A Comparison between XSA and SCAA Assessments of Greenland Halibut based on the Same Input Data

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February 2010

Summary

A number of variants of the SCAA are compared with results from the XSA assessment of Healey and Mahe (2009), where the SCAA uses the same data as for that XSA assessment. Differences in estimates of recent exploitable (B^{5-9}) biomass trends – up for SCAA and down for XSA – are found to be largely resolved by introducing *F*-shrinkage in the SCAA, similar to the approach used for the NAFO XSA. Greater agreement still, including for the 10+ biomass (B^{10+}) is obtained by forcing the commercial 11+ selectivity to be flat and at its level for XSA in the SCAA assessment. However both these adjustments to the SCAA come at the expense of appreciable deterioration in the fit of the SCAA model to the data as measured by the likelihood.

Introduction

This exercise is provided to aid in addressing the request made to the NAFO Scientific Council by the Working Group on Greenland Halibut Management Strategy Evaluation (WGMSE) that met over 28-29 January 2010 in Brussels, Belgium (see Annex 4 of the Report of that meeting).

To aid a review by the Scientific Council of SCAA operating models planned to be used for MSE, applications of SCAA to the same data set as provides inputs to the current NAFO XSA assessment of the resource (Healey and Mahe, 2009) were requested. The details of these applications and their results, particularly in comparison to the results from the XSA, are set out below.

Data and Methodology

The catch and survey based data (including catch-at-age information), together with some biological data that are used in the evaluations of this paper, are listed in the Tables in Appendix A, and are understood to be the same as used for the Healey and Mahe (2009) XSA assessment..

The details of the SCAA assessment methodology applied here are provided in Appendix B of Butterworth and Rademeyer (2009a), with two updates detailed in Butterworth and Rademeyer (2009b) (i.: taking the modelled population age structure to a plus-group age of 20 rather than 14, and ii.: including correlation, in both year and age, in survey proportions-at-age data). The specific settings of the Reference Case (RC) SCAA assessment considered are listed below:

1) Stock recruitment function:
    a. Beverton-Holt;
    b. h=0.9;
    c. σ_R = 0.2;
2) M=0.2;
3) Starting conditions:
    a. θ and ζ are estimated for the year 1975
4) Serial correlations:
    a. Survey CAA: series specific correlation parameters for both the age and the year;
    b. Survey abundance indices: Single serial correlation parameter;
5) Commercial selectivity:
    a. Estimated directly for ages 5 to 11, with an exponential decline assumed from age 12 to 20;
    b. Selectivity variation: σ_Ω = 2;

6) Survey selectivities:
   a. Estimated directly for ages 1 to 11 for Canadian Fall and EU surveys and for ages 1 to 8 for Canadian Spring survey, with an exponential decline assumed from age 12 to 20 for Canadian Fall and EU surveys and from age 9 to 20 for Canadian Spring survey;
   b. Selectivity variation: σ_Ω =0.5;

Results and Discussion

The results of the SCAA variants explored are listed in Table 1. Corresponding estimates of biomass trends and commercial selectivities-at-age are plotted in Figures 1 and 2 respectively, which also include XSA results. It is simplest to introduce and comment on the SCAA variants considered seriatum.

It was unclear in correspondence whether or not the 2008 CAA data should be taken into account in the SCAA fits. Cases 1 and 2 in Table 1 show results with and without these data included. Both comparison of the estimates in that Table, and the corresponding biomass plots in Figure 1 which are virtually indistinguishable, suggest that the decision of whether to include or exclude these 2008 CAA data is of no practical consequence. Accordingly further results have all included those data in the associated analyses.

Case 3 forces a flat commercial selectivity from age 11 (the value of this selectivity is estimated in the fit), rather than allowing the exponential decline with age of the RC (see Figure 2). From Figure 1 it is evident that this leads to reduced biomass estimates in absolute terms. However the "exploitable" biomass ($B^{5\text{-}9}$) still increases appreciably over the most recent five years, unlike for the XSA results.

Case 4 adds *F*-shrinkage to the SCAA to mimic what is done for the NAFO XSA assessment. This was achieved through adding a penalty function with high weight to the SCAA negative log-likelihood to force the most recent (2008) fishing mortality *F* to be very close to its average value over 2003-2007. It is evident from Figure 1 that with this addition, the recent $B^{5\text{-}9}$ trend flattens out much closer to the XSA result than for the RC (Case 2). A higher weight still given to this penalty achieves even closer agreement with the XSA result, but the SCAA then exhibits some convergence difficulties.

