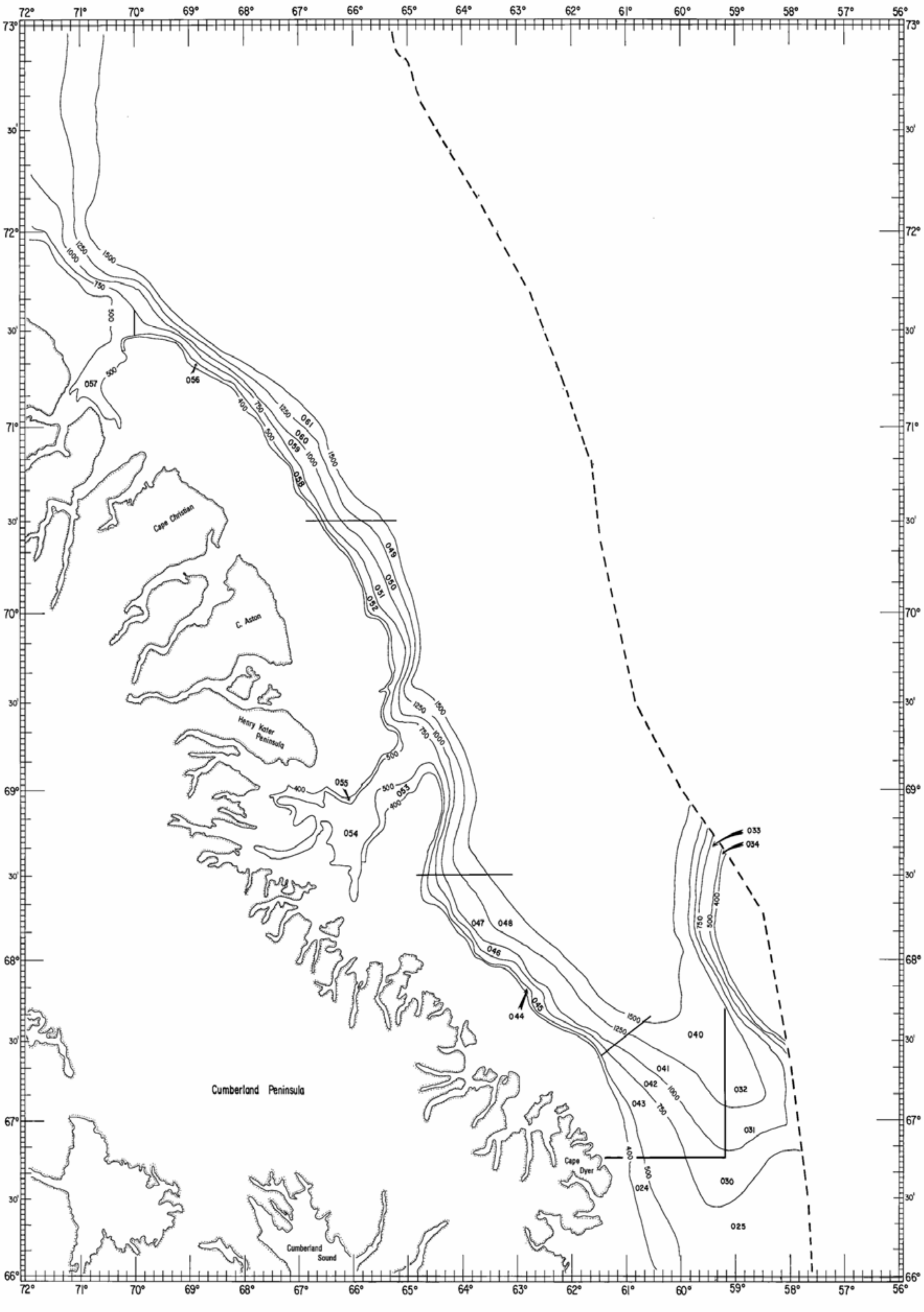


Fig. 1. Stratification scheme for North Atlantic Fisheries Organization Div. 0A, 66° N to 72° N.

