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Bycatch of Greenland Halibut (*Reinhartius hippoglossoides*) in the Offshore Shrimp Fishery

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Abstract

This paper quantifies the impact of 1997 – 1999 2GHJ3K Greenland halibut (*Reinhardtius hippoglossoides*) bycatch, taken by the offshore (>500 tons) component of the shrimp fishing fleet. Analyses indicated that Greenland halibut were abundant and broadly distributed over the entire study area, and that the impact of present bycatch levels could not be detected.

Résumé

La présente étude quantifie l'impact des prises accidentelles du flétan du Groenland (*Reinhardtius hippoglossoides*) de 2GHJ3K entre 1997 et 1999 par la composante hauturière (>500 tonnes) de la flotte de la pêche de la crevette. Selon les analyses, le flétan du Groenland était abondant et largement distribué dans toute la région étudiée, et l'impact des prises accidentelles actuelles n'a pu être démontré.

Introduction

The commercial shrimp fishery (*Pandalus borealis* and *P. montagui*) began off Labrador in Hopedale (56°N), Cartwright (54.5°N) and Hawke (53°N) Channels (Figure 1) during the mid 1970's. Since then it has expanded both northward to the continental slope off northern Labrador and southward to deep areas of the shelf off northeastern Newfoundland. Cumulative catches within NAFO 2GHJ3K increased from about 17,000 tons during 1988, to 22,500 tons in 1993 and 1994 and finally 74,000 tons during 1999. The fishery covers vast areas and is conducted using a modified otter trawl with small mesh, resulting in incidental bycatches of economically important groundfish species such as Atlantic cod (*Gadus morhua*), redfish (*Sebastes* spp.), and Greenland halibut (*Reinhardtius hippoglossoides*). Wherever possible it is important to reduce bycatches since they are of no commercial value to the shrimp industry and require effort in separating them from directed species. Also, some stocks of fish which occur, at times, in the bycatch are currently under moratoria and, therefore, it is important to minimize incidental mortalities on these species. In an attempt to resolve this problem, shrimp fishers have been using Nordmore Grates extensively since 1993. This device has reduced bycatches but where there are high concentrations of very small fish (generally <20cm) mixed with the shrimp, some bycatch passes through the grate and enters the codend. This paper quantifies the Greenland halibut removals and provides theoretical loss of yield due to bycatch mortalities for the years 1997-1999.

Methods

Fishery observers are deployed on all offshore (>500 ton) and 10% of the inshore (<=500 tons) shrimp fishing vessels within the Canadian waters (200 n mi limit). The observers estimated, for each set, the catches of all species, including the amount kept and discarded, using the methods of Kulka (1998). This analysis makes use of data collected by the observer programs in Newfoundland, Nova Scotia and Quebec. In order to reduce the effect of measurement errors and to produce manageable data sets, 19 mm – 24 mm Nordmore Grates were coded as being 22 mm grates while 25 mm – 30 mm grates were coded as being 28 mm. Cumulative percent frequencies (CPF) were produced for each grate size, by year, using length frequency data (Figures 2 and 3). From these CPFs the highest 50 percentile provided a conservative indication of mean size of juvenile fish (LC_{50} = 24cm) susceptible to the gear. The LC_{50} values presented in Figure 3 are in agreement with other studies (Brothers 1998, Hickey *et al.* 1993, Isaken *et al.* 1990, Nicolajsen 1997). Canadian multi-species research survey catches of juvenile Greenland halibut (defined as being <=24 cm according to selectivity curve LC_{50} values) were plotted. These were compared with seasonal distribution maps of Greenland halibut bycatch. All distribution maps were produced using the ACON data visualization software (Black, 1993).

Quantitative impacts were determined as follows:

Observer Data

Using a ratio of weight of fish measured to bycatch weight, the length frequencies were corrected on a set by set basis. The length frequencies were added together by grate size and year. Similarly, the total bycatch weights from which frequencies were derived were added together by grate size and year. Each frequency was then divided by the total bycatch weight to produce an average frequency per kg for each 1 cm length group by grate size and year. These average length frequencies were then merged with the catch records. The frequencies were multiplied by the bycatch weights in an effort to produce length frequency data on a set by set basis. The length frequencies were aggregrated to obtain total removals by length, grate and year. Population adjusted age length keys were applied to these data when estimating removals by age. The population adjusted age length keys were produced as part of stratified analyses (Cochran 1977) from Canadian fall multi-species research survey data. The 1996 research survey population at age estimates were used as the benchmark from which the 1997 bycatch was taken. Therefore, the 1996 research adjusted age length key was applied to the 1997 observer data. The 1998 and 1999 observer data were treated similarly.

The yield per recruit estimates assumed a reference natural mortality of 0.2, a lifespan of 17 years and the average commercial weight at age and partial recruitment values found in Bowering and Brodie (1987). Brodie *et al.* (1998) verified that the commercial weights per age from the mid 1980's were similar to present commercial weights at age. They made use of the 1987 partial recruitment values and weights at age for a Greenland halibut yield per recruit analysis. The yield per recruit analysis was re-run, for the present study, because we wanted to predict the loss of yield for all ages between 0 and 17 years of age rather than just 5-17 years of age as was done in Brodie *et al.* (1998). The yield of 17+ fish was considered to be negligible.

The instantaneous total mortality (Z) of the fish younger than 5 years of age was determined through methodology described in de Melo *et al.* 1997. This calculation alone made use of research population at age estimates of 2J3K Greenland halibut during 1996 – 1998. It was not appropriate to include data from 2GH as the Canadian multi-species research survey sampling intensity, in these areas, was low and inconsistent during this period.

The yield per recruit model was created using an EXCEL spreadsheet routine produced by Mr. D. B. Atkinson (NWAFC, unpublished macro). The instantaneous total mortality (Z) for 5+ fish was determined by adding the reference natural mortality (M=0.2) to the model derived fishing mortality at $F_{0.1}$ (F=0.293). The estimate of survivorship (S) was determined as being e^{-z} and was used in determining the number of fish surviving from one year to the next. In this case we were interested in determining the number of fish that would have survived and subsequently been caught, had the bycatch been allowed to live. The potential catches resulting from each year's bycatch were then multiplied by yield per recruit values to obtain an estimate of loss of yield.

Canadian multi-species research data

The fall multi-species research surveys were conducted onboard the Canadian research vessels **Wilfred Templeman** and **Teleost**. Fishing sets of 15 minute duration and a towing speed of 3 knots were randomly allocated to strata covering 2GHJ3K to a depth of 1500m (Figures 4-7). Both vessels used a Campelen 1800 trawl with a codend mesh size of 40 mm and a 12.7mm liner. SCANMAR sensors estimated that the mean wingspread was 16.8m. Details of the survey and fishing protocols are provided by Brodie (1996).

Results and Discussion

Typically NAFO division 2G has not been thoroughly sampled by the research surveys, on either the shelf or along the edge. However, Saglek Channel and the northeastern edge of the Labrador shelf between 200 and 500m m (Figures 4 and 8, Table 1 strata 909, 901, 908, 927 and 928) account for 41-63% of the Greenland halibut abundance and 16-67% of the biomass, over all years. As indicated in figure 9, these strata were fished by the offshore shrimp fleet between April and December. The maximum and mean removals per set were 37 and 3 kg. respectively.

As one moves further south the research sampling intensity increases (Figure 8). Within 2H, the largest catches of juvenile Greenland halibut are taken from the shallower water within Hopedale Channel and along the edge of the Labrador Shelf, within 50 – 500 m water depths. Strata 944 – 953 and 955 are found in these areas (Figure 5). It is important to note that these strata account for 78-87% of the abundances and 67-78% of the biomass (Table 2). Figure 9 illustrates that Hopedale Channel is fished extensively for shrimp throughout the year with the maximum and mean Greenland halibut removals of 700 and 20 kg respectively. The offshore shrimp vessels fish along the edge of the Labrador shelf, however, this portion of the fishery results in relatively low Greenland halibut removals.

Both shrimp fishing and Greenland halibut distributions are widespread within 2J. Much of the Greenland halibut bycatch, is taken from Cartwright and Hawke Channels (Figure 7 and Table 3; maximum and mean removals are 660 and 11 kg respectively) during the January – September period. The highest research catches of juvenile fish were taken, from within the channels, at depths shallower than 500 m (Figure 8). Brodie *et al.* (1998) also noted that juvenile

Greenland halibut are found mainly within the channels and to a lesser extent along the shelf edge. The total abundances and biomass estimates from these areas (Figure 6 strata 203, 204, 206, 208, 209, 211, 212, 227, 235, 239 accounting for 42 – 72% of the abundance and 46 – 69% of the biomass). There is fishing along the edge of the Labrador Shelf, however, very low levels of Greenland halibut bycatch are taken along the edge.

The best survey coverage of any of these NAFO divisions has been completed in 3K. The distribution of juvenile Greenland halibut is widespread throughout all years, in waters shallower than 500 m. Most sets that were in deeper water contained older, larger fish (Figure 8). The offshore shrimp fishing vessels fish mainly along the shelf edge where the maximum bycatch and mean bycatches were 53 and 7 Kg respectively. The Hawke Channel and edge fisheries are adjacent to St. Anthony Basin and Funk Island Deep respectively, therefore, it is important to consider the abundances and biomasses of Greenland halibut within these channels. Estimated abundances and biomasses within St. Anthony Basin and Funk Island Deep were 36-50% and less than 40% of the respective totals for the entire division.

Figure 10 illustrates the short-term research abundance and biomass trends for Greenland halibut. These indices appeared stable in 2GH. The 2J and combined divisions abundance plots indicate decreases between 1996 and 1998. Abundances increased slightly during 1999. The 3K abundances similarly decreased between 1996 and 1998 then remained stable during 1999. The biomass within 2J has remained stable throughout the period while the 3K biomass is slightly increasing. These trends extend beyond those provided by Brodie *et al* (1998) which notes that biomass has been increasing since the early 1980's, dropped slightly during 1990-1991 then increased until 1997. The strong 1995 year class (Brodie *et al* 1998) may be followed from 1996 through to 1999 (Figure 11). There were no strong year classes after 1995. The number of 0-group Greenland halibut decreased from 1 billion in 1996 to 220 million during 1998. During 1999, there were an estimated 235 million 0-group fish. It is important to note that no more than 1.5% percent of a cohort was removed by the offshore shrimp fishing fleet during the three year study period (97-99, Figure 11).