Case 5 combines the two effects of asymptotically flat selectivity and *F*-shrinkage in the SCAA, resulting in still closer agreement with the $B^{5\text{-}9}$ trend for XSA (Figure 1).

In terms of $B^{10+,}$ however, even for Case 5 estimates in absolute terms are much higher for SCAA than for XSA (Figure 1). This difference is considerably reduced by, rather than allowing the SCAA to estimate the value of a flat commercial selectivity for ages 11+ from the data, instead forcing this value to be similar to that for the XSA assessment (see Figure 2). Biomass trends for this Case 6 are plotted in Figure 1, as well as for Case 7 where the *F*-shrinkage effect is added to the SCAA as well. It is evident that in these circumstances the SCAA and XSA biomass trends are virtually identical for $B^{5\text{-}9}$ and very much closer for B^{10+}.

In Summary

The difference between the SCAA and XSA results for exploitable ($B^{5\text{-}9}$) biomass is primarily the result of applying *F*-shrinkage in XSA. Differences in B^{10+} estimates are greatly reduced if commercial selectivity at large ages is forced to be flat, and set close to the level for XSA rather than the value estimated from the data in the SCAA.

Thus forcing certain features on the SCAA renders its outputs to be virtually identical to those from XSA. However this agreement comes at a cost in terms of the fit of the SCAA model to the data: a loss of about 15 log-likelihood points through forcing *F*-shrinkage, and a further some 15 through forcing the 11+ group commercial selectivity to be higher than the value suggested by the data. Assessments using CAA data always have the difficulties of poor precision for recent year-class strengths because of limited appearances of the cohorts concerned in the fishery or survey: the NAFO Scientific Council XSA addresses this problem by implementing *F*-shrinkage to improve precision; the SCAA does not need to include this feature as shrinkage is effectively already provided through the stock-recruitment relation estimated within the SCAA approach. The relative merits of the two approaches rest on the relative plausibility of the two associated assumptions, noting that variance reduction techniques can introduce bias.

In AIC-weighting terms, these log-likelihood differences are substantial, certainly suggesting that the SCAA RC should be preferred over XSA. However, it should be noted that the SCAA prescription used has not as yet been able to fully remove correlation from model fit residuals (Butterworth and Rademeyer, 2009b), so that this relative statistical preference would not be as great as AIC-based weighting would suggest.

References

Butterworth DS and Rademeyer RA. 2009a. Initial applications of Statistical Catch-at-Age assessment methodology to the Greenland Halibut resource.

Butterworth DS and Rademeyer RA. 2009b. Extensions to SCAA applications reported in: "Further applications of statistical catch-at-age assessment methodology to the 2J3K-O Greenland Halibut resource".

Healey BP and Mahé J-C. 2009. An assessment of Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Subarea 2 and Divisions 3KLMNO. NAFO SRC Doc. 09/39, Ser. No N5675.

Vásquez A and Gonzáles-Troncoso D. 2008. Results from Bottom Trawl Survey on Flemish Cap of June-july 2007. NAFO SRC Doc. 08/34, Ser. No.5535.

Table 1: Results of fits of various SCAA variants (see text for details) to the commercial catch and survey data. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs.

