NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N5028 **NAFO SCR Doc. 04/67**

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2004

By-Catch of Greenland Halibut (*Reinhardtius hippoglossoides*, Walbaum) in the Canadian Fishery for Northern Shrimp (*Pandalus borealis*, Koyer) in NAFO Subarea 2 and Divisions 3KL

W.R. Bowering and D.C. Orr

Department of Fisheries and Oceans, Science, Oceans and Environment Branch
NW Atlantic Fisheries Center, P.O. Box 5667
St. John's, NF, Canada, A1C 5X1

ABSTRACT

The Canadian fishery for Northern shrimp in NAFO Subarea 2 and Divisions 3KL has been increasing substantially in recent years and by 2003 has reached a catch of about 115 000 tons. Since young Greenland halibut and Northern shrimp overlap in distribution, Greenland halibut is one of the most important species taken as by-catch in the Northern shrimp fishery. The most recent assessment of Greenland halibut indicates that the resource has been declining over the last several years and is now at its lowest observed population size since 1975. Therefore, concerns have been raised regarding the potential effect on stock recovery from by-catch of Greenland halibut in the Northern shrimp fishery. This paper estimates removals at age of Greenland halibut in the Canadian fishery for Northern shrimp in NAFO Subarea 2 and Div. 3KL during 1996-2003. Results indicate that during this period less than 5% of an average year-class of Greenland halibut was taken as by-catch in the Northern shrimp fishery. This suggests a potential loss in yield to the Greenland halibut fishery of about 900-1 400 tons annually given recent fishing patterns.

INTRODUCTION

The Northern shrimp (*Pandalus borealis)* fishery off Labrador and Northeastern Newfoundland began during 1977 when large vessels (>500 t; LOA>100') harvested approximately 2 700 tons of shrimp in the deepwater channels off Labrador (NAFO Div. 2JH – Shrimp Fishing Area 5 (Fig. 1)). Total Allowable Catches (TACs) were introduced for NAFO Div. 2GHJ and 3K the following year (Table 1; Fig. 2), at which time the area was divided into management units called Shrimp Fishing Areas (SFAs). SFAs 4, 5 and 6 correspond to the following geographic areas: Division 2G, Hopedale and Cartwright Channels and Hawke Channel –Div. 3K, respectively (Fig. 1). TACs were cautiously increased in a stepwise fashion over the years and the fishery expanded both northward and southward. Catch and TAC trends were similar (Tables 1 and 2; Fig. 2).

During the early- to mid-1990s, many groundfish stocks came under moratoria and shrimp biomass increased off the coasts of Labrador and Northeastern Newfoundland. These resulted in the development of a small vessel (<500 t; LOA<100') shrimp fishery.

Presently the small vessel fleet consists of approximately 300 vessels while the large vessel fleet consists of approximately 12 vessels.

A NAFO regulated shrimp fishery began in Div. 3LNO during 2000. At that time a 6 000 ton quota was established and fishing was restricted to Div. 3L, at depths greater than 200 m. Canadian vessels were allotted 5 000 tons of shrimp in the EEZ while the international fleet was given a 1 000 ton quota to be fished in the NRA. As a result of biomass increases since 1999, Scientific Council (SC) subsequently recommended that the TAC for shrimp in Div. 3L should increase to 13 000 tons for the period 2003-2005.

Given the considerable expansion of the fishery, the total catch and TAC by 2003 had reached 115 000 tons and 143 000 tons, respectively (Tables 2 and 1; Fig. 2)

Throughout all areas, the international and Canadian fishers make use of small mesh (40 mm) shrimp nets. As a result of using small mesh nets, there is a relatively high risk of incidental capture of small fish. In order to decrease the impact of shrimp fishing upon small fish, license conditions require large vessels fishing in SFAs 4-6 to use sorting grates with a minimum bar spacing of 28 mm. In NAFO Div. 3L all vessels must use sorting grates with a minimum bar spacing of 22 mm.

The most recent assessment of Greenland halibut indicates that the resource has been declining over the last several years and is now at its lowest observed population size since 1975. Therefore, concerns have been raised regarding the potential effect on stock recovery from by-catch of Greenland halibut in the Northern shrimp fishery. Since young Greenland halibut and Northern shrimp overlap in distribution, Greenland halibut is one of the most important species taken as by-catch in the Northern shrimp fishery.

The purpose of the present paper is to determine the impact that the Canadian shrimp fishery has upon the recovery of Greenland halibut stock in terms of numbers caught as by-catch relative to population size and potential loss in future yield to the Greenland halibut fishery.

METHODS AND MATERIALS

Data used in this report were obtained from the Canadian Observer database and catches as recorded within the Canadian Atlantic Quota Report. An attempt was made to observe 100% of the Canadian large vessel and 10% of the Canadian small vessel catches. Greenland halibut by-catch is recorded to 1 kg precision for all observed fishing sets. Wherever possible, sexed length frequencies (1 cm precision) were taken from randomly collected samples of Greenland halibut. Using a ratio of weight of fish measured to by-catch weight, the length frequencies were corrected on a set by set basis. Length frequencies were added together and an average length frequency distribution per kg of by-catch was produced and then merged with the catch records. The average frequencies were multiplied by by-catch weights to produce length frequencies on a set by set basis. Thus it was possible to estimate length frequencies for sets that were not sampled. The length frequencies were aggregated to obtain total removals by species, year and size of vessel.

By-catch at age was derived by applying the by-catch length frequencies to population adjusted age length keys from the previous autumn Canadian research bottom trawl survey conducted in the same areas. For illustration, the removals at age by year are shown separately for Div. 2GH, large vessels in Table 3; Div. 2J and 3K, large and small vessels in Tables 4 and 5; and Div. 3L, large and small vessels in Tables 6 and 7. The combined removals at age for all areas investigated during 1996-2003 are provided in Table 8. For ease of comparison, plots of the catch at age between large and small vessels is shown for Div. 2J and 3K separately and combined in Fig. 3 and 4, respectively.

RESULTS AND DISCUSSION

Although sorting grates are required by licence in the Canadian fishery to reduce as much as possible the by-catch of finfish many Greenland halibut are caught in most years up to age 9 although the bulk of the by-catch is at ages 1-3 (Tables 3-8; Fig. 3 and 4). Since many Greenland halibut young of the year go demersal in the early autumn and the small boat shrimp fishery operates until late in the year some Greenland halibut caught as by-catch are 0-Group (Table 8; Fig. 3).

The estimated number of Greenland halibut caught in the Canadian shrimp fishery (all ages) in Subarea 2 and Div. 3KL during 1996-2003 ranged from 3.0 million fish to 5.2 million fish (Table 8; Fig. 5). Removals by year-class over the years they are taken as by-catch indicate a similar range in number. There has been an increasing trend in by-catch since 1996 (Fig. 5), which might be expected given that the shrimp catch is increasing (Table 2; Fig. 2).

The most recent assessment of the Greenland halibut resource estimates average recruitment (age 1) to be about 119 million fish (Darby *et al*., 2004). This would suggest that the Canadian shrimp fishery during the period investigated is removing, on average, less than 5 % of any one year-class of Greenland halibut as by-catch.

Assuming the same selection pattern, weights (kg) at age, natural mortality (M = 0.20) and a fishing mortality of F=0.40, the potential loss in yield to the Greenland fishery because of by-catch in the Canadian fishery for Northern shrimp was estimated to range from 900-1 400 tons annually since 1996 (Table 8).

Acknowledgements

The authors would like to acknowledge the help of Dr. Peter Shelton in evaluating the yield per recruit considerations.

