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Survey for Greenland Halibut in NAFO Divisions 1C-1D, 2011

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Abstract

In 1997 Greenland initiated a survey series covering NAFO Divisions 1CD at depths between 400 and 1 500 m. The survey is designed as a Stratified Random Bottom Trawl Survey aimed primarily at Greenland halibut and roundnose grenadier. The paper gives biomass and abundance estimates and length frequencies for Greenland halibut, roundnose and roughhead grenadier, and deep sea redfish. The biomass of Greenland halibut was estimated as 86591 tons in 2011, which is the highest in the time series. The length distribution showed a mode around 49 cm as in previous years. The biomass of roundnose grenadier was estimated as 940 tons, which is an increase compared to 2010 but still very low compared to the level seen in the 80'ies.

Introduction

During 1987-1995 Japan Marine Fishery Resources Research Center (JAMARC) and Greenland Institute of Natural Resources jointly conducted 12 bottom trawl surveys (Jørgensen, 1998a) and four pelagic surveys (Jørgensen, 1997a) at West Greenland as part of a joint venture agreement on fisheries development and fisheries research in Greenland waters. The bottom trawl surveys were primarily aimed at Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Div. 1B-1D. In 1997 Greenland Institute of Natural Resources continued the bottom trawl surveys series with the Institute's own vessel PAAMIUT, which had been rigged for deep sea trawling. There has unfortunately not been any comparative trawlings between the Japanese research vessel SHINKAI MARU and PAAMIUT making comparisons between the surveys difficult. The PAAMIUT survey traditionally covers NAFO Div. 1CD, but in 2001 the survey area was expanded to include Div. 1A (to 74°N) and Div. 1B and in 2004 the northern part of the Baffin Bay (73°N-77°N) (Div. 1A) was surveyed. In 2010 Div.1A was surveyed to 75.30°N (SCR 11/010)

Materials and Methods

The survey in Div. 1CD in 2011 covered depths between 400 and 1500 m and took place during 01/9-17/9.

Stratification

The survey covered NAFO Div. 1C-1D between the 3-nm line and the 200-nm line or the midline to Canada at depths between 400 and 1 500 m. The survey area was stratified in NAFO divisions and subdivided in 6 depth strata 401-600, 601-800, 801-1 000, 1 001-1 200, 1 201-1 400 and 1 401-1 500 m. The depth stratification was based on Greenland Geological Survey's 10 m depth contour maps, Canadian maps and depth soundings made during previous surveys. The area of each stratum was measured using "MapInfo Version 4.0" (Table 2).

The survey was planned as a Stratified Random Bottom Trawl Survey with in total 70 hauls. Each stratum was allocated at least two hauls. The remaining hauls were allocated in order to minimize the variance in the estimation of the biomass of Greenland halibut. *i.e.* strata with great variation in the catches of Greenland halibut in the previous years surveys have got relatively more hauls than strata with little variation in the catches. In 2004 a new method of selecting stations was introduced. The method combines the use of a minimum between-stations-distance rule (buffer zone) with a random allocation scheme (Kingsley et al. 2004).

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. The Injector otter doors replaced the Perfect doors that have been used until 2003. The average net height was 20 cm higher with the new doors compared to the old, but the difference was not statistically significant (95% level) and it was concluded that the net performance has not changed by the introduction of new doors. 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 time down to 15 min was 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 5 records made during the haul). Trawling took place day and night.

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

Handling of the catch

After each haul the catch was sorted by species and weighed 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 1.0 cm below. In case of large catches subsamples of the catch were measured.

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.

In strata with one haul only SD was estimated as: SD= biomass or abundance.

Results and Discussion

In total 67 successful hauls were made and all depth strata were covered. Haul by haul information on catches, depth, temperature etc. is given in Appendix 1 and the distribution of hauls by strata is given in Table 2.

In total 77 species or groups of fish species were recorded (Appendix 2).

Greenland halibut (*Reinhardtius hippoglossoides*)

Greenland halibut was caught in all hauls except two (Fig. 1, Appendix 1) and the biomass in Div. 1CD 400-1500 m was estimated at 86 591.4 tons (Table 1 and 2) which is an increase compared to 75 522.5 tons in 2010 and the highest in the time series (Table 1, Fig. 2). The increase in biomass was seen in all strata in in Div. 1C and in the large stratum 1001-1200 m in Div. 1D. The other strata in Div. 1D showed minor decreases in biomass. The

estimate from 2011 is not statistically different (95% level) from the estimates since 2000. The highest densities (in weight) were found at depths > 800 m. The weighted mean catch per tow also showed an increase from 1.44 tons km^{-2} in 2010 to 1.66 tons km^{-2} in 2011 (Table 1, Fig 3).

The abundance in was estimated at $74.978*10^6$ which is an increase compared to $64.868*10^6$ in 2010 and above the average for the time series ($68.000 *10^6$) (Table 3, Fig 4). The highest density, about 2500 specimens km^{-2}, was seen in Div. 1CD 1001-1200 m, and at 801-1000 m in Div. 1C.

Estimated abundance by age in Div. 1CD is given in Table 4 (not updated in 2011, because the otolith reading procedure is under revision).

The length ranged from 13 cm to 107 cm (excluding a few larvae on 5 cm). The overall length distribution (weighted by stratum area) was totally dominated by a mode at 49 cm, where the mode uses to be around 47- 50 cm, and very few fish < 40 cm were observed as in the previous years (Fig. 5). Generally the length distributions in the different depth strata were dominated by a single mode and fish size increased with depth and from north to south at the same depth (Fig. 6) as seen in previous surveys (Jørgensen, 1997b).

Table 1. Biomass (tons), mean catch per tow (tons) standardized to km^2 and abundance of Greenland halibut in Div. 1CD and with S.E.

Year	Biomass	S.E.	Mean	S.E.	Abundance ($*10^6$)	S.E.
1997	56 260.2	4 399.6	1.07	0.08	53.613	4.118
1998	70 473.5	8 391.7	1.34	0.16	67.677	7.687
1999	64 398.0	6 912.1	1.27	0.14	61.366	6.265
2000	59 092.4	5 543.3	1.28	0.11	61.710	5.976
2001	77 554.0	13 013.6	1.57	0.26	80.814	14.221
2002	71 932.4	5 613.9	1.56	0.12	71.510	6.223
2003	68 717.2	6 411.9	1.39	0.13	72 556	7.764
2004	75 869.4	5 186.3	1.48	0.10	74.859	5.445
2005	80 865.4	8 365.7	1.54	0.16	73.001	7.317
2006	77 010.3	6 259.6	1.47	0.12	70.715	5.622
2007	74 356.8	9 455.4	1.48	0.19	67.427	8.492
2008	83 465.4	5 456.3	1.60	0.10	72.804	5.334
2009	70 966.2	5 110.3	1.36	0.10	62.507	4.419
2010	75 522.5	5 382.4	1.44	0.10	64.868	5.389
2011	86591.4	5210.4	1.66	0.10	74.978	4.723

Table 2. Mean catch per km^2 and biomass (tons) of Greenland halibut by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Biomass	SE
1C	401-600	3366	1	0.0252	84.8	.
	601-800	16120	5	0.5763	9290.5	1672.9
	801-1000	6066	14	2.4794	15040.2	1991.5
	1001-1200	611	2	3.0190	1844.6	822.0
1D	401-600	903	2	0.1049	94.7	94.7
	601-800	1940	2	0.5127	994.6	994.6
	801-1000	3874	5	1.4116	5468.6	772.0
	1001-1200	10140	17	3.2044	32492.2	3726.3
	1201-1400	6195	14	2.6551	16448.2	1966.8
	1401-1500	3091	5	1.5635	4832.8	593.5
All				1.6554	86591.4	5210.4

Table 3. Mean catch per km^2 and abundance of Greenland halibut by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Abundance	SE
1C	401-600	3366	1	25.8	86831.5	.
	601-800	16120	5	638.8	10297991.6	2231855.8
	801-1000	6066	14	2325.3	14105472.8	1737250.5
	1001-1200	611	2	2523.9	1542088.0	753349.5
1D	401-600	903	2	94.5	85341.6	85341.6
	601-800	1940	2	552.7	1072244.4	1072244.4
	801-1000	3874	5	1280.9	4962080.1	814057.1
	1001-1200	10140	17	2547.4	25830777.9	3069429.3
	1201-1400	6195	14	2160.4	13383500.5	1535876.8
	1401-1500	3091	5	1168.3	3611218.7	369995.3
All				1433.4	74977547.1	4723471.7

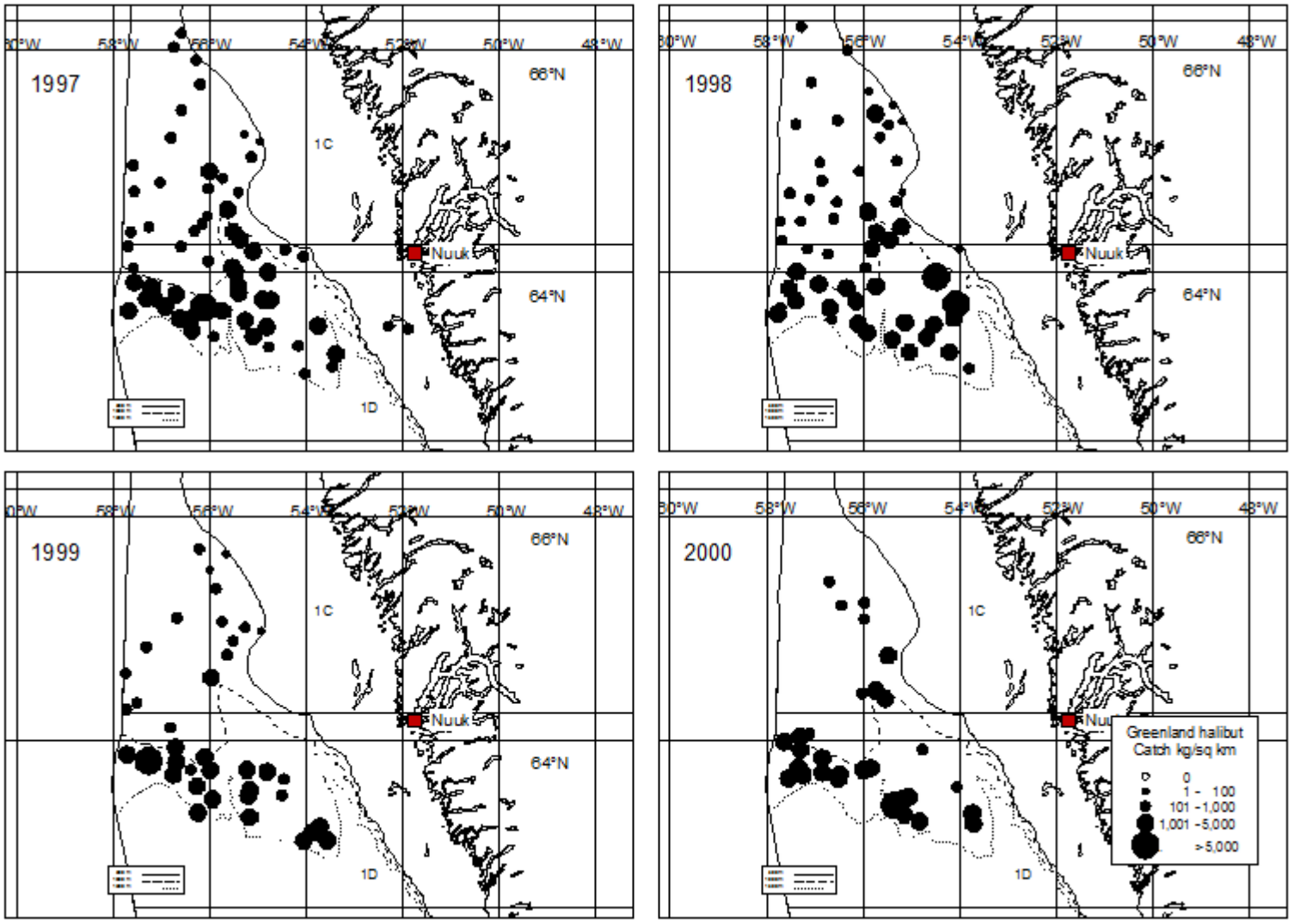

Fig. 1 Distribution of catches of Greenland halibut during 1997-2000 in kg km^{-2}.

