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Distribution and Abundance of Greenland halibut at the Continental Slope of Divisions 3KLMN
Based upon Canadian Deepwater Surveys in 1991, 1994 and 1995

by

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Introduction

Since about 1989, a deepwater fishery for Greenland halibut has developed at the continental slope of the NAFO Regulatory Area in Div. 3LM and more recently in Div. 3N in depths generally exceeding 1000 meters. Catches in this area have been in the range of 50,000-60,000 tons since 1990. The fishery has been carried out mainly by freezer trawlers from EU (Spain) and EU (Portugal) as well as other non-contracting parties. In addition, a small vessel gillnet fishery has also developed in the Canadian zone at the continental slope primarily of Div. 3KL but more recently in Div. 2GH. The catches from the fishery component, however, has been relatively low by comparison to the non-Canadian trawler fishery with catches usually around 3,000 tons or less in the last couple of years. In order to evaluate the distribution and abundance of Greenland halibut, in particular, deepwater trawl surveys were conducted in 1991, 1994 and 1995 in Div. 3KLM in 1991 and included some of Div. 3N in 1994 and 1995. This paper describes the distribution and abundance of Greenland halibut as well as a comparative analysis of the size and age compositions among the three years and divisions surveyed.

Materials and Methods

All three surveys were conducted by large offshore trawlers with the necessary capacity to fish depths beyond 1500 meters. All surveys were conducted using the same fishing gear i.e. an Engel 145' otter trawl with 18" rockhopper footgear and a 28 mm liner in the codend in order to retain the catch of small fish. To standardize sets within and among surveys, the fishing gear was equipped with electronic sensors which recorded when the net was on the bottom, the wing spread, headline height, towing speed and distance towed. This was done to dispel any concern related to the use of different vessels.

The first survey was carried out by the vessel Cape Adair during Sept. 4-30, 1991 in Div. 3KLM with most sets in conducted within a depth range of 750-1500 meters. A total of 106 successful fishing sets were completed, 27 in Div. 3K, 42 in Div. 3L and 37 in Div. 3M. This survey used a line transect design which was later post-stratified according to the stratification scheme described in Bishop (1994).

The second survey was conducted by the vessel Zandvoort during Feb. 3-Mar. 13, 1994 in Div. 3KLMN using a stratified-random design with the same stratification scheme discussed above at depths ranging from 550-1500 meters depending upon the division. A total of 131 successful fishing sets were completed, 22 in Div. 3K, 47 in Div. 3L, 51 in Div. 3M and 11 in Div. 3N.

The 1995 survey was carried out during Mar. 16-April 21 by the Canadian research vessel Teleost in Div. 3KLMN using the same stratified-random design as in 1994 in depths of 500-1500 meters with more extensive coverage in Div. 3K than the previous two surveys. A total of 142 successful sets were conducted, 48 in Div. 3K, 48 in Div. 3L, 37 in Div. 3M and 9 in Div. 3N.

At the end of each fishing set the catch numbers and weights (kg) were collected for each

species caught and where time was available, length frequencies were obtained for the major groundfish species encountered. Detailed sampling was carried out for Greenland halibut in all sets including length, sex and maturity frequencies and otoliths. A description of the results with respect to American plaice, witch flounder, redfish, roundnose grenadier and roughhead grenadier is presented separately in another paper (this meeting).

Results

Distribution

Greenland halibut were widely distributed and were caught in all sets in 1991 and with few exceptions, most sets for the 1994 and 1995 surveys. The only area where no fish were encountered was in the area known as the Beothuck Knoll at the southwest side of the Flemish Cap which is more noted for the abundance of redfish (Fig. 1 and 2). Although the estimates of biomass and abundance varied annually, the relative distribution remained very much the same throughout the three surveys with most of the catch occurring in Div. 3K and along the slope of Div. 3L out to the Sackville Spur and along the western side of the Flemish Pass. There were no fishing stations occupied in Div. 3N in the 1991 survey, but in 1994 there were relatively large catches in the northeastern part of this area. In the 1995 survey, however, the catches here were much lower relative to the remainder of the survey area especially Div. 3K and the western part of Div. 3L.

