CPUE-based Assessments of the Greenland Halibut Resource using SCAA

Doug S. Butterworth and Rebecca A. Rademeyer

April 2009

Summary

SCAA is used to assess the Greenland halibut resource as in Butterworth and Rademeyer (2009), but here using CPUE rather than surveys to provide indices of abundance. The approach is essentially that of an ASPM – a standard production model except that age-structure of the commercial catch is also taken into account. A base case ("Baseline CPUE") is selected which allows variability over time in commercial selectivity-at-age sufficient in extent to eliminate most of the systematic patterns evident if this selectivity is kept temporally invariant. The resultant biomass trends estimated are quite similar to, though slightly steadier than those for the comparative survey-based assessment, with both showing recent increases. This contrasts with the XSA assessment for which the biomass estimates are much lower.

Introduction

The core issue in the present debate about the current status of the Greenland halibut resource in NAFO Subarea 2 and Divisions 3KLMNO is the contrast between pessimistic appraisals arising from the survey-based XSA assessment, and optimistic industrial perceptions generated by an appreciable increase in commercial CPUE over recent years. It is therefore of interest to consider the results of an assessment that is based on CPUE as the index of trends in abundance in addition to those from assessments for which surveys play that role.

The assessments presented in this paper for the Greenland halibut resource use the same methodology as described in Butterworth and Rademeyer (2009), except that instead of fitting to survey indices of abundance and survey catch-at-age information, the model is fit to CPUE series treated as indices of relative abundance. The contribution by the CPUE series to the log-likelihood is described in Appendix B of Butterworth and Rademeyer (2009). Five CPUE series are available from the Canadian, Spanish and Portuguese fleets (see Appendix A, Table A1). Since the Portuguese CPUE consists of three series, one for each of Divisions 3L, 3M and 3N, their contributions to the log-likelihood has been averaged, i.e. each is given a weight of 1/3 relative to the Spanish and Canadian series.

The assessment approach taken is thus that of a production model fitted to CPUE as an index of abundance, except in this case the simpler age-aggregated form of the standard production model is extended to an Age-Structured Production Model (ASPM), which also includes allowance for variability about the stock-recruitment relationship to better incorporate information available from the commercial catch-at-age (CAA) data.

Results and Discussion

Table 1 shows results Baseline B1 for the survey-based SCAA together with variants 1-4 of the CPUE-based approach which correspond to cases 1-4 of Butterworth and Rademeyer (2009) for the survey-based approach.

Variant 4 has been chosen as the Baseline-CPUE assessment. It has a better –lnL overall and a better fit to CPUE series, and the lowest σ_{comCAA}. Results for variant 4 are illustrated in Figs. 1-5 which show the estimated 1+ (total), 5+ and 10+ (spawning) biomasss trend and selectivity vector, the stock-recruitment relationship fitted, and the model fits to data for the CPUE series and commercial proportions-at-age. Fig. 5 compares the CAA residuals for different values of σ_{Ω}, and shows that when this is set to 2, much of the systematic pattern evident for the time-invariant selectivity of variant 1 has disappeared. The biomass trends for these four variants are compared in Fig. 6.

Table 2 shows results for variations of variant 4. Variant 5 allows for serial correlation in the residuals to the fits for the CPUE series (see also Fig. 3b. Unlike in the survey-based case (Butterworth and Rademeyer 2009), including serial correlation is scarcely AIC-justified, so that this was not included in the Baseline-CPUE choice. Variant 6 sets selectivity flat from age 10 rather than exponentially decreasing (similar to the XSA results with their equal selectivities for ages 13 and 14+), while variant 7 increases σ_R to 0.5 (see also Fig. 4). The biomass trends for these four variants are compared in Fig. 7.

Table 2 also includes results the survey-based equivalent of variant 4. Biomass trends estimated for these two approaches, together with the corresponding estimates from the XSA assessment of Healey and Mahe (2008), are compared in Fig. 8.

When the biomass trend estimates shown in Figs 6-8 are compared to the survey-based results of Butterworth and Rademeyer (2009), it is noticeable that the biomass trends estimated from the CPUE data are somewhat more stable than their survey-based equivalents. This is a result of lesser estimated fluctuations in recruitment – note that here the values of σ_R _out are much less than the σ_R value input, unlike for the survey-based assessment results.

The CPUE fits (Fig. 3) are all as good as one would typically expect – σ_{cpue} values in the range 0.1 to 0.3. The only exception is the poorish fit in variance terms is to the Portuguese series for 3L. A higher value for serial correlation might have improved that, but the single value of ρ estimated across all the series is "diluted" by the absence of any strong indication of serial correlation in the other series.