	1) SCAA starting in 1975: new 2008 catch but 2008 CAA not included in likelihood			2) SCAA starting in 1975: new 2008 catch and 2008 CAA included in likelihood			3) as 2) with flat commercial selectivity at older ages (11+)			4) as 2) with F shrinkage			5) as 2) with F shrinkage and flat commercial selectivity at older ages (11+)			6) as 2) but commercial selectivity flat and up for age 11+			7) as 2) with F shrinkage and commercial selectivity flat and up for age 11+		
'-lnL:overall	-622.5			-630.8			-625.3			-619.3			-616.7			-610.6			-602.2		
'-lnL:Survey	-29.9			-29.9			-30.2			-30.7			-30.9			-30.7			-29.6		
'-lnL:CAA	-214.2			-222.8			-220.6			-216.3			-214.9			-203.0			-202.3		
'-lnL:CAAsurv	-462.8			-462.8			-463.6			-459.8			-461.1			-463.4			-457.3		
'-lnL:RecRes	17.6			17.6			17.6			16.3			16.5			23.0			20.3		
'-lnL:SelPen	66.8			67.0			71.5			69.4			72.4			63.5			65.4		
-lnL:ShrinkPen	-			-			-			1.8			1.2			-			1.3		
h	**0.90**			**0.90**			**0.90**			**0.90**			**0.90**			**0.90**			**0.90**		
θ	0.30			0.31			0.18			0.19			0.13			0.04			0.04		
ϕ	0.28			0.28			0.34			0.33			0.37			0.46			0.50		
ρ - surveys	0.60			0.60			0.57			0.45	0.45	0.45	0.43	0.43	0.43	0.50	0.50	0.50	0.43	0.43	0.43
ρ_{CAAage}	0.49	0.28	0.35	0.49	0.28	0.35	0.49	0.28	0.35	0.52	0.28	0.38	0.52	0.28	0.38	0.50	0.29	0.34	0.53	0.30	0.38
ρ_{CAAyr}	-0.69	-0.32	-0.49	-0.69	-0.32	-0.49	-0.69	-0.32	-0.49	-0.68	-0.32	-0.48	-0.69	-0.32	-0.48	-0.69	-0.32	-0.49	-0.68	-0.30	-0.47
K^{sp}	340	(0.06)		340	(0.06)		328	(0.06)		320	(0.06)		321	(0.07)		422	(0.07)		417	*	
$B^{sp}{}_{2008}$	36	(0.42)		37	(0.42)		25	(0.58)		15	(0.60)		12	(0.52)		9	(0.27)		5	*	
$B^{5\text{-}9}{}_{2008}$	129			128			114			86			82			94			72		
$B^{10+}{}_{2008}$	52			53			38			25			20			16			10		
MSYL^{sp}	0.18	(0.17)		0.18	(0.14)		0.19	(0.18)		0.18	(0.20)		0.19	(0.19)		0.20	(0.07)		0.19	*	
$B^{sp}{}_{MSY}$	60	(0.19)		60	(0.17)		61	(0.19)		58	(0.20)		62	(0.18)		83	(0.10)		81	*	
MSY	27	(0.05)		27	(0.05)		27	(0.06)		27	(0.07)		28	(0.08)		38	(0.07)		38	*	
σ_{comCAA}	0.07			0.07			0.07			0.07			0.07			0.08			0.08		
Survey	q's x10^6	σ_{surv}	$\sigma_{survCAA}$	q's x10^6	σ_{surv}	$\sigma_{survCAA}$	q's x10^6	σ_{surv}	$\sigma_{survCAA}$	q's x10^6	σ_{surv}	$\sigma_{survCAA}$	q's x10^6	σ_{surv}	$\sigma_{survCAA}$	q's x10^6	σ_{surv}	$\sigma_{survCAA}$	q's x10^6	σ_{surv}	$\sigma_{survCAA}$
CanFall	422	0.17	0.02	421	0.17	0.02	454	0.16	0.02	507	0.16	0.02	527	0.16	0.02	509	0.15	0.02	561	0.17	0.02
EU	218924	0.28	0.05	218744	0.28	0.05	237401	0.28	0.05	261109	0.28	0.05	269411	0.28	0.05	264673	0.29	0.05	283334	0.29	0.05
CanSpr	22	0.41	0.05	22	0.41	0.05	23	0.40	0.05	25	0.41	0.05	26	0.41	0.05	25	0.41	0.05	26	0.41	0.05
σ_R_out	0.21			0.21			0.21			0.20			0.20			0.24			0.23		