References

Darby, Chris, Brian Healey, Jean-Claude Mahe, and W. R. Bowering. 2004. Greenland Halibut (*Reinhardtius hippoglossoides*) in Subarea 2 and Divisions 3KLMNO: An Assessment of Stock Status Based on Extended Survivors Analysis, ADAPT, and ASPIC Analysis, with Stochastic Projections of Potential Stock Dynamics. *NAFO SCR Doc*., No. 55, Serial No. N5008, 53 p.

Table 1 Quotas of Northern shrimp (*Pandalus borealis*) by Shrimp Fishing Area (SFA), 1978 - 2003.

YEAR	DIV 2G	HOPE	CART	HAWKE	DIV 3K	DIV 3L	TOTAL
	SFA4	SFA5		SFA6		SFA7	
1978	500	4500	800	800	500		7100
1979	500	3200	800	1750	500		6750
1980	500	4000	800	850	500		6650
1981	500	4000	800	850	500		6650
1982	500	4000	800	850	500		6650
1983	500	4000	800	850	500		6650
1984	500	3500	700	850	500		6050
1985	500	2800	770	850	500		5420
1986	500	3400	1000	850	1200		6950
1987	500	4000	800	1500	1500		8300
1988	500	4000	800	1500	1500		8300
1989	2580	4400	1600	2000	3600		14180
1990	2580	4400	1600	2000	3600		14180
1991	2635	4760	1615	2210	2091		13311
1992	2635	4760	1615	3910	3655		16575
1993	2735	4760	1615	3846	5334		18290
1994	4000	7650		11050			22700
1995	5200	7650		11050			23900
1996	5200	7650		11050			23900
1997	5200	15300		23100			43600
1998	8320	15300		46200			69820
1999	8320	15300		58632			82252
2000	8320	15300		60908		4191	88719
2001	8359	15300		61623		5000	90282
2002	8320	15300		61632		5000	90252
2003	14242	33084		85575		10833	143734

Table 2 Nominal catches (tons) of Northern shrimp (*Pandalus borealis*) by Shrimp Fishing Area (SFA), 1977 - 2003.

YEAR	DIV 2G	HOPE	CART	HAWKE	DIV 3K	DIV 3L	TOTAL
	SFA4	SFA5		SFA6		SFA7	
1977	-	1272	1414	<1	<1	-	2686
1978	-	2109	1521	-	-	-	3630
1979	3	2693	1034	5	-	-	3735
1980	<1	3938	170	-	-	-	4108
1981	2	3382	67	135	-	-	3586
1982	5	1829	154	<1	-	-	1988
1983	30	997	3	-	-	-	1030
1984	-	712	290	-	-	-	1002
1985	-	1687	2	-	-	-	1689
1986	2	3498	1328	-	-	-	4828
1987	7	4538	1418	1678	167	-	7808
1988	1083	6584	1254	3747	4102	-	16770
1989	3842	4329	1656	1855	4807	-	16489
1990	2945	3769	1591	1929	3669	-	13903
1991	2561	4501	1617	1976	3524	-	14179
1992	2706	4680	1635	3015	3594	-	15630
1993	2723	4273	1446	3672	4363	-	16477
1994	3982	7499		10978		-	22459
1995	5104	7616		10914		-	23634
1996	5160	7383		10923		-	23466
1997	5217	15103		21246		-	41566
1998	8051	15170		46337		-	69558
1999	7884	15109		51202		-	74195
2000	7529	14729		63796		4111	90165
2001	8116	15116		52656		4986	80874
2002	8393	15332		60198		5417	89340
2003	12823	26750		64391		10685	114649

Table. 3 Greenland halibut by-catch in the large vessel shrimp fishery in Divisions 2GH during 1996-2003.

	Estimated number at age (yrs)							
Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
SFA 4+5 shrimp logbook catch (tons)	12543	20319	22745	22556	22499	22992	23000	26350
SFA 4+5 shrimp observed catch (tons)	9313	15327	15208	17430	17115	16748	17567	21342
Correction factor	1	1	1	1	1	1	1	1
Div. 2GH shrimp observed catch (tons)	4898	9951	7964	10102	9355	9485	9910	15108
Div. 2GH shrimp corrected catch (tons)	6596	13193	11912	13072	12298	13021	12975	18653
Observed G. halibut bycatch (tons)	14	109	25	34	18	13	25	32
Corrected G. halibut bycatch (tons)	19	145	38	44	23	18	33	40
Number of G. halibut measured	1064	15087	6033	6823	6193	3195	2870	6198
Kg. of G. halibut/ ton shrimp	3	11	3	3	2	1	3	2
Ages								
1	29808	681227	101471	61305	20,964	65352	157703	376875
2	118183	778284	302237	660390	125,304	288658	301880	448479
3	80986	792589	170067	180897	137,720	77160	105683	133942
4	32341	256867	75825	66918	36,650	18321	34310	29237
5	10350	66507	45857	23001	19,576	6136	23110	13248
6	5081	22689	7464	3499	3,257	659	5282	1496
7	372	1337	278	163	371	8	424	68
8	0	12	0	3	26	0	10	0
Grand total	277121	2599512	703198	996176	343869	456295	628404	1003345

Table. 4 Greenland halibut by-catch in the large vessel shrimp fishery in Divisions 2J3K during 1996-2003.

	Estimated number at age (yrs)							
Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
SFA 6 shrimp logbook catch (tons)	10923	14954	16264	17587	20714	19905	20520	20146
SFA 6 shrimp observed catch (tons)	8147	12181	12894	14050	16892	15073	16605	14829
Correction factor	1	1	1	1	1	1	1	1
Div. 2J3K shrimp observed catch (tons)	12932	17823	20641	21528	25236	23037	24924	22216
Div. 2J3K shrimp corrected catch (tons)	17338	21881	26036	26947	30947	30421	30800	30181
Observed G. halibut bycatch (tons)	99	81	119	59	41	52	60	62
Corrected G. halibut bycatch (tons)	132	99	150	73	50	69	74	84
Number of G. halibut measured	18701	19483	43522	26296	31919	20059	10667	15514
Kg. G. halibut/ ton shrimp	8	5	6	3	2	2	2	3
Ages								
1	476325	209667	74494	273228	393342	335053	307344	469747
2	1115296	1140935	588840	895681	362909	1026836	780082	861701
3	1043653	607833	781466	424385	439474	362213	271610	412764
4	106528	120346	438890	120471	50126	45984	72525	48701
5	20041	16394	163057	31376	19312	9523	21217	11823
6	5668	3079	18023	5127	3289	1526	3926	1801
7	880	438	1323	386	262	173	496	109
8	1	0	42	15	50	0	19	67
9	0	0	0	0	1	0	0	27
Grand total	2768393	2098693	2066135	1750669	1268768	1781308	1457217	1806739

Table. 5 Greenland halibut by-catch in the small vessel shrimp fishery in Divisions 2J3K during 1996-2003.

	Estimated number at age (yrs)					
Year	1998	1999	2000	2001	2002	2003
SFA 6 shrimp logbook catch (tons)	30073	33673	42651	32736	39841	41859
SFA 6 shrimp observed catch (tons)	1189	1986	3584	1958	2239	2302
Correction factor	25	17	12	17	18	18
Div. 2J3K shrimp observed catch (tons)	1205	2012	3633	1958	2252	2305
Div. 2J3K shrimp corrected catch (tons)	30474	34106	43241	32735	40069	41917
Observed G. halibut bycatch (tons)	2	5	8	7	9	6
Corrected G. halibut bycatch (tons)	61	93	91	109	162	118
Number of G. halibut measured	2112	4614	5492	3544	4879	3666
Kg. G. halibut/ton shrimp	2	3	2	3	4	3
Ages						
0	48555	39990	349306	801034	675151	887677
1	490455	1474265	2166458	997785	2176480	943799
2	240928	678250	485275	589150	820041	571950
3	172699	113172	54495	101954	98491	67161
4	45419	23902	5534	30869	22844	22769
5	4527	2085	607	5619	1139	1855
6	177	17	24	50	18	164
7	0	0	0	0	0	273
8	0	0	0	0	0	273
Grand total	1002759	2331680	3061699	2526460	3794162	2495919

Table. 6 Greenland halibut by-catch in the large vessel shrimp fishery in Division 3L during 2000-2003.