The other variants whose results are shown in Fig. 6 indicate that an assumption of flat selectivity for older ages yields lesser biomasses in both absolute and relative terms, though the reductions are not as large as for a similar comparison of survey-based results in Butterworth and Rademeyer (2009). In contrast, increasing σ_R has the opposite effect. This is linked to a noticeable improvement in the fit to the Canadian CPUE index, brought about by allowing the possibility of greater variability in recruitment.

The plots in Fig. 8 comparing biomass trends estimated using different methodologies show little difference for the SCAA fits presented whether they are based on survey or CPUE indices of abundance. However both differ appreciably from the XSA results, with biomasses much greater in absolute terms and showing recent trends that are positive rather than stable-to-decreasing.

Fig. 8 and Table 2 also include results for two variants which fit the SCAA model to the "new" standardised CPUE data for Canada, Portugal and Spain developed in Brandão *et al*. (2009). Their two sets of series as standardised with interactions are used, and reproduced as Table A2 of Appendix A. The fits of these models, termed variants 8 and 9 to these new CPUE series are shown in Fig. 9. The biomass trends estimated for variants 8 and 9 are not as optimistic as those for Baseline-CPUE, but do nevertheless show a recent upward trend.

A reservation with these analyses is that the same selectivity pattern (even if varying with time) has been assumed to apply for all three national fleets considered. Ideally a different pattern should be allowed (or at least explored) for each fleet. However that would require the commercial CAA data to be provided in a form that disaggregates on a fleet basis.

Acknowledgments

Scientists from Canada, Portugal and Spain are thanked for their assistance in providing the data upon which the analyses of this paper are based.

References

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Table 1: Results of fits of various SCAA variants (see text for details) to the commercial catch and CPUE data compared to the survey-based Baseline assessment B1 of Butterworth and Rademeyer (2009), which also provides definitions of the symbols used. Biomass-related quantities are given in '000 tons. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs.

	Baseline B1			1) as B1 but fit to CPUE rather than survey series		2) as 1) but with serial correlation in the CPUE residuals		3) as 1) but with variations in commercial selectivity ($\sigma_\Omega = 0.5$)		Baseline CPUE 4) as 3) but $\sigma_\Omega = 2$ instead 0.5	
'-lnL:overall	-52.8			-105.5		-111.5		-207.8		-273.8	
'-lnL:Survey	-27.9			-		-		-		-	
-lnL:CPUE	-			-52.6		-55.5		-53.2		-62.4	
'-lnL:CAA	-56.3			-63.7		-67.3		-204.1		-237.5	
'-lnL:CAAsurv	-4.2			-		-		-		-	
'-lnL:RecRes	35.6			10.8		11.2		13.8		16.5	
'-lnL:SelPen	-			-		-		35.7		9.5	
h	**0.90**	-		**0.90**	-	**0.90**	-	**0.90**	-	**0.90**	-
θ	**1.0**	-		**1.0**	-	**1.0**	-	**1.0**	-	**1.0**	-
ϕ	**0.0**	-		**0.0**	-	**0.0**	-	**0.0**	-	**0.0**	-
ρ	**0**	**-**		**0**	**-**	0.48	**-**	**0**	**-**	**0**	**-**
K^{sp}	603	(0.15)		560	(0.19)	487	(0.16)	420	(0.05)	496	(0.12)
$B^{sp}{}_{2008}$	364	(0.34)		255	(0.43)	176	(0.48)	113	(0.14)	248	(0.31)
$B^{sp}{}_{2008}/K$	0.60	(0.20)		0.45	(0.25)	0.36	(0.33)	0.27	(0.12)	0.50	(0.19)
MSYL^{sp}	0.17	(0.09)		0.17	(0.11)	0.18	(0.12)	0.17	(0.03)	0.17	(0.12)
$B^{sp}{}_{MSY}$	105	(0.23)		98	(0.28)	85	(0.27)	73	(0.07)	84	(0.22)
MSY	45	(0.15)		42	(0.18)	37	(0.15)	32	(0.05)	36	(0.12)
σ_{comCAA}	0.14			0.14		0.13		0.07		0.06	
Survey	$q'sx10^6$	σ_{surv}	$\sigma_{survCAA}$								
CanFall1	92	0.29	0.11								
CanFall2	172	0.28	0.07								
EU	61272	0.48	0.11								
CanSpr	10	0.53	0.12	$q'sx10^6$	σ_{cpue}	$q'sx10^6$	σ_{cpue}	$q'sx10^6$	σ_{cpue}	$q'sx10^6$	σ_{cpue}
Canada				3.10	0.30	3.68	0.30	5.18	0.31	4.13	0.26
Spain				5.91	0.19	7.30	0.16	10.57	0.13	7.85	0.11
Portugual 3L				1.45	0.39	1.75	0.33	2.53	0.47	1.96	0.46
Portugual 3M				1.45	0.24	1.75	0.29	2.53	0.28	1.96	0.26
Portugual 3N				1.45	0.22	1.75	0.23	2.53	0.31	1.96	0.28
σ_R_out	0.24			0.13		0.14		0.15		0.17	

Table 2: Results of fits of various SCAA variants (see text for details) to the commercial catch and CPUE data and the survey-based variant 4 of Butterworth and Rademeyer (2009), which also provides definitions of the symbols used. Biomass-related quantities are given in '000 tons. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs.