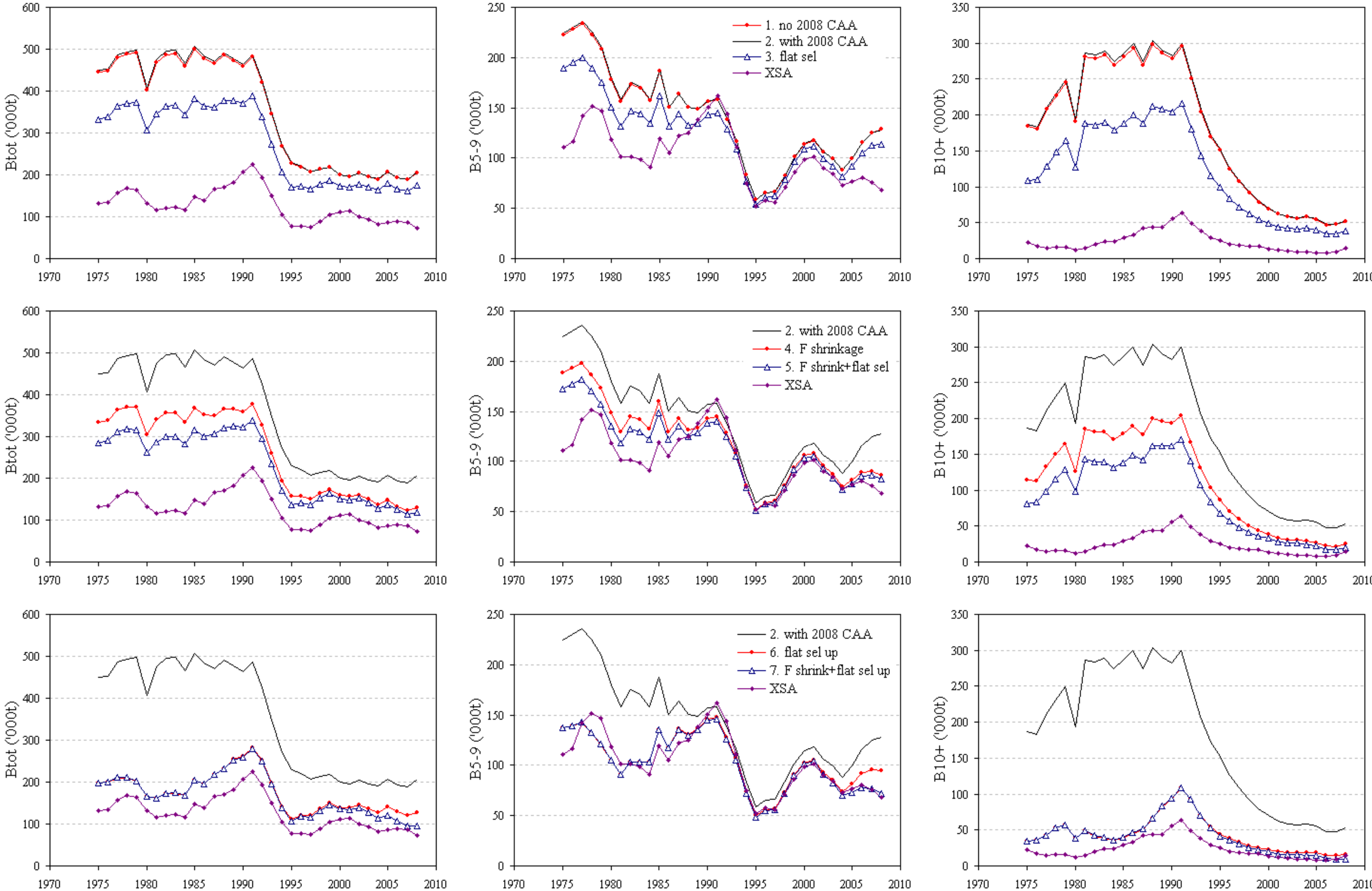

Fig. 1: Biomass trajectories for a series of SCAA variants and the 2008 XSA (Healy and Mahe, 2009).