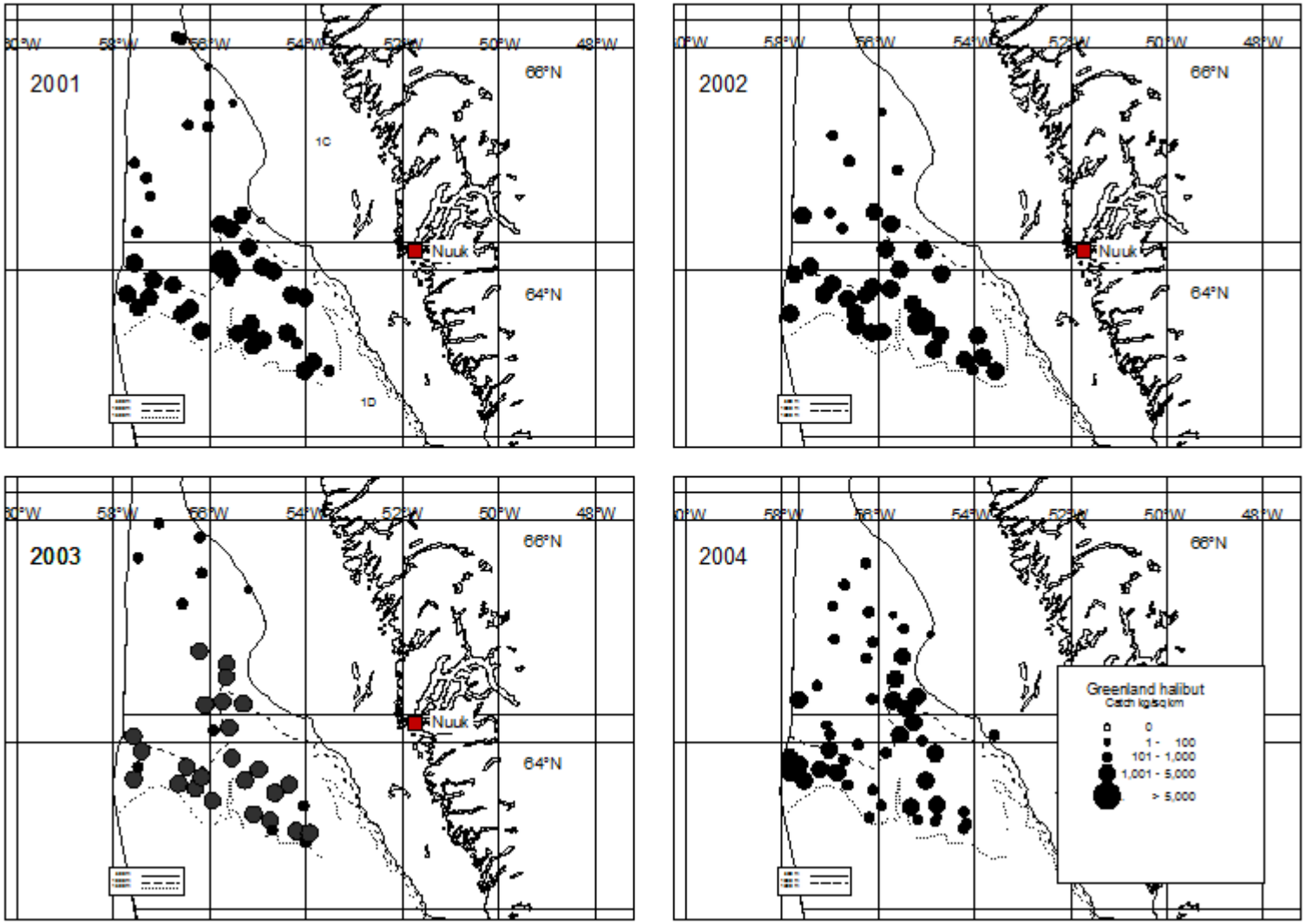

Fig. 1 (cont). Distribution of catches of Greenland halibut in 2001 - 2004 in kg km^{-2}

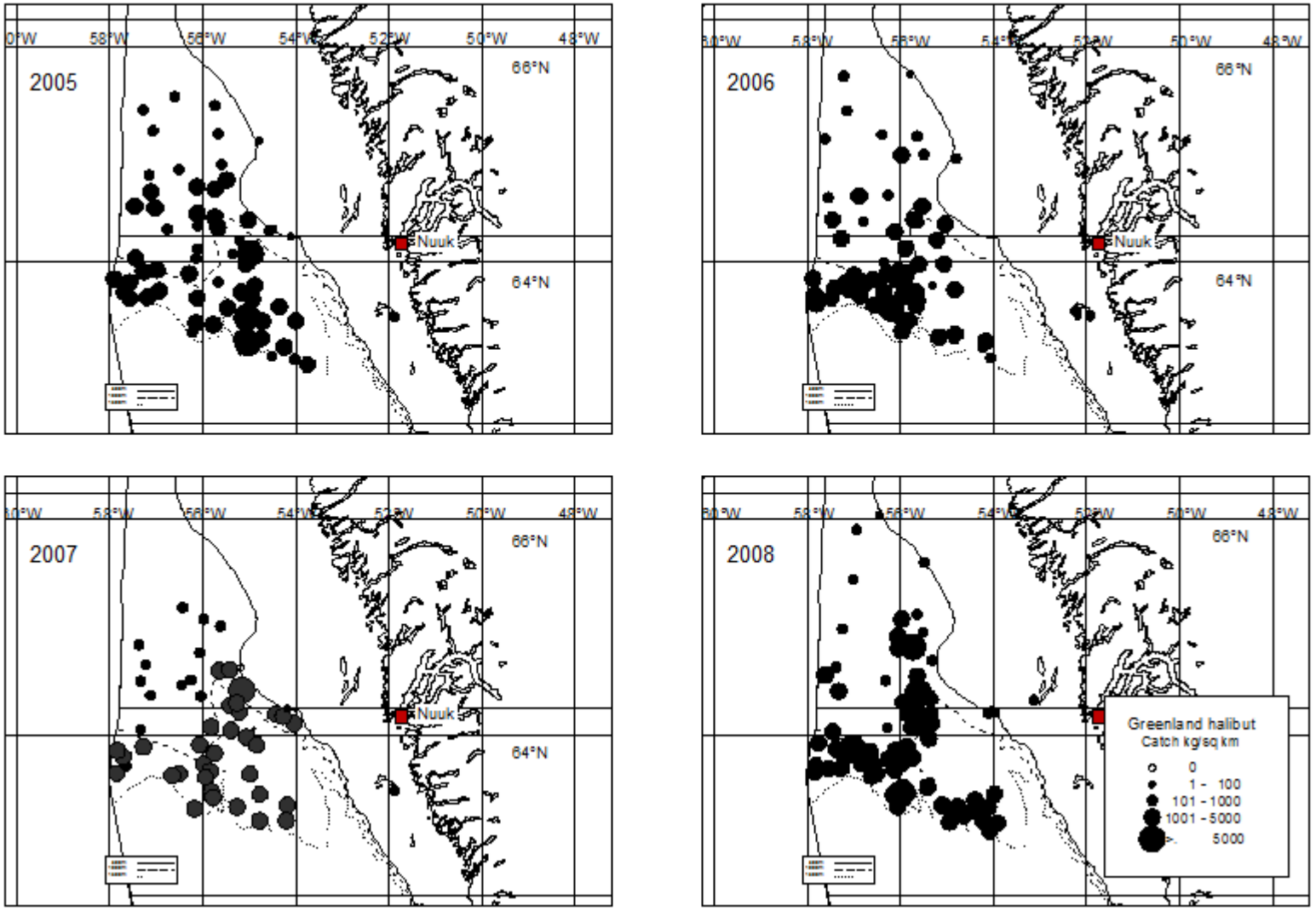

Fig. 1 (cont). Distribution of catches of Greenland halibut in 2005 - 2008 in kg km^{-2}

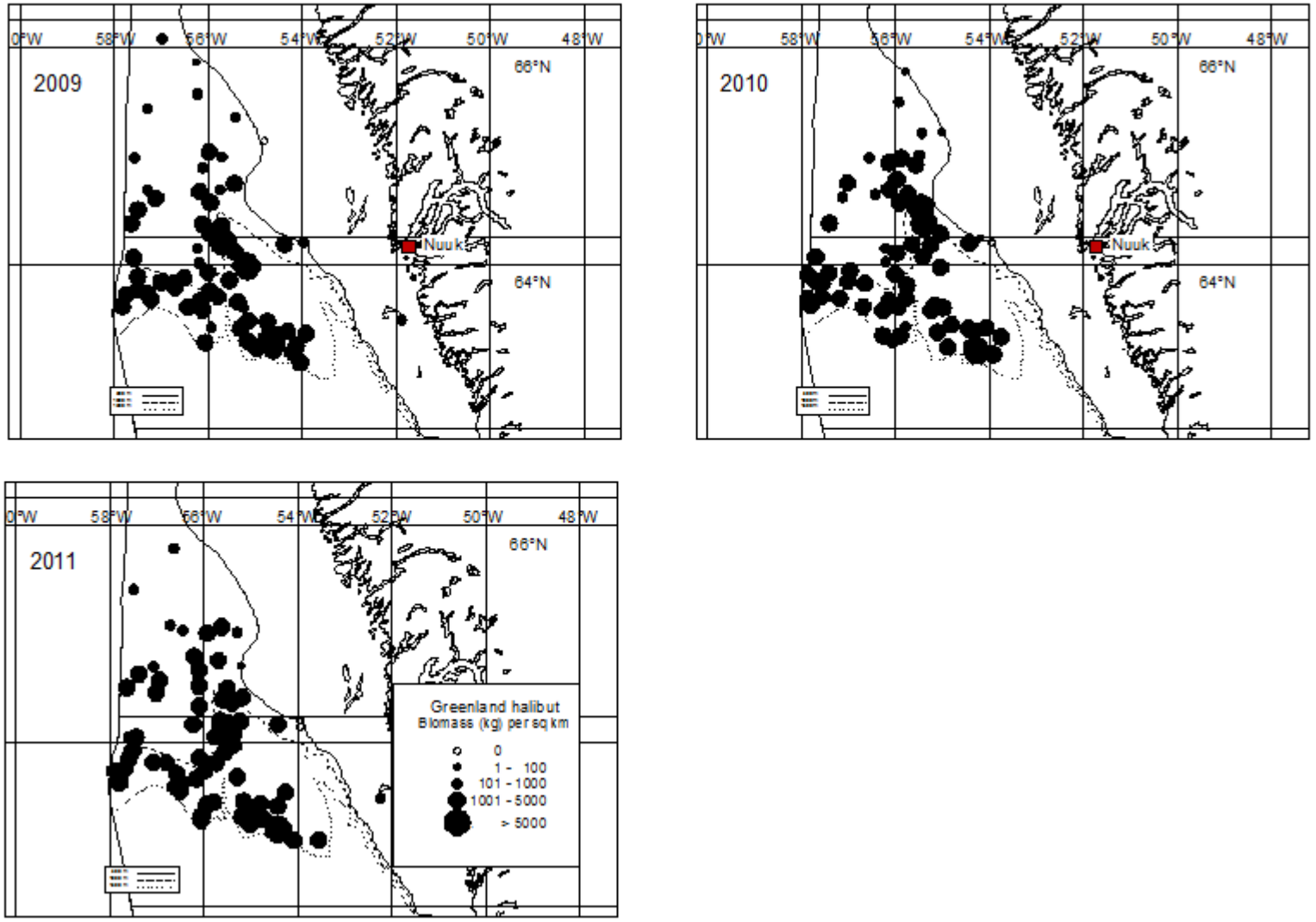

Fig. 1 (cont). Distribution of catches of Greenland halibut in 2009 - 2011 in kg km^{-2}

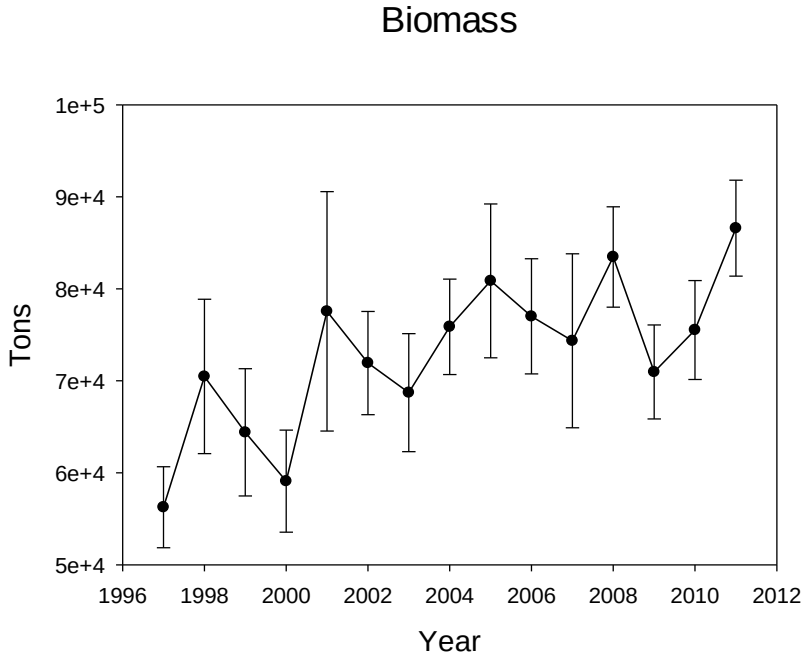

Fig. 2. Biomass (tons) of Greenland halibut in Div. 1CD by year with 1*S.E.

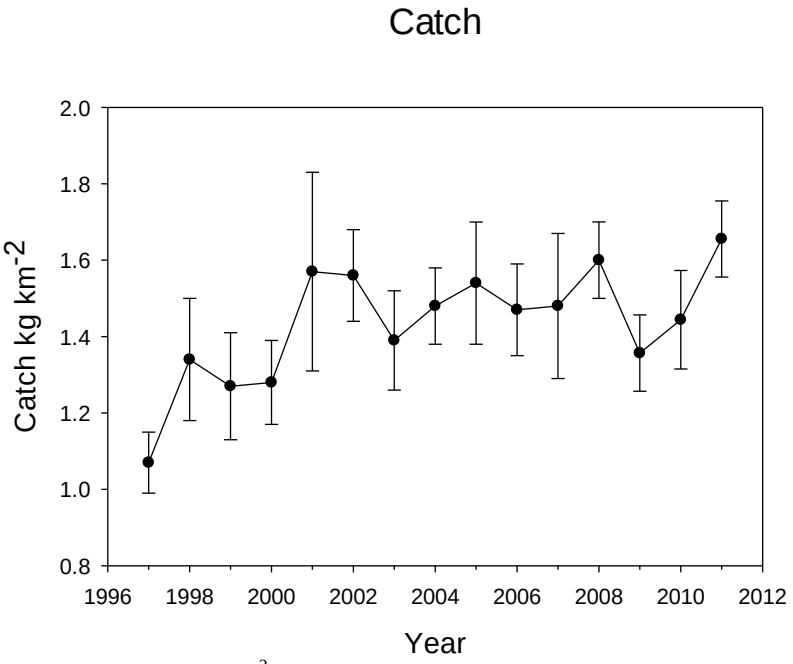

Fig. 3. Mean catch of Greenland halibut km^{-2} km (tons) in Div. 1CD standardized by stratum area with 1*S.E.