	Variant 4) of Butterworth and Rademeyer (2009) (Survey equivalent to Baseline CPUE)			Baseline CPUE		5) as Baseline CPUE but with serial correlation in the CPUE residuals		6) as Baseline CPUE but with flat commercial selectivity from age 10		7) as Baseline CPUE but with σ_R=0.5 instead of 0.25		8) as Baseline CPUE but new CPUE series (Model 4, with interactions)		9) as Baseline CPUE but new CPUE series (Model 5, with interactions)	
'-lnL:overall	-226.0			-273.8		-275.0		-266.3		-296.9		-275.8		-255.6	
'-lnL:Survey	-30.6			-		-		-		-		-			
-lnL:CPUE	-			-62.4		-61.9		-62.7		-72.4		-62.1		-40.8	
'-lnL:CAA	-234.8			-237.5		-237.6		-236.4		-244.2		-235.3		-238.3	
'-lnL:CAAsurv	-2.3			-		-		-		0.0		0.0		0.0	
'-lnL:RecRes	31.8			16.5		15.1		16.5		8.7		13.0		15.2	
'-lnL:SelPen	9.9			9.5		9.4		16.3		11.0		8.5		8.3	
h	**0.9**	-		**0.9**	-	**0.9**	-	**0.9**	-	**0.9**	-	**0.9**	-	**0.9**	-
θ	**1**	-		**1**	-	**1**	-	**1**	-	**1**	-	**1**	-	**1**	-
ϕ	**0**	-		**0**	-	**0**	-	**0**	-	**0**	-	**0**	-	**0**	-
ρ	**0**	-		**0**	-	0.27	-	**0**	-	**0**	-	**0**	-	**0**	-
K^{sp}	523	(0.15)		496	(0.12)	480	(0.13)	432	(0.09)	682	(0.22)	477	(0.14)	446	(0.13)
B^{sp}_{2008}	291	(0.38)		248	(0.31)	226	(0.33)	185	(0.26)	412	(0.40)	204	(0.39)	156	(0.44)
B^{sp}_{2008}/K	0.56	(0.24)		0.50	(0.19)	0.47	(0.22)	0.43	(0.19)	0.60	(0.21)	0.43	(0.26)	0.35	(0.32)
MSYL^{sp}	0.17	(0.14)		0.17	(0.12)	0.17	(0.62)	0.18	(0.62)	0.17	(0.63)	0.17	(0.64)	0.17	(0.55)
B^{sp}_{MSY}	88	(0.27)		84	(0.22)	82	(0.65)	77	(0.64)	118	(0.69)	83	(0.67)	77	(0.59)
MSY	38	(0.14)		36	(0.12)	35	(0.12)	33	(0.09)	51	(0.22)	36	(0.13)	34	(0.12)
σ_{comCAA}	0.07			0.06		0.06		0.06		0.06		0.06		0.06	
Survey	$q'_s x10^6$	σ_{surv}	$\sigma_{survCAA}$												
CanFall1	102	0.29	0.11												
CanFall2	152	0.22	0.08												
EU	71875	0.49	0.11												
CanSpr	12	0.53	0.12	$q'_s x10^6$	σ_{cpue}	$q'_s x10^6$	σ_{cpue}	$q'_s x10^6$	σ_{cpue}	$q'_s x10^6$	σ_{cpue}	$q'_s x10^6$	σ_{cpue}	$q'_s x10^6$	σ_{cpue}
Canada				4.13	0.26	4.31	0.27	4.76	0.26	3.05	0.19	14.96	0.25	14.82	0.28
Spain				7.85	0.11	8.24	0.12	9.11	0.11	5.81	0.11	8.49	0.10	10.63	0.15
Portugual 3L				1.96	0.46	2.04	0.40	2.26	0.45	1.45	0.43	9.05	0.07	10.84	0.26
Portugual 3M				1.96	0.26	2.04	0.28	2.26	0.26	1.45	0.29				
Portugual 3N				1.96	0.28	2.04	0.26	2.26	0.28	1.45	0.25				
σ_R_out	0.23			0.17		0.16		0.17		0.30		0.15		0.16	