The yield per recruit analysis (Figure 12) indicated that if the Greenland halibut stock was being fished at $F_{0.1}$, the fishing mortality would be 0.292 and the yield per recruit would be 0.1994 kg per fish and total losses would be as follows:

Year	Grate size	Potential loss of yield
1997	22 mm	193 tons
	28 mm	161 tons
	combined grates including N.S. data	449 tons
1998	22 mm	97 tons
	28 mm	106 tons
	combined grates including N.S. data	275 tons
1999	22 mm	105 tons
	28 mm	97 tons

These theoretical losses are relatively low and one must take the nature of the losses into account. The 449 tons that are predicted as a loss due to the 1997 shrimp fishery are theoretical losses over the 17 year lifespan of the fish. The potential loss of yield due to grate type does not show a clear trend and can not be distinguished from noise within the data. The removals per unit of unstandardized effort was used as a fourth index to monitor bycatch.

Year effort	Grate size	Effort	Removal	Removal/unit (unstandardized)
1997	22 mm	6365.3 hrs.	97.7 tons	15.3 kg/hr.
	28 mm	8691.1 hrs.	92.2 tons	10.6 kg/hr.
	combined grates including N.S. data	19358.4 hrs.	241.9 tons	12.5 kg/hr.
1998	22 mm	5328.8 hrs.	66.3 tons	12.4 kg/hr.
	28 mm	8865.9 hrs.	77.6 tons	8.8 kg/hr.
	combined grates including N.S. data	19235.5 hrs.	195.5 tons	9.9 kg/hr.
1999	22 mm	6571.2 hrs.	41.4 tons	6.3 kg/hr.
	28 mm	8012.7 hrs.	44.0 tons	5.5 kg/hr.

The amount of effort remained stable during the study period, however, unstandardized removal per unit of effort has decreased, therefore, the decrease in theoretical loss of yield is due to a decrease in removal per unit of effort rather than a decrease in effort. The decrease in removal per unit of effort may have been associated with a shift in fishing patterns or due to a change in length frequency over time. Figure 13 illustrates changes in research length frequencies of Greenland halibut taken from within the channels that are fished extensively for shrimp (plus St. Anthony Basin and Funk Island Deep). As the 1995 year class gets older, the fish become larger and therefore less susceptible to the gear. At the same time, the total estimated abundances of Greenland halibut decreased within these areas (576 million in 1996, 481 million in 1997, to 275 million in 1998 then increased slightly to 342 million during 1999).

In conclusion, a high percentage of the juvenile Greenland halibut population is found within the channels where much of the offshore shrimp fishing effort is expended. Even though the fishing effort has remained stable between 1997 and 1999, the unstandardized removals per unit effort and the potential loss of yield indices have decreased. These decreases correspond to decreases in population sizes at the same time as Greenland halibut are growing thereby reducing their susceptibility to the gear. Because the abundance of juvenile fish has decreased, reducing bycatch beyond the low levels observed in the present study seems appropriate. It should be pointed out that the potential loss of yield is only theoretical. There may be density dependent compensatory effects. Possibly the removal of a portion of the population increases the changes of survival among the rest of the population.

This type of monitoring exercise should be conducted on an annual basis and expanded to include other species to ensure that the fishery is conducted in a precautionary manner. It is also necessary that the study be extended to include the inshore component of the fleet. An attempt was made to include the inshore bycatch, however, the observer coverage was less than 10%. There was not enough information to study. As a result of the low coverage, sampling conducted by the observers may not be representative of inshore fleet activities.

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Table 1. Abundances (000's) and biomass (tons) by stratum of Greenland halibut (*Reinhardtius hippoglossoides*) from fall research surveys by the Teleost and Wilfred Templeman in Div. 2G.

Depth Range (m	Area (nmi2)	Stratum	Abundances (000's) 1996	1997	1998	1999	Biomass (tons) 1996	1997	1998	1999
<=200	2773	909	6755	.	8786	1763	150	.	271	122
	2339	910	826	.	606	2310	24	.	12	136
	1804	925	365	.	.	1563	16	.	.	94
201 - 300	1213	901	14577	6434	.	14239	533	884	.	1628
	585	908	9614	5408	3407	3348	646	609	458	320
	692	911	5009	12246	7241	2130	255	981	544	221
	756	924	4312	6431	.	7217	225	820	.	399
	433	926	1476	1468	.	1237	454	455	.	319
301 - 400	120	902	2432	1002	220	407	322	254	71	110
	73	912	.	899	246	185	.	227	89	67
	186	923	870	974	.	437	200	207	.	82
	832	927	15748	5890	.	10194	7075	1654	.	3565
401 - 500	80	903	.	641	335	299	.	116	131	99
	62	913	.	182	141	47	.	36	40	19
	186	922	.	830	.	422	.	277	.	195
	783	928	15740	8425	.	2908	7412	3182	.	1134
501 - 750	153	904	.	1033	617	558	.	249	265	188
	113	914	.	315	605	241	.	88	225	63
	142	921	.	1391	.	512	.	470	.	130
	1261	929	24827	7168	.	.	6265	2745	.	.
501 - 750	164	905	.	.	1075	729	.	.	720	501
	96	915	.	.	.	.	.	.	.	.
	172	920	.	.	.	.	.	.	.	.
1001 -1250	229	906	.	1017	660	764	.	810	734	815
	146	916	.	.	1306	.	.	.	1092	.
	316	919	.	2457	.	.	.	1952	.	.
1251 -1500	360	907	.	.	.	353	.	.	.	747
	165	917	.	.	.	.	.	.	.	.
	515	918	.	.	.	.	.	.	.	.
Grand total	16749		102552	64211	25244	51863	23576	16016	4652	10953
<=200	6916		7946	.	9392	5636	189	.	283	351
201 - 300	3679		34989	31986	10648	28171	2113	3749	1002	2888
301 - 400	1211		19050	8766	466	11222	7597	2342	160	3824
401-500	1111		15740	10078	476	3677	7412	3611	171	1446
501 - 750	1669		24827	9907	1223	1310	6265	3553	490	381
501 - 750	432		.	.	1075	729	.	.	720	501
1001 -1250	691		.	3474	1966	764	.	2762	1825	815
1251-1500	1040		.	.	.	353	.	.	.	747

. Refers to a stratum that was not sampled

Table 2. Abundances (000's) and biomass (tons) by stratum of Greenland halibut (*Reinhardtius hippoglossoides*) from fall research surveys by the Teleost and Wilfred Templeman in Div. 2H.

Depth Range (m)	Area (nmi2)	Stratum	Abundances (000's) 1996	1997	1998	1999	Biomass (tons) 1996	1997	1998	1999
<=200	1028	930	5732	.	373	716	162	.	97	180
	971	954	2101	.	276	4524	97	.	36	134
	1051	956	723	.	1482	1195	12	.	103	52
	1371	957	596	.	223	1696	16	.	29	46
201 - 300	276	931	6761	683	1091	1237	192	71	181	155
	354	943	5297	2374	1846	2451	351	225	461	250
	261	950	2129	10101	.	1245	290	1434	.	225
	291	953	1368	13105	3160	1536	189	677	634	262
	389	955	53060	5048	1357	1798	1567	363	363	289
	294	958	2135	8795	3287	5220	190	408	279	296
301 - 400	55	932	2550	1313	804	705	134	166	97	109
	860	944	7049	53118	10681	25198	524	5918	2391	3257
	206	949	29457	7391	.	.	3985	839	.	.
	177	952	6391	6708	14938	17019	356	1227	2596	2940
	178	959	1183	4035	2351	718	157	729	708	187
401 - 500	50	933	946	2253	487	281	110	310	107	92
	55	942	266	944	438	269	65	144	106	85
	461	945	10051	20135	5661	18467	1302	2081	1369	3085
	246	948	26794	24482	60457	.	3341	3821	10682	.
	234	951	11846	21110	7033	12457	1737	2684	1396	2544
	107	960	217	1253	1235	534	103	332	390	190
501 - 750	78	934	835	841	603	722	323	204	177	276
	89	941	275	1223	474	1161	82	523	181	378
	721	946	31017	35819	33248	26906	4737	7177	8061	6320
	227	947	10865	14184	16098	8608	2067	2872	4185	2298
	211	961	684	867	787	719	299	229	283	272
751 -1000	96	935	.	767	1281	1304	.	478	519	794
	97	940	455	1358	1132	968	285	673	525	665
	242	962	1584	2464	1671	2394	905	952	1171	1923
1001 -1250	78	936	.	571	1001	.	.	507	942	.
	130	939	742	535	.	791	832	629	.	695
	265	963	1215	2157	672	1306	1060	1960	574	1303
1251 -1500	94	937	.	401	159	.	.	389	208	.
	191	938	263	519	358	755	447	779	635	851
	342	964	447	565	1248	980	860	815	1190	1412
Grand total	11776		225034	245120	175912	143877	26776	39616	40677	31562
<=200	4421		9151	.	2355	8131	286	.	265	411
201 - 300	1865		70749	40107	10740	13486	2779	3178	1918	1477
301 - 400	1476		46630	72565	28774	43640	5157	8879	5792	6493
401 - 500	1153		50121	70177	75312	32007	6658	9372	14051	5995
501 - 750	1326		43677	52935	51210	38116	7509	11005	12887	9543
751 -1000	435		2039	4589	4084	4665	1190	2102	2215	3382
1001 -1250	473		1957	3264	1674	2097	1891	3097	1516	1998
1251 -1500	627		710	1485	1765	1735	1307	1983	2034	2264

. Refers to a stratum that was not sampled

Table 3. Abundances (000's) and biomass (tons) by stratum of Greenland halibut (*Reinhardtius hippoglossoides*) from fall research surveys by the Teleost and Wilfred Templeman in Div. 2J.