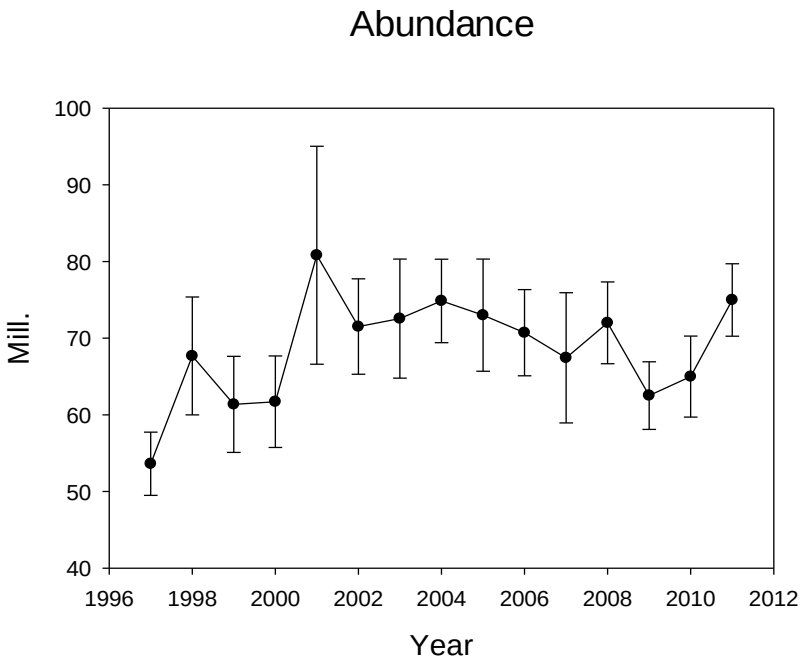

Fig. 4. Abundance (millions) of Greenland halibut in Div. 1CD by year with 1*S.E.

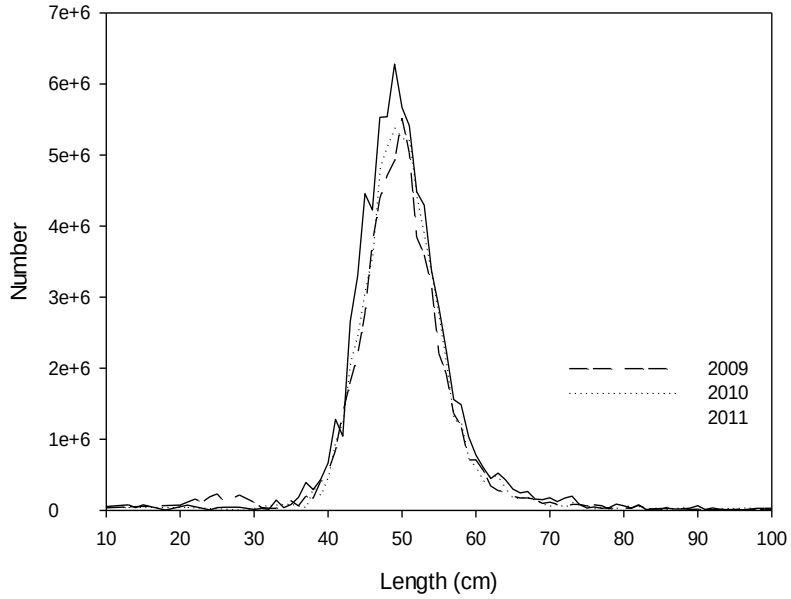

Fig. 5. Overall length distribution of Greenland halibut in numbers (weighted by stratum area) in Div. 1CD by year.

Table 4. Number by age by year of Greenland halibut (excluding larvae, age 0). No data from 2008 and 2010-2011.

AGE	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2009
1	0	0	0	78826	15585	71512	833452	314358	200672	132147	0	
2	536130	609093	184098	109496	281013	214536	3187890	255511	201882	641030	99520	613665
3	1704893	3722237	920490	479059	511722	285367	1468105	274564	569831	524114	268062	773577
4	3023773	4662948	4172888	3074341	4835796	2361529	2417001	4465950	1749900	2959669	802718	704747
5	9961295	14760362	11291344	15090231	20601616	11779876	12348567	14877198	12218823	13324592	12509462	7823793
6	15370847	19057854	15893794	16838191	26595603	26697300	21816458	30067732	19867351	20210890	18237159	12339572
7	13558728	14083592	19759852	14711646	17922784	18561065	18499540	14298142	21303055	15509156	19469186	22722253
8	5436358	5766084	4786548	5026106	4674899	6201987	6534966	6252194	12674030	13224793	11815872	9358562
9	1200931	1515966	859124	3214208	2550178	1857799	2403542	1724259	385774	731747	360855	3065130
10	948950	1211419	920490	1040152	780082	1340261	1244102	944766	1881136	1342871	1960085	2058523
11	584382	764751	613660	717770	705656	905723	581491	392534	158664	362986	0	1095209
12	466433	527881	675026	350292	369836	166242	224915	230820	1044342	958082	1030110	741972
13	187646	351921	429562	318336	345397	257412	264203	158687	36861	122337	26403	558339
14	96503	155657	429562	122157	195607	143024	207745	163836	410090	459693	502253	346258
15	262704	236870	184098	230208	225277	263139	67270	218713	85460	114617	27483	199826
16	187646	115051	61366	128242	91540	178780	206590	71775	13547	102977	182091	50494
17	64336	128586	61366	95352	80275	107268	72546	96352	118365	28973	49422	26348
18	16084	0	61366	57045	22628	35756	41219	6650	35465	0	26001	
19	0	0	0	27474	32325	83431	58531	37874	45452	0	0	
20	0	0	0	0	8081	0	22258				46549	
21						0	7419					
SUM	53607639	67670271	61304634	61709132	80845900	71512007	72507812	74851915	73000702	70750676	67413231	62478267

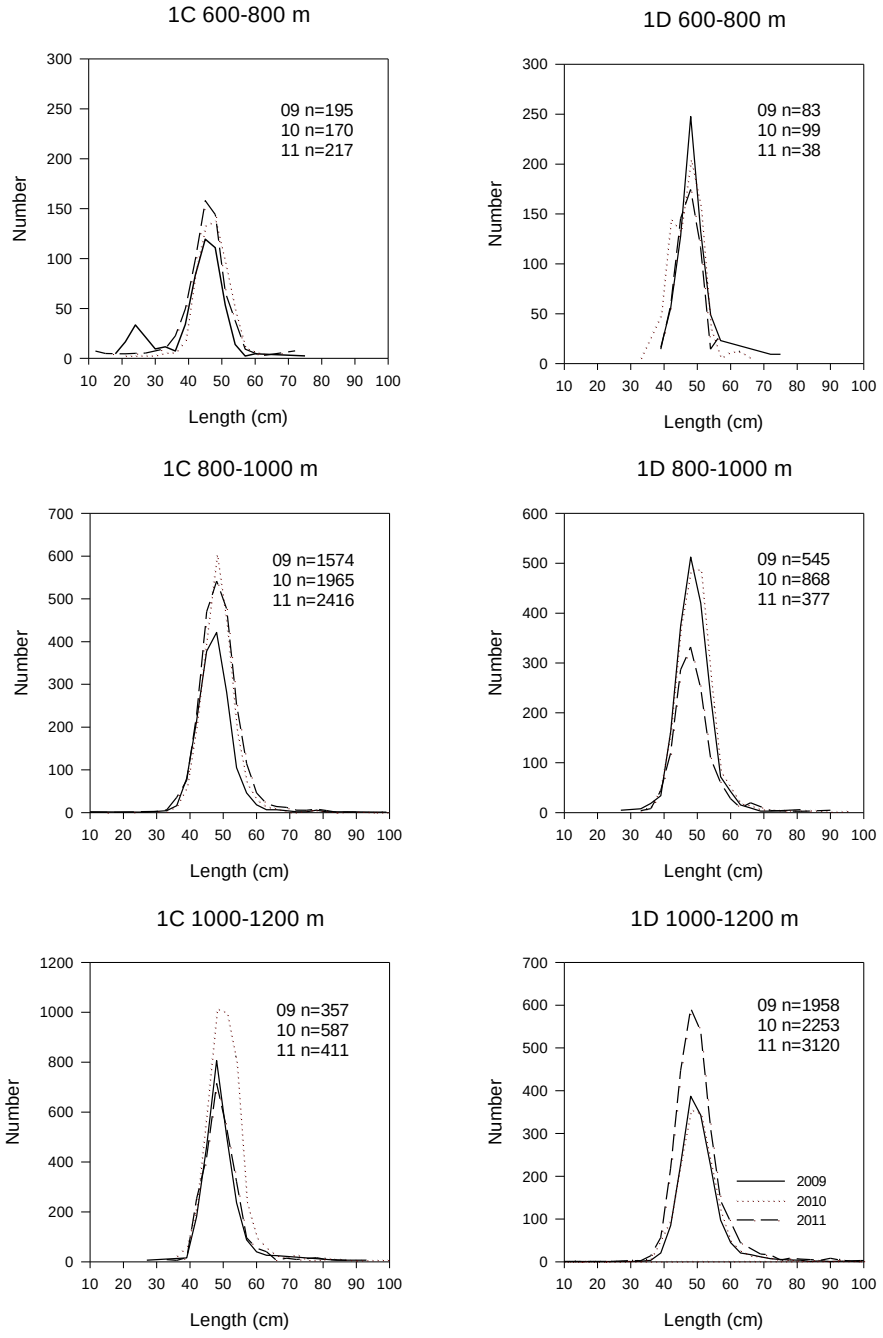

Fig. 6. Length distribution of Greenland halibut in numbers km^{-2} by Division and depth stratum. Div 1CD 600-1200 m.

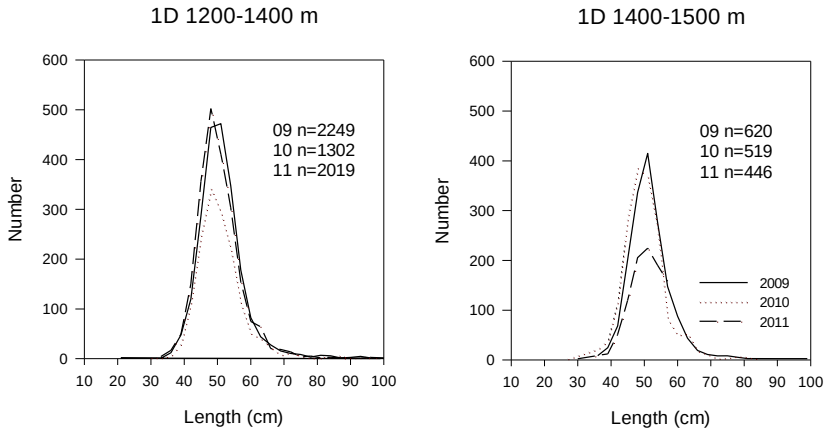

Fig. 6. cont. Length distribution of Greenland halibut in numbers km^{-2} by Division and depth stratum. Div. 1D 1200-1500 m.

Table 5. Mean weight and length by year and age. No data 2008 and 2010-2011.

	1997		1998		1999		2000		2001		2002		2003		2004		2005		2006		2007		2009	
AGE	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length	weight	length
1							25	13.5	28	14.4	20	16.0							18	13.3				
2	23	15.3	38	18.7	64	21.0	75	21.0	85	21.0	60	21.7	85	23.0			69	21.5	71	21.1	70	22.0	91	23.3
3	58	19.8	176	28.5	206	27.4	146	26.3	173	26.7	200	29.6	192	29.4			169	28.5	180	28.6	181.7	28.7	162	27.1
4	137	26.1	348	35.3	342	34.4	329	33.6	366	34.2	341	35.5	355	35.7	487	39.1	382	36.6	397	36.8	352.6	35.9	377	36.6
5	272	32.8	551	40.9	571	40.3	528	39.5	574	39.7	487	39.9	522	40.2	646	42.8	550	41.3	594	41.8	565.8	41.6	544	40.7
6	444	38.0	854	46.8	793	45.6	764	44.5	849	44.9	747	45.6	763	45.4	917	47.5	831	46.7	867	47.0	859.6	47.2	771	45.4
7	737	43.9	1218	51.9	1196	51.4	1074	49.8	1159	49.9	1132	51.7	1116	51.2	1293	52.5	1137	51.6	1142	51.4	1072	51.1	1025	50.0
8	1070	49.9	1572	56.8	1665	57.9	1376	53.7	1541	54.8	1370	55.6	1419	55.9	1638	56.5	1569	56.5	1531	56.1	1541	56.6	1540	56.3
9	1454	55.6	2075	60.6	2057	61.1	1631	56.8	1844	58.0	1844	60.7	1861	59.8	1942	60.2	1754	58.8	2189	61.2	1635	57.5	1856	59.8
10	2043	61.2	2293	63.1	2441	64.1	2077	61.5	2259	61.8	2037	62.5	2115	62.6	2191	62.3	2301	63.8	2502	64.2	2123	62.4	2208	62.9
11	2815	66.7	2867	66.5	2812	66.9	2503	63.9	3316	65.0	2508	66.0	2668	66.8	2924	67.8	2878	68.0	3588	70.9			2816	67.7
12	3828	72.6	3453	69.9	4000	72.9	3014	67.5	3450	68.7	3011	69.7	3190	70.4	3237	68.2	3464	71.2	3450	70.2	3049	68.6	3492	70.9
13	4840	77.3	4538	74.7	5679	79.5	3612	70.4	3866	71.3	3558	71.6	3178	70.6	3683	72.4	4617	77.0	4951	77.5	3300	70.0	4019	73.3
14	6679	84.0	5112	77.6	7613	86.7	3893	72.8	5257	77.8	4650	78.5	3845	75.5	3889	71.1	5305	79.1	5324	79.0	4548	76.4	5586	79.8
15	7711	87.8	7141	85.1	8477	91.2	5409	78.3	6324	81.9	5149	79.0	4340	76.0	4740	74.8	6468	86.0	7029	86.1	6443	85.5	6709	83.9
16	9166	94.6	8385	88.9	9925	88.5	6873	85.5	7203	86.0	6786	84.8	5747	81.3			13320	100.0	8415	89.3	8402	90.8	9700	94.0
17	10797	97.8	10684	95.4			8492	91.8	8954	92.4	8520	90.3	6200	84.0	6498	82.0			9588	95.0	9565	92.5	9198	93.0
18					12500	99.0	8590	92.3	8760	93.0	9385	93.0			893	93.0	9570	97.0			9200	95.0		
19			12850	99.0			9645	91.5	11500	102.0	8553	90.3			10220	93.0	14150	101.0						
20									14400	105.0											12330	102.0		

Roundnose grenadier (*Coryphaenoides rupestris*)

Roundnose grenadier was caught in 64 of the 67 valid hauls but the catches were very low (Fig. 7, Appendix 1). The biomass has been very low for more than a decade (Table 6) and far below the level seen in the late 80'. The biomass in the 2011 was estimated as 939.8 tons compared to 580.7 tons in 2010. Most of the biomass was found in Div 1D at depths greater than 801 m (Table 7).