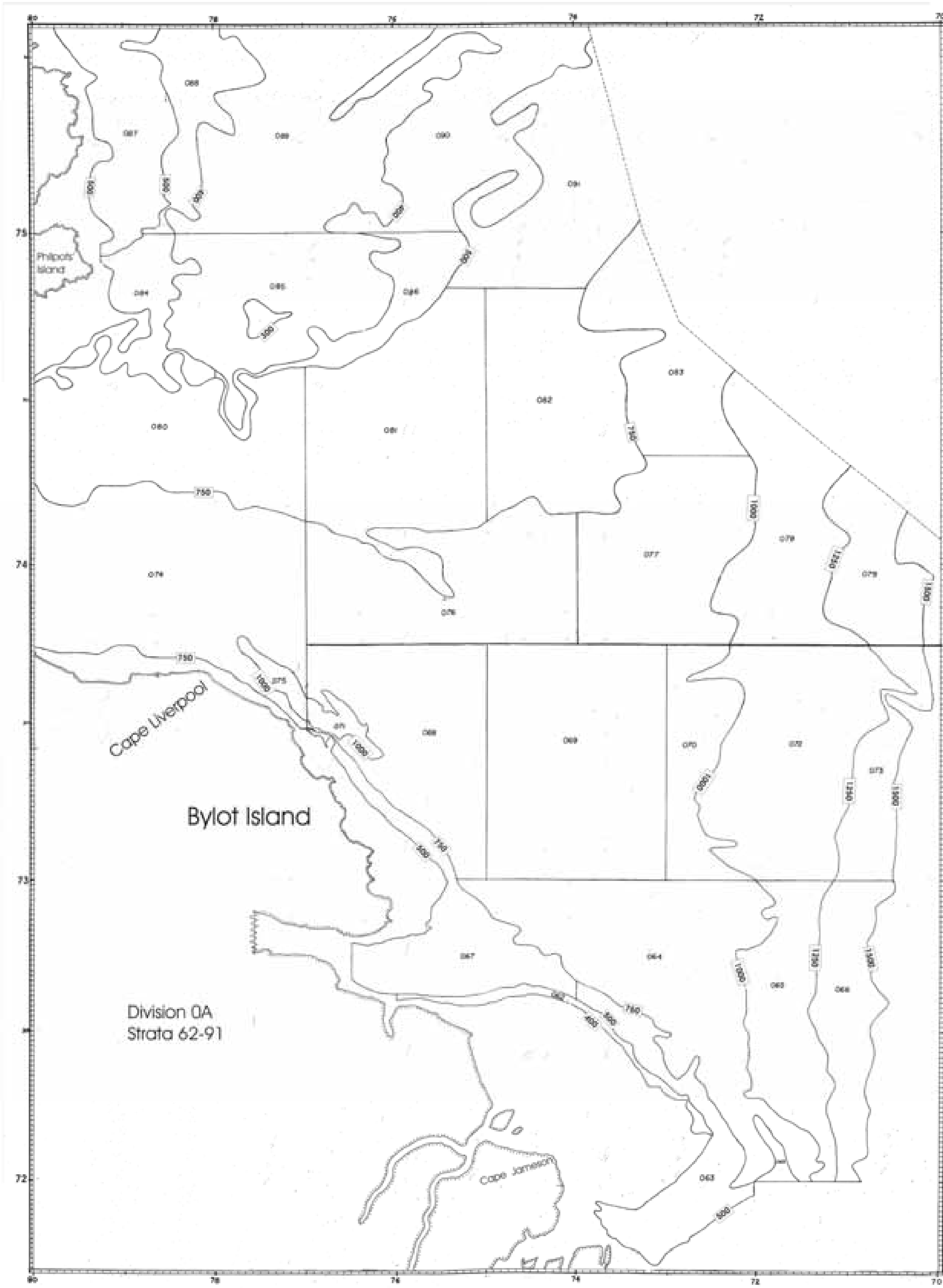


Fig. 2. Stratification scheme for North Atlantic Fisheries Organization Div. 0A, 72° N to 76° N.