Depth Range (m)	Area (nmi2)	Stratum	Abundances (000's) 1996	1997	1998	1999	Biomass (tons) 1996	1997	1998	1999
101 - 200	633	201	2351	218	778	0	86	26	96	0
	1594	205	17162	787	4241	4446	545	36	518	554
	1870	206	42310	5324	4442	5917	1123	423	361	430
	2264	207	1188	551	750	879	58	54	77	193
	733	237	108	36	215	2976	1	4	20	341
	778	238	321	0	642	0	15	0	84	0
201 - 300	621	202	1068	2794	4046	23782	89	159	593	1797
	680	209	17444	4141	1760	43769	1081	427	298	2351
	1035	210	49120	5543	10519	10327	3904	950	1100	654
	1583	213	34860	18629	16380	20131	1366	1207	1995	1521
	1341	214	102676	14876	9981	23206	4057	1342	1546	1970
	1302	215	14274	22605	13163	14328	1258	1460	1912	2119
	2196	228	117123	41478	35510	22163	5709	3793	4518	2728
	530	234	2625	5301	1786	1176	163	765	352	366
301 - 400	487	203	5996	20366	28342	22045	959	2381	3362	2894
	588	208	75750	123723	34166	67095	3707	12765	6911	11101
	251	211	16642	17346	4182	24371	1343	1967	926	3881
	360	216	2351	4434	5748	3344	522	1148	1736	976
	450	222	12382	5369	1857	2410	1782	986	394	801
	536	229	15100	7100	14152	3500	3948	1994	2543	1286
401 - 500	288	204	26841	63672	51944	23524	3823	8187	6320	4202
	241	217	3699	2405	1977	2246	958	721	639	751
	158	223	1927	1113	1734	1316	447	453	603	525
	598	227	36195	37336	7664	47399	6194	9860	1841	13483
	414	235	26827	44193	14670	19226	4630	8922	3473	4606
	133	240	1654	1425	683	1591	554	534	255	685
501 - 750	557	212	26022	47403	12436	52634	5162	11451	4546	15410
	362	218	5951	3316	3296	2629	1783	1255	1350	1191
	228	224	2023	1336	989	686	702	650	425	331
	185	230	3153	4139	1400	4723	1380	1665	547	2379
	120	239	19473	23350	38586	36598	2660	2899	5173	4335
751 -1000	283	219	583	2325	3758	2367	431	1842	2399	1495
	186	231	1663	1180	3610	3002	1013	668	1724	1860
	193	236	850	538	1077	1614	698	406	750	1181
1001 -1250	303	220	1751	689	1032	.	1296	537	1240	.
	195	225	899	573	590	663	888	706	655	490
	228	232	643	786	793	2860	717	997	666	2168
1251 -1500	330	221	78	993	425	339	131	1329	730	605
	201	226	148	236	1129	518	294	434	1377	633
	237	233	359	365	581	574	889	636	563	446
Grand total	25272		691588.2	537992.5	341034.9	500374.6	66364.96	86039.31	64617.17	92737.37
101 - 200	7872		63440	6915	11068	14218	1828	543	1156	1518
201 - 300	9288		339190	115367	93145	158882	17626	10103	12314	13506
301 - 400	2672		128221	178338	88448	122765	12260	21240	15871	20938
401 - 500	1832		97144	150143	78671	95301	16606	28678	13131	24251
501 - 750	1452		56622	79544	56707	97270	11686	17920	12041	23646
751 -1000	662		3095	4043	8445	6983	2142	2916	4873	4536
1001 -1250	726		3292	2048	2415	3524	2901	2240	2561	2658
1251 -1500	768		585	1594	2135	1431	1315	2399	2670	1684

. Refers to a stratum that was not sampled

Table 4. Abundances (000's) and biomass (tons) by stratum of Greenland halibut (*Reinhardtius hippoglossoides*) from fall research surveys by the Teleost and Wilfred Templeman in Div. 3K.

Depth Range (m)	Area (nmi2)	Stratum	Abundance (000's) 1996	1997	1998	1999	Biomass (tons) 1996	1997	1998	1999
101 - 200	798	608	0	312	117	.	0	47	39	.
	445	612	0	914	0	.	0	144	0	.
	250	616	0	37	128	.	0	5	24	.
	1347	618	236	93	148	132	20	11	16	1
	1753	619	448	462	0	129	30	59	0	0
201 - 300	342	609	876	1606	609	.	122	411	204	.
	573	611	465	1429	607	.	113	283	167	.
	251	615	249	460	832	.	41	72	187	.
	2545	620	50857	11258	8466	9385	4256	1345	1192	1455
	2537	621	42420	14884	15498	4226	4142	1380	2647	915
	1105	624	44516	16682	18741	15661	2677	1690	1823	1934
	1555	634	29370	19688	12319	11050	2443	2261	1365	2062
	1274	635	11915	18547	12081	7440	1399	1635	1315	1036
	1455	636	27698	10123	5711	5871	2449	1232	1087	1069
	1132	637	11280	6274	11372	5357	1752	883	2131	1235
301 - 400	256	610	2239	4865	7628	.	350	672	1708	.
	263	614	1389	3222	984	.	157	425	196	.
	593	617	48930	42462	22980	18769	2828	5270	4049	3043
	494	623	53141	23648	34072	24065	3671	1957	6548	3569
	888	625	71406	29873	40024	29343	4510	3248	4203	6945
	1113	626	63597	141396	67513	94231	5622	10968	10024	20484
	1085	628	11654	27841	13225	31294	1856	2832	3189	10957
	495	629	55777	20047	39476	37660	6630	2324	6628	6294
	332	630	34027	34539	13056	26818	5120	3478	1665	5455
	2067	633	32400	48302	17130	40492	3579	6935	4363	8181
	2059	638	45105	47811	40329	9689	4017	7226	8430	2565
	1463	639	9662	9839	4835	3774	1440	1660	1327	1173
401 - 500	30	613	474	1577	562	.	54	192	94	.
	691	622	137549	109680	65482	79607	7110	12499	10554	14262
	1255	627	122016	217601	165915	180779	16275	23211	26857	51358
	1321	631	168694	101004	68576	84804	26508	15181	14343	19959
	69	640	400	152	104	66	111	63	37	39
	216	645	629	397	225	178	193	164	79	114
	134	650	654	718	511	95	147	251	238	36
501 - 750	230	641	1111	371	912	2136	408	210	373	1118
	325	646	1369	2501	358	210	583	1257	168	88
	359	651	871	2770	2871	1684	333	1446	1084	851
751 -1000	418	642	1257	3402	4569	4773	811	2179	2680	3081
	360	647	1411	3645	5863	3856	749	2161	3159	2337
	516	652	6788	5170	10728	4933	3686	2681	4966	3246
1001 -1250	733	643	2402	9716	8772	4403	2262	7285	5658	3480
	228	648	1877	1607	2526	2550	1727	1158	1799	1588
	531	653	2966	2264	6467	6426	2389	1746	3904	4376
1251 -1500	474	644	602	2017	2808	1695	900	2172	2964	1480
	212	649	171	1167	218	622	413	1156	301	676
	479	654	1037	4403	6109	3839	1061	3825	4808	3479
Grand total	37051		1101933	1006774	741457	757841	124741	137288	148591	189939
101 - 200	4593		684	1817	394	260	50	264	79	2
201 - 300	12769		219645	100952	86235	58990	19393	11193	12118	9705
301 - 400	11108		429327	433845	301251	316135	39579	46996	52329	68666
401 - 500	3716		430416	431128	301375	345529	50398	51560	52203	85768
501 - 750	914		3350	5642	4141	4030	1324	2913	1625	2057
751 -1000	1294		9457	12216	21161	13562	5246	7020	10805	8664
1001 -1250	1492		7245	13587	17765	13378	6378	10188	11360	9444
1251 -1500	1165		1810	7587	9135	5957	2374	7152	8073	5635