The abundance increased from $6.78*10^6$ in 2010 to $11.57*10^6$ specimens in 2011. The highest densities were found in Div. 1D 801-1000 m (Table 8) as in recent years.

Table 6. Biomass (tons) and abundance of roundnose grenadier with 1*S.E. by year.

Year	Biomass	S.E.	Abundance ($*10^6$)	S.E. ($10*^6$)
1997	5 686.5	926.4	32.44	7.06
1998	7 263.3	2 530.2	75.24	27.36
1999	2 771.8	445.5	29.10	8.96
2000	5 593.7	2 616.8	99.52	67.31
2001	1 577.2	516.4	24.70	8.80
2002	1 593.1	462.7	18.61	8.91
2003	774.2	144.0	6.90	1.27
2004	633.0	98.2	10.56	2.53
2005	733.0	116.0	12.18	3.75
2006	658.6	192.2	10.83	4.28
2007	838.0	206.4	13.16	4.50
2008	546.1	81.3	4.75	0.70
2009	1 151.1	516.1	16.58	10.01
2010	580.7	81.1	6.78	1.80
2011	939.8	244.9	11.57	4.64

Table 7. Mean catch per km^2 and biomass (tons) of roundnose grenadier by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Biomass	SE
1C	401-600	3366	1	0.0143	48.0	.
	601-800	16120	5	0.0087	141.0	138.8
	801-1000	6066	14	0.0175	106.2	24.4
	1001-1200	611	2	0.0096	5.8	5.4
1D	401-600	903	2	0.0128	11.6	10.4
	601-800	1940	2	0.0092	17.8	12.0
	801-1000	3874	5	0.0587	227.3	188.5
	1001-1200	10140	17	0.0118	119.6	24.7
	1201-1400	6195	14	0.0301	186.7	35.1
	1401-1500	3091	5	0.0245	75.9	13.0
All				0.0178	939.8	244.9

Table 8. Mean catch per km^2 and abundance of roundnose grenadier by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Abundance	SE
1C	401-600	3366	1	25.8	86831.5	.
	601-800	16120	5	231.0	3724493.4	3617975.9
	801-1000	6066	14	229.7	1393308.0	398910.0
	1001-1200	611	2	178.9	109277.5	87668.3
1D	401-600	903	2	93.8	84665.2	73286.3
	601-800	1940	2	96.6	187310.4	74442.6
	801-1000	3874	5	796.2	3084381.9	2821917.7
	1001-1200	10140	17	122.4	1240769.5	267378.3
	1201-1400	6195	14	215.3	1333793.2	506537.9
	1401-1500	3091	5	106.0	327495.0	96912.8
All				221.2	11572325.6	4644965.0

Pre anal fin length ranged from 2 to cm 19 cm. The grenadiers were generally small and the over all length distribution (weighted by stratum area) showed a mode at 5-6 cm (Fig. 8).

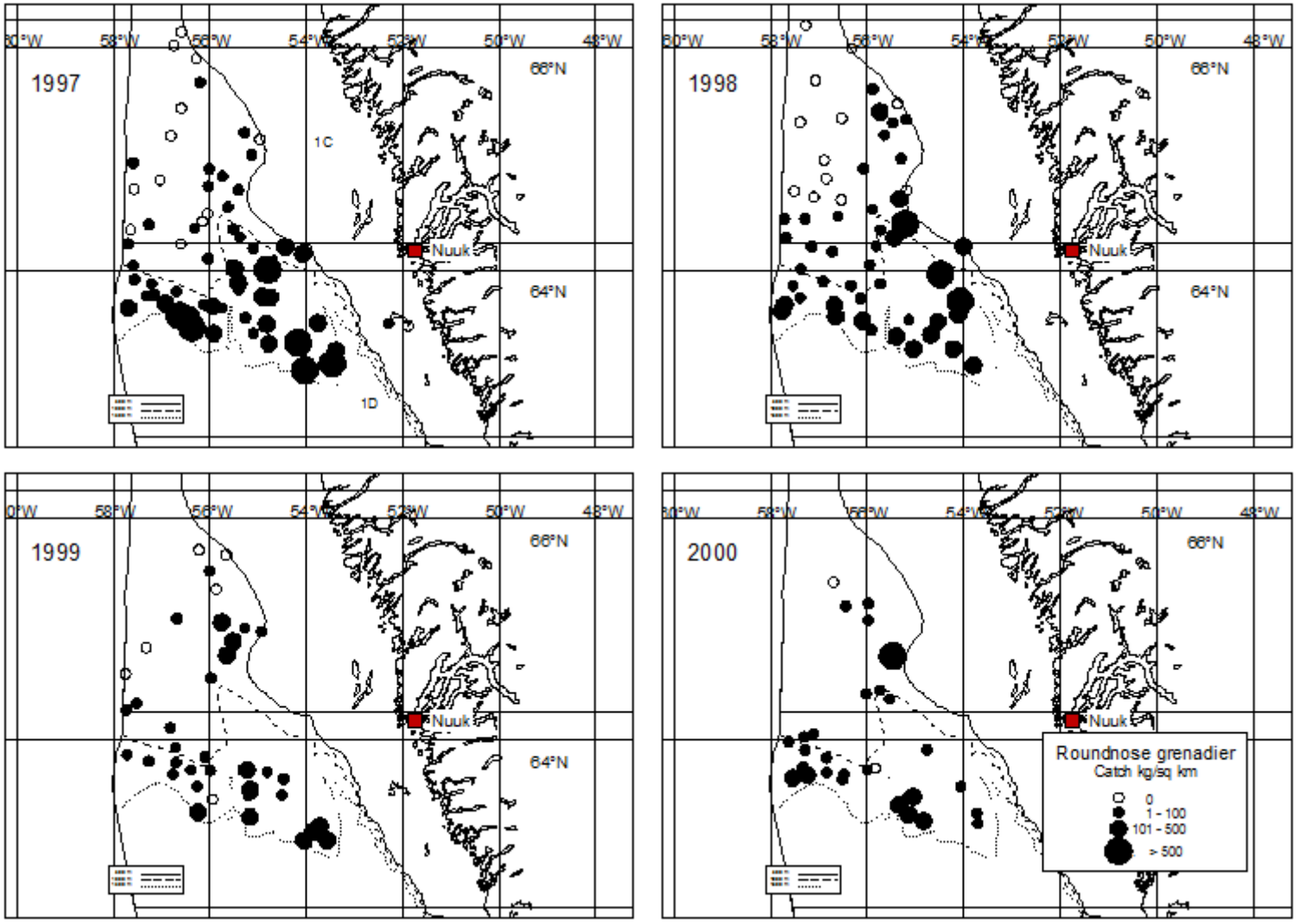

Fig. 7. Distribution of catches of roundnose grenadier in 1997-2000 in kg km^{-2}

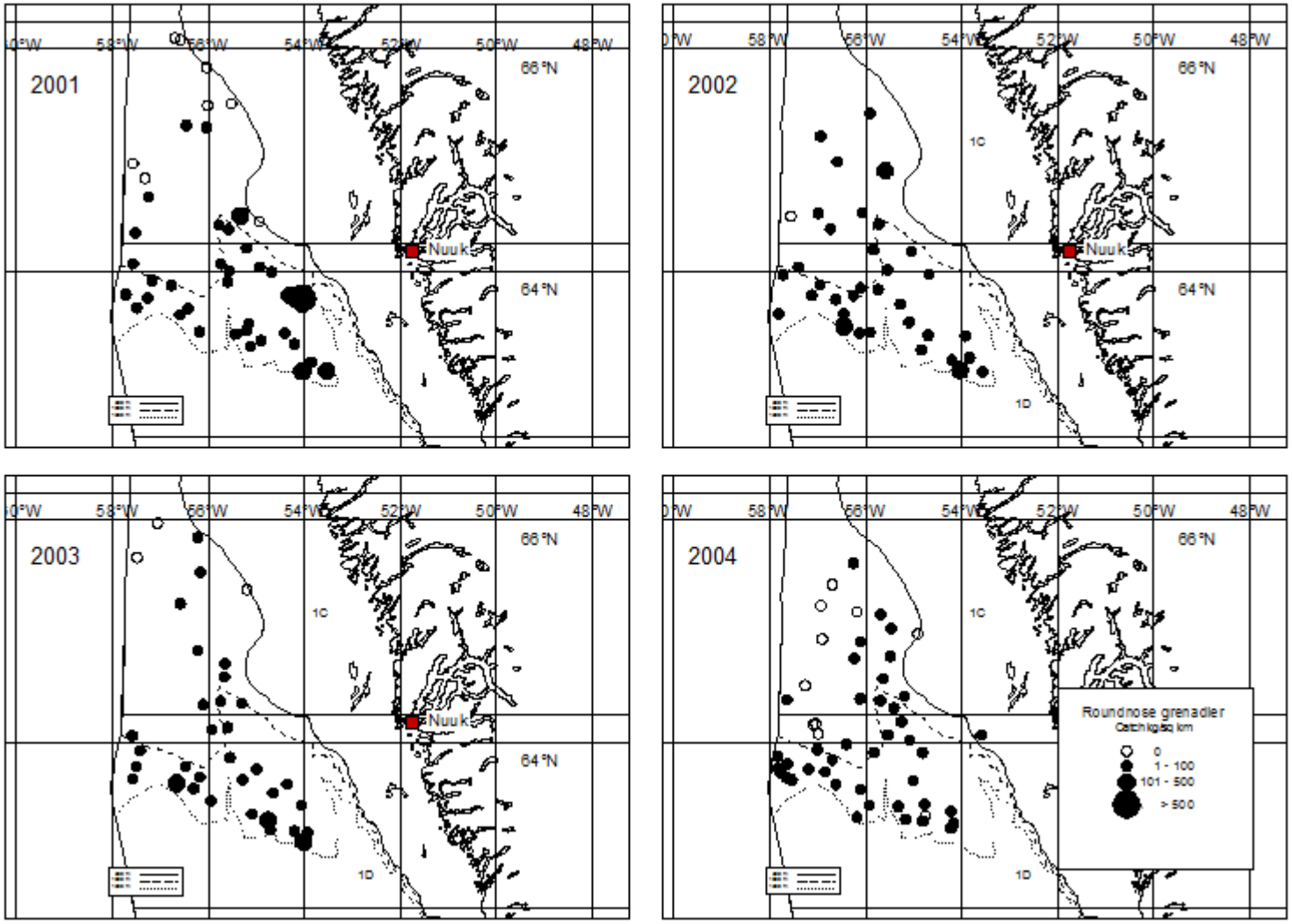

Fig. 7 cont. Distribution of catches of roundnose grenadier during 2001-2004 in kg km^{-2}.

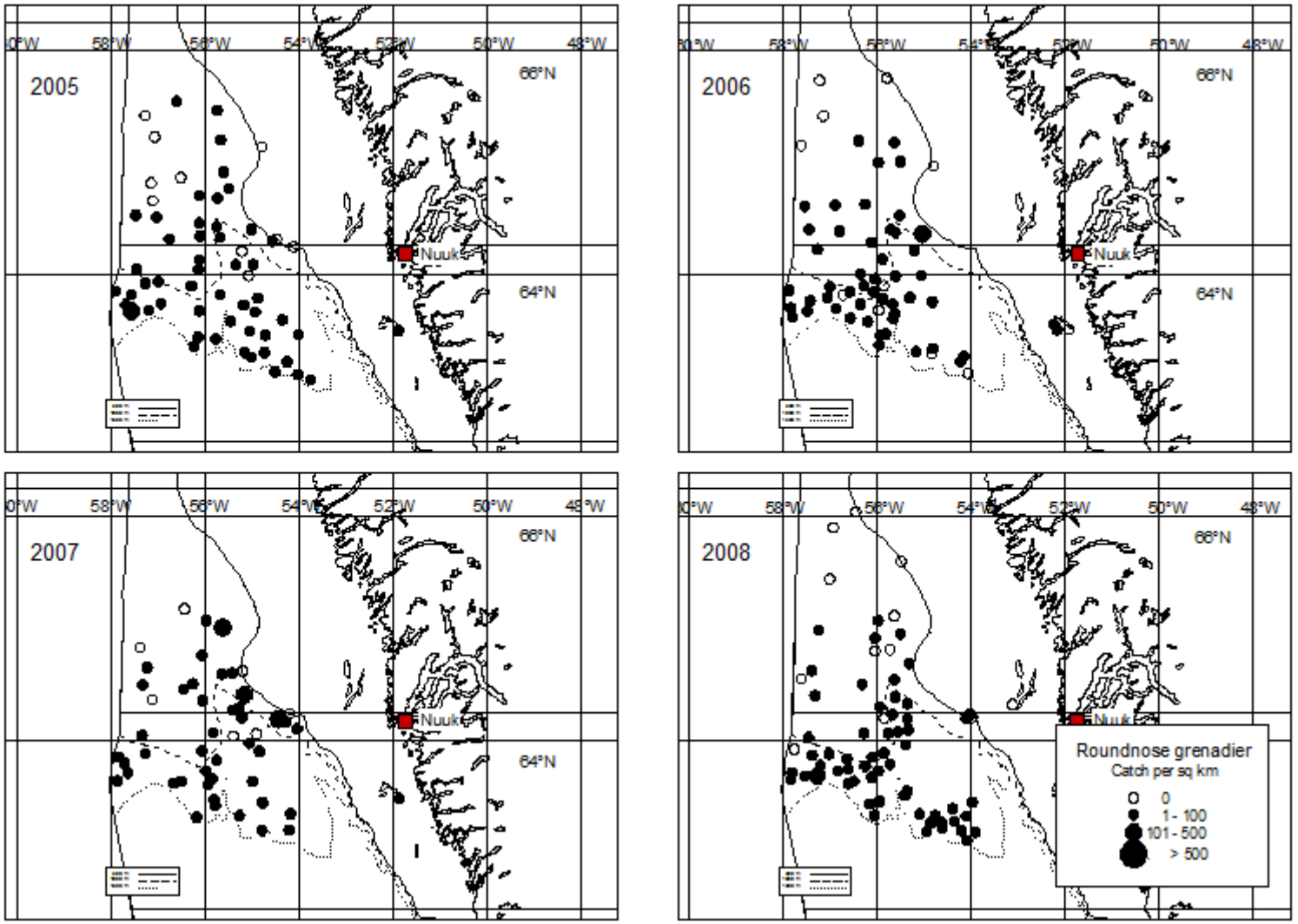

Fig. 7 cont. Distribution of catches of roundnose grenadier during 2005-2008 in kg km^{-2}.