	Estimated number at age (yrs)			
Year	2000	2001	2002	2003
Div 3L shrimp logbook catch (tons)	1033	2394	2456	3328
Div 3L shrimp observed catch (tons)	873	2314	2342	3930
Correction factor	1	1	1	1
Div. 3L shrimp corrected catch (tons)	1033	2394	2456	3328
Observed G. halibut bycatch (tons)	2	6	4	7
Corrected G. halibut bycatch (tons)	3	6	4	6
Number of G. halibut measured	985	2732	1333	1555
Kg. G. halibut/ton shrimp	2	2	2	2
Ages				
1	239	1339	721	2333
2	7746	6809	9793	9935
3	4953	24792	10680	22297
4	8016	13247	13013	12066
5	2299	7413	6699	4791
6	940	865	992	1255
7	362	145	164	70
8	11	11	0	24
9	0	0	16	1
Grand total	24566	54622	42077	52774

Table. 7 Greenland halibut by-catch in the small vessel shrimp fishery in Division 3L during 2000-2003.

	Estimated number at age (yrs)			
Year	**2000**	**2001**	**2002**	**2003**
Div 3L shrimp logbook catch (tons)	3217	2590	2961	6656
Div 3L shrimp observed catch (tons)	70	91	175	248
Correction factor	46	29	17	27
Div. 3L shrimp corrected catch (tons)	3217	2590	2961	6656
Observed G. halibut bycatch (tons)	0	0	0	1
Corrected G. halibut bycatch (tons)	3	2	3	19
Number of G. halibut measured	0	58	0	616
Kg. G. halibut/ton shrimp	1	1	1	3
Ages				
0		486		12296
1		15,748		113103
2	**No Data**	2,315	**No Data**	90413
3		5,573		38844
4		3,601		8626
5		143		188
Grand total		27866		263470

Table. 8 Greenland halibut by-catch at age (numbers) in both the large and small vessel shrimp fishery in Divisions 2GH, 2J3K and 3L during 1996-2003 and the potential loss in yield (t). due to by-catch mortality at ages 1-9.

All Areas and Vessel Classes Combined

Year Ages	1996	1997	1998	1999	2000	2001	2002	2003
0	0	0	48555	39990	349306	801520	675151	899973
1	506132	890895	666419	1808797	2581003	1415278	2642247	1905857
2	1233479	1919219	1132006	2234321	981234	1913768	1911796	1982478
3	1124639	1400422	1124231	718454	636642	571692	486464	675008
4	138869	377214	560134	211291	100326	112022	142691	121400
5	30392	82901	213441	56462	41795	28833	52165	31905
6	10749	25768	25664	8643	7511	3100	10217	4715
7	1251	1775	1601	549	995	326	1083	520
8	1	12	42	18	87	11	29	363
9	0	0	0	0	1	0	16	28
Total	3045514	4698204	3723537	5038535	4349595	4045031	5246709	4722274
Yield (t) at F=0.4 & M=0.2	23793	23793	23793	23793	23793	23793	23793	23793
Yield (t) at F=0.4 & M=0.2 & by-catch	22869	22362	22588	22389	22644	22677	22397	22504
Loss in yield (t) due to by-catch	924	1431	1205	1404	1149	1116	1396	1289

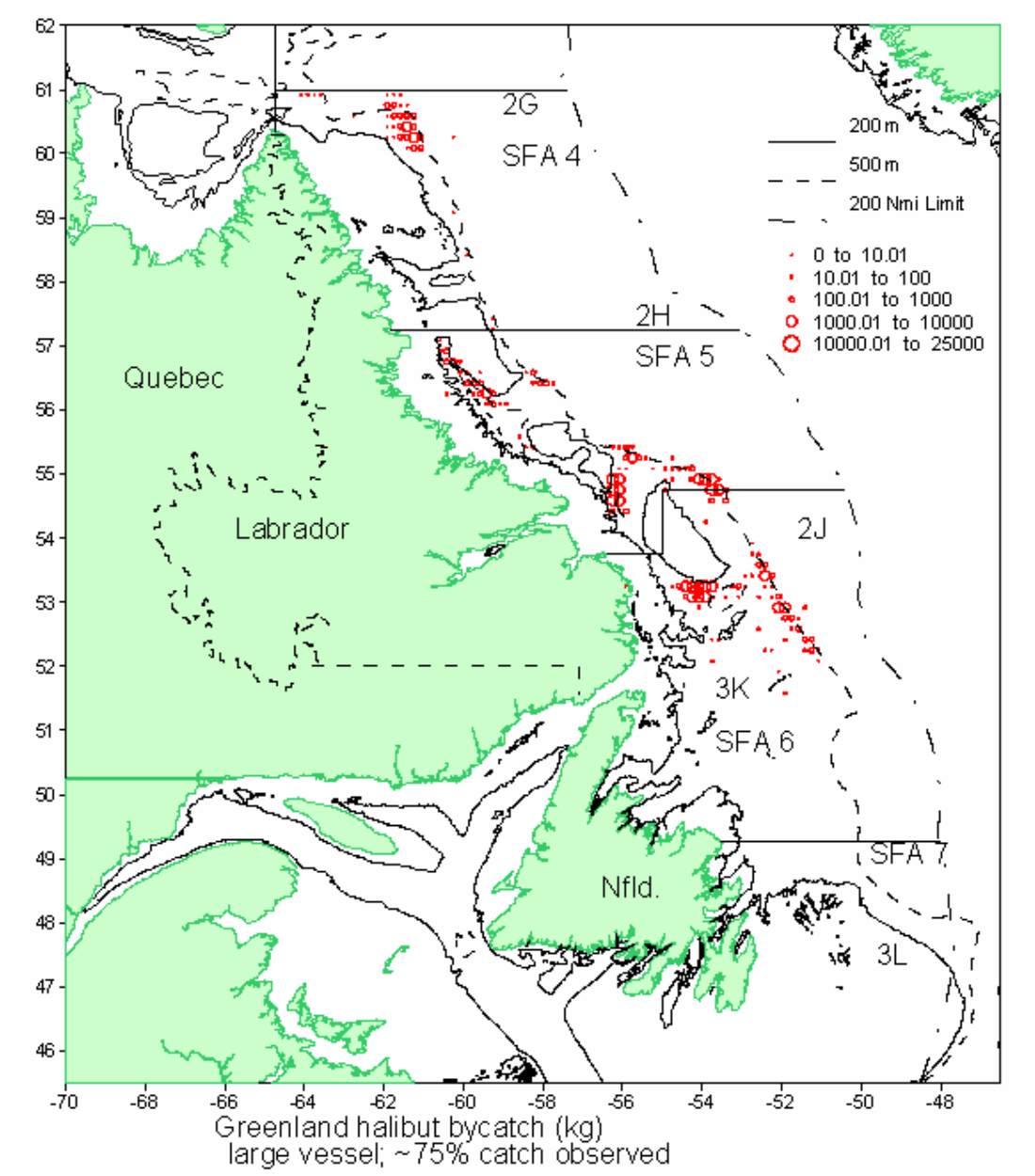

Fig. 1a. Greenland halibut by-catch within the 1996 large vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