. Refers to a stratum that was not sampled

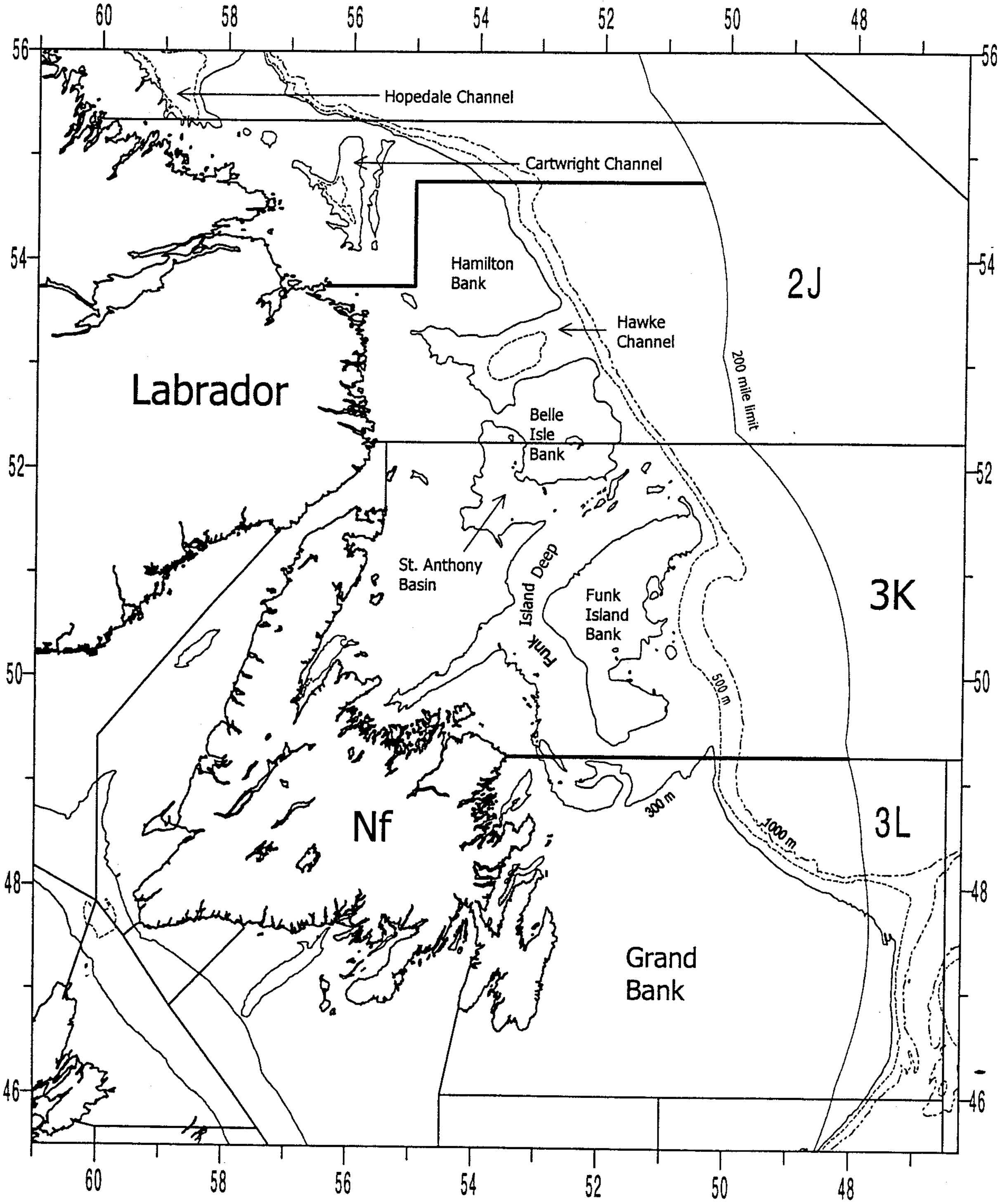

Figure 1. NAFO divisions 2GHJ3K indicating the positions of Hopedale, Cartwright and Hawke Channels.

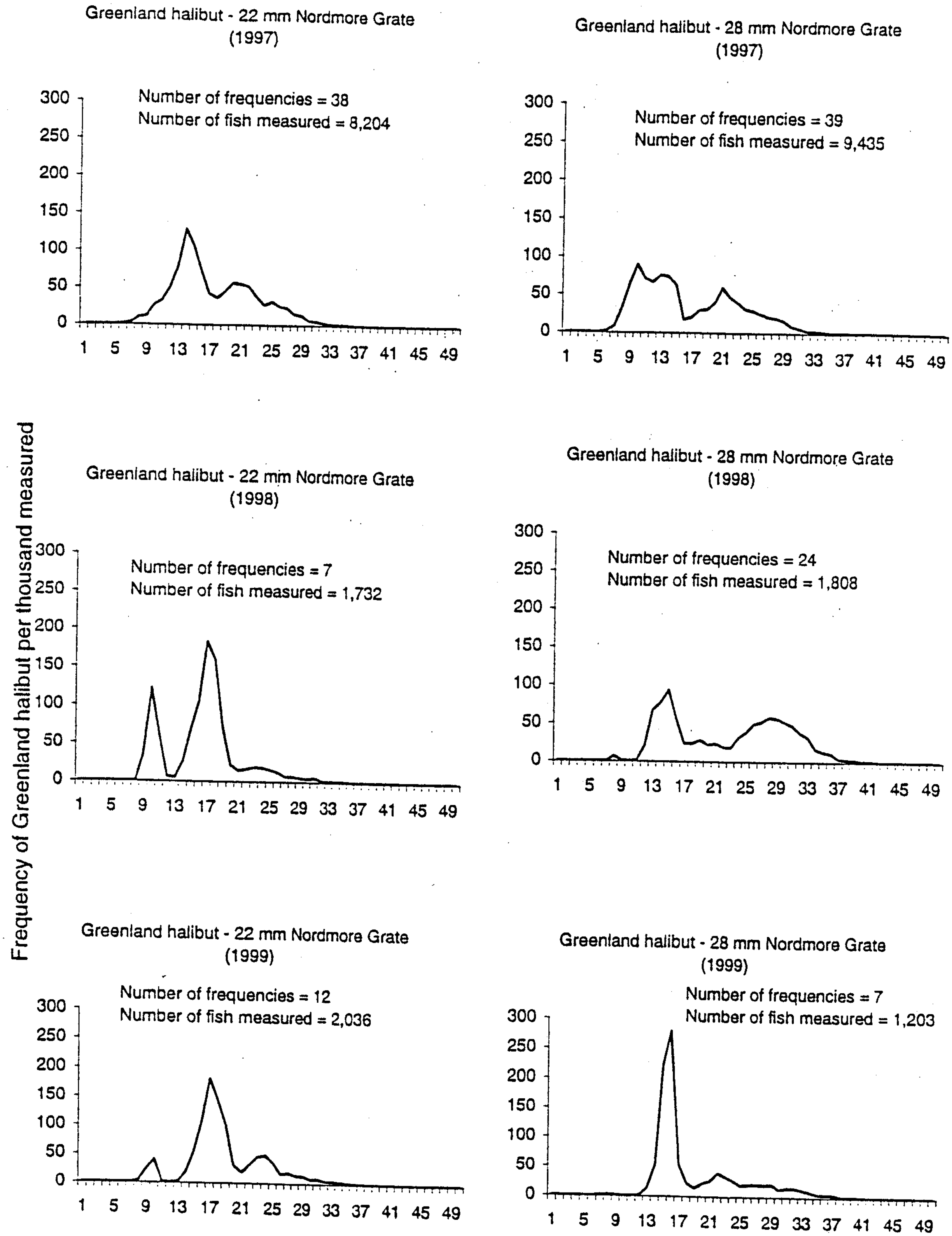

Figure 2. Length frequencies of Greenland halibut collected during the period 1997-1999 by offshore shrimp (>500 ton) vessels.

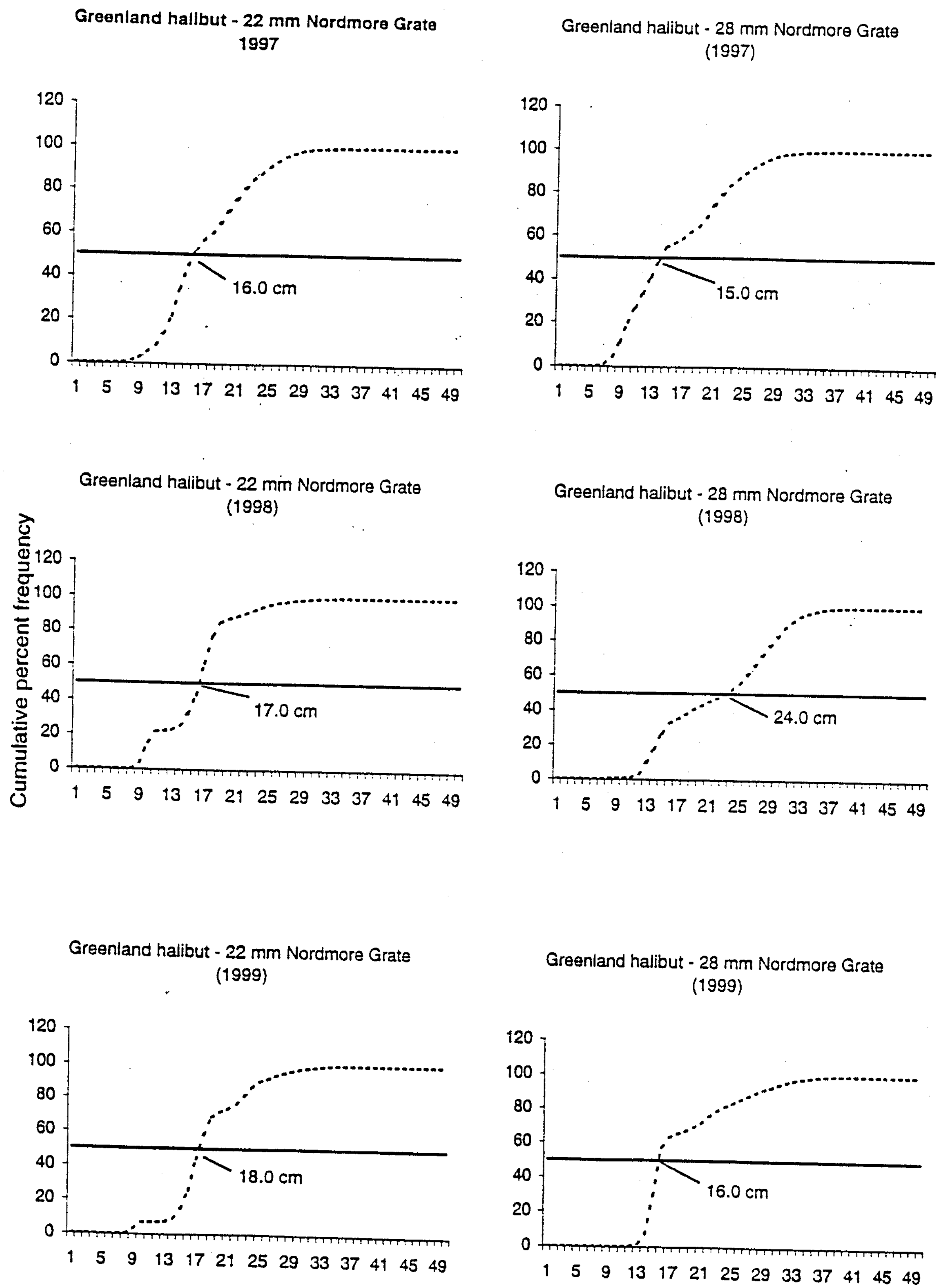

Figure 3. Cumulative percent frequencies of Greenland halibut passing through 22 and 28 mm Nordmore Grates during the period 1997 - 1999. LC_{50} values are indicated.