Biomass and Abundance

The trawlable biomass of Greenland halibut declined considerably between 1991 and 1994 but showed an equal or greater increase between 1994 and 1995 except for Div. 3M which was little better than 1994 (Table 1). The largest biomass was in Div. 3K followed by Div. 3L which together accounted for more than 70% of the total biomass for the common strata surveyed in all years. However, for strata not covered in all three years, primarily in the 550-1000 meter depth range in Div. 3K, there was a substantial portion of the total biomass unaccounted for (about 50%) in the comparisons of common strata. The total biomass estimated for the entire survey area in 1995 was about 72,000 tons compared to 30,000 tons in 1994 and 70,000 tons in 1991. For comparable strata the estimated biomass in 1995 is 46,000 tons compared to 30,000 tons in 1994 and 45,000 tons in 1991. The estimated abundance of Greenland halibut, on the other hand, showed some increase overall between 1991 and 1994 which when compared to the considerable reduction in biomass indicated a substantial shift in size composition towards smaller fish (Table 2). The abundance estimate for 1995 is very much higher than the previous estimates for Div. 3K and 3L with only slight differences between years for Div. 3M and 3N. Overall this indicates an even greater increase in the abundance of smaller, younger fish between 1994 and 1995 compared to between 1991 and 1994. The total abundance estimated for the entire survey area in 1995 is 129 million fish compared to 42 million fish in 1994 and 40 million fish in 1991. For the common strata the 1995 overall estimate of abundance is 57 million fish compared to 28 million fish in 1994 and 23 million fish in 1991. In Div. 3K in a depth range of 500-1000 meters, the 1995 estimate of abundance is 58 million fish which is between 50-60% higher than the estimated abundance in the entire survey area of either the 1991 or the 1994 survey.

Length and Age Composition

Length compositions for the three surveys are shown in Fig. 3 for Div. 3KLM combined. Only strata common to all surveys are shown in the presentation. The 1991 survey was dominated by Greenland halibut larger than 45 cm in length and peaked in the range of 45-55 cm while there were few fish (about 5%) less than 40 cm observed. Both the 1994 and 1995 surveys were dominated, on the other hand, by much smaller fish with more than half the estimated abundance comprised of fish less than 40 cm and peaked in the range of 32-38 cm (Fig. 3). The estimated abundance of fish greater than 48 cm was highest in the 1991 survey and lowest in the 1994 survey, however, for both the 1994 and 1995 surveys there were very few fish beyond a length of 64 cm compared to the survey of 1991 (Fig. 3).

Age compositions from the three surveys are shown separately by division for common strata in Fig. 4 and for common strata for Div. 3KLM combined in Fig. 5. The abundance at age in Fig. 5 was converted to biomass at age and results presented in Fig. 6. The age composition, of course, follow similar trends as the length composition in that the 1991 survey is dominated by larger older fish compared to the 1994 and 1995 surveys (Fig. 4). In Div. 3K and 3L the age compositions are

dominated by 4-6 year olds in 1994 followed by 5-7 year olds in 1995 indicating a significant presence of the 1988-90 year classes. It is difficult to quantify the effect of these year classes from the short time series of these data. In Div. 3M, on the other hand, the abundance is much lower and the younger age groups do not stand out as in Div. 3K and 3L. The abundance in Div. 3N is too low for the area surveyed to indicate much from the age compositions (Fig. 4). The combined abundance at age for Div. 3KLM is similar to Div. 3K which is not surprising since most of the overall abundance is located in Div. 3K.

The biomass at age (Table 3; Fig. 6) indicates that the stock weight estimated during the 1991 survey was comprised mainly of ages 9-14. More than half the estimated biomass in 1991 was comprised of fish in the age range of 10-17 years whereas in the 1994 survey ages 10-17 comprised only about 10% of the biomass and 20% of the estimated biomass in 1995. These figures, however, are only indicative of the biomass in strata commonly fished in all three years.

Discussion

Based upon the results presented here it appears that most of the stock for the surveyed area is located in Div. 3K and 3L and the general geographic distribution patterns among the three years seem to be similar. There has been a substantial reduction in the numbers of larger, older fish since 1991 despite the large estimated increase in abundance between 1994 and 1995. The increase is made up mainly of very young fish with a very significant contribution from the 1990 year class and was readily apparent in both 1994 and 1995. While there may have been some expected increase of younger fish in the 1995 survey due to increased partial recruitment to the survey gear of these year classes, the magnitude of the increase is difficult to fully reconcile given that it is across many age classes. In the 1994 assessment, it was indicated that there was a considerable increase in stock size in the traditional fall surveys in Div. 2J and 3KL based upon the 1990 and 1991 year classes which appeared in higher numbers in 1993 than in 1992. The 1994 estimate from this survey series does not support this observation to anywhere the same degree unless there was a mass migration from the area and/or increased mortality (see Bowering et al. (this meeting) for more information). The increase observed in the 1995 deepwater survey may reflect some of this possible migration.

References

Bishop, C.A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO SCR Doc. 94/43, Serial No. N2413, 23p.