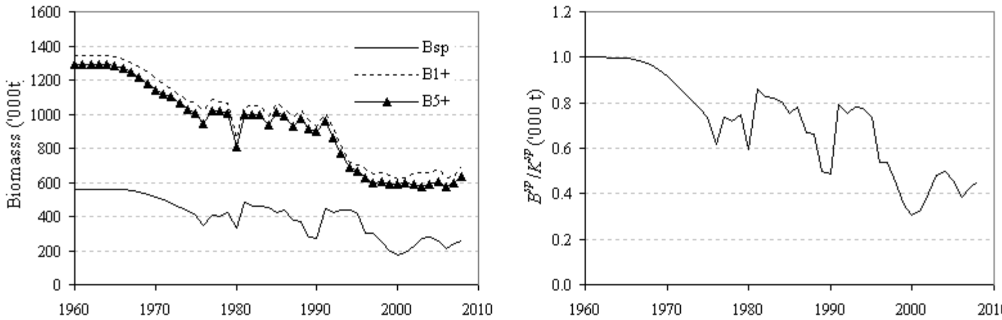

Fig. 1: Spawning biomass trajectories (in absolute terms and relative to pre-exploitation level) and B1+ and B5+ biomasses for the Baseline CPUE model.

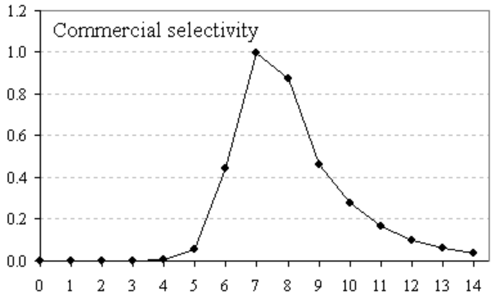

Fig. 2: Commercial fishing selectivities-at-age estimated for Baseline CPUE model.

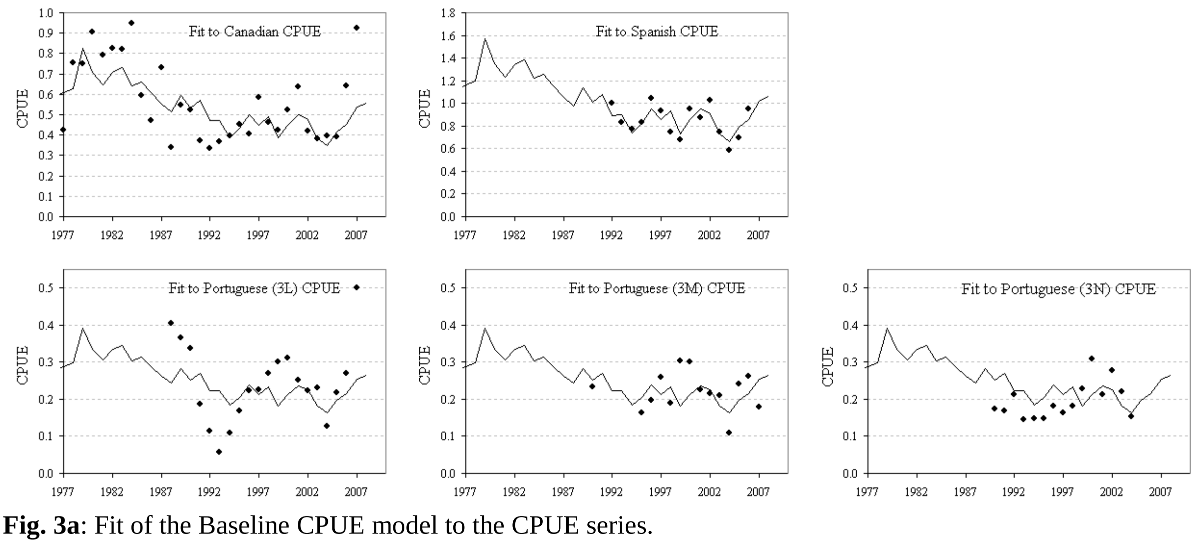

Fig. 3a: Fit of the Baseline CPUE model to the CPUE series.