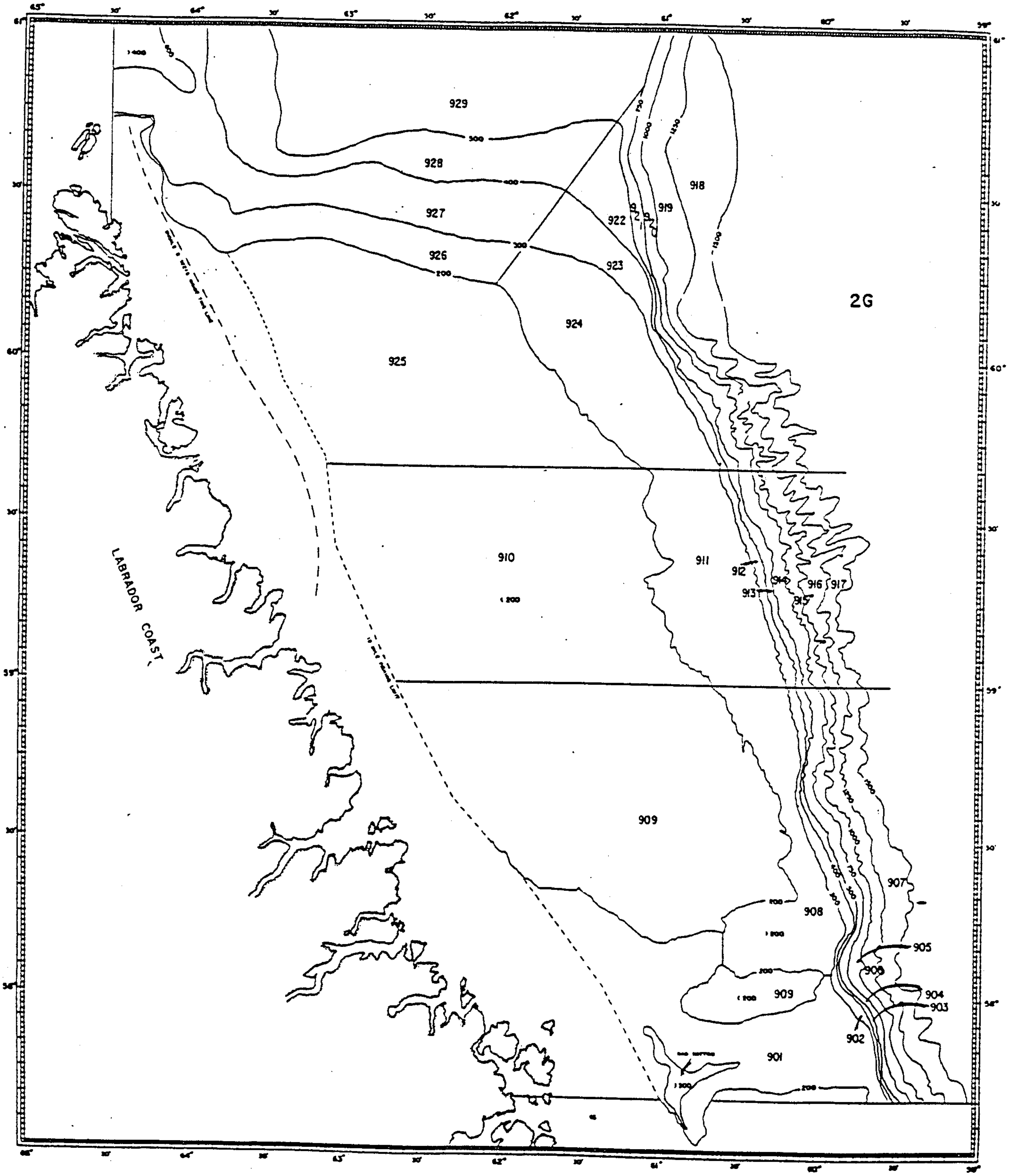

Figure 4. NAFO division 2G stratum boundary map.

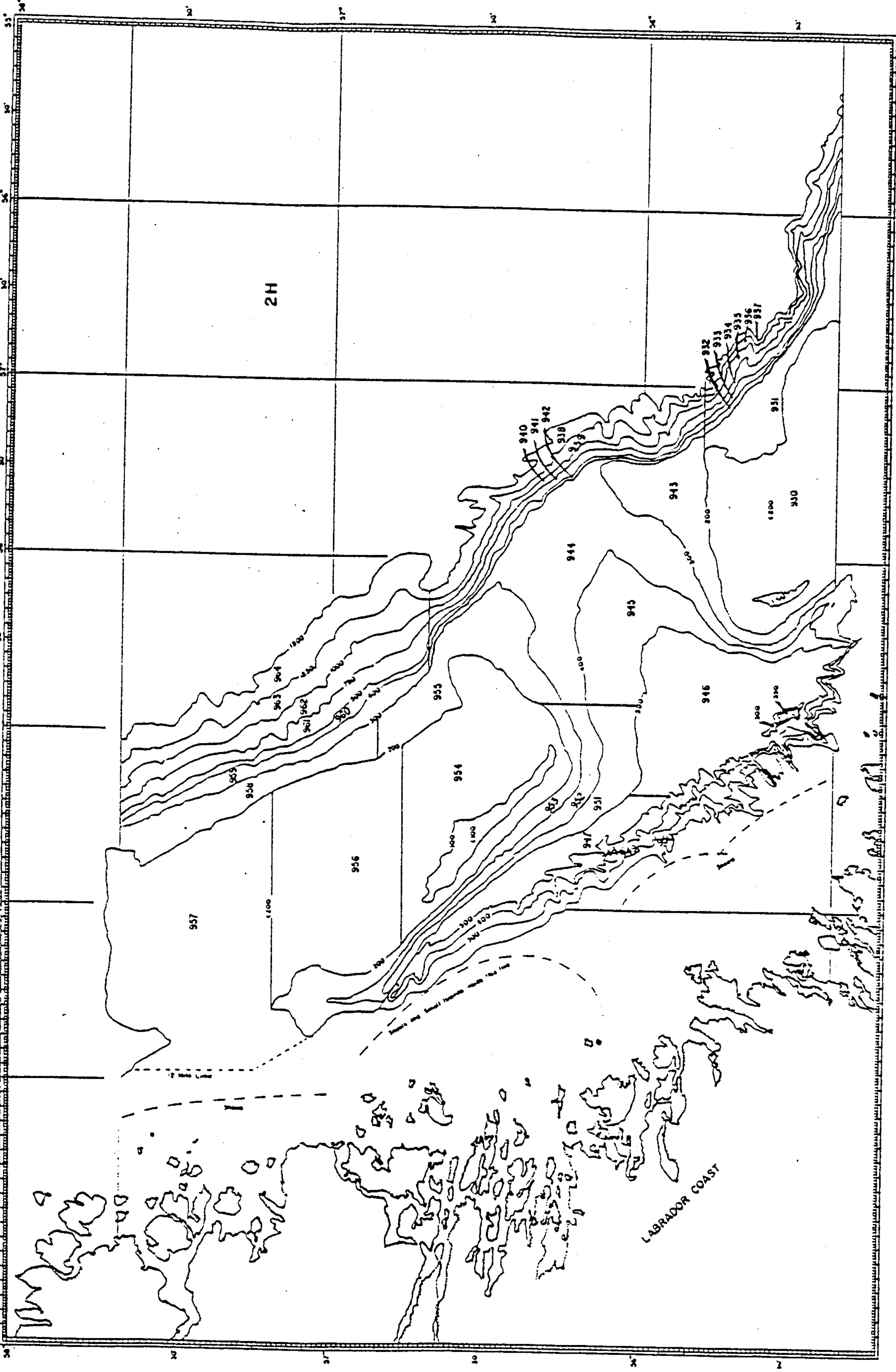

Figure 5. NAFO division 2H stratum boundary map.