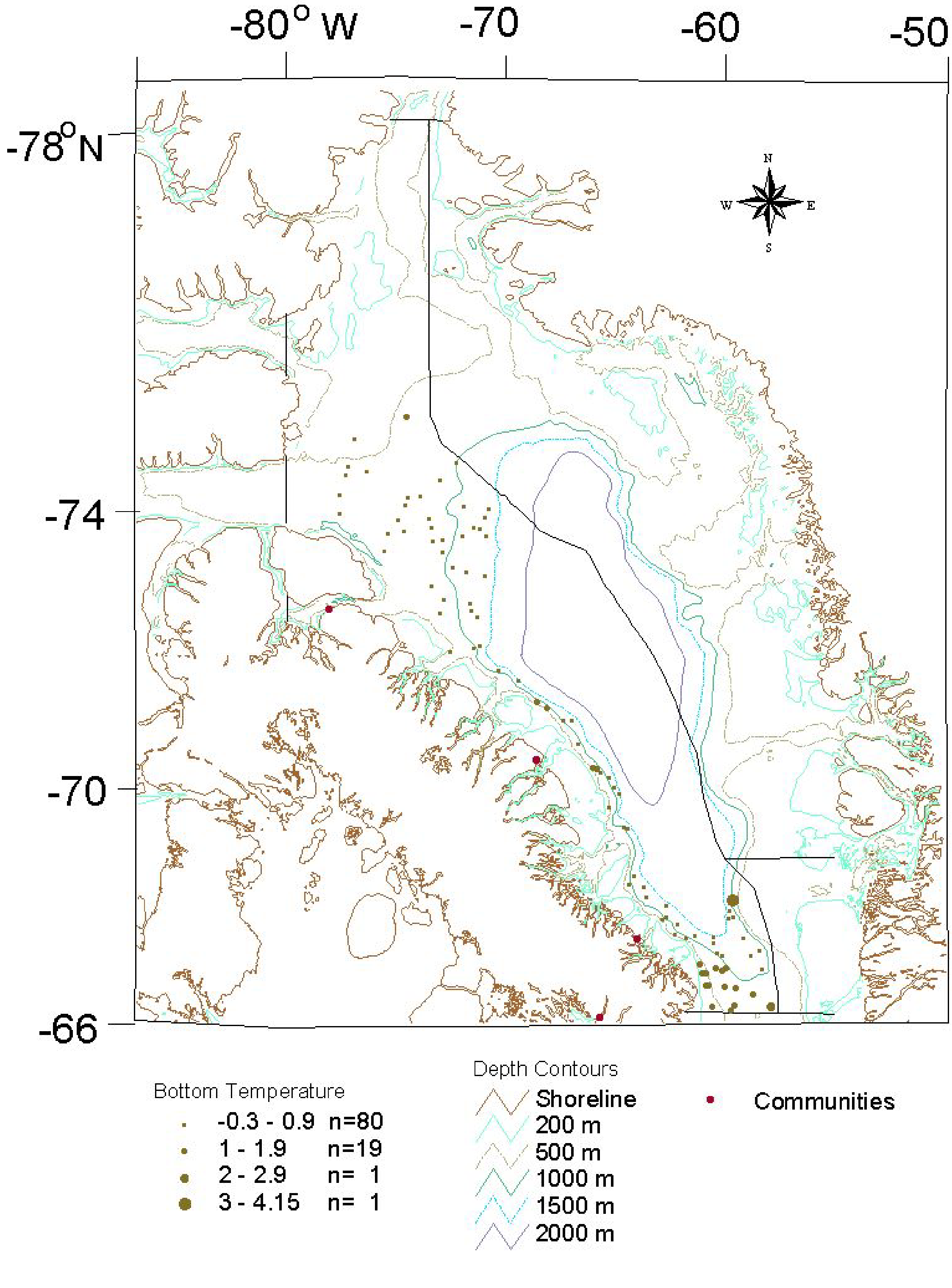


Fig. 3. Distribution of bottom temperatures (degrees Celsius) in Baffin Bay (Div. 0A) during fall survey 2004.