Stratified biomass (t) of G. halibut from the summer survey 1991 and the winter surveys in 1994 and 1995
 based on the new stratification system

Stratum	Area (sq. nm)	Trawlable Units(000)	Biomass 1991	Biomass 1994	Biomass 1995
1	299	17	-	-	1294
2	418	31	-	-	6250
3	325	24	-	-	1919
4	359	27	-	-	940
Total					10404
5	363	27	11737	-	3210
6	516	39	4038	-	6945
Total			15775	-	10155
7	733	55	4163	2118	5137
8	228	17	4056	2563	3154
9	13	40	2278	784	3923
Total			10497	5465	12214
10	179	36	2995	502	1877
11	212	16	2037	336	3507
12	139	36	1410	696	1909
Total			6342	1594	7092
Total			32615	7059	39865
13			18910	-18786	30398
14			46320	32904	49334
Total			15839	7059	19306

Stratum	Area (sq. nm)	Trawlable Units(000)	Biomass 1991	Biomass 1994	Biomass 1995
15	70	13	-	724	-
16	201	17	-	637	150
17	228	17	428	112	1248
18	125	13	-	754	1604
Total			428	2227	3002
19	227	17	843	812	767
20	123	17	827	399	1242
21	345	26	1395	1245	3566
22	13	12	-	457	-
Total			3065	2913	5575
23	225	17	-	399	725
24	136	13	993	368	777
25	392	29	2637	585	2008
26	116	9	-	607	552
Total			3630	1959	4062
27	261	19	-	545	766
28	211	16	1360	334	1673
29	254	54	2054	1245	786
30	44	42	1182	447	1417
Total			-	-	769
31			4596	2571	5411
32		30	866	420	1939
33		21	812	-	1647
Total			1677	420	3596
34			13337	10090	21636
35			8945	7139	15083
Total			17849	12982	27139
Total			12584	5967	15422

Div 3M						
Depth range (m)	Stratum	Area (sq. nm)	Trawlable Units(000)	Biomass 1991	Biomass 1994	Biomass 1995
367-549	537	102	8	-	-	-
Total				-	-	-
550-731	538	194	15	-	-	-
Total				-	-	-
732-914	520	525	39	2890	-	-
	524	253	19	-	-	-
	528	530	40	3587	-	-
	533	96	7	-	-	-
Total	539	133	10	6477	1456	1094
915-1097	521	517	39	2185	-	-
	529	488	37	2667	-	-
	532	238	18	1778	-	-
Total	534	486	36	6630	3563	1094
1098-1280	522	533	40	2288	-	-
	530	1134	85	7601	3403	2038
Total	535	92	7	9889	4403	1094
1281-1463	523	284	21	-	-	-
	527	171	13	-	-	-
	531	203	15	1065	-	-
Total	536	112	8	1065	-	-
Biomass(t)				24060	10022	12094
95% Lower				13783	8311	11094
95% Upper				28337	11714	15094
Biomass common strata				15623	5000	1094

Div 3N						
Depth range (m)	Stratum	Area (sq. nm)	Trawlable Units(000)	Biomass 1991	Biomass 1994	Biomass 1995
550-731	728	156	12	-	-	-
Total				-	-	-
732-914	752	134	10	-	-	-
Total				-	-	-
915-1097	753	130	10	-	-	-
Total				-	-	-
1098-1280	754	120	14	-	-	-
Total				-	-	-
1281-1463	755	385	29	-	-	-
Total				-	-	-
Biomass(t)				24060	10022	12094
95% Lower				13783	8311	11094
95% Upper				28337	11714	15094
Biomass common strata				15623	5000	1094

Table 2 . Estimated numbers (ooo) per stratum of G. halibut from the summer survey 1991 and the winter surveys in 1994 and 1995. Based on the new stratification system.

Div. 3K						
Depth range (m)	Stratum	Area (sq. nm)	Trawlable Units(000)	Abundance 1991	Abundance 1994	Abundance 1995
501-750	641	230	17	-	-	5154
	642	418	31	-	-	16810
	646	325	24	-	-	6286
	651	359	27	-	-	4163
Total						32413
751-1000	647	360	27	8936	-	6931
	652	516	39	2944	-	19289
Total				11880	-	26220
1001-1250	643	733	55	2678	3045	7841
	648	228	17	1888	3834	5072
	653	531	40	986	1408	6075
Total				5552	8287	18988
1251-1500	644	474	36	1361	498	1466
	649	212	16	756	214	3262
	654	479	36	580	557	1460
Total				2697	1269	6188
Abundance 95% Lower				20129	9557	83808
Abundance 95% Upper				11771	-31113	51979
Abun. for common strata				8249	9556	25176