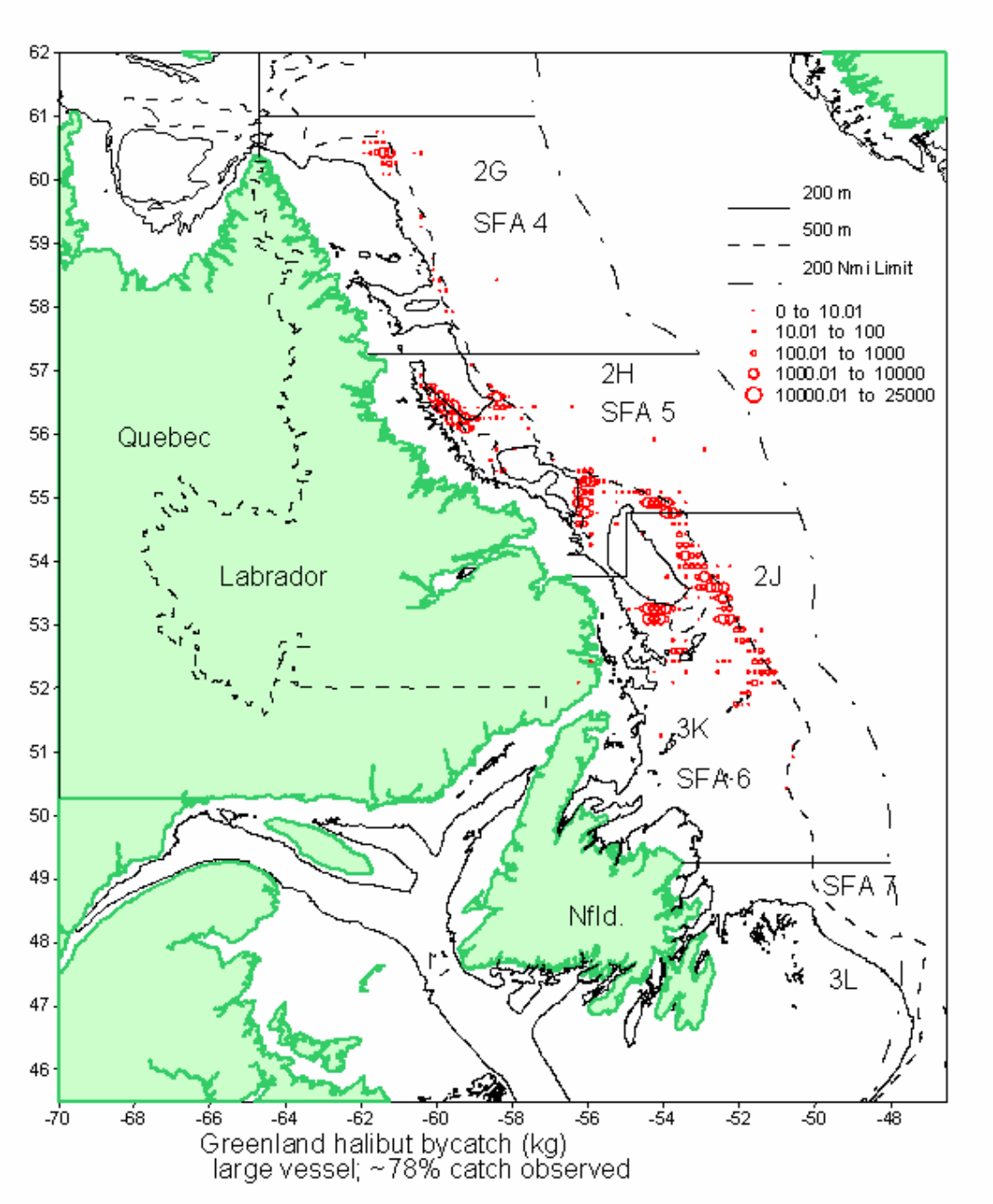

Fig. 1b. Greenland halibut by-catch within the 1997 large and small vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

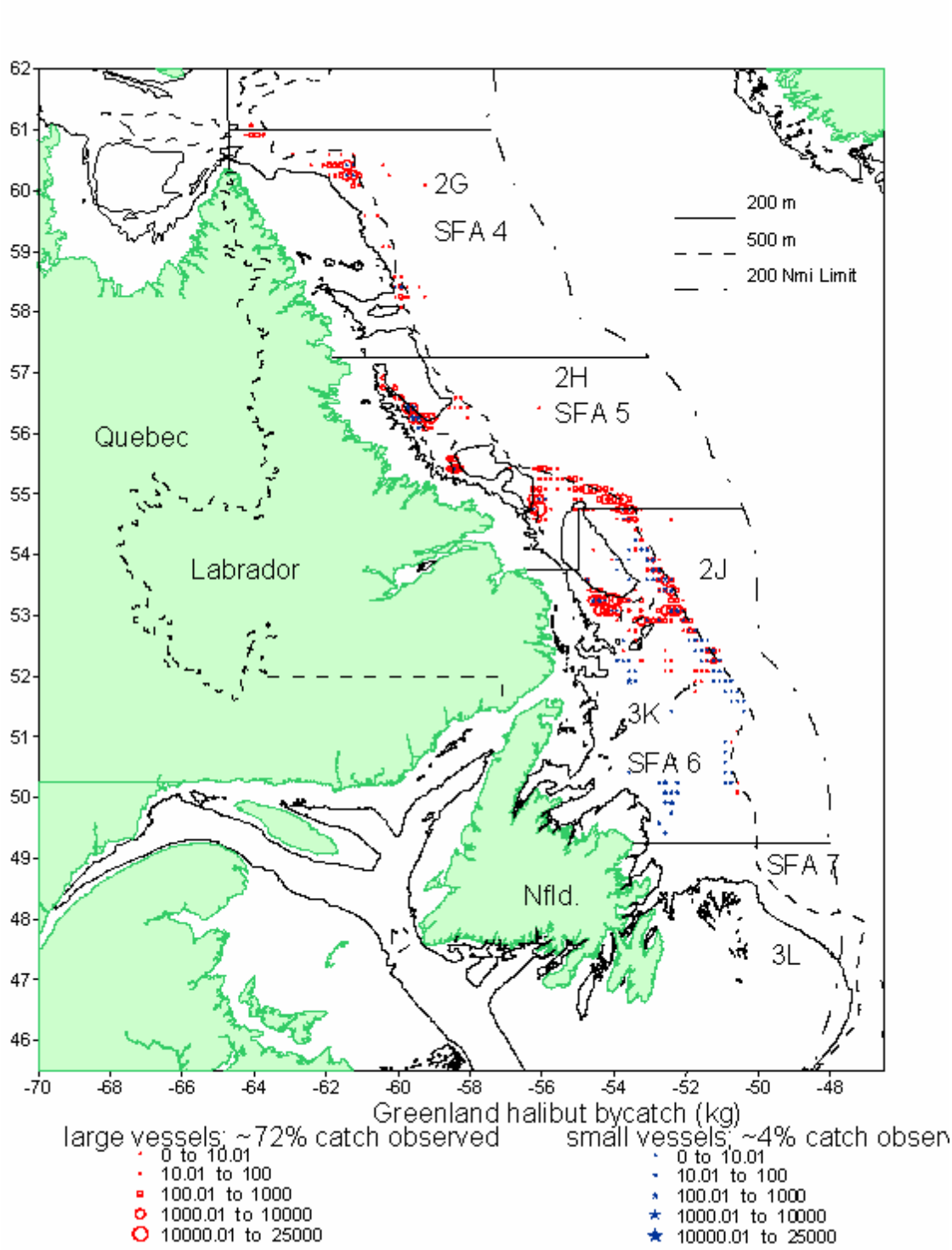

Fig. 1c. Greenland halibut by-catch within the 1998 large and small vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