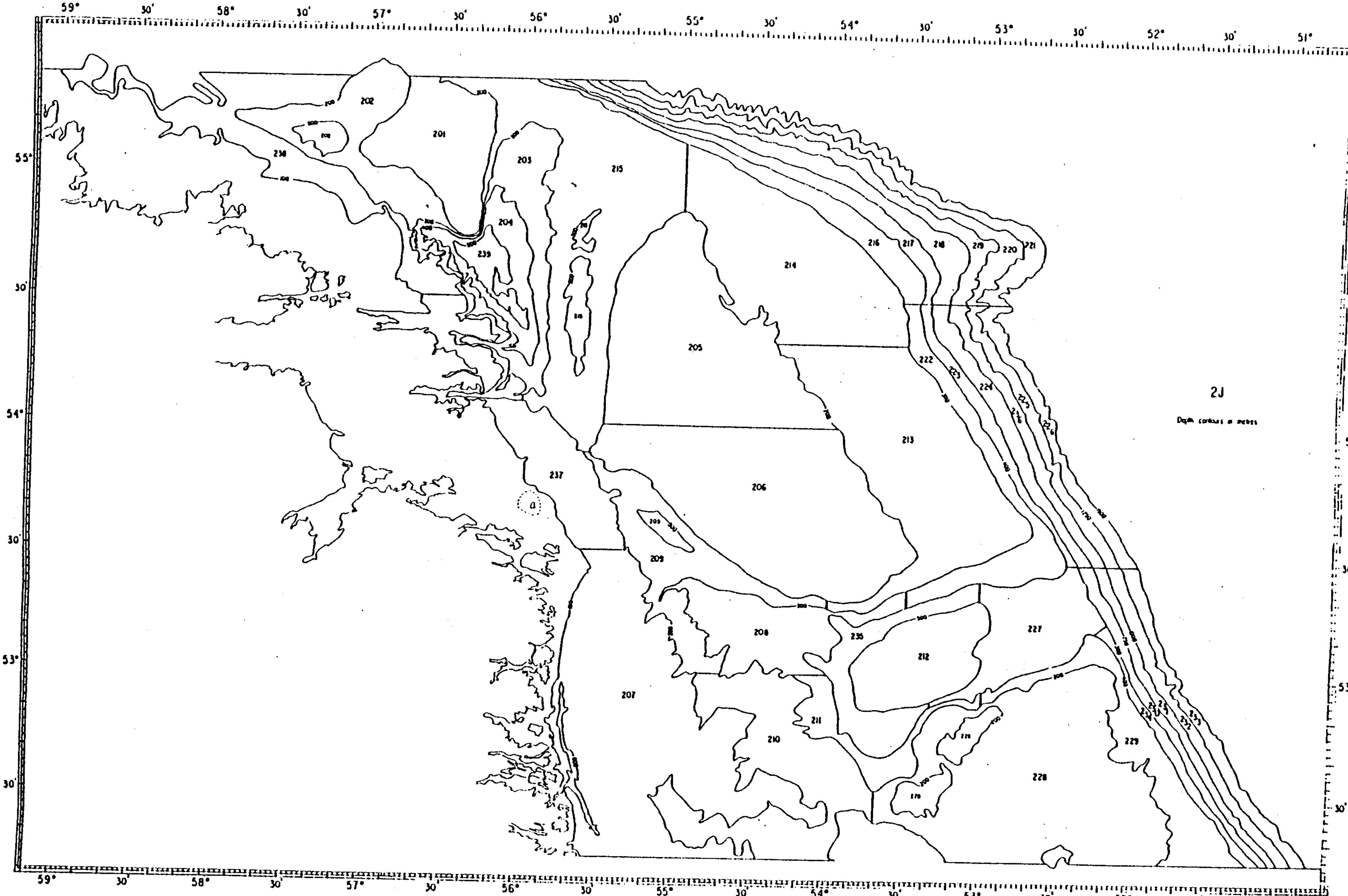

Figure 6. NAFO division 2J stratum boundary map.

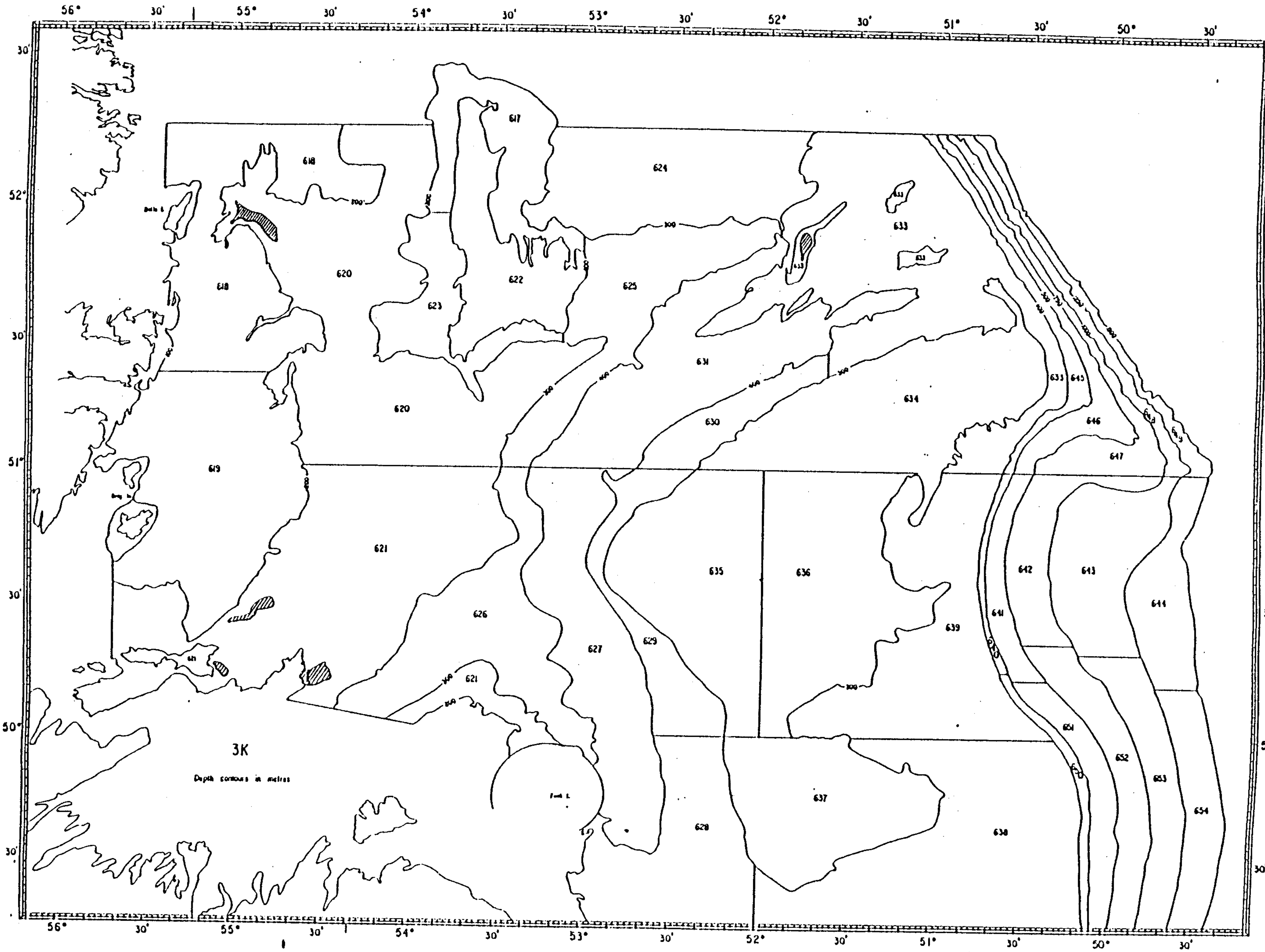

Figure 7. NAFO division 3K stratum boundary map.

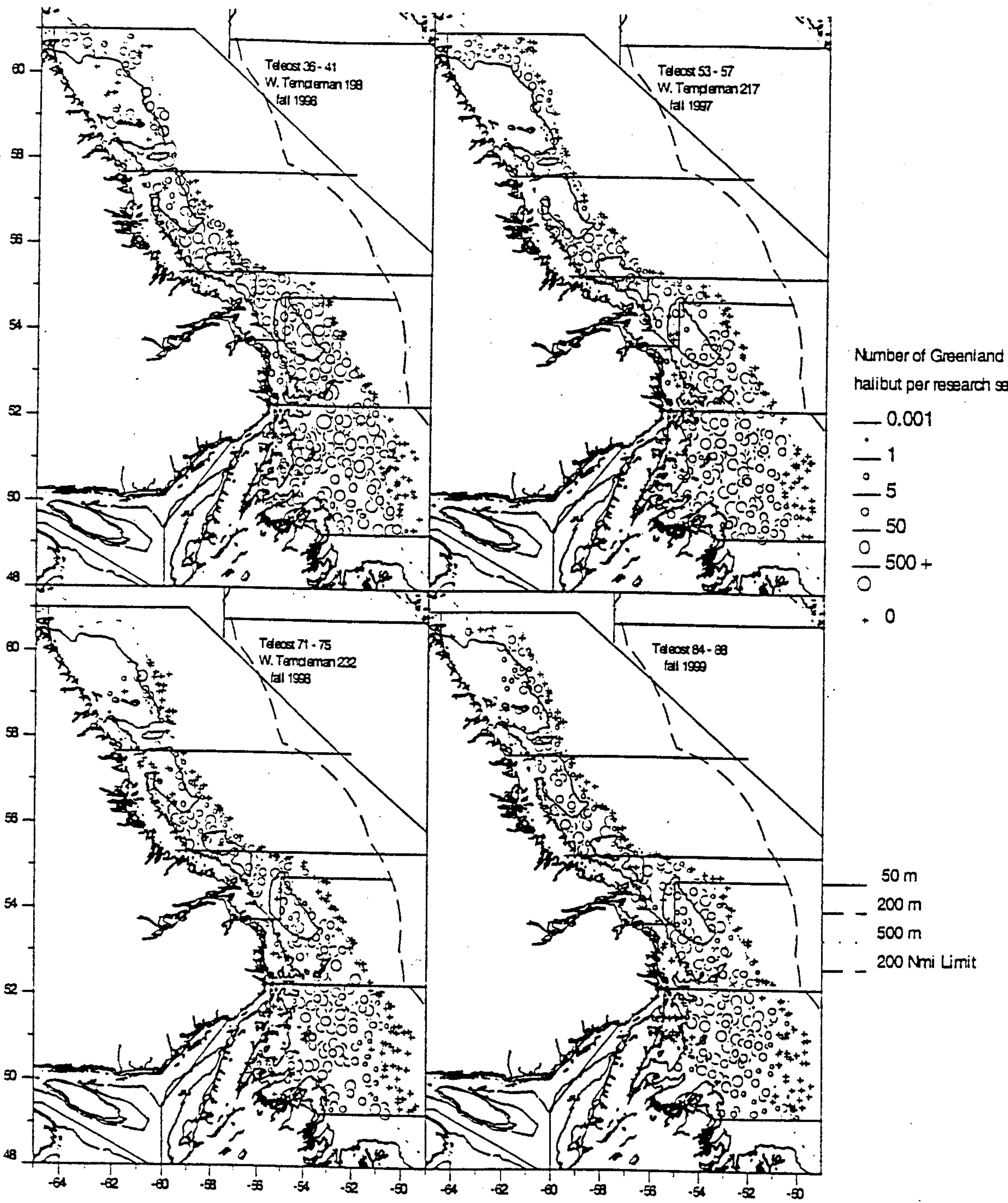

Figure 8. The distribution of juvenile (<=24 cm total length) Greenland halibut collected during the 1996 - 1999 Canadian fall multi-species research surveys by the Teleost and the) Wilfred Templeman. (Tows standardized to 15 min.)