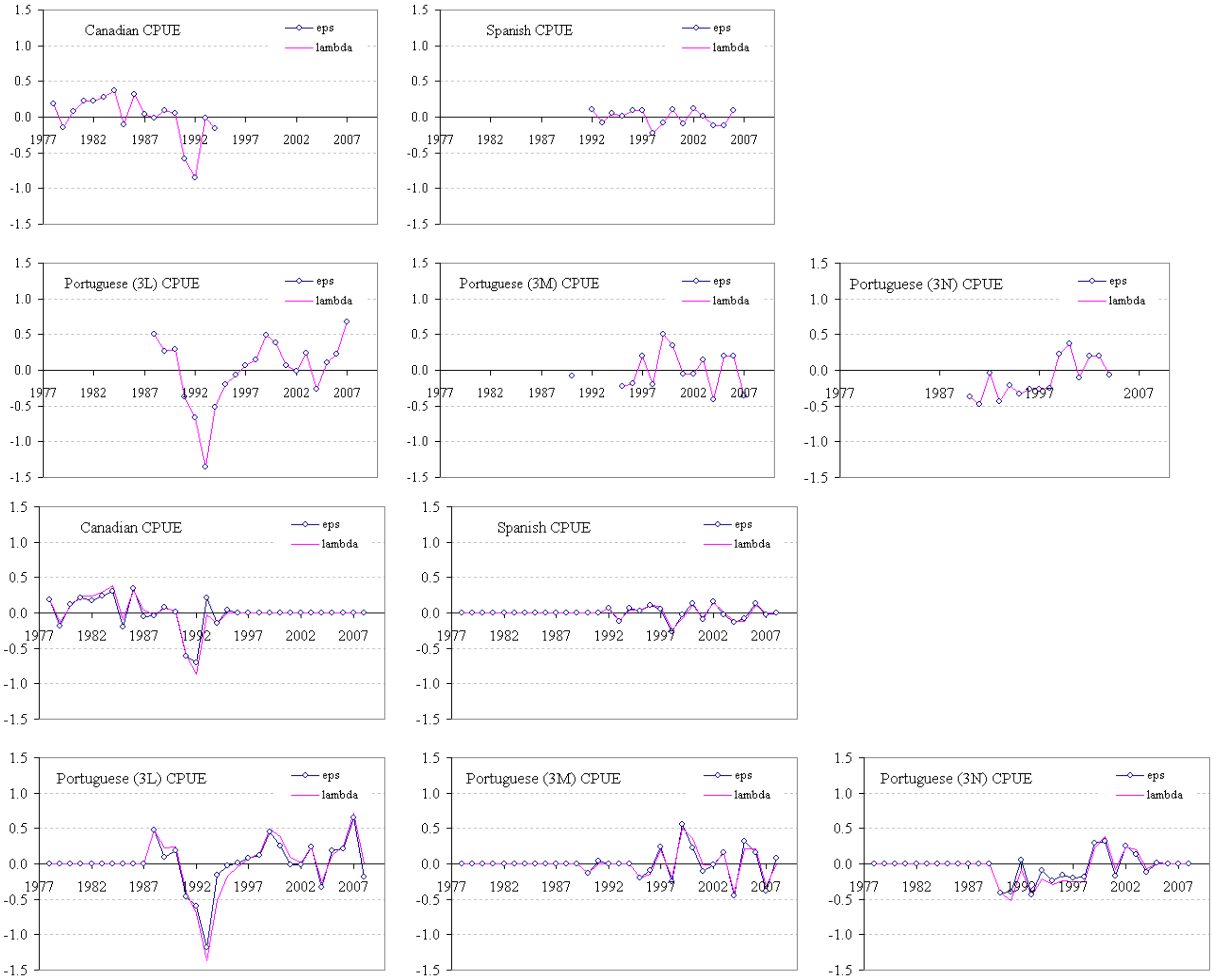

Fig. 3b: CPUE residuals for the Baseline CPUE model (first two rows) and variant 5 (last two rows) with serial correlation in the CPUE residuals.

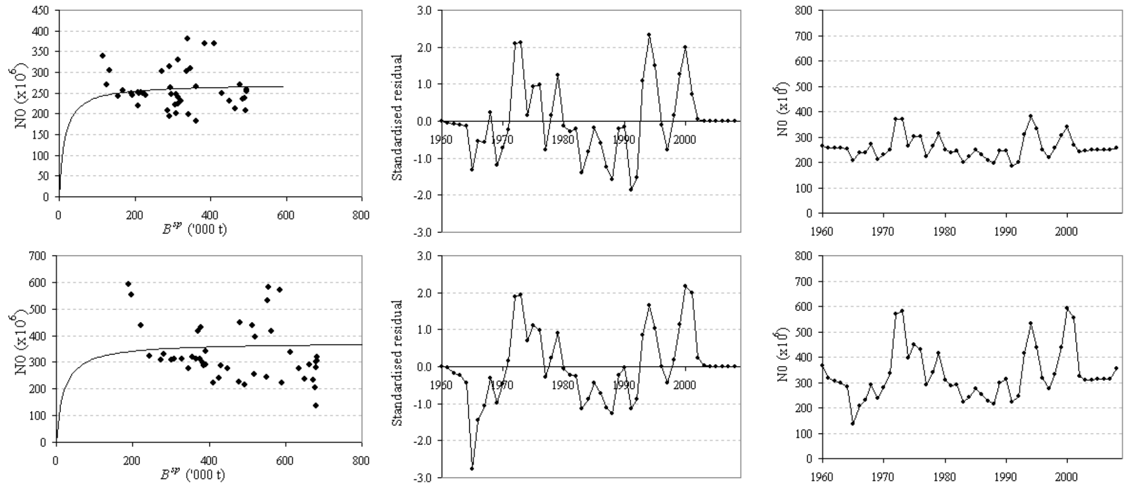

Fig. 4: Stock-recruitment curve and time series of recruitment and standardised stock-recruitment residuals for the Baseline CPUE model (σ_R =0.25, top row) and variant 7 (σ_R=0.5, bottom row).