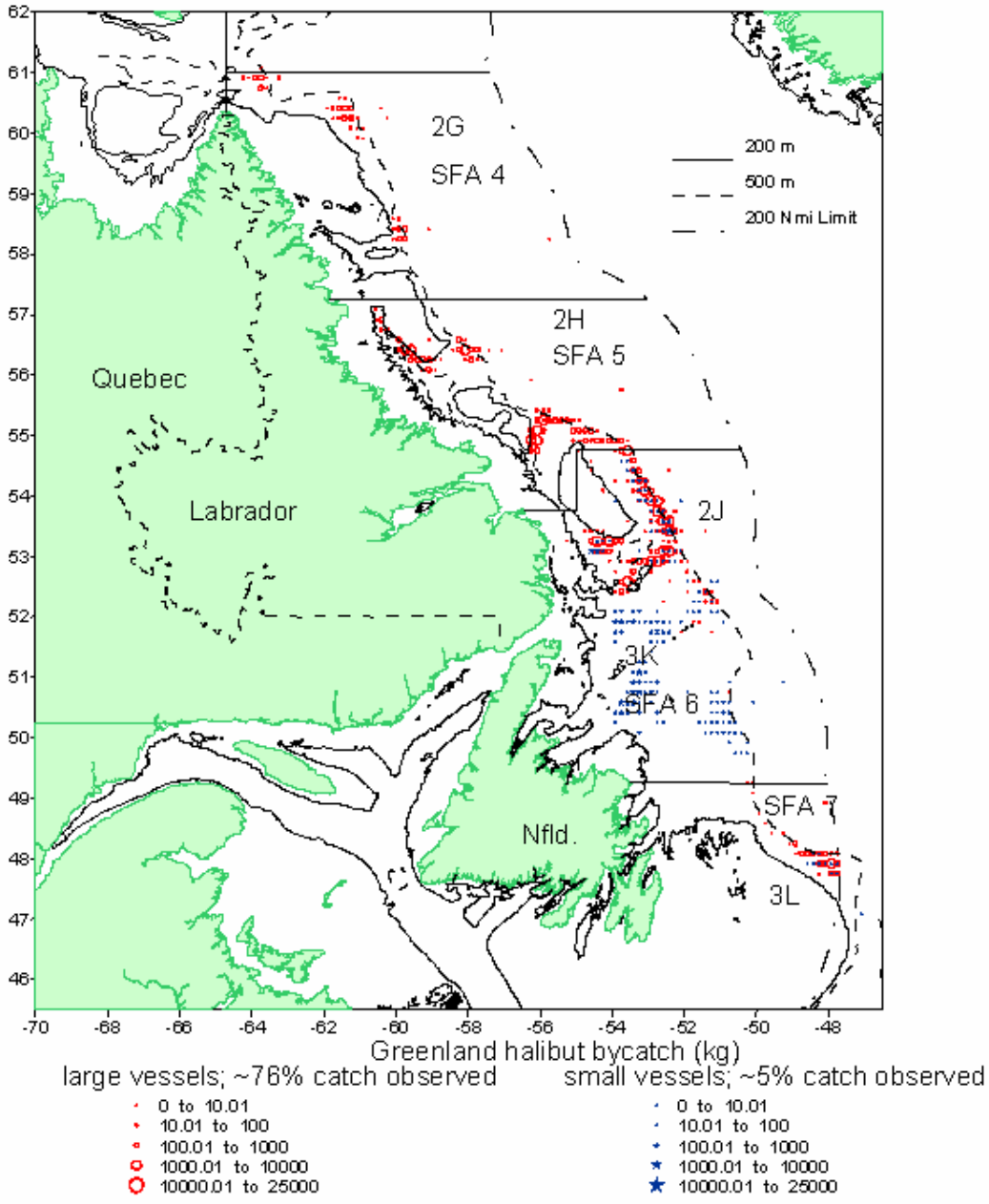

Fig. 1d. Greenland halibut by-catch within the 1999 large vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

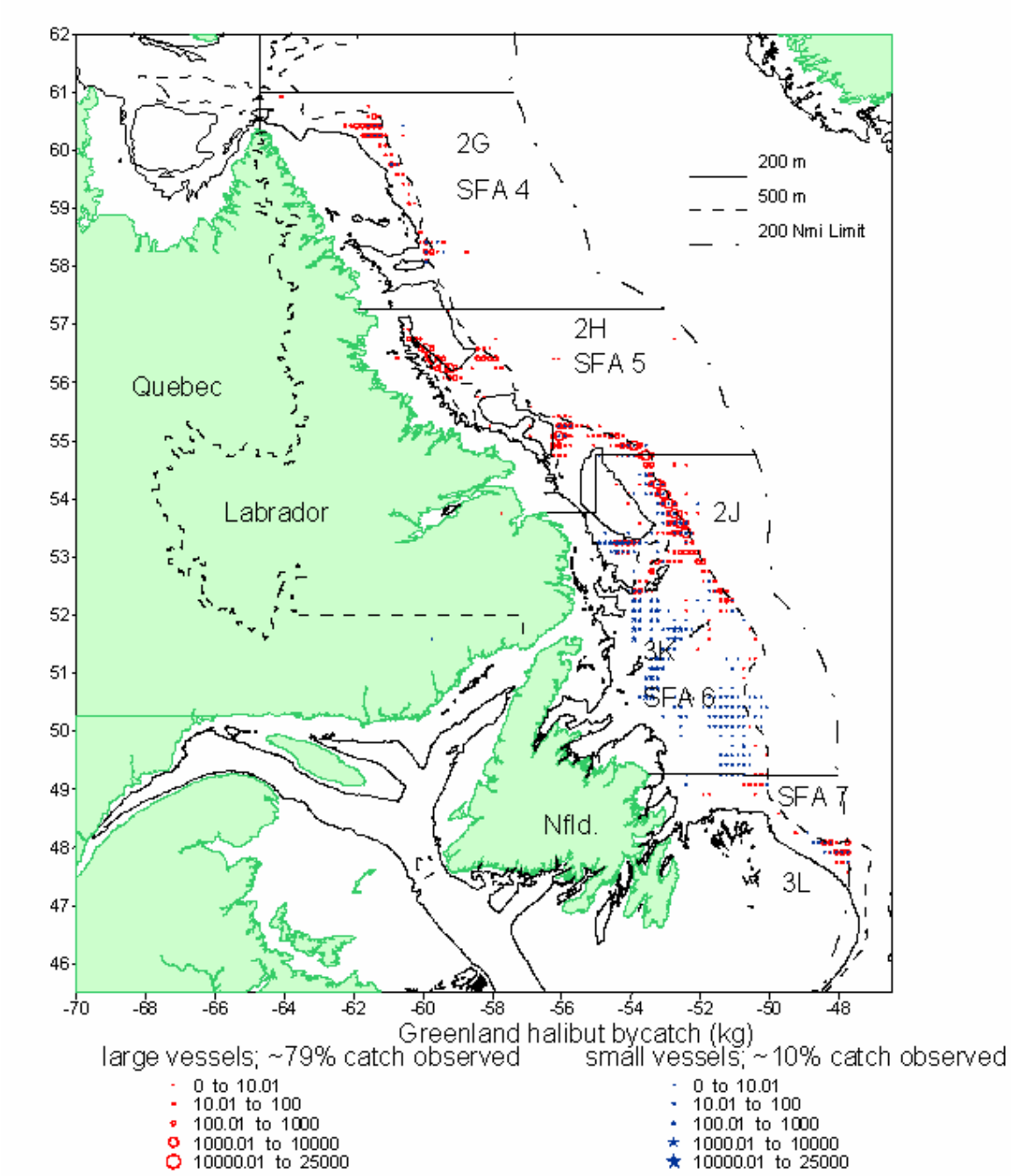

Fig. 1e. Greenland halibut by-catch within the 2000 large and small vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