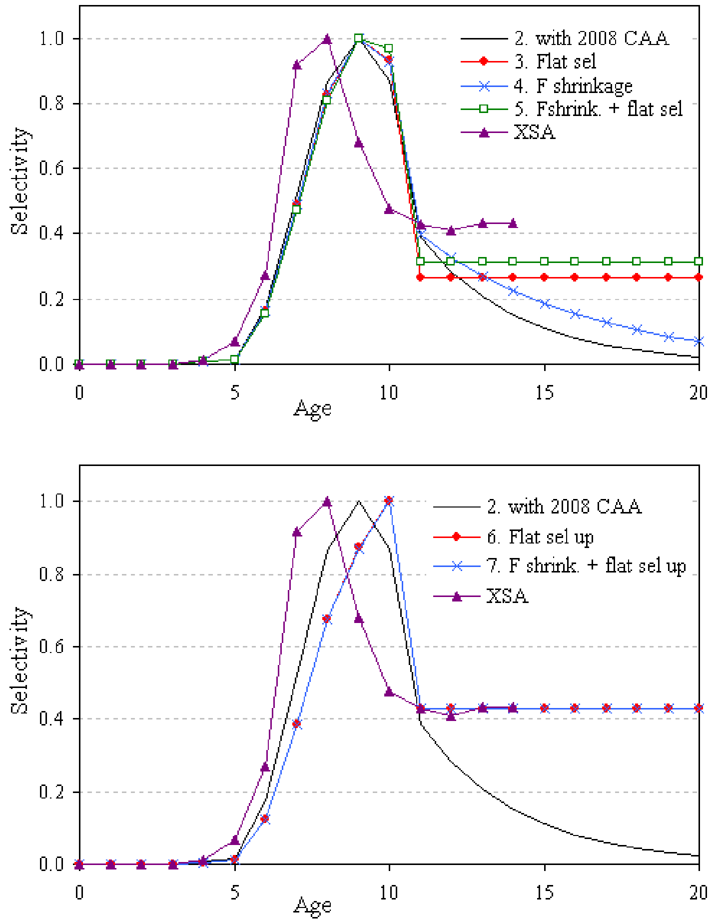

Fig.2: Commercial selectivities for a series of SCAA variants and the 2008 XSA (Healy and Mahe, 2009).

APPENDIX A – Data

Table A1: Landings (tons) for Greenland Halibut in Sub-area 2 and Div. 3KLMNO (Healey and Mahé, 2009).

Year	Landings (t)	Year	Landings (t)
1960	938	1985	20347
1961	741	1986	17976
1962	588	1987	32442
1963	1621	1988	19215
1964	4252	1989	20034
1965	10069	1990	47454
1966	19276	1991	65008
1967	26525	1992	63193
1968	32392	1993	62455
1969	37275	1994	51029
1970	36889	1995	15272
1971	24834	1996	18840
1972	30038	1997	19858
1973	29105	1998	19946
1974	27588	1999	24226
1975	28814	2000	34177
1976	24611	2001	38232
1977	32048	2002	34062
1978	39070	2003	35151
1979	34104	2004	25486
1980	32867	2005	23255
1981	30754	2006	23531
1982	26278	2007	22747
1983	27861	2008	21178
1984	26711		

Table A2. Catch at age matrix (000s) for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO (Healey and Mahé, 2009).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1975	0	0	0	0	334	2819	5750	4956	3961	1688	702	135	279	288
1976	0	0	0	0	17	610	3231	5413	3769	2205	829	260	101	53
1977	0	0	0	0	534	5012	10798	7346	2933	1013	220	130	116	84
1978	0	0	0	0	2982	8415	8970	7576	2865	1438	723	367	222	258
1979	0	0	0	0	2386	8727	12824	6136	1169	481	287	149	143	284
1980	0	0	0	0	209	2086	9150	9679	5398	3828	1013	128	53	27
1981	0	0	0	0	863	4517	9806	11451	4307	890	256	142	43	69
1982	0	0	0	0	269	2299	6319	5763	3542	1684	596	256	163	191
1983	0	0	0	0	701	3557	9800	7514	2295	692	209	76	106	175
1984	0	0	0	0	902	2324	5844	7682	4087	1259	407	143	106	183
1985	0	0	0	0	1983	5309	5913	3500	1380	512	159	99	87	86
1986	0	0	0	0	280	2240	6411	5091	1469	471	244	140	70	117
1987	0	0	0	0	137	1902	11004	8935	2835	853	384	281	225	349
1988	0	0	0	0	296	3186	8136	4380	1288	465	201	105	107	129
1989	0	0	0	0	181	1988	7480	4273	1482	767	438	267	145	71
1990	0	0	0	95	1102	6758	12632	7557	4072	2692	1204	885	434	318
1991	0	0	0	220	2862	7756	13152	10796	7145	3721	1865	1216	558	422
1992	0	0	0	1064	4180	10922	20639	12205	4332	1762	1012	738	395	335
1993	0	0	0	1010	9570	15928	17716	11918	4642	1836	1055	964	401	182
1994	0	0	0	5395	16500	15815	11142	6739	3081	1103	811	422	320	215
1995	0	0	0	323	1352	2342	3201	2130	1183	540	345	273	251	201
1996	0	0	0	190	1659	5197	6387	1914	956	504	436	233	143	89
1997	0	0	0	335	1903	4169	7544	3215	1139	606	420	246	137	89
1998	0	0	0	552	3575	5407	5787	3653	1435	541	377	161	92	51
1999	0	0	0	297	2149	5625	8611	3793	1659	623	343	306	145	151
2000	0	0	0	271	2029	12583	21175	3299	973	528	368	203	129	104
2001	0	0	0	448	2239	12163	22122	5154	1010	495	439	203	156	75
2002	0	0	0	479	1662	7239	17581	6607	1244	659	360	224	126	81
2003	0	0	0	1279	4491	10723	16764	6385	1614	516	290	144	76	85
2004	0	0	0	897	4062	8236	10542	4126	1307	529	289	184	87	75
2005	0	0	0	534	1652	5999	10313	3996	1410	444	244	114	64	46
2006	0	0	0	216	1869	6450	12144	4902	1089	372	136	47	32	40
2007	0	0	0	88	570	3732	11912	5414	1230	472	163	80	41	29
2008	0	0	0	29	448	3312	10697	5558	1453	393	115	46	26	15