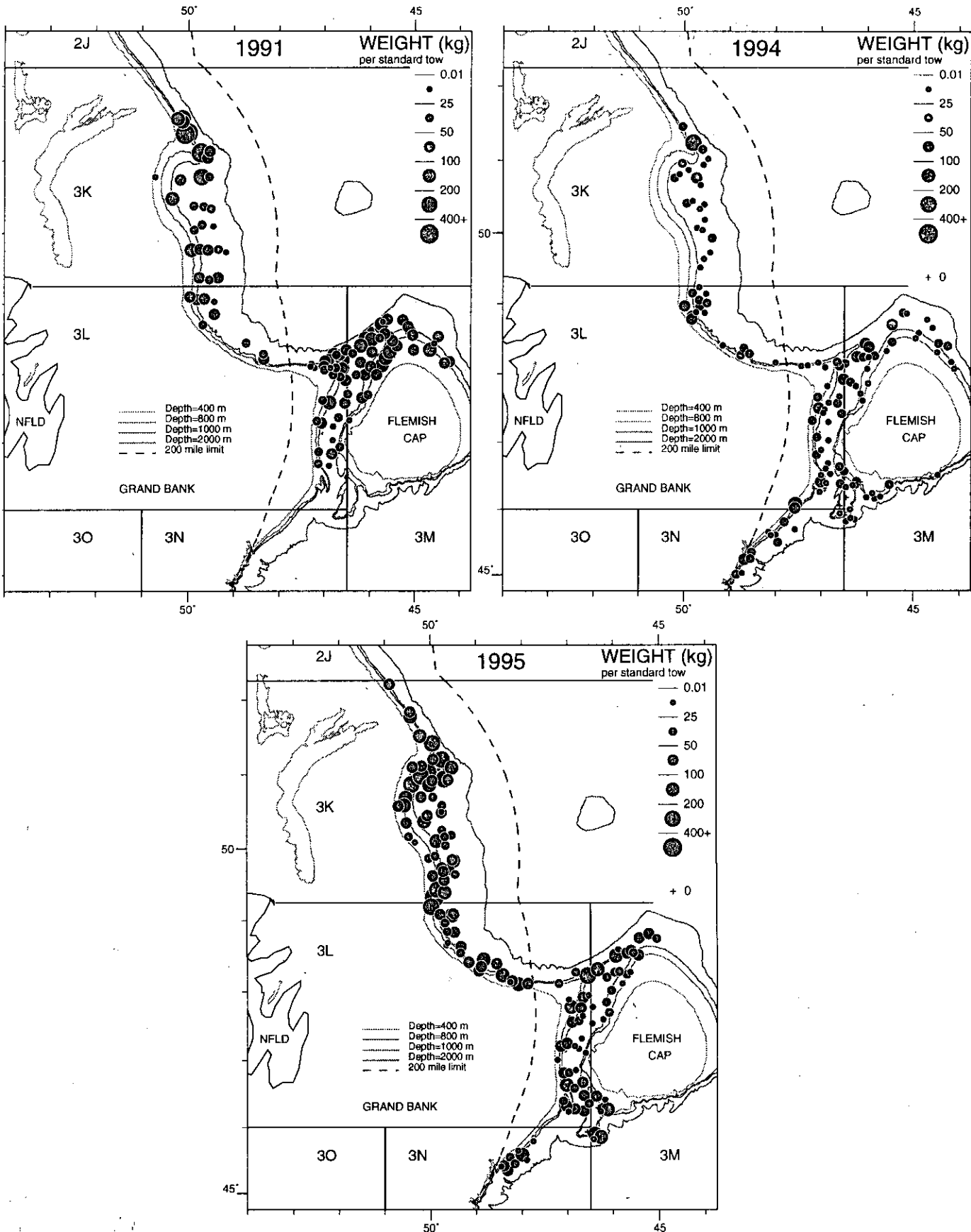
Div. 3L						
Depth range (m)	Stratum	Area (sq. nm)	Trawlable Units(000)	Abundance 1991	Abundance 1994	Abundance 1995
550-731	730	170	13	-	1608	-
	732	231	17	-	2488	468
	734	228	17	365	471	4612
	736	175	13	-	2535	5432
Total				365	7102	10512
732-914	737	227	17	866	2650	1355
	741	223	17	998	1122	3013
	745	348	26	1145	2943	7123
	748	159	12	-	937	-
Total				3009	7652	11490
915-1097	738	221	17	-	705	1012
	742	206	15	561	897	990
	746	392	29	1072	777	1766
	749	126	9	-	350	544
Total				1633	2729	4311
1098-1280	739	254	19	-	928	680
	743	211	16	449	459	1568
	747	724	54	794	879	634
	750	556	42	508	292	906
Total				1751	2558	3788
1281-1463	740	264	20	220	515	2431
	744	280	21	300	-	1226
	-	-	-	-	-	550
	751	229	17	-	515	4207
Total				520	515	4207
Abundance 95% Lower				7279	20555	34309
Abundance 95% Upper				5484	13458	11929
Abun. for common strata				9074	27653	56888
Abun. for common strata				6978	11005	24397

Div. 3M						
Depth range (m)	Stratum	Area (sq. nm)	Trawlable Units(000)	Abundance 1991	Abundance 1994	Abundance 1995
367-549	-	-	-	-	-	-
	537	102	8	-	0	-
Total					0	-
550-731	-	-	-	-	-	-
	538	194	15	-	32	0
Total					32	0
732-914	520	525	39	2253	532	-
	524	253	19	-	177	-
	528	530	40	3358	896	1607
	533	98	7	-	-	143
	539	133	10	-	60	205
Total				5611	1664	1955
915-1097	521	517	39	1411	750	-
	529	488	37	1513	733	815
	532	238	18	776	1018	1992
	534	486	36	-	905	2058
Total				3700	3406	4865
1098-1280	522	533	40	974	520	-
	530	1134	85	2057	2564	2097
	535	92	7	-	45	411
Total				3031	3129	2508
1281-1463	523	284	21	-	160	-
	527	171	13	-	45	-
	531	203	15	250	-	-
	536	112	8	-	63	177
Total				250	268	177
Abundance 95% Lower				12591	8499	9505
Abundance 95% Upper				10520	7001	8154
Abun. for common strata				14663	9998	10855
Abun. for common strata				7704	5210	6511