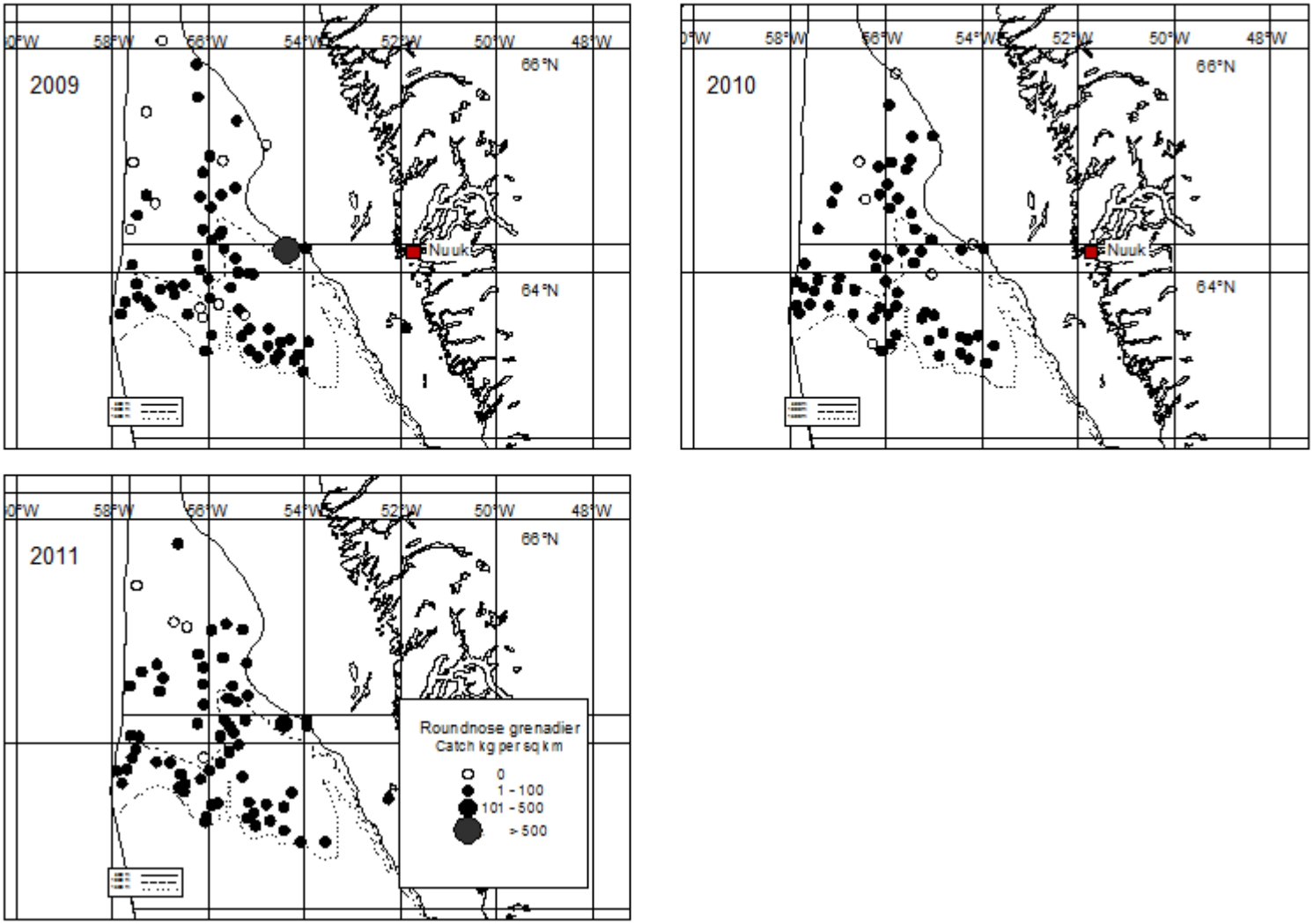

Fig. 7 cont. Distribution of catches of roundnose grenadier during 2009-2011 in kg km^{-2}.

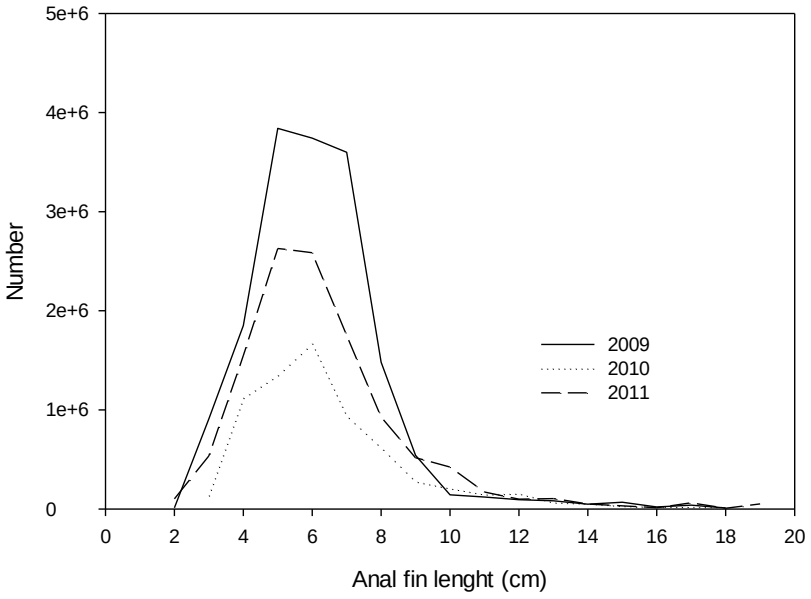

Fig. 8. Overall length distribution of roundnose grenadier (pre anal fin length) in numbers (weighted by stratum area) in Div. 1CD by year.

Roughhead grenadier (*Macrourus berglax*)

Roughead grenadier was caught in all hauls except one. The catches were, however, generally low (Fig. 9, Appendix 1). The biomass was estimated at 3084.5 tons compared to 4025.8 tons in 2010 and the 2011 estimate is the second lowest in the time series (Table 9).

The highest densities were found between at depths at 1401-1500 m in Div. 1D but the largest biomass was found in Div. 1D 1001-1200 m (Table 10)

Table 9. Biomass and abundance of roughhead grenadier by year in Div. 1CD with S.E.

Year	Biomass	S.E.	Abundance ($*10^6$)	S.E. ($*10^6$)
1997	2 258.6	250.1	4.60	0.45
1998	4 314.1	377.9	11.62	1.01
1999	5 166.2	854.1	14.07	2.04
2000	7 178.1	2 226.5	20.28	7.18
2001	4 576.6	456.3	13.87	1.55
2002	7 907.6	823.6	19.62	1.76
2003	5 657.5	700.8	15.37	2.57
2004	4 314.3	452.6	11.16	1.32
2005	5 602.6	419.5	14.00	1.31
2006	5 148.2	621.2	11.84	1.09
2007	3 467.6	374.6	8.18	1.08
2008	4 533.7	970.2	9.94	1.35
2009	3 795.7	299.2	8.21	0.67
2010	4 025.8	564.5	8.21	1.10
2011	3 084.5	265.3	7.39	0.65

Table 10. Mean catch km^{-2} and biomass (tons) of roughhead grenadier by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Biomass	SE
1C	401-600	3366	1	0.0000	0.0	.
	601-800	16120	5	0.0360	579.7	115.3
	801-1000	6066	14	0.0468	284.1	46.6
	1001-1200	611	2	0.0420	25.7	10.5
1D	401-600	903	2	0.0264	23.9	19.2
	601-800	1940	2	0.0962	186.6	79.1
	801-1000	3874	5	0.0383	148.5	34.6
	1001-1200	10140	17	0.0918	931.3	191.4
	1201-1400	6195	14	0.0967	598.9	86.6
	1401-1500	3091	5	0.0990	305.9	53.4
All				0.0590	3084.5	265.3

Table 11. Mean catch per km^{-2} and abundance of roughhead grenadier by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Abundance	SE
1C	401-600	3366	1	0.0	0.0	.
	601-800	16120	5	104.1	1677537.6	392299.3
	801-1000	6066	14	117.4	711985.7	79766.7
	1001-1200	611	2	132.9	81188.1	26858.2
1D	401-600	903	2	67.3	60738.7	37981.0
	601-800	1940	2	172.9	335357.9	109622.2
	801-1000	3874	5	138.2	535431.8	112526.1
	1001-1200	10140	17	245.5	2489794.7	464165.8
	1201-1400	6195	14	168.5	1044005.2	125195.9
	1401-1500	3091	5	145.4	449512.2	68908.1
All				141.21	7385552.0	650366.7

The total abundance was estimated at $3.39*10^6$ as in 2011 which is the lowest estimate since 1997 (Table 9). The highest densities were found in Div. 1D 1001-1200 m (Table 11).

Pre anal fin length ranged from 4 to 39 cm and the over all length distribution showed mode at 16-17 cm (Fig. 10).

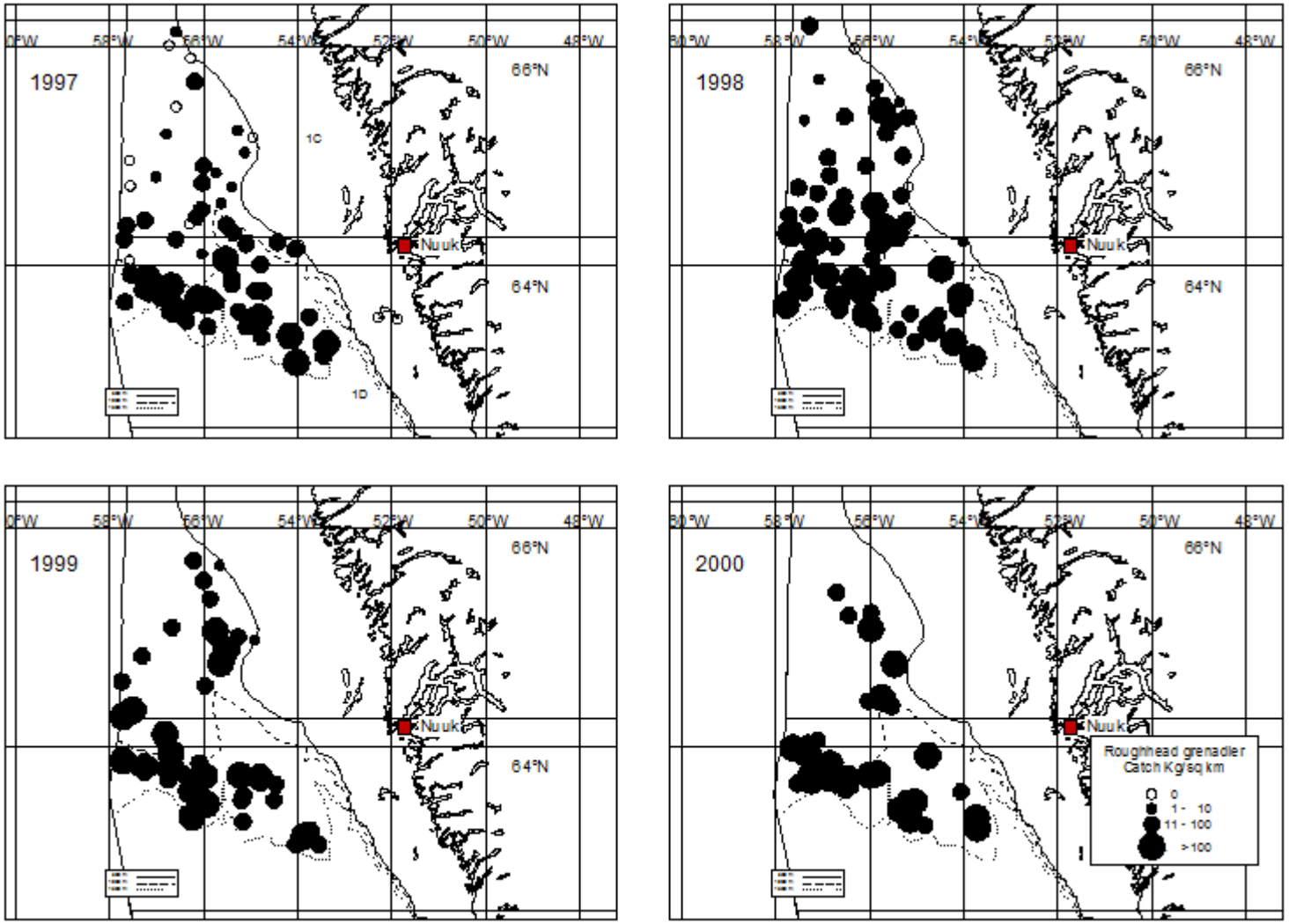

Fig. 9 Distribution of catches of roughhead grenadier in 1997-2000 in kg km^{-2}.