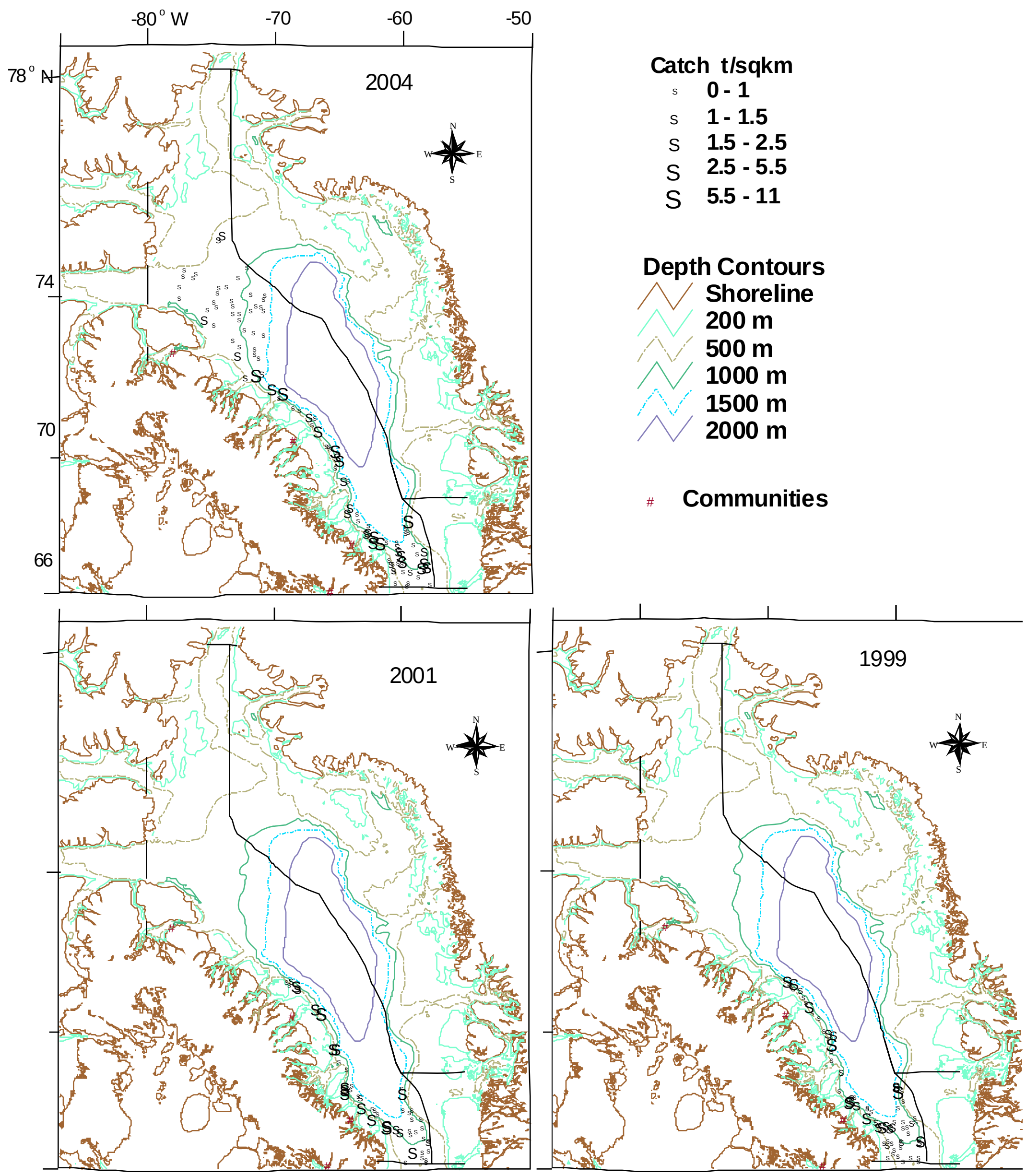


Fig. 4. Distribution of survey catches (t/km^2) in Div. 0A, 1999, 2001 and 2004.

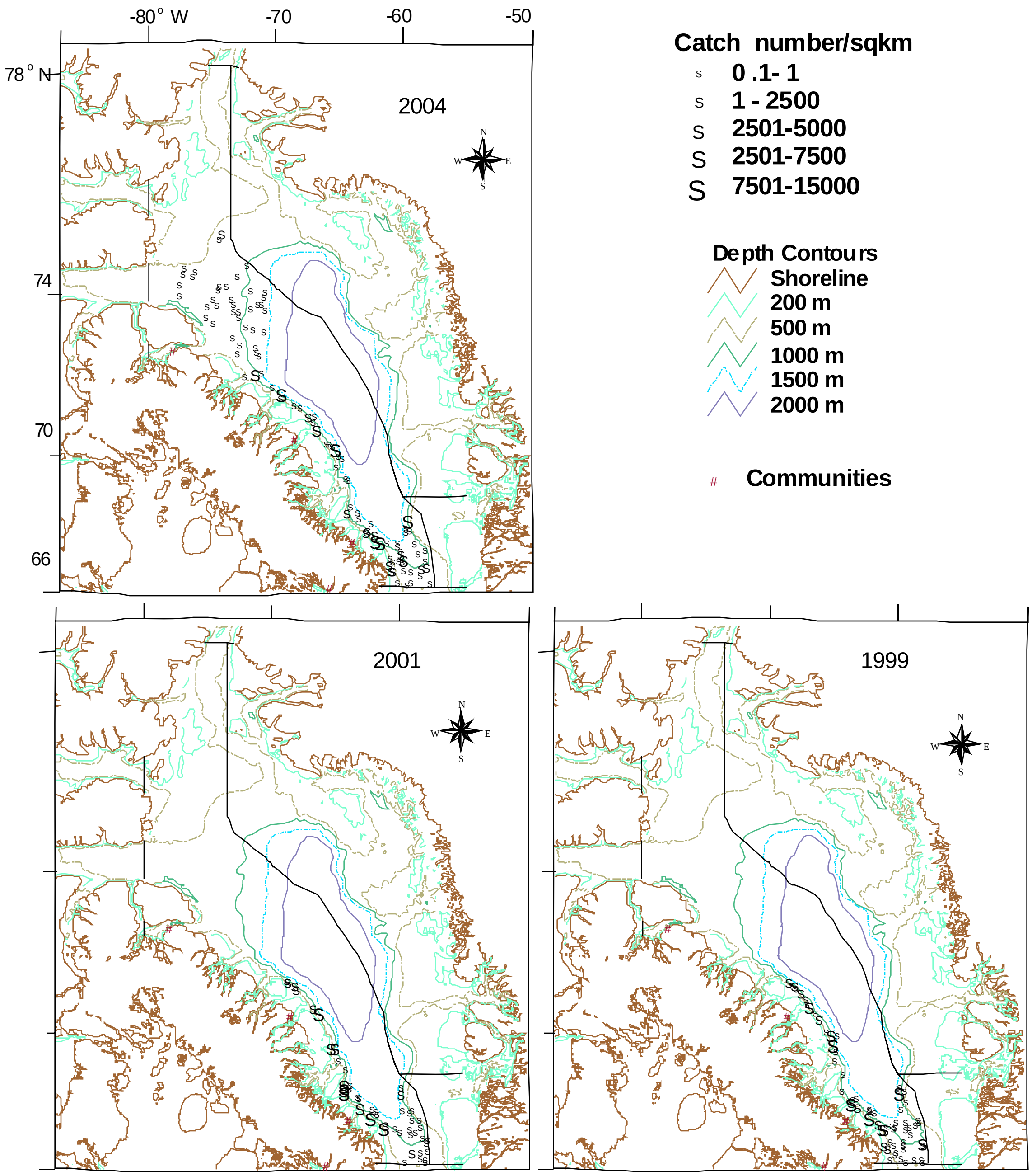


Fig. 5. Distribution of survey catches (numbers/km^2) in Div. 0A, 1999, 2001 and 2004.