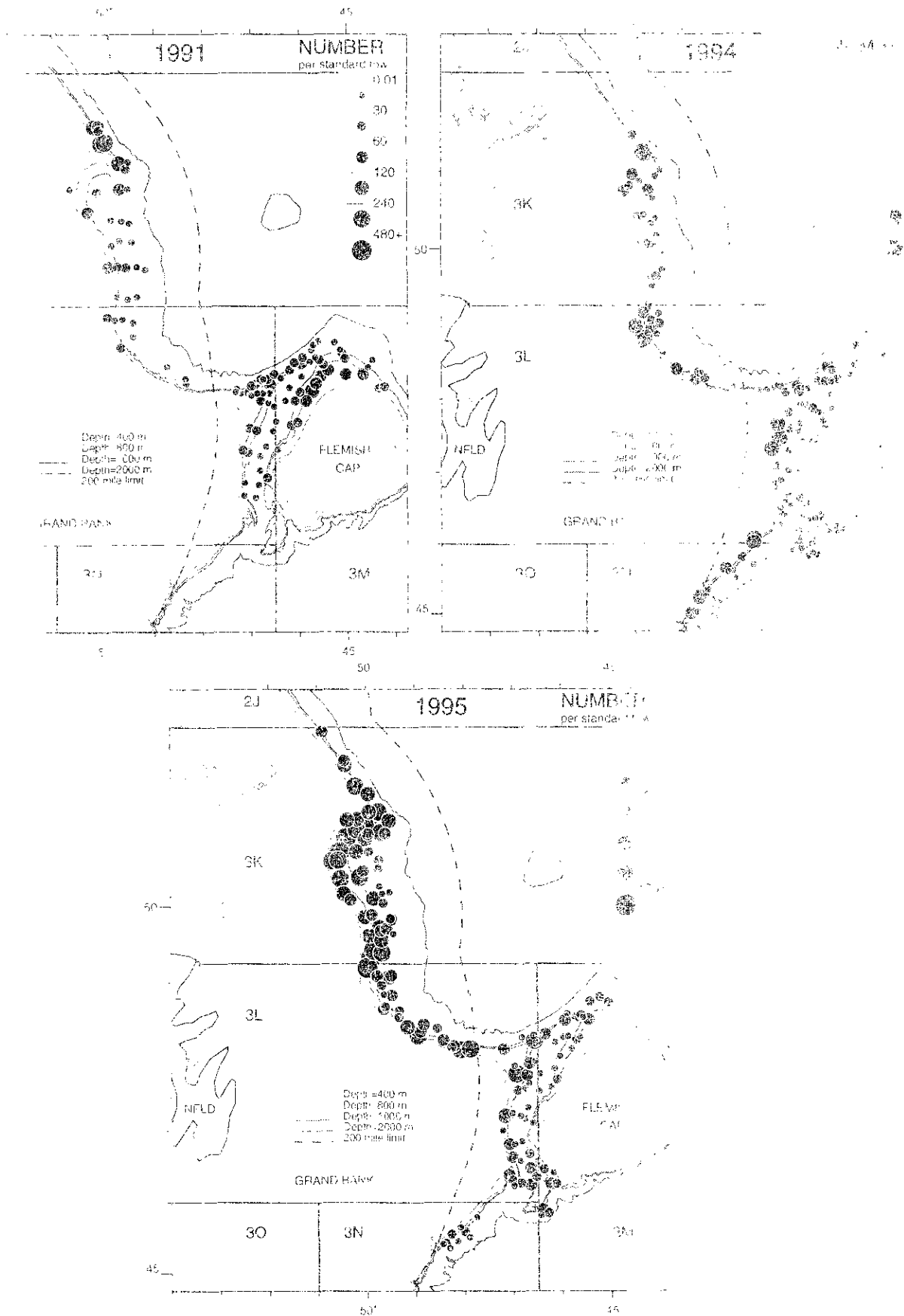
Div. 3N						
Depth range (m)	Stratum	Area (sq. nm)	Trawlable Units(000)	Abundance 1991	Abundance 1994	Abundance 1995
550-731	-	-	-	-	-	-
	728	156	12	-	989	-
Total					989	-
732-914	-	-	-	-	-	-
	752	134	10	-	1046	443
Total					1046	443
915-1097	-	-	-	-	-	-
	753	138	10	-	119	212
Total					119	212
1098-1280	-	-	-	-	-	-
	754	180	14	-	108	486
Total					108	486
1281-1463	-	-	-	-	-	-
	755	385	29	-	355	279
Total					355	279
Abundance 95% Lower					2618	1421
Abundance 95% Upper					-7412	538
Abun. for common strata					12647	2304
Abun. for common strata					1628	1421