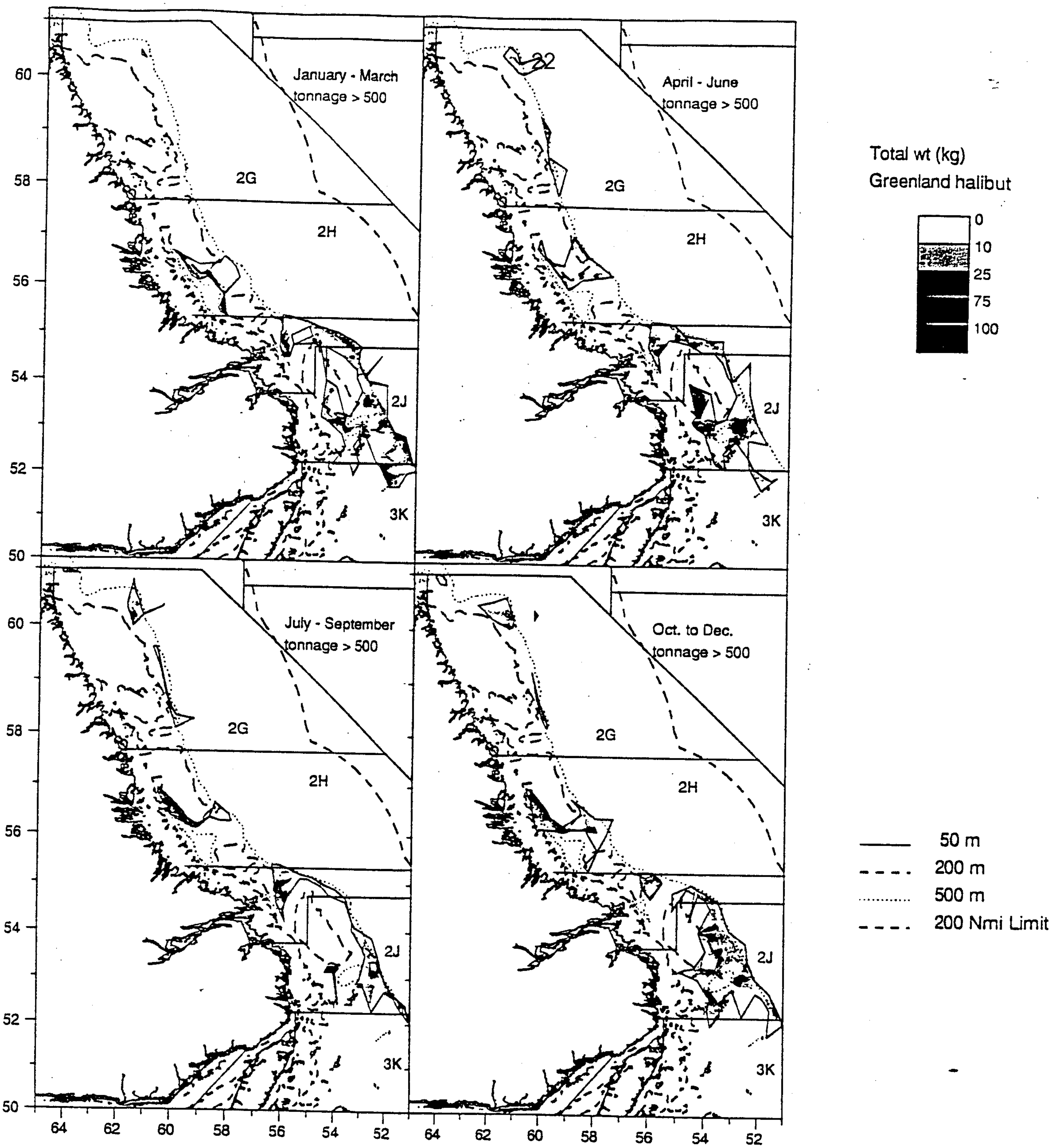

Figure 9. Seasonality of Greenland halibut bycatch within the 1997-1999 NAFO divisions 2GHJ3K offshore shrimp (>500 ton) fishery.

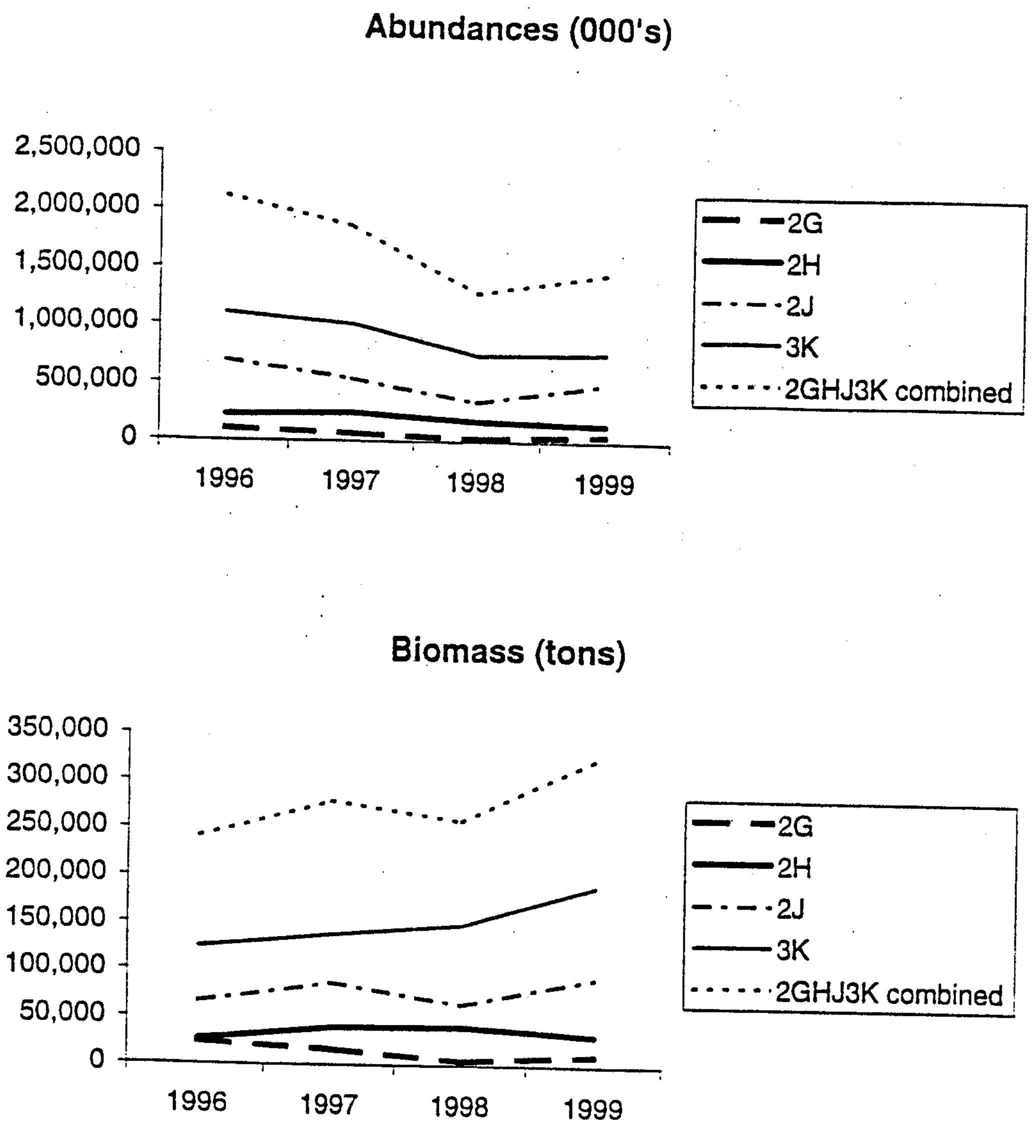

Figure 10. A summary of the Greenland halibut abundance (000's) and biomass (ton) estimates for 1997 - 1999 derived by areal expansion from the Canadian fall multi-species research surveys.