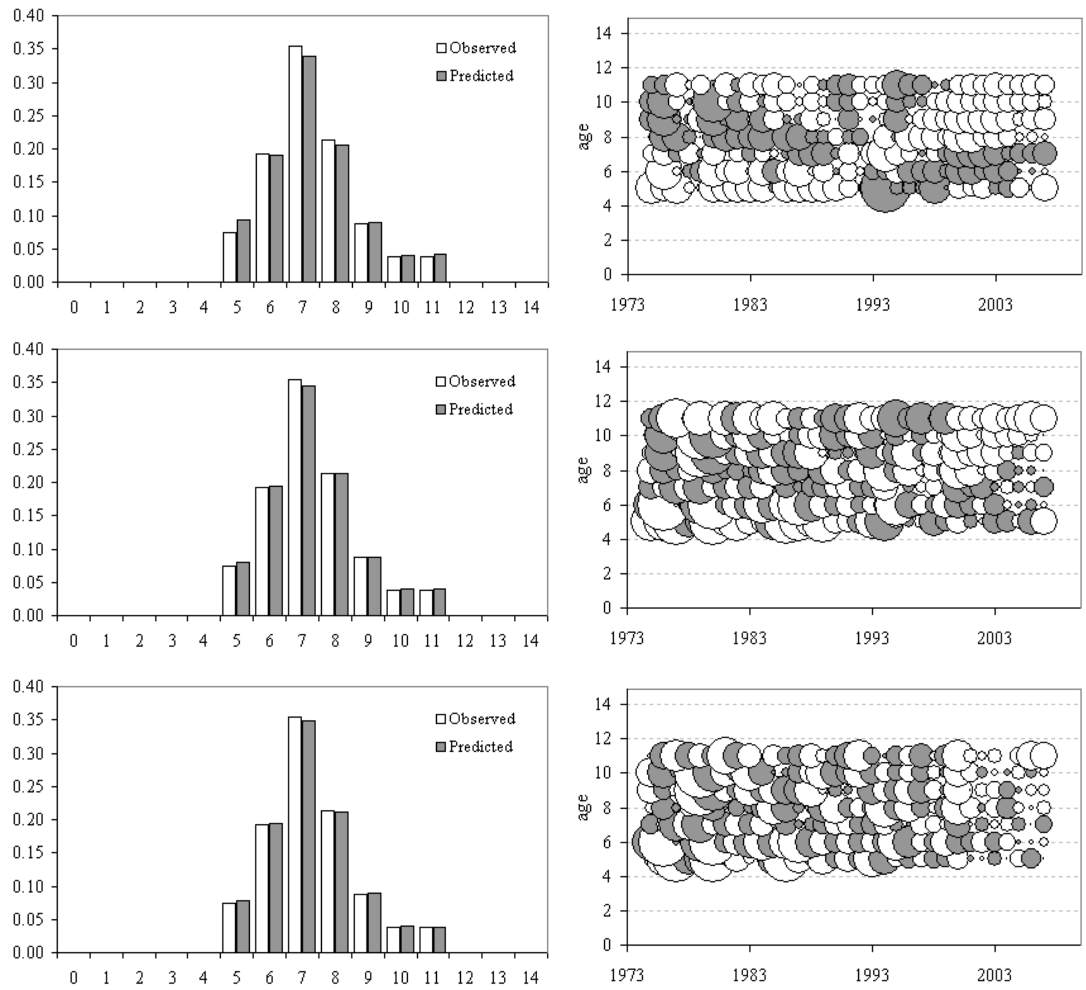

Fig. 5: Fit to commercial CAA for variant 1 (top panels) and for variants 3 and 4 (middle and lower panels respectively) with varying commercial selectivity (in 2 year periods) where the $\Omega_{y,a}$ are estimated.