to all years are included

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	Ages 1-5	Ages 6-9	Ages 10-17
Biomass (t)	0	0	7	32.54	0.253	2	0	5	19.07	0.042	0	0	23	19.86	0.048	0	0	0	0	0	0	0	0	0	0	0	42585	273	19456	22956	
	0	0	0	0.08	0.600	0.272	0	2288	26.9	0.180	305	0	182	24.16	0.093	17	0	0	0	0	0	0	0	0	0	0	14779	4464	8575	1742	
	0	0	0	0.253	0.600	0.272	0	7248	32.13	0.242	1753	0	452	29.43	0.180	799	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	6028	37.28	0.399	2406	0	1599.7	35.03	0.324	8334	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	4972	42.51	0.621	3085	0	16481	40	0.506	8334	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	2903	47.15	0.879	2565	0	10009	35.44	0.776	7768	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	1322	54.65	1.444	1909	0	4737	51.55	1.187	5621	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	473	61.62	2.162	1023	0	2219	57.86	1.749	3880	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	196	68.17	3.036	595	0	618	63.54	2.397	1481	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	131	75.4	4.261	558	0	334	69.97	3.142	1050	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	81	80.9	5.399	437	0	439	74.07	4.014	1762	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	14	83.59	6.027	84	0	357	80.24	5.253	1875	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	0	88.96	7.431	0	0	194	84.03	6.134	1190	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	9	89	7.442	67	0	40	89.82	7.675	307	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	0	98.5	10.466	84	0	35	93.23	8.699	313	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	
	0	0	0	0.253	0.600	0.272	0	0	98.5	10.466	84	0	0	93.23	8.699	313	0	0	0	0	0	0	0	0	0	0	19456	273	19456	22956	



1. Distribution of Greenland halibut catches from Greenland halibut directed Canadian surveys of NAFO Divisions 3KLMN from 1991-1995. Surveys were conducted by the Cape Adair (1991, 650 m - 1800 m), Zandvoort (1994, 750 m - 1500 m) and RV Teleost (1995, 500 m - 1700 m). Circles represent catch weight (kg) per standard tow (1.75 nautical miles). Dashed line represents division between the Canadian economic zone and the NAFO Regulatory area (east of line)



Distribution of Greenland halibut catches from Greenland halibut directed Canadian surveys of NAFO Regulatory Area from 1991 to 1995. Surveys were conducted by the Cape Adair (1991, 650 m - 1800 m), Randvorn (1994, 1000 m - 1700 m), and Cape Adair (1995, 500 m - 1700 m). Circles represent catch number per standard tow (1.75 nautical miles). Dashed line indicates the division between the Canadian economic zone and the NAFO Regulatory area (east of line).