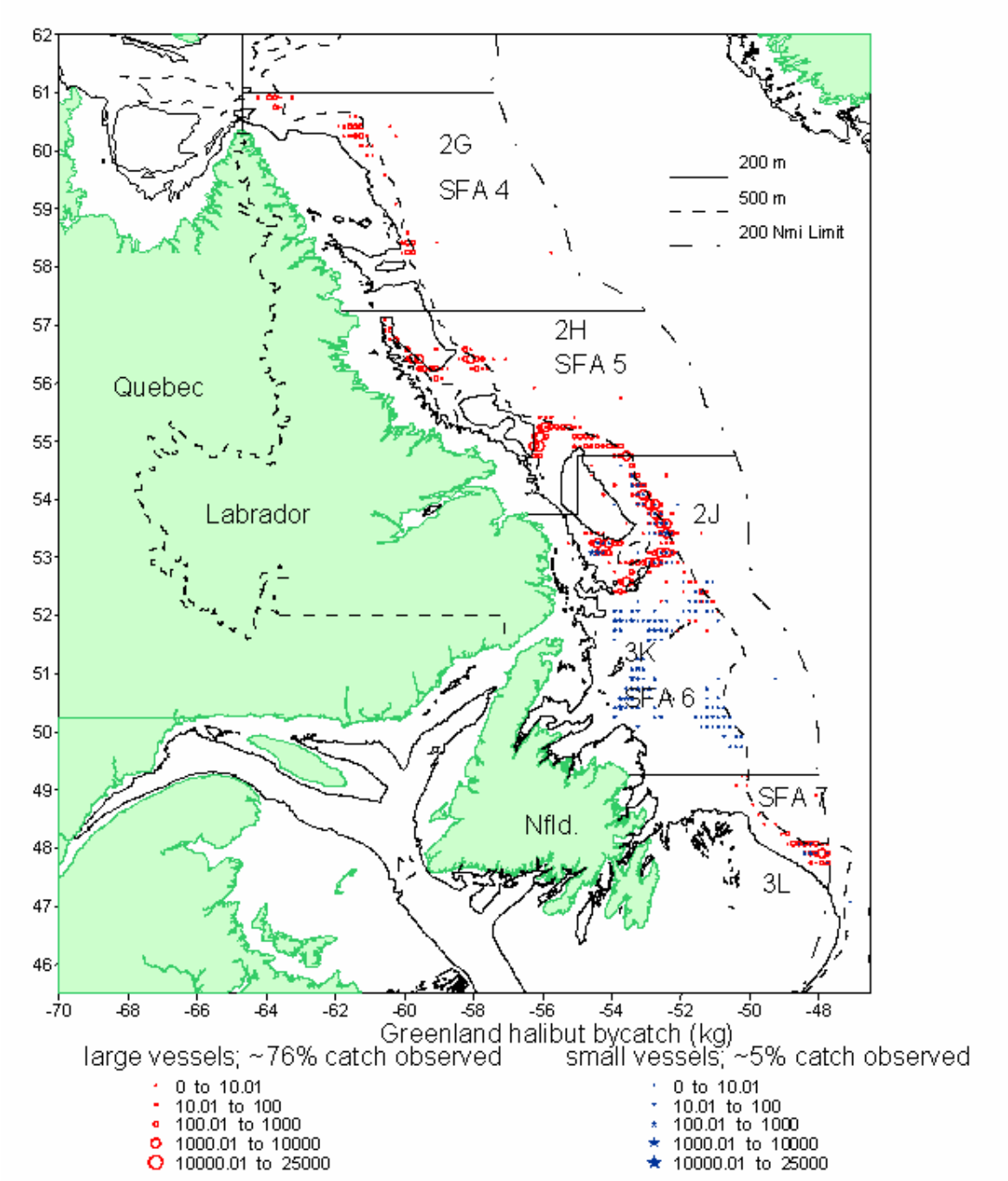

Fig. 1f. Greenland halibut by-catch within the 2001 large and small vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

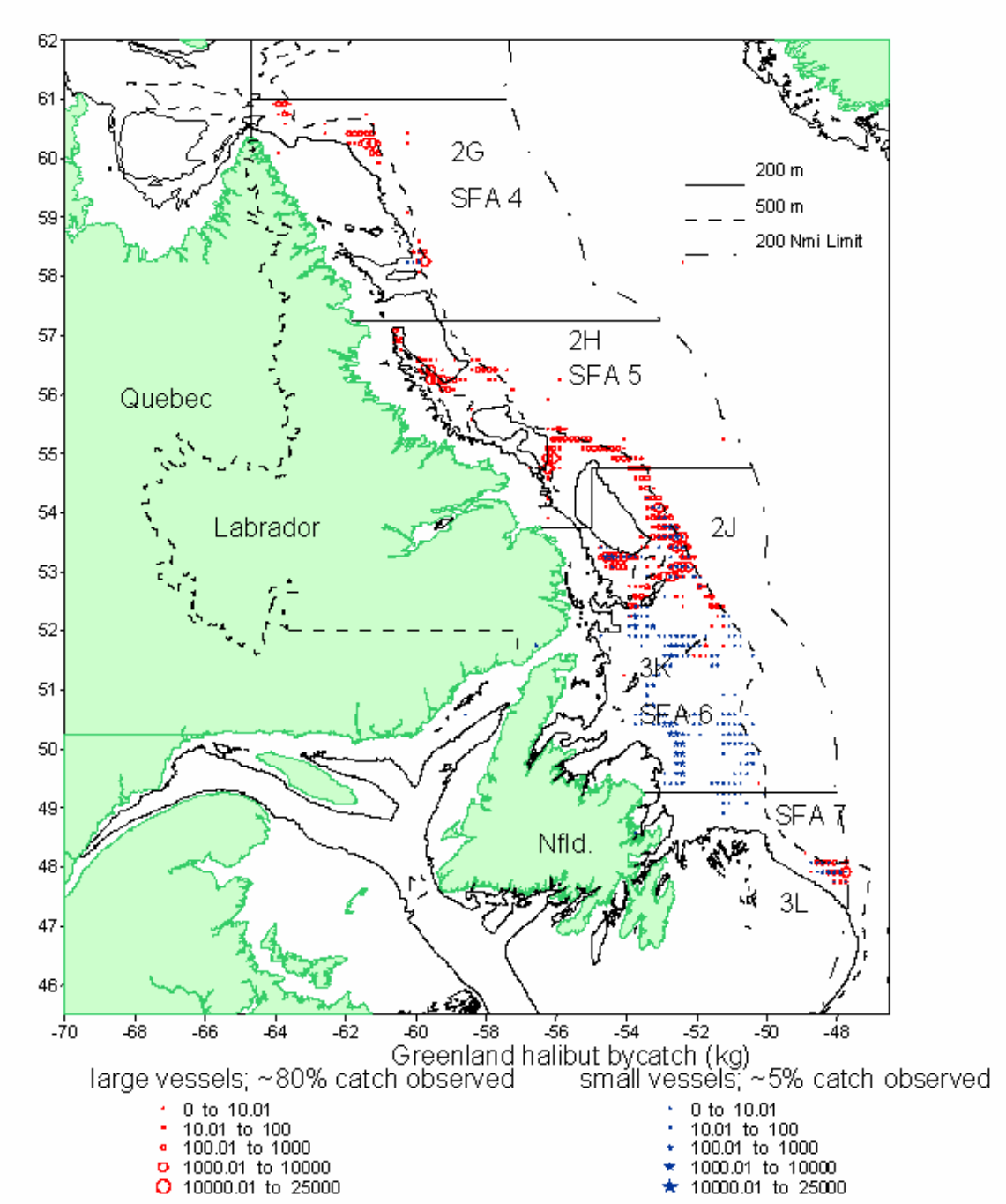

Fig. 1g. Greenland halibut by-catch within the 2002 large and small vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