Table A3. Catch weights-at-age (kg) matrix for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO (Healy and Mahé, 2009).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1975	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.764
1976	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.144
1977	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.992
1978	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	5.894
1979	0.000	0.000	0.126	0.244	0.609	0.760	0.955	1.190	1.580	2.210	2.700	3.370	3.880	6.077
1980	0.000	0.000	0.126	0.244	0.514	0.659	0.869	1.050	1.150	1.260	1.570	2.710	3.120	5.053
1981	0.000	0.000	0.126	0.244	0.392	0.598	0.789	0.985	1.240	1.700	2.460	3.510	4.790	7.426
1982	0.000	0.000	0.126	0.244	0.525	0.684	0.891	1.130	1.400	1.790	2.380	3.470	4.510	7.359
1983	0.000	0.000	0.126	0.244	0.412	0.629	0.861	1.180	1.650	2.230	3.010	3.960	5.060	7.061
1984	0.000	0.000	0.126	0.244	0.377	0.583	0.826	1.100	1.460	1.940	2.630	3.490	4.490	7.016
1985	0.000	0.000	0.126	0.244	0.568	0.749	0.941	1.240	1.690	2.240	2.950	3.710	4.850	7.010
1986	0.000	0.000	0.126	0.244	0.350	0.584	0.811	1.100	1.580	2.120	2.890	3.890	4.950	7.345
1987	0.000	0.000	0.126	0.244	0.364	0.589	0.836	1.160	1.590	2.130	2.820	3.600	4.630	6.454
1988	0.000	0.000	0.126	0.244	0.363	0.569	0.805	1.163	1.661	2.216	3.007	3.925	5.091	7.164
1989	0.000	0.000	0.126	0.244	0.400	0.561	0.767	1.082	1.657	2.237	2.997	3.862	4.919	6.370
1990	0.000	0.000	0.090	0.181	0.338	0.546	0.766	1.119	1.608	2.173	2.854	3.731	4.691	6.391
1991	0.000	0.000	0.126	0.244	0.383	0.592	0.831	1.228	1.811	2.461	3.309	4.142	5.333	7.081
1992	0.000	0.000	0.175	0.289	0.430	0.577	0.793	1.234	1.816	2.462	3.122	3.972	5.099	6.648
1993	0.000	0.000	0.134	0.232	0.368	0.547	0.809	1.207	1.728	2.309	2.999	3.965	4.816	6.489
1994	0.000	0.000	0.080	0.196	0.330	0.514	0.788	1.179	1.701	2.268	2.990	3.766	4.882	6.348
1995	0.000	0.000	0.080	0.288	0.363	0.531	0.808	1.202	1.759	2.446	3.122	3.813	4.893	6.790
1996	0.000	0.000	0.161	0.242	0.360	0.541	0.832	1.272	1.801	2.478	3.148	3.856	4.953	6.312
1997	0.000	0.000	0.120	0.206	0.336	0.489	0.771	1.159	1.727	2.355	3.053	3.953	5.108	6.317
1998	0.000	0.000	0.119	0.228	0.373	0.543	0.810	1.203	1.754	2.351	3.095	4.010	5.132	6.124
1999	0.000	0.000	0.176	0.253	0.358	0.533	0.825	1.253	1.675	2.287	2.888	3.509	4.456	5.789
2000	0.000	0.000	0.000	0.254	0.346	0.524	0.787	1.192	1.774	2.279	2.895	3.645	4.486	5.531
2001	0.000	0.000	0.000	0.249	0.376	0.570	0.830	1.168	1.794	2.367	2.950	3.715	4.585	5.458
2002	0.000	0.000	0.217	0.251	0.369	0.557	0.841	1.193	1.760	2.277	2.896	3.579	4.407	5.477
2003	0.000	0.000	0.188	0.247	0.389	0.564	0.822	1.199	1.651	2.166	2.700	3.404	4.377	5.409
2004	0.000	0.000	0.180	0.249	0.376	0.535	0.808	1.196	1.629	2.146	2.732	3.538	4.381	5.698
2005	0.000	0.000	0.252	0.301	0.396	0.564	0.849	1.247	1.691	2.177	2.705	3.464	4.264	5.224
2006	0.000	0.000	0.129	0.267	0.405	0.605	0.815	1.092	1.495	1.874	2.396	3.139	3.747	4.701
2007	0.000	0.000	0.000	0.276	0.389	0.581	0.833	1.137	1.500	1.948	2.607	3.057	3.869	4.954
2008	0.000	0.000	0.000	0.278	0.404	0.617	0.891	1.195	1.605	2.038	2.804	3.247	4.232	4.721