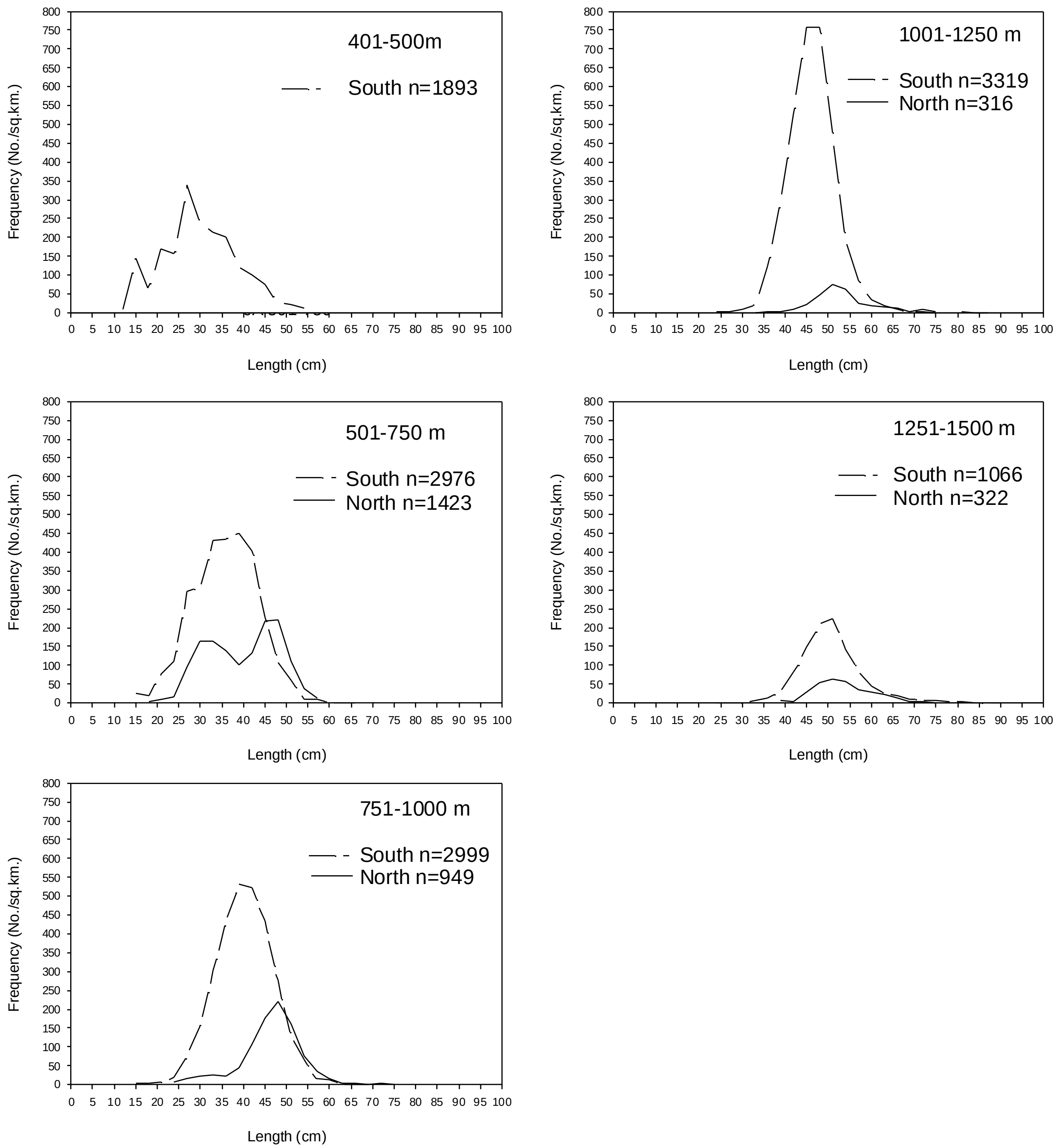


Fig. 6. Greenland halibut length distribution, by depth for Div. 0A, 2004 (standardized to numbers/km^2 and weighted by number of tows in each depth strata).