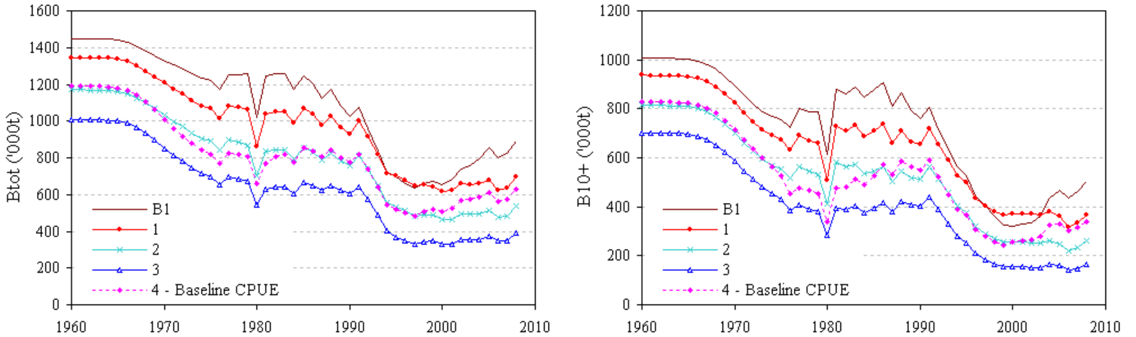

Fig.6: Comparison of total (1+) and spawning (10+) biomass for the survey-based assessment B1 of Butterworth and Rademeyer (2009) and four variants of the SCAA assessments fitting to CPUE series.

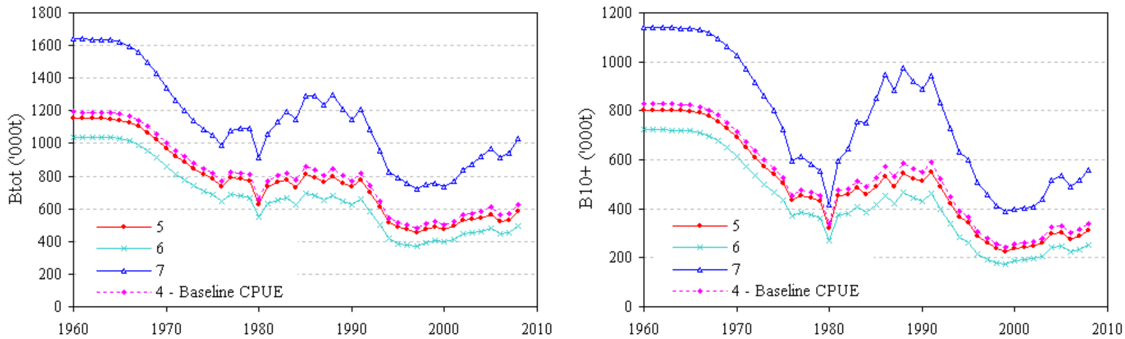

Fig.7: Comparison of total (1+) and spawning (10+) biomass for the Baseline CPUE model and three variants thereof.

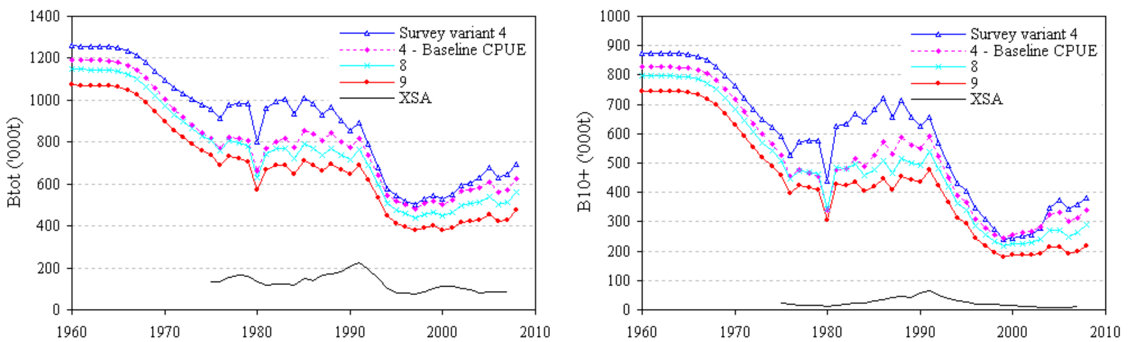

Fig.8: Comparison of total (1+) and spawning (10+) biomass for the Baseline CPUE, variants 8 and 9 with the new standardised CPUE of Brandão *et al.* (2009), the comparable survey-based variant 4 of Butterworth and Rademeyer (2009) and the XSA assessment.