Table A4: Proportion mature-at-age for Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO (Healy pers. comm.). Note in the assessment, the maturity-at-age in 2008 and pre-1975 is taken as the average over the 1975-2007 period.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1975	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.04	0.04	0.03	0.12	0.21	0.34	0.50	0.77
1976	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.06	0.07	0.06	0.21	0.34	0.50	0.72
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.04	0.11	0.12	0.14	0.34	0.50	0.79
1978	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.03	0.08	0.18	0.20	0.29	0.50	0.78
1979	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.06	0.06	0.16	0.28	0.31	0.50	0.80
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.11	0.12	0.28	0.41	0.45	0.76
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.07	0.18	0.23	0.45	0.55	0.76
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.06	0.13	0.28	0.40	0.63	0.77
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.12	0.24	0.40	0.59	0.80
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.11	0.21	0.38	0.54	0.84
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.19	0.35	0.56	0.78
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.13	0.30	0.51	0.79
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.10	0.22	0.43	0.77
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.04	0.15	0.17	0.34	0.71
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.09	0.33	0.29	0.57
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.16	0.08	0.21	0.58	0.52
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.15	0.97	0.25	0.41	0.74
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.38	1.00	0.56	0.73
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.11	0.68	1.00	0.84
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.26	0.25	0.88	0.99
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.17	0.53	0.47	0.98
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.08	0.36	0.78	0.80
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.10	0.20	0.61	0.91
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.10	0.21	0.43	0.86
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.09	0.21	0.41	0.80
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.12	0.21	0.41	0.73
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.18	0.53	0.41	0.69
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.36	0.53	0.90	0.71
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.17	0.82	0.85	0.93
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.24	0.35	0.97	0.97
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.24	0.56	0.58	1.00
2006	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.24	0.56	0.80	0.86
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.24	0.49	0.79	0.94

Table A5: Survey data (mean numbers per tow) of Greenland Halibut in Sub-Area 2 and Divisions 3KLMNO. Decimalized year reflects the timing of each survey series (e.g. EU Summer survey). (Healey and Mahé, 2009)

2J3K Canadian Fall, 1995-2007

	1	2	3	4	5	6	7	8	9	10	11	12	13+
1996.9	98.68	47.82	32.01	9.54	6.28	2.47	0.84	0.19	0.18	0.04	0.02	0.01	0.02
1997.9	28.05	58.62	43.61	21.13	10.37	5.01	2.00	0.64	0.20	0.06	0.03	0.02	0.01
1998.9	23.35	25.07	31.19	21.87	10.86	4.45	2.07	0.57	0.13	0.06	0.03	0.02	0.01
1999.9	15.99	34.42	24.07	28.28	20.04	10.53	3.81	0.70	0.14	0.07	0.02	0.01	0.03
2000.9	38.57	21.94	16.43	13.20	13.76	7.21	2.16	0.50	0.06	0.03	0.02	0.00	0.00
2001.9	43.90	22.72	17.00	14.07	9.77	7.59	3.40	0.69	0.11	0.02	0.01	0.00	0.01
2002.9	40.67	24.08	12.50	9.68	6.03	1.97	0.72	0.19	0.04	0.01	0.00	0.00	0.00
2003.9	45.70	26.67	11.69	9.49	6.39	2.27	0.89	0.27	0.04	0.02	0.01	0.01	0.00
2004.9	32.49	32.93	13.89	12.31	9.21	2.68	1.20	0.36	0.08	0.03	0.01	0.00	0.01
2005.9	16.06	16.15	8.56	13.84	10.98	6.85	3.96	0.66	0.12	0.03	0.03	0.01	0.01
2006.9	32.34	17.98	8.50	17.60	13.03	9.11	4.18	1.15	0.18	0.03	0.02	0.01	0.00
2007.9	32.61	14.51	12.81	18.77	9.57	10.35	6.17	2.14	0.34	0.08	0.04	0.02	0.01