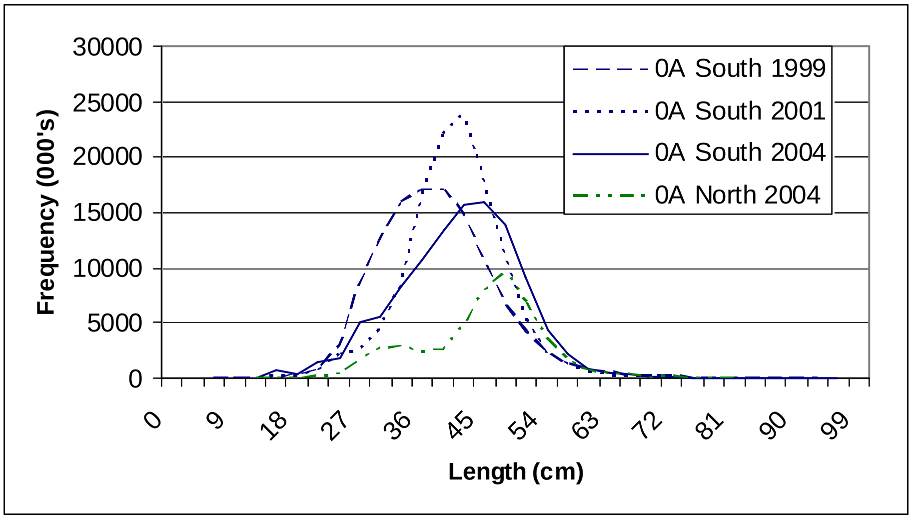
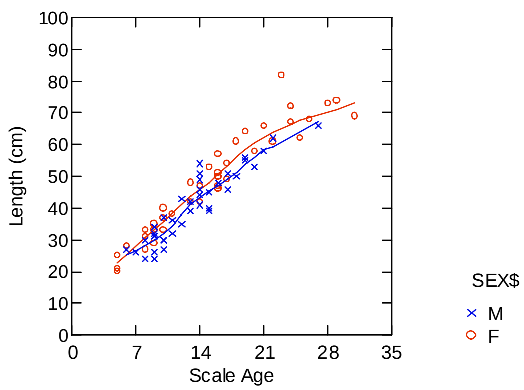
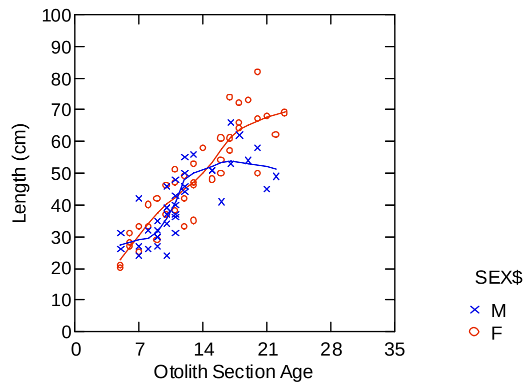


Fig. 7. Estimated abundance at length for the Greenland halibut in NAFO Div. 0A, 1999, 2001 and 2004 (weighted by stratum area).





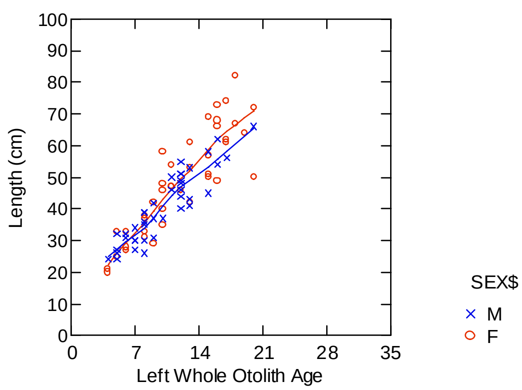
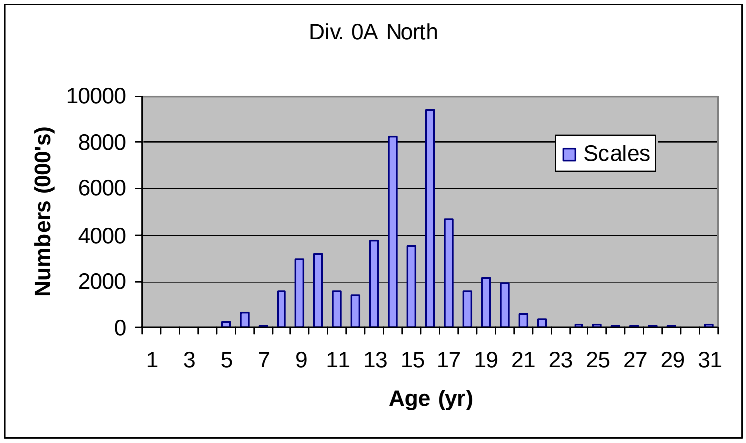
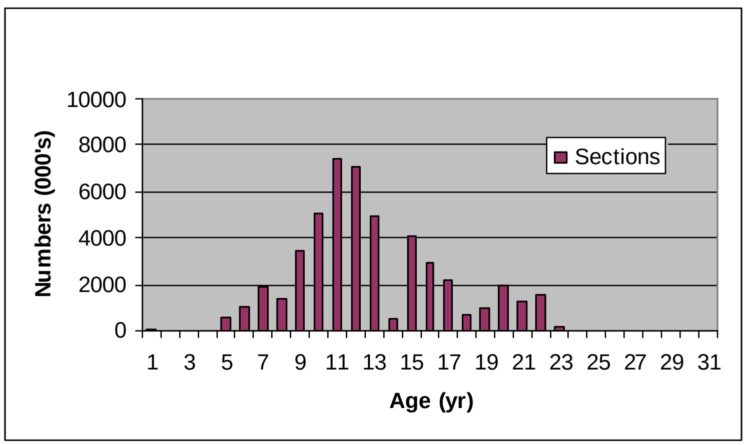