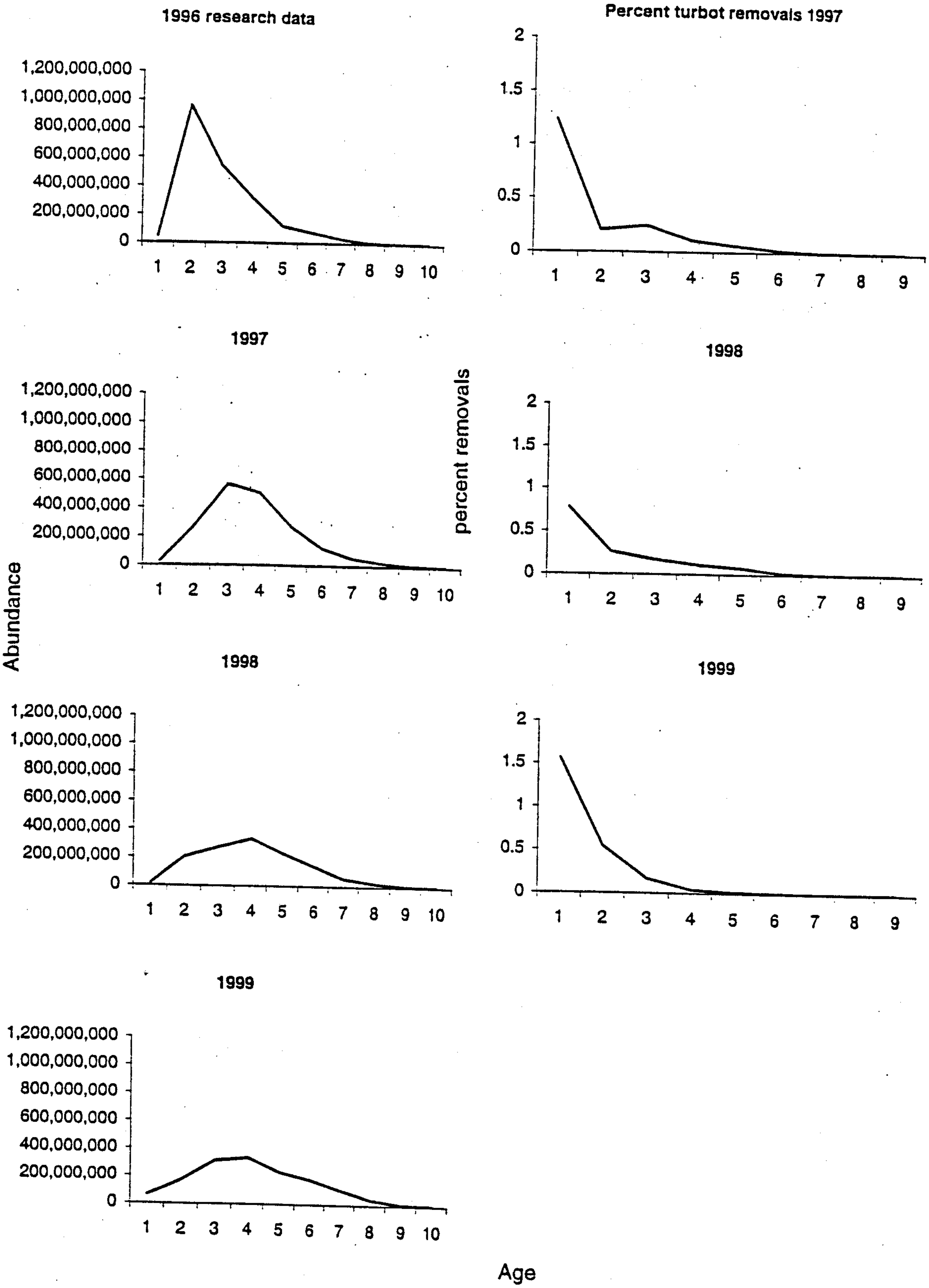

Figure 11. A comparison between Canadian fall research multi-species survey abundance at age estimates and the corresponding percent removal at age by the offshore shrimp (>500 ton) fishery.

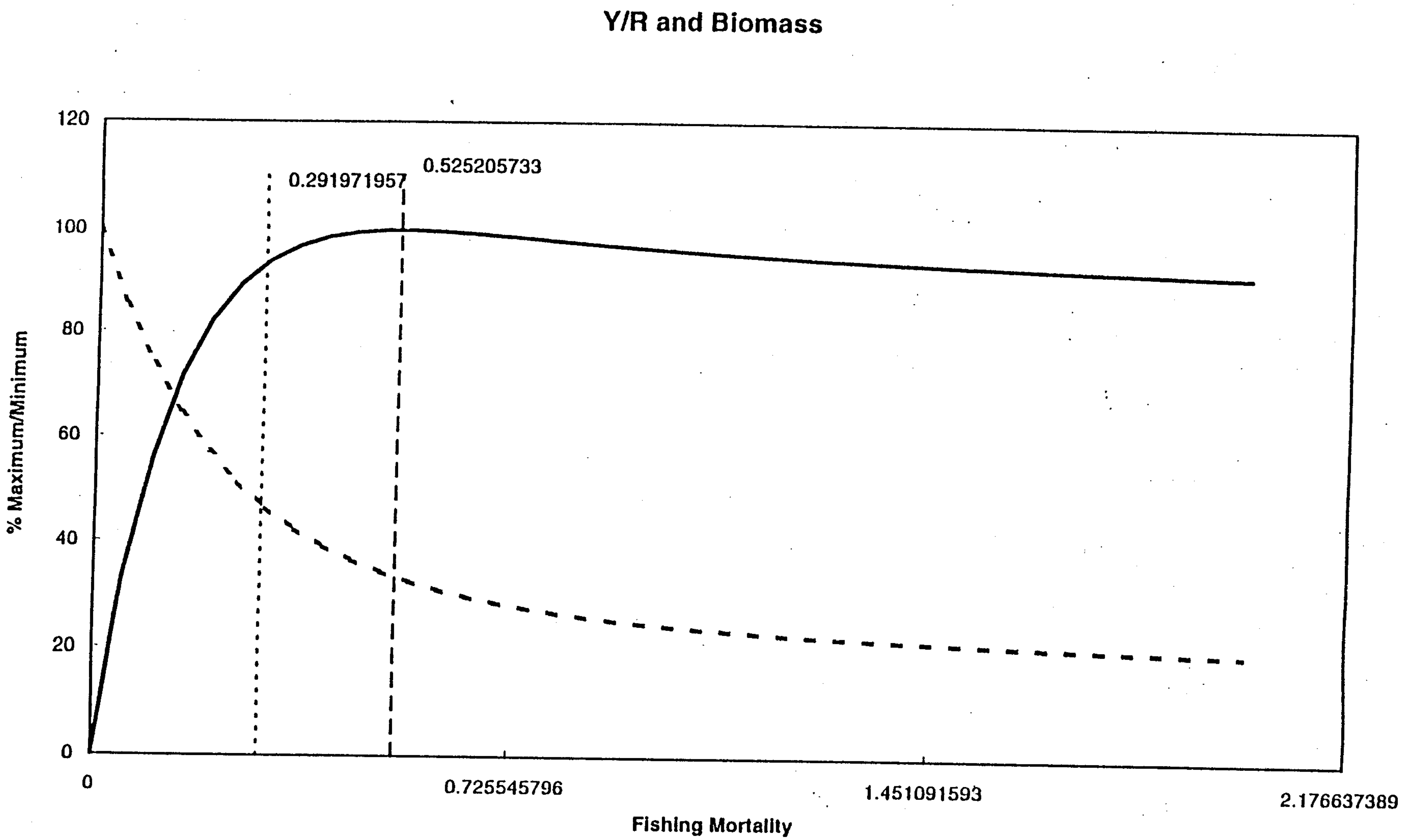

Figure 12. A plot of the Greenland halibut yield per recruit output under various fishing mortality scenarios.

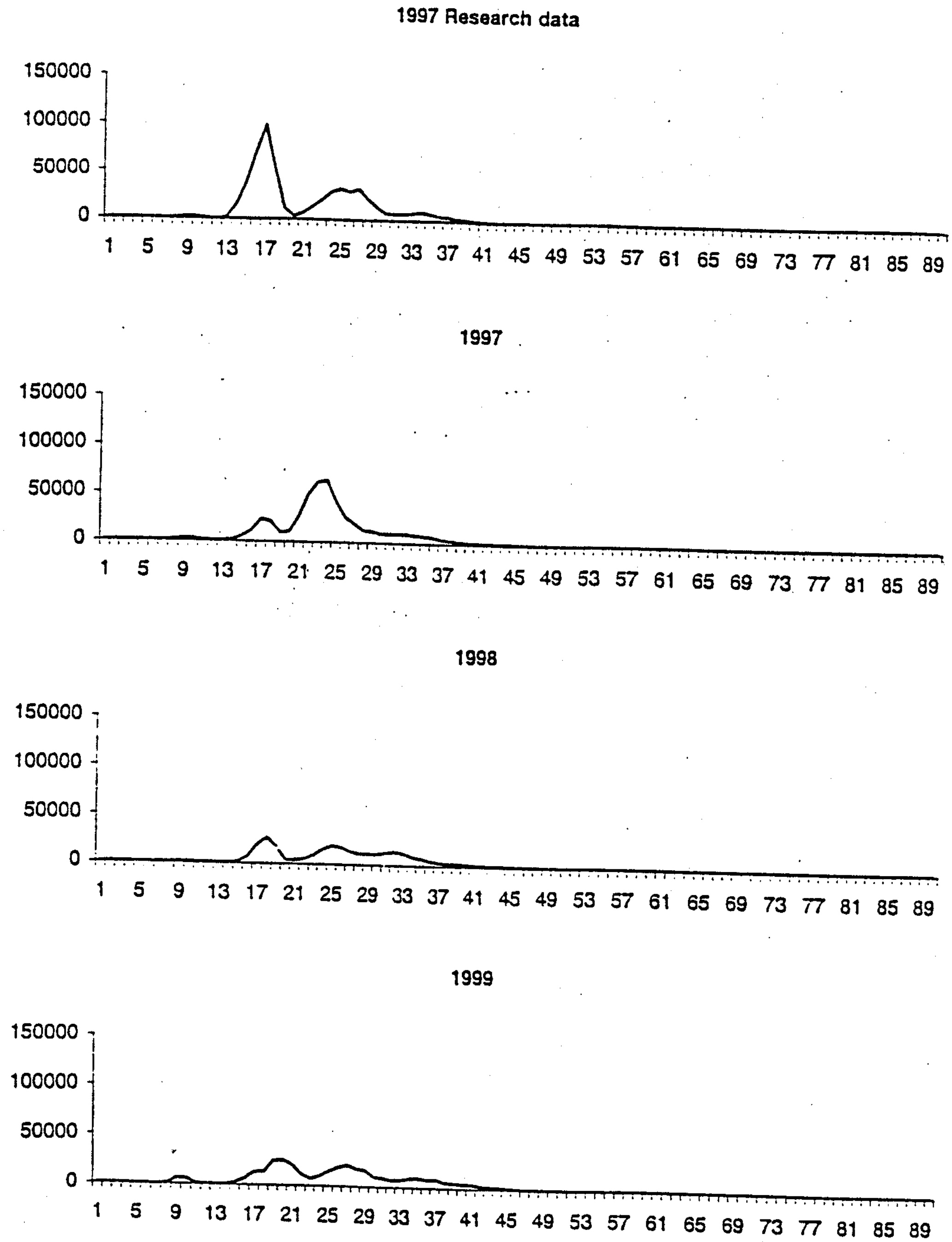

Figure 13. Greenland halibut population estimates at length produced from Canadian fall multi-species research data. The data were from Saglek Bay, Hopdale Channel, Cartwright Channel, Hawke Channel, St. Anthony Basin and Funk Island Deep.