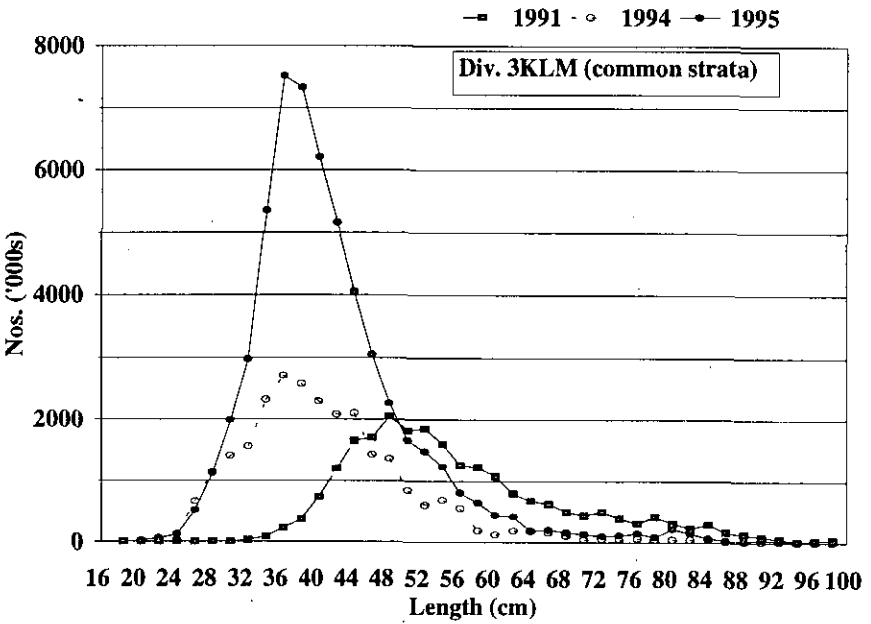
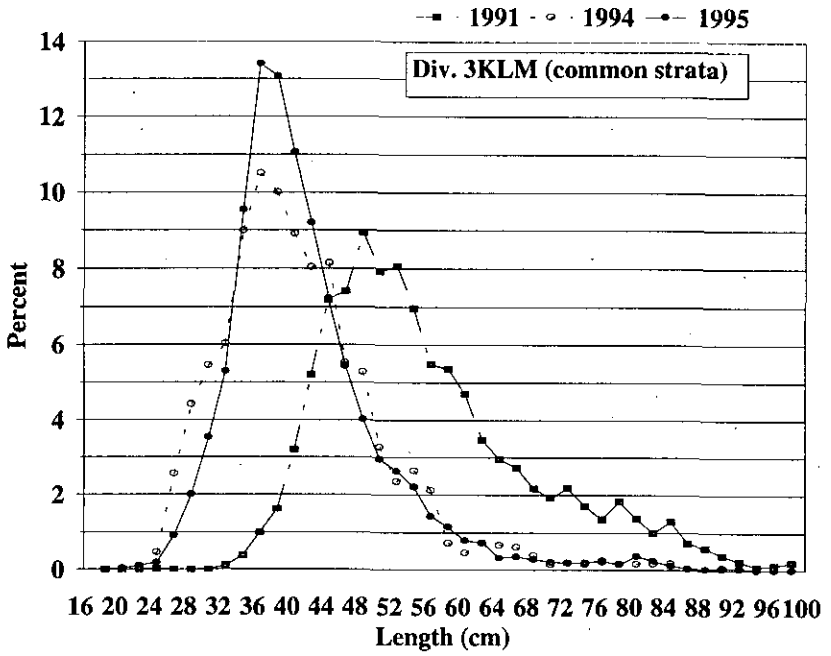
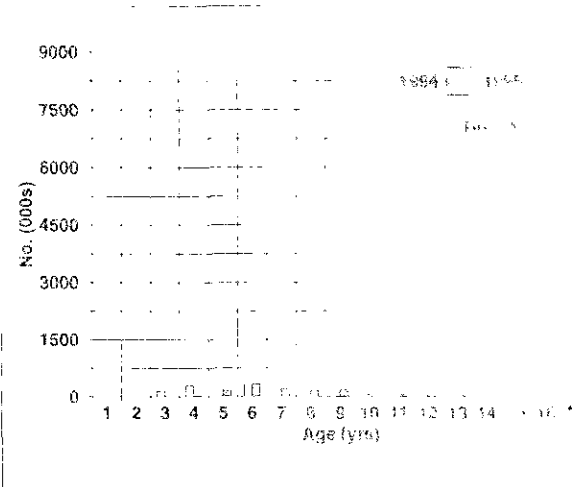
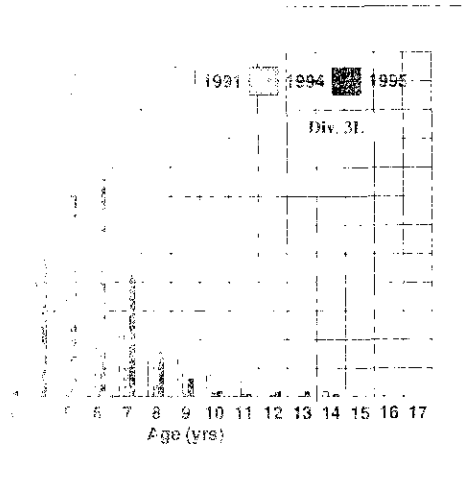
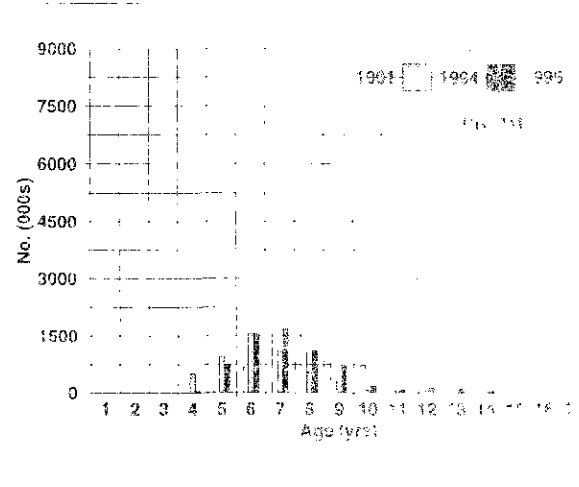
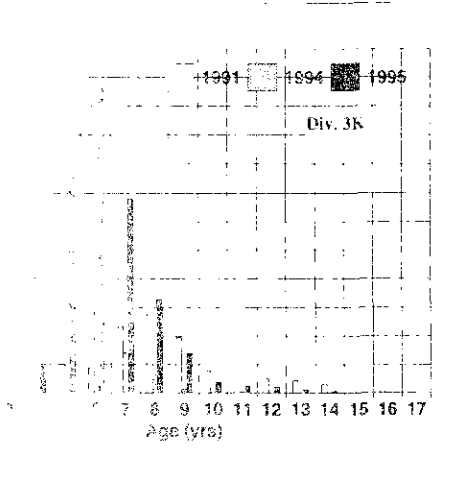


Fig. 3 Percent and abundance (000s) at length of *G. halibut* in commonly surveyed strata in Div. 3KLM during 1991, 1994 and 1995.