EU Summer, 1995-2007

	1	2	3	4	5	6	7	8	9	10	11	12+
1995.6	12.41	2.54	2.23	1.91	2.66	5.10	3.77	2.12	1.31	0.26	0.07	0.02
1996.6	5.84	7.97	2.42	3.04	4.20	5.82	2.49	1.62	0.42	0.09	0.03	0.04
1997.6	3.33	3.78	6.00	6.50	7.11	8.46	4.99	2.15	0.66	0.22	0.03	0.02
1998.6	2.74	2.13	7.69	11.00	12.33	11.30	7.84	2.62	0.75	0.20	0.03	0.01
1999.6	1.06	0.70	3.01	10.47	13.41	12.58	5.55	1.82	0.35	0.10	0.01	0.00
2000.6	3.75	0.29	0.60	2.17	7.09	14.10	5.40	2.32	0.45	0.11	0.05	0.00
2001.6	8.03	1.43	1.81	0.99	2.79	7.79	6.63	3.21	0.18	0.05	0.01	0.00
2002.6	4.08	2.94	2.80	1.67	3.79	5.59	5.73	1.28	0.13	0.06	0.02	0.01
2003.6	2.20	1.00	0.61	1.51	2.48	2.94	1.93	0.47	0.13	0.10	0.02	0.01
2004.6	2.19	3.29	4.37	1.97	6.97	7.80	2.54	0.64	0.29	0.13	0.08	0.05
2005.6	0.54	0.81	3.18	2.50	6.89	7.59	2.92	0.61	0.11	0.12	0.06	0.02
2006.6	0.68	0.40	0.65	1.17	5.98	7.46	3.31	0.77	0.22	0.18	0.13	0.06
2007.6	0.42	0.09	0.57	0.34	3.44	7.37	5.76	1.51	0.31	0.21	0.08	0.05

3LNO Canadian Spring, 1996-2007

	1	2	3	4	5	6	7	8+
1996.4	1.62	4.24	4.60	2.18	0.83	0.28	0.06	0.00
1997.4	1.16	3.92	5.16	3.23	1.46	0.51	0.10	0.01
1998.4	0.22	0.81	3.85	6.19	4.96	1.24	0.33	0.07
1999.4	0.29	0.55	1.15	1.98	3.39	1.09	0.24	0.05
2000.4	0.79	1.07	1.07	1.51	1.95	2.04	0.56	0.03
2001.4	0.57	0.71	0.74	0.68	0.80	0.72	0.28	0.02
2002.4	0.64	0.57	0.60	0.58	0.61	0.21	0.05	0.01
2003.4	0.93	2.14	1.66	1.57	1.06	0.21	0.05	0.01
2004.4	0.66	0.57	1.18	1.18	1.16	0.26	0.04	0.02
2005.4	0.35	0.31	1.09	0.95	1.37	0.82	0.21	0.03
2006.4	Survey not completed							
2007.4	1.60	0.52	0.80	0.40	1.41	1.49	1.12	0.18

Table A6: Survey data in terms of weight for ages combined: 2J3K Fall and 3LNO Spr (Healey, 2009), EU survey (Vázquez and González-Troncoso, 2008).

	2J3K Fall	EU survey	3LNO - Spr
Year	Mean weight (kg)/tow	Biomass (tons)	Mean weight (kg)/tow
1995		10875	
1996	21.6	11594	1.43
1997	24.8	16098	2.10
1998	23.8	24229	3.50
1999	32.5	21207	2.33
2000	23.9	16959	2.30
2001	22.7	13872	1.13
2002	14.1	12100	0.53
2003	15.3	6214	1.13
2004	17.5	12292	0.87
2005	20.3	11698	1.23
2006	25.7	11706	
2007	29.1	13040	2.17