Fig. 8. Age and length (cm) by sex, plotted for scale (polarized transmitted light), otolith section and left whole otolith ages and fitted with a lowess regression. Data are from an age structure comparison study (Treble *et al*., 2005).

a)



b)



c)

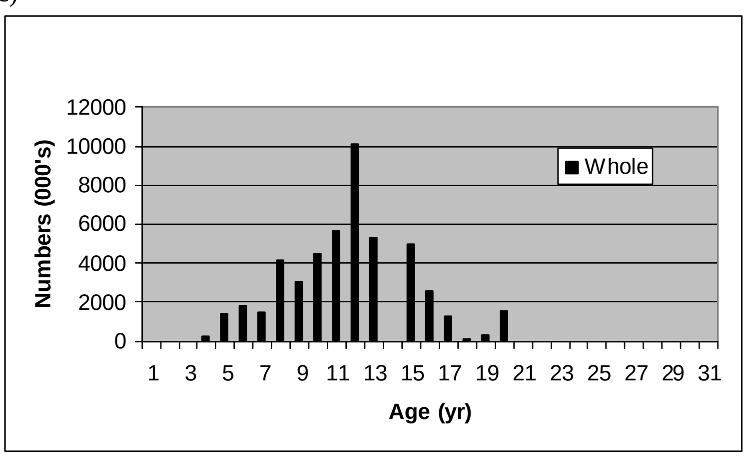


Fig. 9. Abundance at age for Greenland halibut from NAFO Div. 0A-North, 2004. Samples from age comparison (Treble *et al*., 2005) of scales (polarized transmitted light (n = 80), otolith sections (n = 81) and left whole otolith (n = 81)) used as an age-length key applied to the abundance in Table 8 and shown in Fig. 7.

Appendix 1. List of species caught during the 2004 NAFO Div. 0A -North survey, including maximum weight, maximum numbers per tow (not standardized to km^2 swept), minimum and maximum depth, minimum and maximum temperature and maximum latitude.

Code	Species	Max. Wght.	Max. No.	Min. Depth	Max Depth	Min. Temp.	Max. Temp.	Max. Pos.
ARA	*Artediellus atlanticus*	0.054	2	340.5	664.5	0.3	1	75.19
BAT	*Bathylagus euryops*	0.012	1	1078.5	1078.5	0.3	0.3	73.98
POC	*Boreogadus saida*	5.7	208	340.5	1269	0	1	75.19
CRM	*Careproctus micropus*	0.01	1	914	1345	0.1	0.7	73.14
CAR	*Careproctus reinhardti*	0.362	3	620.5	1345	0.1	1	75.07
COM	*Cottunculus microps*	19	9	683	1179.5	0	1	74.32
COS	*Cottunculus sadko*	0.92	2	914	1345	0	0.7	73.96
CLM	*Cyclothone microdon*	0.005	1	690.5	1218	0.2	0.8	74.36
ONN	*Gaidropsaurus ensis*	12.6	43	787.5	1374.5	-0	1	74.50
GOF	*Gonatus fabricii*	0.346	2	886.5	1173.5	0.2	0.7	73.70
GON	*Gonatus sp.*	0.105	1	783	1218	0.1	0.6	74.09
EUD	*Leptagonus decagonus*	0.024	1	340.5	340.5	0.3	0.3	74.80
LIF	*Liparis fabricii*	0.69	24	340.5	1374.5	-0	1	75.19
LYY	*Lycenchelys sp.*	0.026	1	863	1179.5	0.1	0.7	72.94
LAD	*Lycodes adolfi*	0.294	12	1166	1289	-0	0.2	73.85
LYN	*Lycodes eudipleurostictus*	2.43	11	914	914	0.7	0.7	72.11
LMA	*Lycodes macallister*	31	3	710	1173.5	0.2	0.8	74.00
LPA	*Lycodes paamiuti*	0.16	2	914	914	0.7	0.7	72.11
LYR	*Lycodes reticulatus*	0.068	1	340.5	340.5	0.3	0.3	74.80
LSE	*Lycodes seminudus*	1.65	6	657.5	1374.5	-0	1	75.07
RHG	*Macrourus berglax*	2.748	4	863	1218	0.3	0.7	74.29
NOT	*Notacanthus chemnitzii*	0.798	1	967	967	0.5	0.5	73.38
OCT	*Octopus sp.*	4.8	13	886.5	1374.5	-0	0.5	74.50
ONS	*Onogadus sp.*	0.562	1	876	876	0.7	0.7	72.94
PAB	*Paraliparis bathybius*	0.68	11	967	1374.5	-0	0.5	73.96
RBT	*Rajella bathyphila*	1.12	1	1166	1166	0	0	72.59
RHB	*Amblyraja hyperborea*	73.7	46	620.5	1374.5	-0	1	75.19
RRD	*Amblyraja radiata*	0.27	1	683	683	1	1	74.32
GHL	*Reinhardtius hippoglossoides*	627.35	537	620.5	1374.5	-0	1	75.19
RHO	*Rhodichthys regina*	0.13	3	1166	1374.5	-0	0.3	73.96
TRN	*Triglops nybelini*	0.088	6	340.5	967	0.3	0.7	74.80