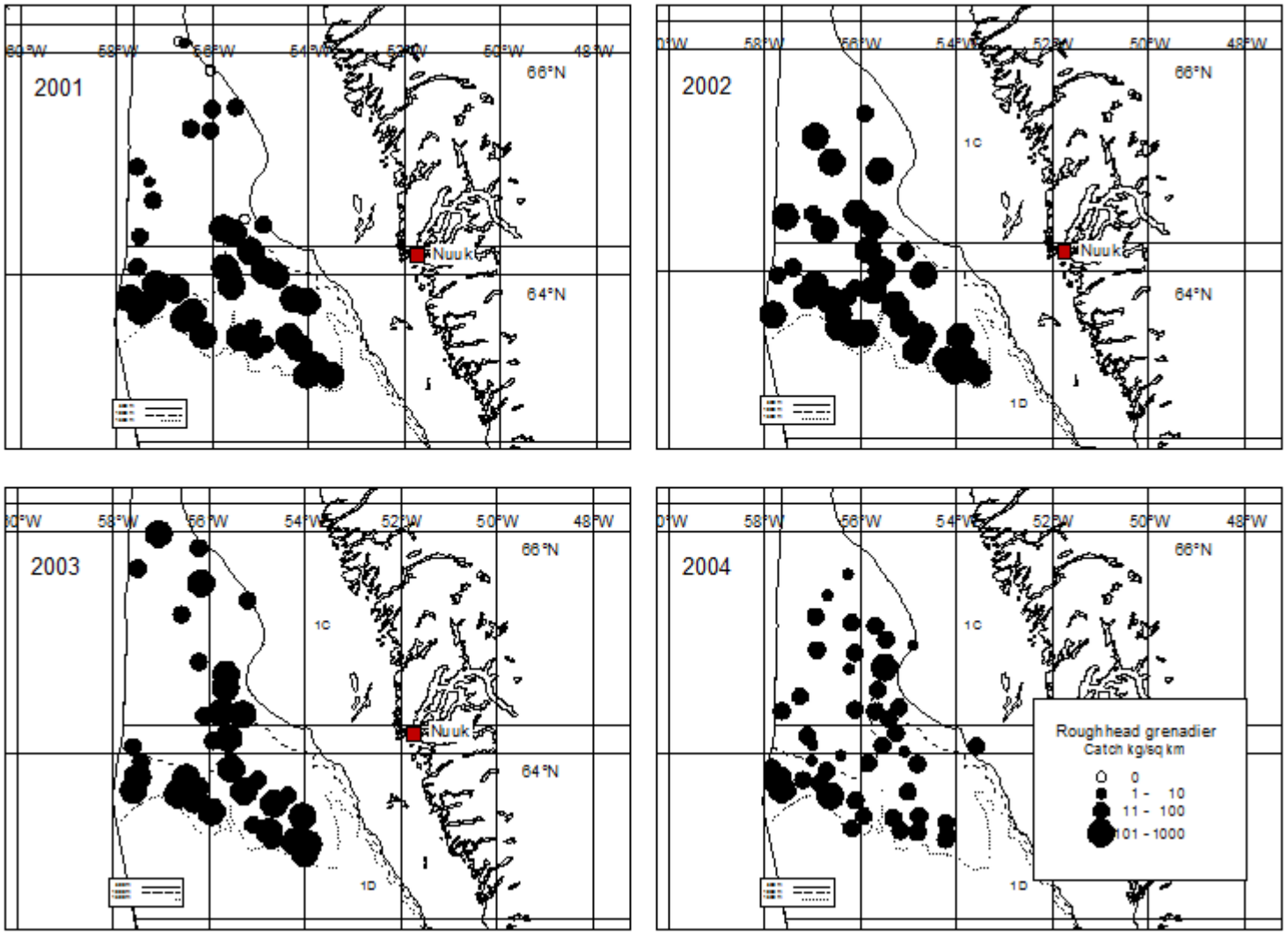

Fig. 9 cont. Distribution of catches of roughhead grenadier during 2001-2004 km^{-2}.

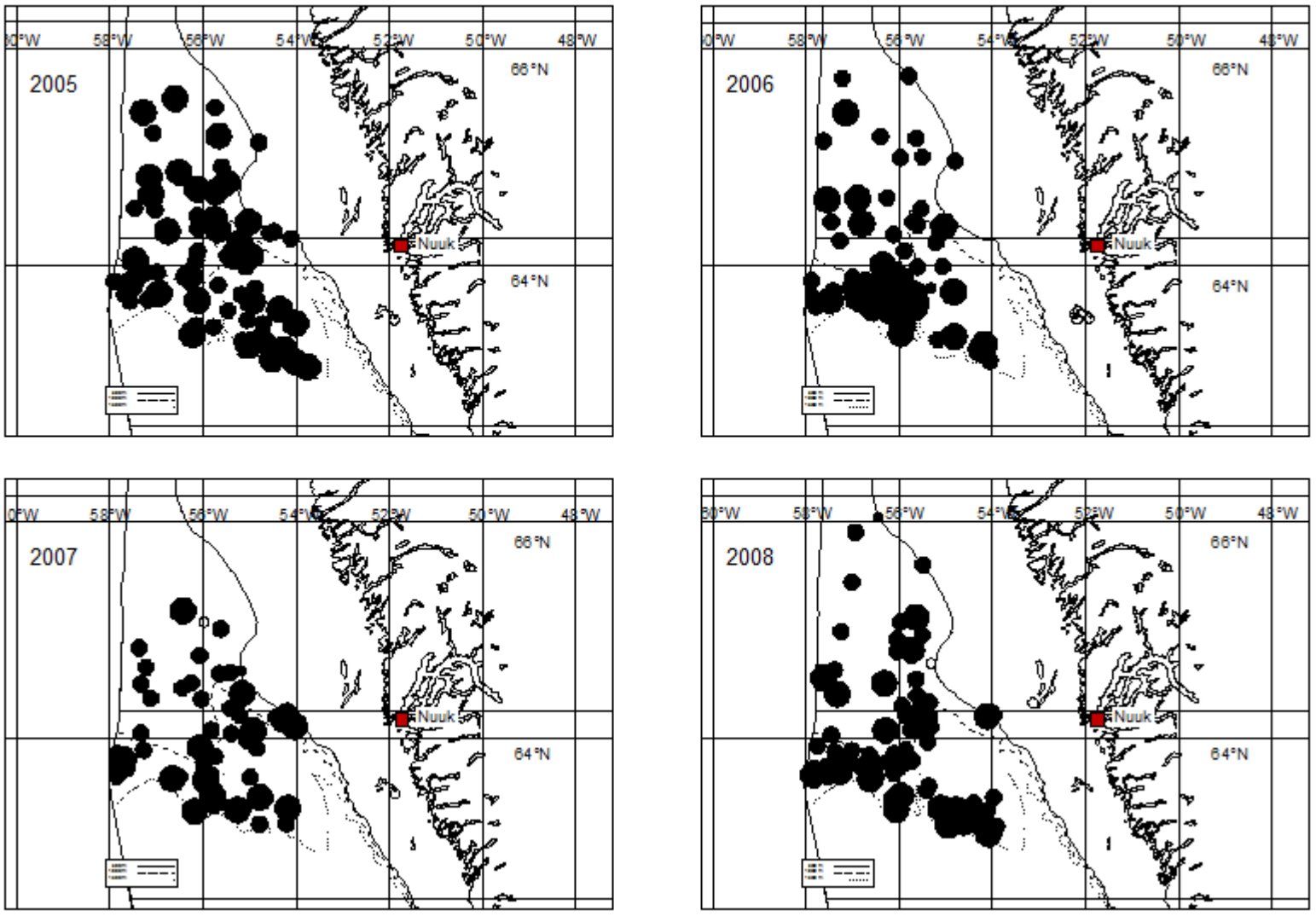

Fig. 9 cont.. Distribution of catches of roughhead grenadier during 2005-2008 km^{-2}.

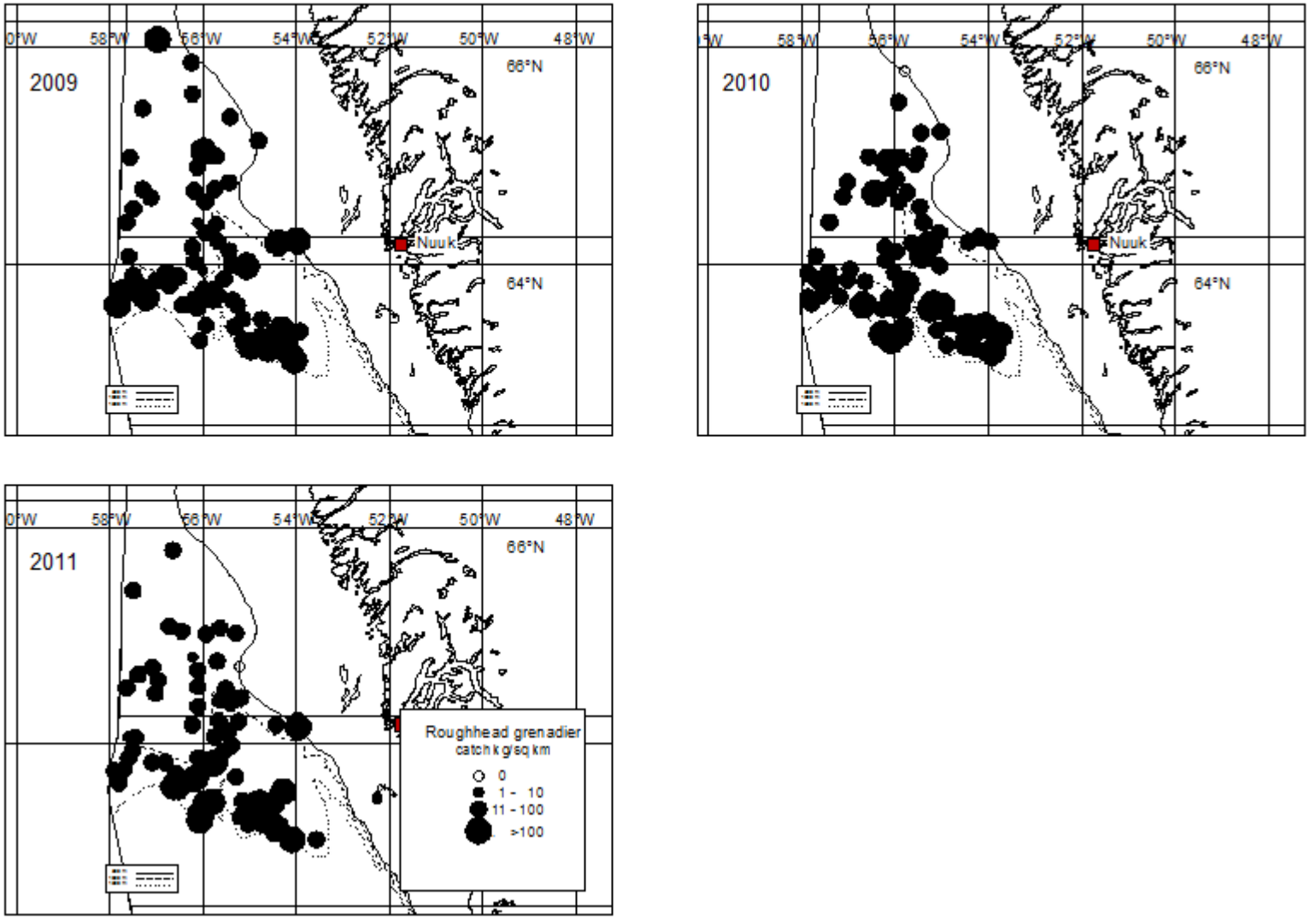

Fig. 9 cont.. Distribution of catches of roughhead grenadier during 2009-2011 km^{-2}.

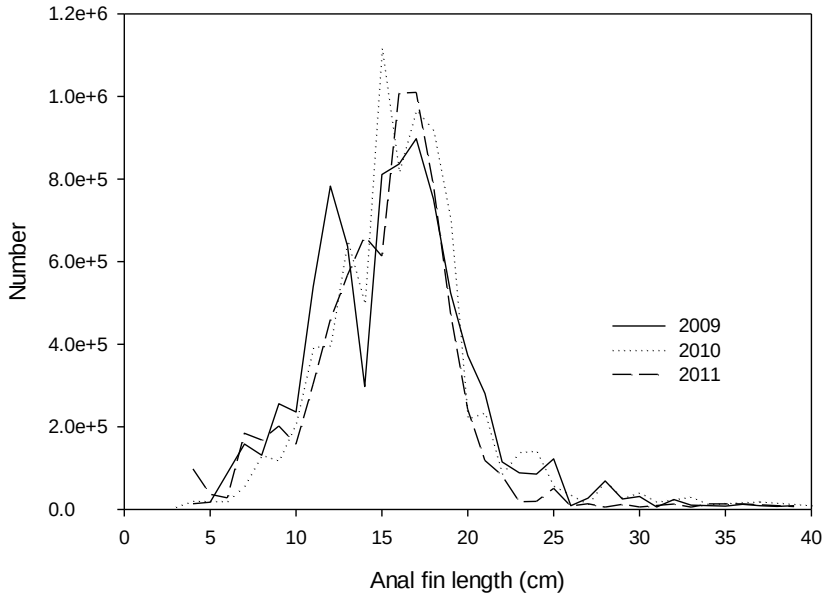

Fig. 10. Overall length distribution (pre anal fin length) of roughhead grenadier in numbers (weighted by stratum area) in Div. 1CD by year.

Deep-sea redfish (*Sebastes mentella*)

Deep-sea redfish was caught in 29 of the 67 valid hauls (Fig 12). The biomass was estimated at 9623.9 tons compared to 4065.6 in 2010 (Table 12). The Biomass estimate is to a large extend driven by a few large catches (Appendix 1). Almost all the biomass was found at depths < 600 m and more than half was found in Div. 1C 401-800 m, while the highest density was found in Div. 1D 401-600 m (Table 13)

The abundance was estimated at $32.42*10^6$ compared to $17.83*10^6$ in 2010. All most all the abundance was found in Div. 1C < 800 m with the highest density in Div. 1C 401-600 m (Table 14) as in previous years.

The length ranged from 15 to 44 cm with modes 24, 26 and 29 cm, which probably corresponds to the modes at 19, 21 and 26 cm seen in 2009. The signal was somewhat weaker in 2010, where modes at 21, 24 and 26 cm were seen. The deep-sea redfish have not been aged, but the 24 cm mode probably represents age 4, but there were no sign of them as age one in 2008 (Fig. 11).

Table 12. Biomass and abundance of deep-sea redfish including a few redfish sp. by year in Div. 1CD with 1*S.E.

Year	Biomass	S.E.	Abundance $*10^6$	S.E.$*10^6$
1997	2 464.3	787.1	14.69	5.50
1998	2 408.1	503.9	18.83	4.50
1999	2 484.9	1 007.7	12.93	4.09
2000[1)]				
2001	2 063.4	873.5	16.34	6.47
2002[1)]				
2003	1 493.4	684.5	7.13	3.08
2004	2 329.1	1 986.8	13.34	11.31
2005	2 546.2	1 683.3	7.28	3.16
2006	2 188.4	700.7	18.20	8.40
2007[1)]	574.2	230.0	3.00	1.31
2008	13 199.0	6 482.9	52.94	17.70
2009	7 796.4	3 916.8	35.04	17.72
2010	4 065.6	1 329.4	17.83	3.17
2011	9 623.9	4 883.7	32.42	16.19

[1)] Poor coverage of relevant depths.

Table 13. Mean catch km^{-2} and biomass (tons) of Deep Sea Redfish by division and depth stratum, 2011.