Figures of *O. tshawytscha* in commonly surveyed strata during 1991, 1994 and 1995 for Div. 3K, 3B, 3L and 3C separately.

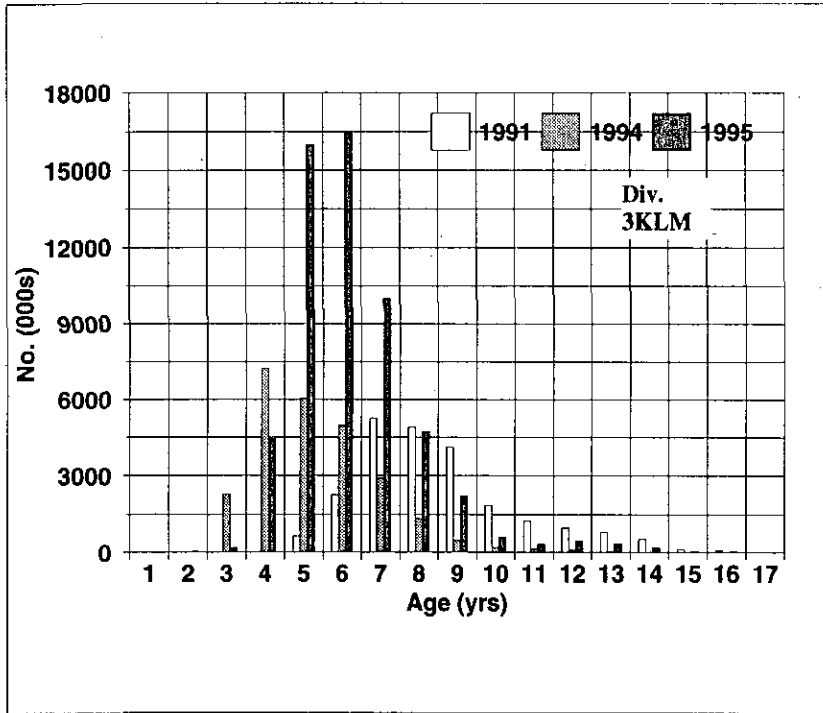


Fig. 5 Abundance of *G. halibut* in commonly surveyed strata during 1991, 1994 and 1995 in Divisions 3KLM.

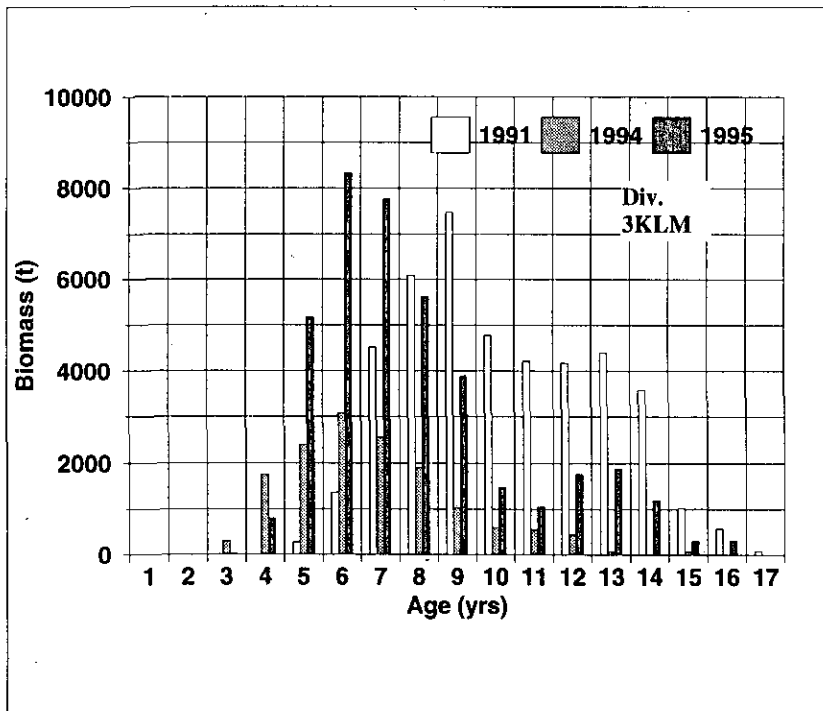


Fig. 6 Biomass of *G. halibut* in commonly surveyed strata during 1991, 1994 and 1995 in Divisions 3KLM.