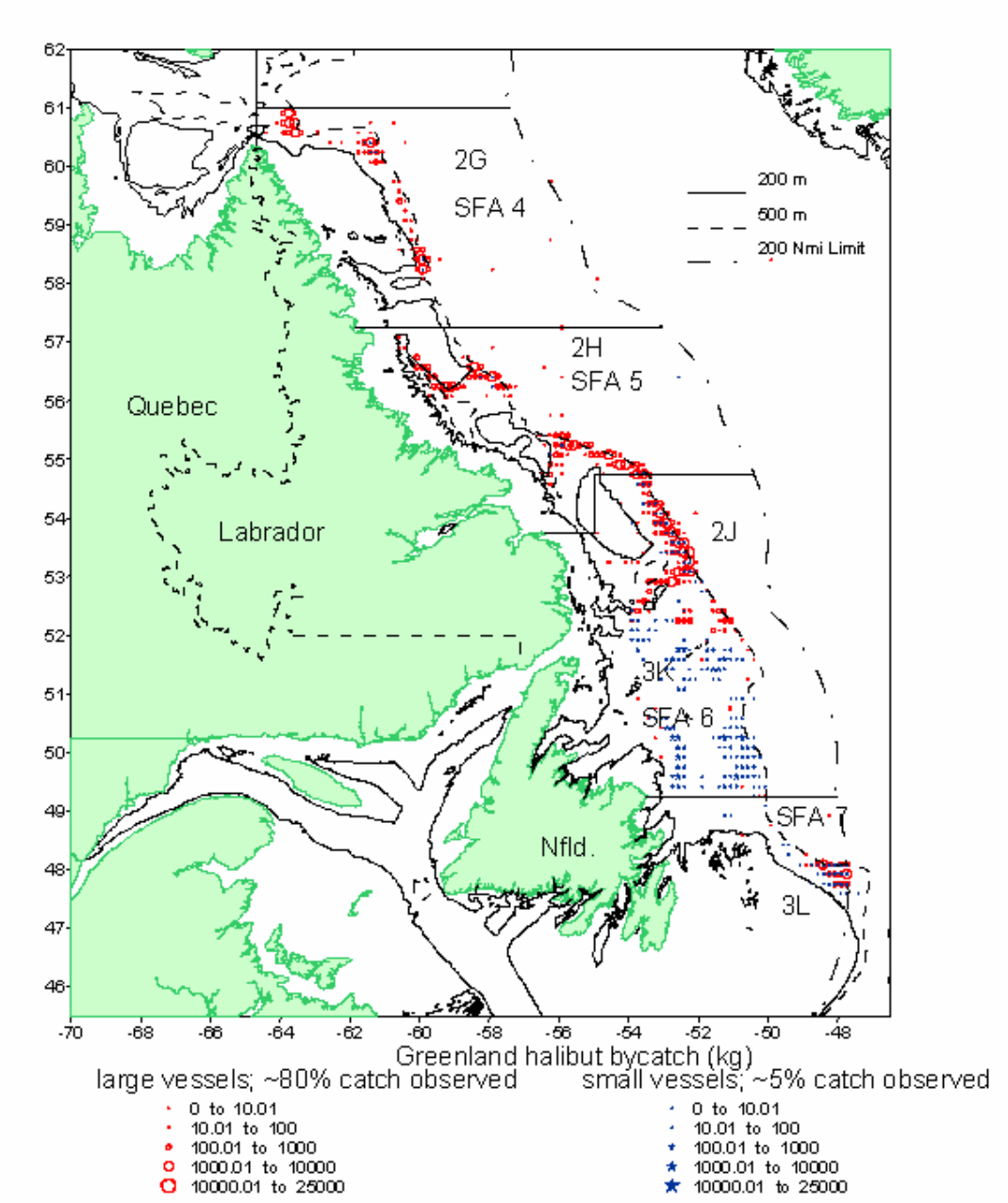

Fig. 1h. Greenland halibut by-catch within the 2003 large and small vessel shrimp fishery off the coasts of Labrador and northeastern Newfoundland (10' x10' grid).

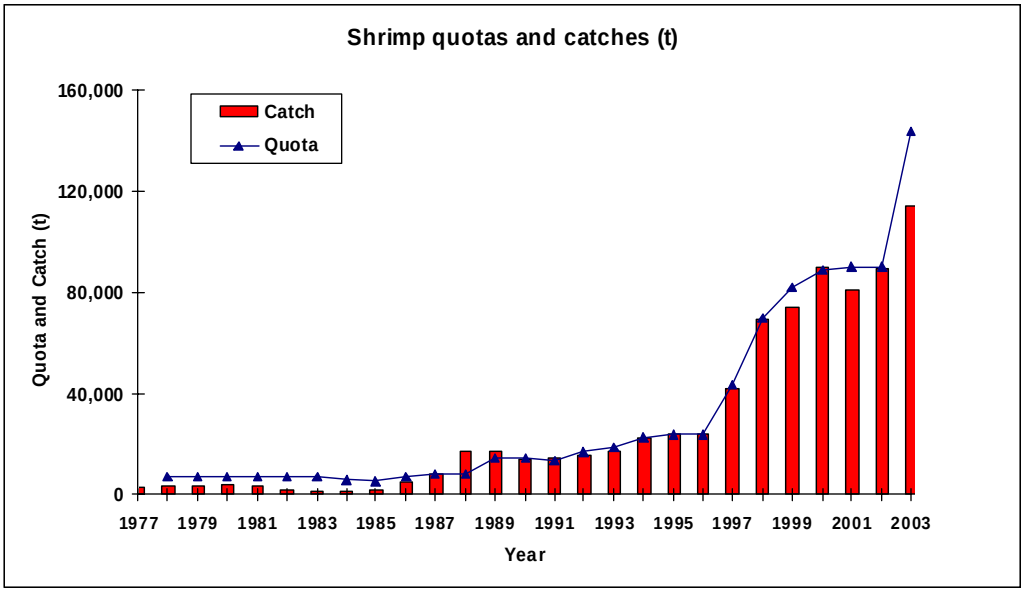

Fig. 2 Combined catches and quotas (tons) of Northern shrimp in NAFO Subarea 2 and Div. 3KL during 1977-2003.