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,Div.     Stratum(m)  Area      Hauls    ,Mean sq km ,  Biomass  ,    SE     ,
‡ƒƒƒƒƒƒƒƒƒ…ƒƒƒƒƒƒƒƒƒ…ƒƒƒƒƒƒƒƒƒ…ƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ‰
,1C       ,401-600  ,3366     ,1         ,     1.2066,     4061.5,          .,
,         ‡ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ‰
,         ,601-800  ,16120    ,5         ,     0.2052,     3308.6,     2295.0,
,         ‡ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ‰
,         ,801-1000 ,6066     ,14        ,     0.0122,       74.0,       31.3,
,         ‡ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ‰
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,1D       ,401-600  ,903      ,2         ,     1.3055,     1178.9,     1101.5,
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,         ‡ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ‰
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,         ‡ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ`ƒƒƒƒƒƒƒƒƒƒƒ‰
,         ,1401-1500,3091     ,5         ,     0.0008,        2.5,        2.5,
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,All                                        ,     0.1840,     9623.9,     4883.7,
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Table 14. Mean catch km^{-2} and abundance of Deep Sea Redfish by Division and depth stratum, 2011.

Div.	Stratum(m)	Area	Hauls	Mean sq km	Abundace	SE
1C	401-600	3366	1	3603.2	12128485.7	.
	601-800	16120	5	949.7	15309795.1	10247847.1
	801-1000	6066	14	34.3	207872.0	86313.4
	1001-1200	611	2	8.8	5402.3	5402.3
1D	401-600	903	2	3402.4	3072333.4	2799240.3
	601-800	1940	2	838.6	1626952.1	1514084.3
	801-1000	3874	5	0.0	0.0	0.0
	1001-1200	10140	17	4.0	40095.4	18625.6
	1201-1400	6195	14	3.9	24144.1	13367.2
	1401-1500	3091	5	2.6	8096.5	8096.5
All				619.9	32423176.7	16194283.1

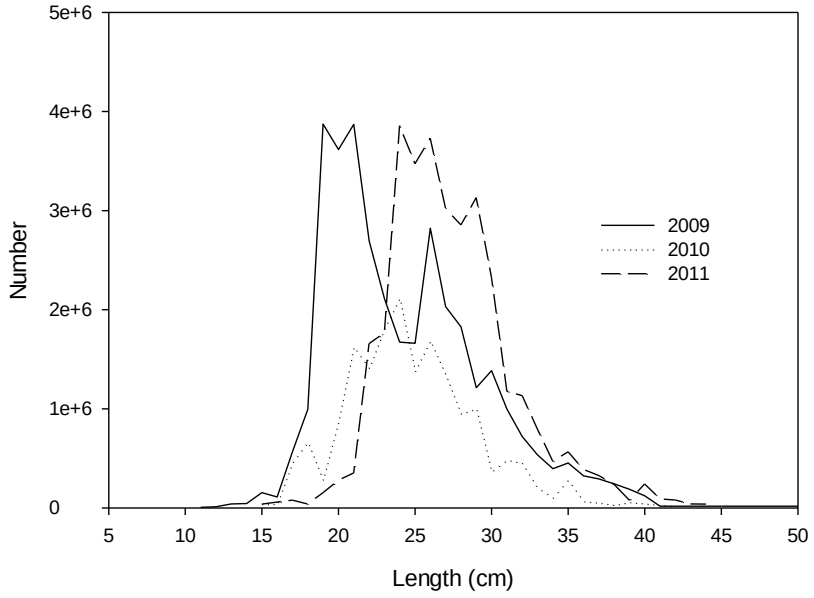


Fig. 11. Overall length distribution of deep sea redfish in numbers (weighted by stratum area) by year

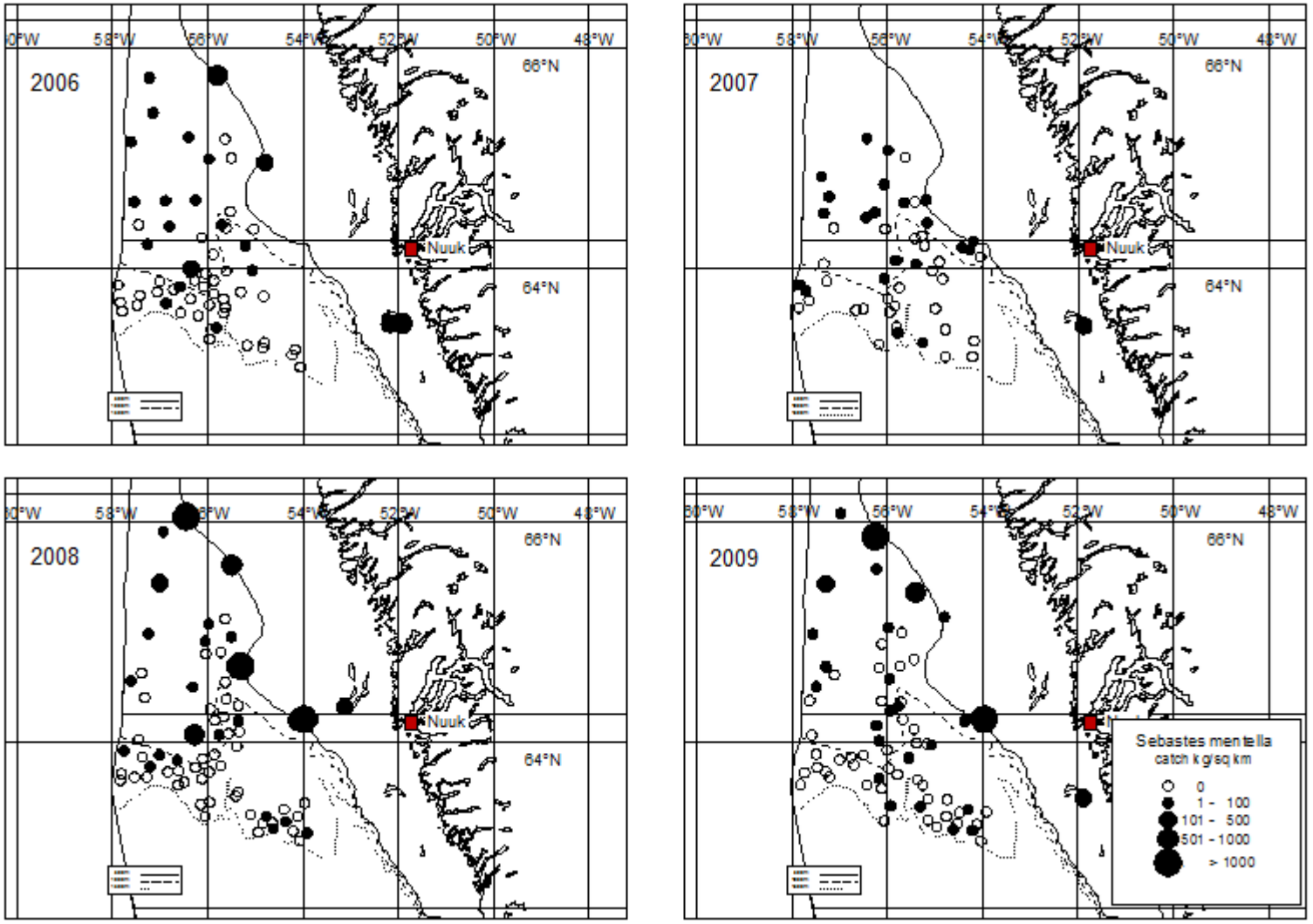


Fig. 12. Distribution of catches of deep sea redfish during 2006-2009 km^{-2}.

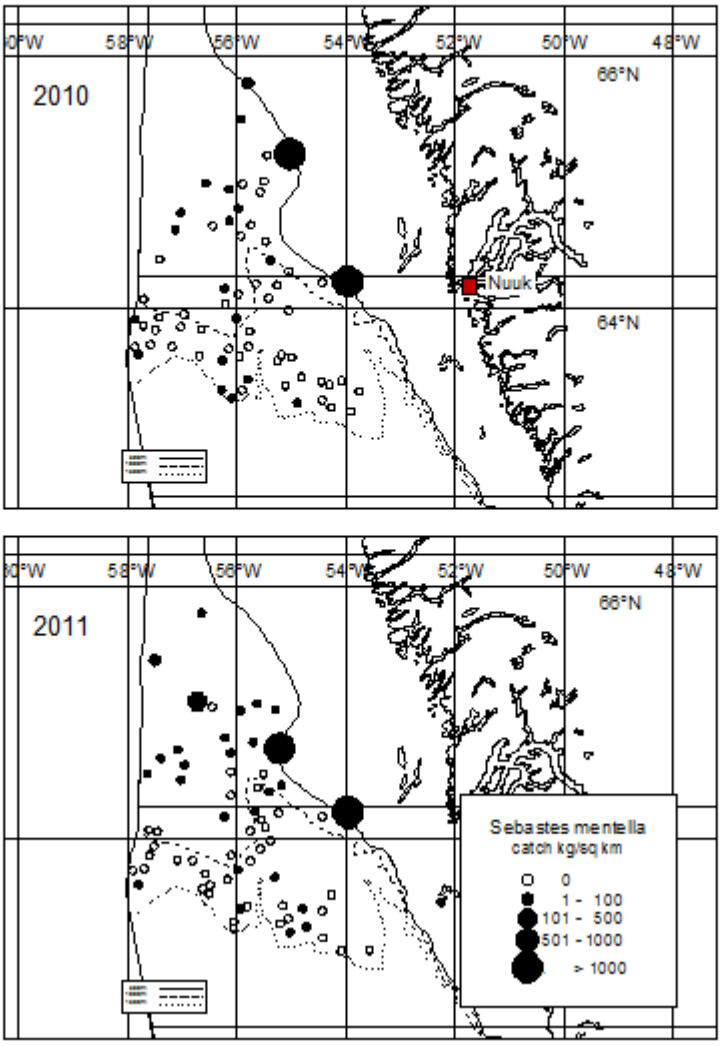


Fig. 12. Distribution of catches of deep sea redfish during 2010 and 2011 in kg km^{-2}.

Temperature

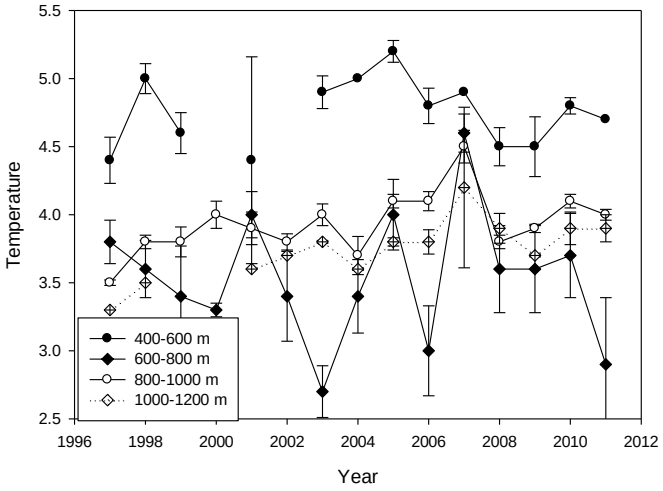
The bottom temperature ranged from 2.9°C to 4.7°C. The mean temperature was generally decreasing by depth as in previous years (Table 15).

The mean temperatures decreased slightly in all strata except in Div. 1D 801-1000 and Div.1D 1401-1500 where the temperature increased by 0.1°C, and the temperature was stable in Div. 1C 1001-1200 compared to 2010. Temperatures by Division, depth stratum and year is given in Fig. 13

Table 15. Mean temperature, S.E and number of observations by NAFO Division and depth stratum.

Div.	Depth stratum (m)																	
	401-600			601-800			801-1000			1001-1200			1201-1400			1401-1500		
	°C	SE	n	°C	SE	n	°C	SE	n	°C	SE	n	°C	SE	n	°C	SE	n
1C	4.7		1	2.9	.49	6	4.0	.04	14	3.9	.10	2						
1D	4.7	.24	2	4.3	.61	2	4.1	.10	5	3.7	.06	18	3.6	.13	14	3.6	.02	5

Div. 1C



Div. 1D

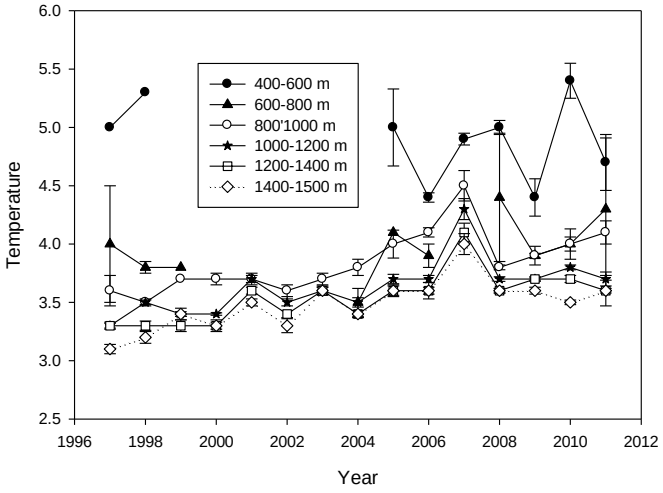


Fig 13. Mean temperatures by division depth stratum and year with 1*S.E.

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Appendix 1. Catch weight and - numbers (not standardized to kg/km^2) of Greenland halibut, roundnose and roughhead grenadier and deep-sea redfish by haul. Depth in m, swept area in km^2 and bottom temperature in °C.