Appendix 2. .List of species caught during the 2004 NAFO Div. 0A - South survey, including maximum weight, maximum numbers per tow (not standardized to km^2 swept), minimum and maximum depth, minimum and maximum temperature and maximum latitude.

Species Code	Species	Max. Wght.	Max. No.	Min. Depth	Max. Depth	Min. Temp.	Max. Temp.	Max. Pos.
PAN	*Pandalus* sp.	1.91	45	445.5	546	1.1	1.3	67.11
RHB	*Amblyraja hyperborea*	6.855	5	638.5	1498.5	-0.2	1.4	71.77
RRD	*Amblyraja radiata*	1.352	6	445.5	845.5	0.8	1.9	71.32
CAS	*Anarhichas minor*	.	1	866	876	0.8	0.9	66.83
ACT	*Arctogadus glacialis*	0.15	2	439	439	0.8	0.8	69.73
ARZ	*Arctozenius rissoi*	0.162	4	445.5	1351	0	4.2	68.20
ARA	*Artediellus atlanticus*	0.378	5	439	1276	0	1.1	71.32
BAT	*Bathylagus euryops*	0.15	7	688	1498.5	-0.1	1.4	71.52
BAA	*Bathypolypus arcticus*	0.204	2	871	911.5	1	1.1	66.83
BEG	*Benthosema glaciale*	0.06	12	439	1437.5	-0	1.9	71.04
POC	*Boreogadus saida*	1.335	65	439	1437.5	-0.3	1.9	71.52
CRM	*Careproctus micropus*	0.08	1	618	1351	0	0.8	69.94
CAR	*Careproctus reinhardti*	0.144	2	546	1098.5	0.8	1.4	71.52
CIM	*Cirroteuthis mulleri*	218	31	638.5	1498.5	-0.3	1.1	71.77
HER	*Clupea harangus*	0.17	1	445.5	445.5	1.1	1.1	67.11
RNG	*Coryphaenoides rupestris*	0.001	1	697	697	4.2	4.2	68.20
COM	*Cottunculus microps*	0.468	2	510	1098.5	0.8	2.3	67.01
CLM	*Cyclothone microdon*	0.014	1	750.5	1302	0.3	1.4	67.94
ONN	*Gaidropsaurus ensis*	9.505	24	448.5	1498.5	-0.3	1.9	71.77
GOF	*Gonatus fabricii*	0.84	5	445.5	1437.5	0	1.9	70.34
GON	*Gonatus* sp.	1.874	7	510	1498.5	-0.3	2.3	71.77
PLA	*Hippoglossoides platessoides*	0.92	5	439	1410.5	-0.3	4.2	71.52
LIF	*Liparis fabricii*	0.878	26	439	1498.5	-0.3	4.2	71.77
LYN	*Lycodes eudipleurostictus*	1.362	7	447	1102.5	0.5	2.3	71.05
LMA	*Lycodes macallister*	0.392	2	881	1102.5	0.5	1	70.33
LPA	*Lycodes paamiuti*	0.2	3	439	1102.5	0.5	2.3	70.20
LYR	*Lycodes reticulatus*	1.584	3	618	618	0.8	0.8	67.63
ELZ	*Lycodes sp.*	0.03	1	1337	1337	0.2	0.2	69.39
RHG	*Macrourus berglax*	7.645	8	563.5	1359.5	0	2.3	70.69
NOT	*Notacanthus chemnitzii*	2.416	2	697	1162.5	0.5	4.2	70.90
OCT	*Octopus*	0.346	2	870	870	0.9	0.9	66.87
PAB	*Paraliparis bathybius*	0.32	6	1276	1498.5	-0.3	0.3	71.77
GHL	*Reinhardtius hippoglossoides*	839.35	988	439	1498.5	-0.3	4.2	71.77
RHO	*Rhodichthys regina*	0.18	4	1145	1437.5	0	0.4	69.39
REG	*Sebastes marinus*	7.206	5	563.5	563.5	2.3	2.3	66.34
REB	*Sebastes mentella*	6.968	89	445.5	697	1.1	4.2	68.20
STO	*Stomias boa*	0.008	1	1098.5	1098.5	0.8	0.8	67.01
TRN	*Triglops nybelini*	1.05	66	439	1337	0.2	1.9	69.73
TRP	*Triglops pingeli*	0.04	1	656	656	0.7	0.7	68.47
XEC	*Xenodermichthys copei*	0.044	1	697	697	4.2	4.2	68.20