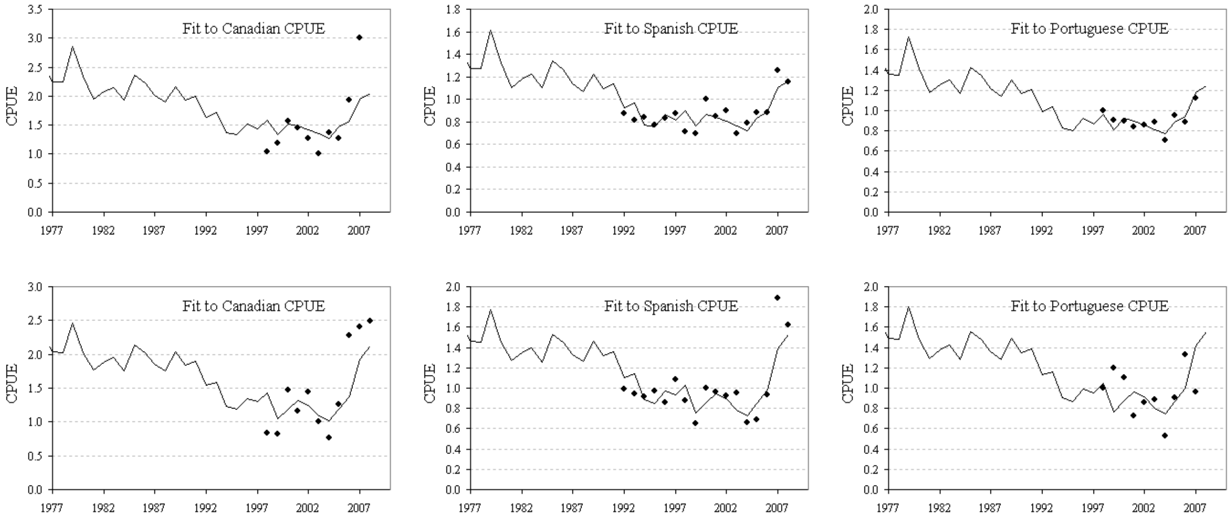

Fig. 9: Fit of variants 8 (top row) and 9 (bottom row) to the new standardised CPUE series with interactions.

APPENDIX A – Data

Table A1: Standardized CPUE for Greenland halibut from Canadian otter trawl fleet, Div. 2HJ3KL (Brodie *et al*., 2008), from Spanish fleet, Div. 3LMNO (Fernández *et al*., 2007) and from Portuguese fleet, by Division, for Div. 3LMN (Vargas *et al*., 2008).

	Canadian standardised CPUE	Spanish standardised CPUE	Portuguese standardised CPUE		
	Div. 2HJ3KL	Div. 3LMNO	Div. 3L	Div. 3M	Div. 3N
1976	0.311				
1977	0.426				
1978	0.756				
1979	0.748				
1980	0.904				
1981	0.794				
1982	0.827				
1983	0.823				
1984	0.949				
1985	0.593				
1986	0.471				
1987	0.731				
1988	0.338		0.404		
1989	0.546		0.367		
1990	0.524		0.338	0.233	0.175
1991	0.374		0.187		0.168
1992	0.333	1.000	0.115		0.213
1993	0.37	0.828	0.058		0.144
1994	0.397	0.774	0.109		0.148
1995	0.454	0.836	0.168	0.164	0.148
1996	0.406	1.041	0.222	0.198	0.182
1997	0.583	0.938	0.227	0.260	0.164
1998	0.463	0.744	0.269	0.190	0.181
1999	0.426	0.680	0.300	0.304	0.228
2000	0.525	0.955	0.311	0.302	0.309
2001	0.637	0.873	0.252	0.226	0.213
2002	0.421	1.024	0.222	0.215	0.277
2003	0.383	0.743	0.231	0.210	0.221
2004	0.394	0.590	0.126	0.109	0.154
2005	0.391	0.700	0.218	0.241	
2006	0.642	0.949	0.270	0.262	
2007	0.925		0.501	0.178	

Table A2: Standardized CPUE for Greenland halibut from Canadian, Spanish and Portuguese fleets for the GLMs models 4 and 5 with interaction from Brandão *et al*. (2009).

	Model 4 (Div*Year interaction)			Model 5 (Depth*Year interaction)		
	Canada 2HJ3K	Spain 3MNO	Portugal 3LMNO	Canada 2HJ3K	Spain 3MNO	Portugal 3LMNO
1992		0.8760			0.9891	
1993		0.8149			0.9471	
1994		0.8430			0.9187	
1995		0.7757			0.9684	
1996		0.8322			0.8631	
1997		0.8749			1.0884	
1998	1.0473	0.7134	1.0000	0.8312	0.8740	1.0000
1999	1.1870	0.6956	0.9035	0.8141	0.6527	1.1989
2000	1.5633	1.0000	0.8969	1.4740	1.0000	1.1068
2001	1.4473	0.8451	0.8360	1.1666	0.9651	0.7264
2002	1.2662	0.9041	0.8586	1.4434	0.9219	0.8614
2003	1.0000	0.6967	0.8833	1.0000	0.9559	0.8839
2004	1.3721	0.7857	0.7083	0.7585	0.6577	0.5307
2005	1.2738	0.8797	0.9529	1.2576	0.6876	0.9099
2006	1.9351	0.8860	0.8899	2.2769	0.9385	1.3262
2007	2.9977	1.2560	1.1241	2.4124	1.8900	0.9639
2008		1.1511		2.4926	1.6184	