					Grl. halibut		Roundnose gre.		Roughhead gre.		*S. mentella*	
St. No	S. Area	Div.	Depth	Temp.	Weight	Number	Weight	Number	Weight	Number	Weight	Number
1	0.0562	1D	1255.5	3.7	68.3	66	1.2	9	4.5	10	0.0	0
3	0.0797	1D	1429.0	3.6	167.8	107	2.4	14	8.7	13	0.0	0
4	0.0851	1D	1343.0	3.6	460.5	344	5.5	31	10.5	15	0.0	0
5	0.0766	1D	1344.0	3.7	195.3	132	2.2	10	5.4	8	0.3	1
7	0.0618	1D	1361.0	3.7	82.3	57	1.2	4	3.9	8	0.0	0
8	0.0606	1D	1237.0	3.8	166.7	143	5.0	74	1.4	3	0.0	0
9	0.0467	1D	1124.0	3.7	132.6	93	0.6	13	6.7	22	0.3	1
11	0.0865	1D	1100.0	3.8	143.1	82	1.4	25	21.0	47	0.0	0
12	0.0833	1D	1154.0	3.8	119.7	88	1.8	19	3.6	15	0.0	0
14	0.0588	1D	1285.0	3.7	169.2	123	2.0	12	9.3	12	0.4	1
16	0.0794	1D	484.0	4.4	16.7	15	0.1	1	0.4	2	6.8	24
17	0.0457	1D	563.5	4.9	0.0	0	1.1	8	2.2	5	115.5	297
18	0.0783	1C	925.5	4.1	318.7	277	0.6	8	4.1	10	5.9	16
19	0.0828	1C	979.0	4.0	292.4	260	1.1	17	4.2	13	0.0	0
20	0.0775	1C	566.5	4.7	2.0	2	1.1	2	0.0	0	93.6	279
21	0.0858	1C	915.5	4.2	129.2	119	2.3	47	2.9	11	2.0	6
22	0.0826	1C	839.0	4.2	106.2	120	0.1	3	3.2	12	0.7	2
23	0.0808	1C	820.0	4.2	85.9	106	3.8	73	5.3	9	0.5	2
24	0.0638	1C	772.5	4.3	23.2	21	2.8	72	2.3	8	2.4	6
27	0.0736	1C	666.0	3.1	67.7	82	0.0	1	1.2	2	2.6	12
28	0.0774	1C	631.0	4.0	32.4	32	0.0	1	4.5	11	58.8	260
31	0.0829	1C	623.0	1.7	39.3	50	0.0	0	3.7	13	16.0	94
32	0.0436	1C	736.0	3.1	30.8	32	0.0	0	1.1	3	0.0	0
33	0.0795	1C	853.5	3.9	239.5	219	0.1	5	0.3	2	0.2	1
34	0.0813	1C	901.5	4.0	193.4	184	0.1	1	4.2	5	0.7	1
35	0.0702	1C	907.0	3.8	199.9	160	0.5	7	6.9	10	0.0	0
36	0.0807	1C	816.0	3.8	58.4	60	0.5	4	1.3	4	0.5	1
37	0.0823	1C	805.0	4.1	241.7	231	1.2	11	2.4	11	0.3	1
38	0.0783	1C	826.0	4.0	133.7	129	3.3	21	2.8	10	0.5	1
39	0.0829	1C	819.0	4.2	109.7	103	2.2	34	7.9	16	1.0	3
40	0.0516	1C	822.5	4.1	196.2	206	1.6	13	3.8	9	1.0	3
42	0.0344	1D	789.5	3.7	35.3	38	0.1	2	1.9	4	0.7	2
45	0.0514	1D	941.5	4.1	62.0	52	1.1	4	2.1	6	0.0	0
47	0.0710	1D	948.5	4.0	63.1	61	1.0	6	0.4	3	0.0	0
48	0.0806	1D	1079.0	3.8	167.4	151	0.2	1	1.4	5	0.0	0
49	0.0810	1D	1169.0	3.7	209.4	188	1.0	3	6.1	16	0.0	0
50	0.0802	1D	1296.5	3.7	249.7	211	2.3	11	6.0	14	0.0	0
51	0.0786	1D	1284.0	3.7	304.9	276	3.6	16	6.2	8	0.0	0
52	0.0764	1D	1472.5	3.6	120.7	109	0.6	2	4.8	7	0.3	1
53	0.0819	1D	1460.5	3.7	83.1	67	2.6	15	9.2	11	0.0	0
54	0.0545	1D	1227.5	3.7	154.5	149	1.0	4	2.1	5	0.0	0
55	0.0797	1D	1174.0	3.7	199.0	178	0.1	1	1.7	7	0.0	0
56	0.0795	1D	1262.0	3.7	138.9	120	1.1	2	7.5	18	0.0	0
58	0.0813	1D	1362.0	3.7	145.8	116	0.3	1	9.2	8	0.0	0
59	0.0600	1D	1438.0	3.6	77.6	57	1.5	5	3.5	7	0.0	0
60	0.0742	1D	1189.0	2.7	139.8	100	2.5	25	11.8	26	0.6	1
61	0.0683	1D	1340.0	1.8	78.5	74	1.3	2	15.9	20	0.0	0
62	0.0813	1D	1445.5	3.7	148.4	106	2.3	5	12.4	18	0.0	0
63	0.0419	1D	1309.5	3.7	115.0	94	0.5	5	5.1	11	0.0	0
64	0.0509	1D	1132.5	3.7	125.8	88	1.7	4	2.7	6	0.0	0
66	0.0408	1D	1276.5	3.7	154.3	114	1.2	11	3.5	11	0.4	1
67	0.0515	1D	1065.5	3.8	65.9	57	0.7	3	1.8	6	0.3	1
68	0.0684	1D	1181.5	3.8	287.4	214	0.4	1	8.7	20	0.0	0
69	0.0426	1D	924.5	3.9	56.7	45	.	0	1.7	8	0.0	0
70	0.0361	1D	1150.0	3.7	147.7	118	0.2	3	10.5	27	0.0	0
72	0.0858	1D	1106.5	3.7	262.7	220	0.1	1	5.1	13	0.0	0
73	0.0748	1D	1143.5	3.7	240.3	205	0.2	6	4.9	12	0.0	0
75	0.0821	1D	985.5	3.8	170.9	166	0.4	9	5.0	17	0.0	0
76	0.0771	1D	1075.5	3.7	486.8	342.57	0.8	12	2.5	7	0.0	0
77	0.0606	1C	888.5	3.9	274.3	242	1.2	8	0.7	4	0.0	0
78	0.0900	1C	1050.0	3.8	392.7	338	1.7	29	2.2	8	0.0	0

79	0.0566	1C	1045.5	4.0	94.7	73	0.0	2	3.3	10	0.2	1
80	0.0773	1D	1054.0	3.7	304.5	261	1.1	9	3.8	9	0.3	1
81	0.0801	1D	1096.5	3.7	485.1	438	0.9	18	7.5	25	0.0	0
82	0.0798	1D	1143.0	3.8	389.3	296	0.3	5	4.3	14	0.0	0
84	0.0364	1D	914.0	4.4	56.6	53	9.2	135	1.6	5	0.0	0
86	0.0741	1D	667.0	4.9	0.0	0	1.1	10	10.2	17	73.0	120

Appendix 2. List of species and groups of species recorded in Div. 1C-D in 2011 with observed maximum catch weight (kg), maximum number per tow, minimum and maximum depth (m), minimum and maximum bottom temperature (°C) and most northern observation, respectively.

Obs	art	species	maxwgt	maxno	mindepth	maxdepth	mintemp	maxtemp	maxpos
1	ALA	Alepocephalus agassizzi	30.5	61	773	1473	2.7	4.3	65.0186
2	RFL	Amblyraja fyllae	1.0	2	623	1361	1.7	4.2	65.4126
3	RRD	Amblyraja radiata	0.9	1	676	676	1.4	1.4	66.1544
4	CAD	Anarhichas denticulatus	14.3	2	484	1256	1.4	4.9	66.1544
5	CAS	Anarhichas minor	3.8	1	484	567	4.4	4.7	64.7118
6	ANC	Anopologaster cornuta	0.1	1	889	889	3.9	3.9	64.3407
7	ATP	Anoptopterus pharo	0.5	1	1284	1284	3.7	3.7	63.7460
8	ANT	Antimora rostrata	22.1	41	736	1473	1.8	4.4	65.0400
9	ARZ	Arctozenus rissoi	0.1	1	564	676	1.4	4.9	66.1544
10	ARS	Argentina silus	6.1	22	564	667	4.9	4.9	64.2113
11	BAM	Bajacalifornia megalops	0.1	1	1150	1429	3.6	3.7	63.8191
12	BAT	Bathylagus euryops	11.4	196	484	1473	1.7	4.4	65.7870
13	BAS	Bathylagus sp.	2.8	46	823	1361	3.7	4.1	64.5123
14	BSP	Bathyraja spinicauda	30.0	1	816	816	3.8	3.8	64.7029
15	BEG	Benthosema glaciale	0.2	59	484	1473	1.7	4.4	65.7870
16	BOA	Borostomias antarctica	0.7	7	819	1461	2.7	4.4	64.6757
17	CFB	Centroscyllium fabricii	19.1	17	631	1461	2.7	4.9	65.7870
18	CHO	Ceratias holboelli	0.3	1	1133	1262	3.7	3.7	63.7207
19	CRT	Ceratidae	0.2	1	1143	1143	3.8	3.8	64.2019
20	CHA	Chauliodus sloani	0.2	30	484	1473	3.6	4.4	65.0105
21	CHN	Chiasmodon niger	0.2	5	902	1438	2.7	4.0	64.6757
22	CBB	Coryphaenoides brevibarbis	0.1	4	1310	1473	3.6	3.7	63.6349
23	CGR	Coryphaenoides guntheri	4.5	52	484	1473	1.8	4.4	64.4005
24	RNG	Coryphaenoides rupestris	9.2	135	484	1473	1.8	4.9	65.7870
25	COM	Cottunculus microps	0.3	3	631	1285	3.7	4.2	65.0853
26	COT	Cottunculus thomsonii	1.8	3	631	1310	2.7	4.2	65.0853
27	LUM	Cyclopterus lumpus	1.8	1	826	926	4.0	4.1	64.5798
28	CLM	Cyclothone microdon	0.0	2	819	1150	3.7	4.2	64.5798
29	EUR	Eurypharynx pelecanoides	0.1	1	823	1343	3.6	4.1	64.5123
30	COD	Gadus morhua	27.1	27	484	484	4.4	4.4	63.4929
31	ONA	Gaidropsarus argentatus	0.5	6	623	1361	1.7	3.9	65.4126
32	ONN	Gaidropsarus ensis	2.3	6	567	1473	1.4	4.7	66.1544
33	WIT	Glyptocephalus cynoglossus	1.3	2	736	839	3.1	4.3	65.0685
34	GOB	Gonostoma bathyphilum	0.1	2	907	1446	3.7	3.9	64.5260
35	PLA	Hippoglossoides platessoides	21.0	92	484	820	1.7	4.9	65.4126
36	HOA	Holtbyrnia anomala	0.2	3	902	1297	3.7	4.0	64.6757
37	HAF	Hydrolagus affinis	41.1	6	1343	1446	3.6	3.7	63.5584
38	LAI	Lampanyctus intricarius	0.0	3	942	1228	3.7	4.1	64.2019
39	LMC	Lampanyctus macdonaldi	5.1	292	484	1473	1.8	4.4	65.7870
40	LEP	Lepidion eques	0.4	5	564	1446	3.7	4.9	65.0186
41	LIF	Liparis fabricii	0.2	5	623	907	1.4	3.8	66.1544
42	LOA	Lophodoles alanthogantus	0.0	.	1343	1343	3.6	3.6	63.2111
43	LYS	Lycenchelys sarsi	0.1	1	979	979	4.0	4.0	64.5084
44	LYE	Lycodes esmarki	0.1	1	666	666	3.1	3.1	65.7870
45	LYN	Lycodes eudipleurostictus	0.5	3	623	676	1.4	1.7	66.1544
46	LPA	Lycodes paamiuti	0.7	4	623	1343	1.7	4.0	65.4126
47	LYR	Lycodes reticulatus	0.1	1	666	666	3.1	3.1	65.7870
48	LYM	Lycodonus mirabilis	0.0	1	1284	1284	3.7	3.7	63.7460
49	RHG	Macrourus berglax	21.0	47	484	1473	1.4	4.9	66.1544
50	MAA	Magnisudis atlantica	0.6	5	666	1237	3.1	4.0	65.7870
51	MAL	Malacosteus niger	0.1	1	820	1237	3.7	4.2	65.0685
52	MMI	Maulisia microlepis	0.2	2	823	1446	2.7	4.1	64.5123
53	WHB	Micromesistius poutassou	0.2	1	564	564	4.9	4.9	64.2113
54	BLI	Molva dypterygia	2.4	2	667	667	4.9	4.9	64.1513
55	MYP	Myctophum punctatum	0.0	4	790	1473	2.7	4.1	64.4242
56	NZA	Nezumia aequalis	0.1	1	986	986	3.8	3.8	64.0592
57	NZB	Nezumia bairdi	0.4	2	773	1297	3.7	4.3	65.0186
58	PMO	Normichthys operosa	0.0	1	839	889	3.9	4.2	65.0105
59	NOT	Notacanthus chemnitzii	4.9	6	567	1473	3.1	4.7	65.7870
60	NOK	Notoscopelus kroeyri	0.1	3	484	1361	1.4	4.9	66.1544
61	PAC	Paraliparis copei	0.0	1	1050	1438	3.6	3.8	64.4005
62	PSP	Paraliparis sp.	0.0	6	666	1079	3.1	4.3	65.7870
63	POL	Polyacanthonotus rissoanus	0.5	5	666	1461	2.7	4.4	65.7870
64	RBI	Raja bigelowi	0.1	1	1133	1133	3.7	3.7	63.4672
65	SKA	Raja. sp.	0.1	1	1189	1189	2.7	2.7	63.4410
66	RBT	Rajella bathyphila	3.0	2	1046	1340	1.8	4.0	64.3703

67	GHL	Reinhardtius hippoglossoides	486.8	438	484	1473	1.4	4.7	66.1544
68	ROM	Rouleina maderensis	0.1	1	1054	1228	3.7	3.8	64.2103
69	SCO	Scopelosaurus lepidus	3.6	32	623	1473	1.7	4.9	65.7870
70	REG	Sebastes marinus	3.6	2	564	667	4.7	4.9	64.7118
71	REB	Sebastes mentella	115.5	297	484	1473	1.4	4.9	66.1544
72	SEK	Serasia koefoedi	0.0	1	1182	1182	3.8	3.8	63.6746
73	SER	Serrivomer beani	0.5	4	819	1473	1.8	4.2	64.6757
74	STO	Stomias boa	0.1	7	484	1473	2.7	4.4	65.7870
75	SYN	Synaphobranchus kaupi	3.7	28	666	1473	1.8	4.9	65.7870
76	TRA	Trachyrhynchus murrayi	1.4	4	839	1182	3.7	4.4	65.0105
77	XEC	Xenodermichthys copei	0.0	16	773	1285	3.7	4.3	65.0186