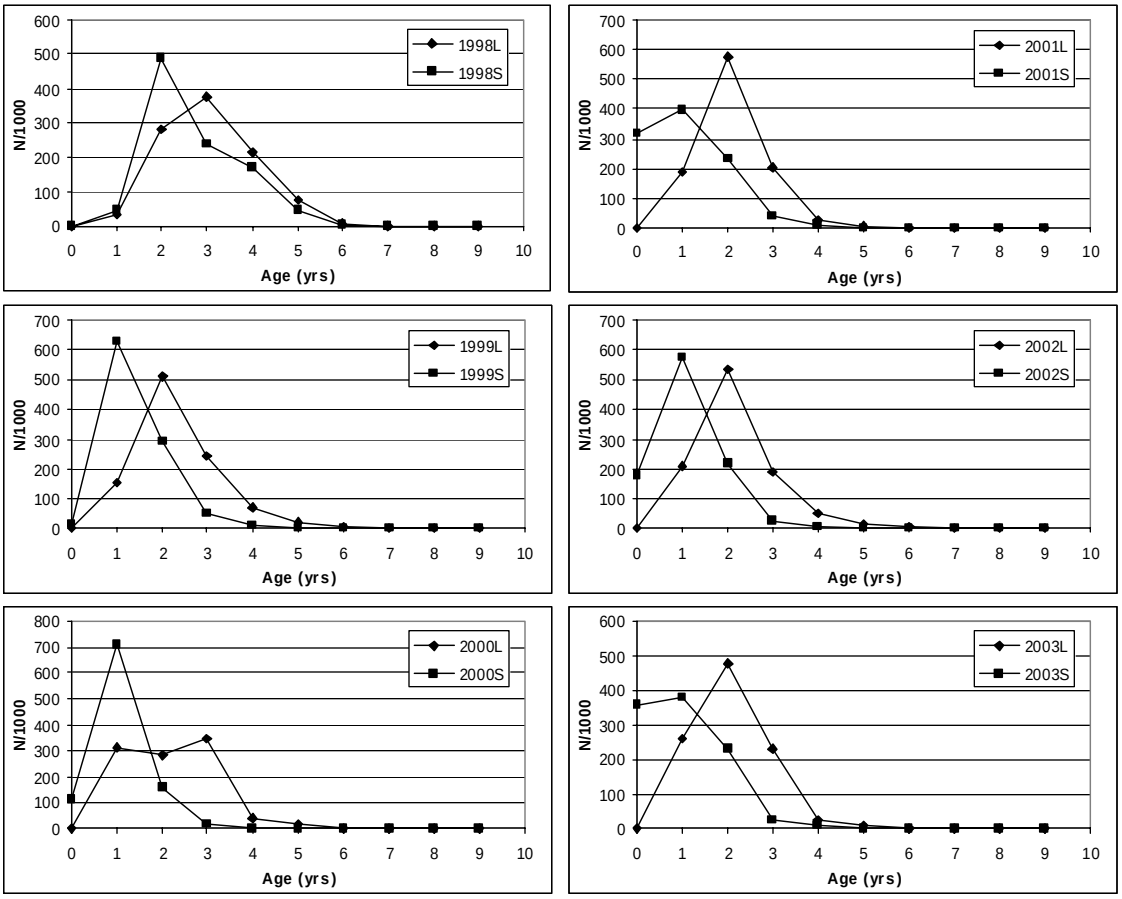

Fig. 3. A comparison of Greenland halibut age distributions from shrimp fishery by-catch in the large and small vessels separately from Divisions 2J & 3K during 1998-2003.

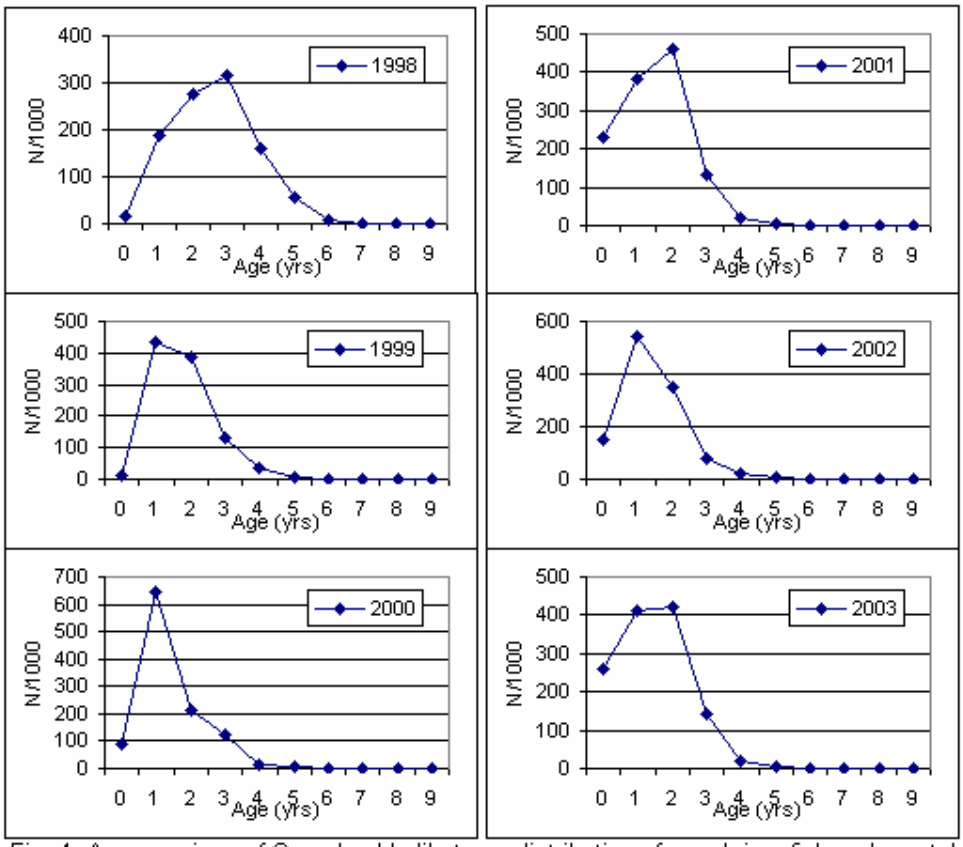

Fig. 4 A comparison of Greenland halibut age distributions from shrimp fishery by-catch in the large and small vessels combined from Divisions 2J & 3K during 1998-2003.

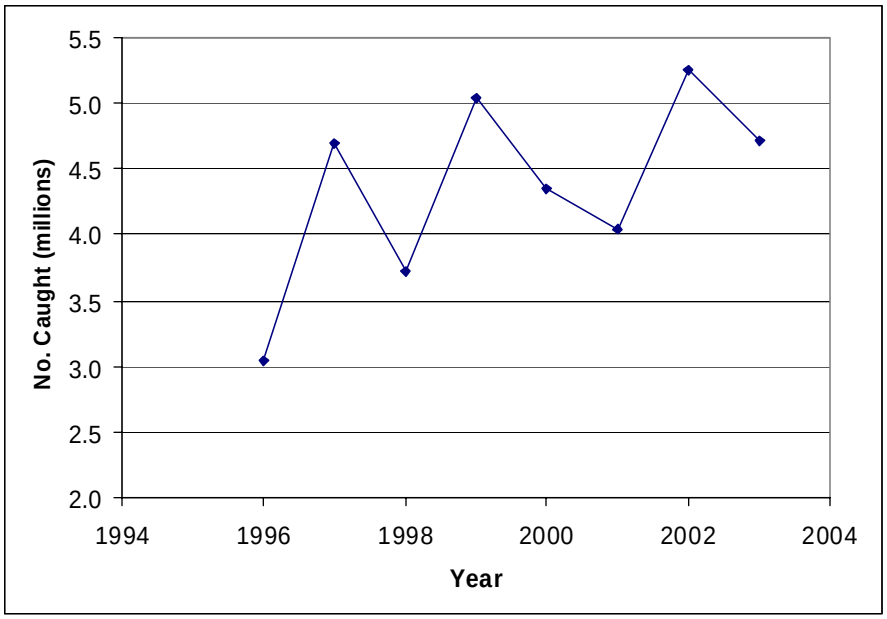

Fig. 5. Number of Greenland halibut caught as by-catch in the Canadian fishery for Northern shrimp in NAFO Subarea 2 and Div. 3KL during 1996-2003.