Extensions to SCAA Applications Reported in:

"Further Applications of Statistical Catch-at-Age Assessment Methodology to the 2J3K-O Greenland Halibut Resource"

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Summary

This document reports refinements to the survey-based SCAA assessments reported at an earlier meeting in Vigo, and attempts to provide results for the set of future analyses requested there. Particular attention has been paid to attempting to reduce the residual patterning evident in earlier assessments through taking further account of serial correlation. These efforts seem to have been reasonably successful for the overall survey indices and commercial catch-at-age proportions, but less so for the survey catch-at-age proportions, which consequently remain somewhat overweighted in the fitting process. A simpler age-structured production model is also fitted to the data, and gives similar results to the New Baseline SCAA assessment that is developed, with Bayesian estimates of precision computed for both these approaches. Despite these efforts to incorporate serial correlation, some conflict remains amongst the different sets of input data, and partly in consequence the absolute scale of biomass is poorly determined by assessments. The most pessimistic (in stock status terms) of the SCAA variants considered produce biomass estimates that do not differ that greatly from those from XSA. Importantly however, even in those cases the SCAA assessments provide results for recent years more in line with survey index (and CPUE) trends, and give more positive projections for future abundance: for example all SCAA projections under a constant TAC of 22750 tons increase, whereas XSA projects a decrease in those circumstances.

Introduction

This paper continues the development of the application of Statistical Catch-at-Age (SCAA) methodology to the 2J3K-O Greenland halibut resource beyond the results presented in Butterworth and Rademeyer (2009a). Updates include:

1) Taking the modelled population age structure to a plus-group age of 20 rather than 14 so that any decreasing selectivity trend continues to a larger age. For the commercial selectivity, the estimated decrease from ages 11 to 12 are assumed to continue exponentially to age 20+. Similarly for the survey selectivities, the estimated decrease from ages 10 to 11 (7 to 8 for the Canadian spring survey) is assumed to continue exponentially to age 20+.

2) The inclusion of correlation, in both year and age, in survey proportions-at-age data. Butterworth and Rademeyer (2009a) noted the non-randomness of the residuals for the fits of the survey proportions-at-age data. To allow for serial correlation between the survey proportion-at-age residuals, equation B21 of Butterworth and Rademeyer (2009b) is replaced by:

$$-\ell n L^{CAA} = \sum_{i=1}^{n_{surv}} \left\{ \begin{array}{l} \displaystyle\sum_{y=2}^{n} \sum_{a=a_{\min us}+1}^{a_{plus}} \left[\ell n \left(\sigma^i_{surv} / \sqrt{p^i_{y,a}} \right) + p^i_{y,a} \left(\eta^i_{y,a} \right)^2 / 2 \left(\sigma^i_{surv} \right)^2 \right] \\ \displaystyle + \sum_{a=a_{\min us}}^{a_{plus}} \left(\sum_{y=1}^{n} p^i_{y,a} - \sum_{y=1}^{n} p^i_{y,a} \right)^2 \end{array} \right\} \qquad (1)$$

with

$$\eta^i_{y,a} = \left(\varepsilon^i_{y,a} - \rho^i_{CAAage}\varepsilon^i_{y,a-1}\right) - \rho^i_{CAAyr}\left(\varepsilon^i_{y-1,a} - \rho^i_{CAAage}\varepsilon^i_{y-1,a-1}\right) \quad (2)$$

$$\varepsilon^i_{y,a} = \sqrt{p^i_{y,a}}\left(\ell n\, p^i_{y,a} - \ell n\, \hat{p}^i_{y,a}\right) \quad (3)$$

and

$$\hat{\sigma}^i_{surv} = \sqrt{\sum_y \sum_a \eta^2_{y,a} / \sum_y \sum_a 1} \quad (4)$$

ρ^i_{CAAage} is the age serial correlation coefficient for survey series *i*, which is estimated, and

ρ^i_{CAAyr} is the year serial correlation coefficient for survey series *i*, which is estimated.

The second term in the likelihood has been added so that the average predicted proportion-at-age is close to that observed. This is necessary here because taking account of serial correlation loses the information otherwise in the likelihood to fit to data for the youngest age-class.

Results

New Baseline

Extending the model to age 20 (compared to 14 in Rademeyer and Butterworth, 2009a) has little effect on the results (Case 1, Table 1). Residual patterns for the survey catch-at-age data are improved by allowing for serial correlation in both age and year as described above (Cases 2 and 3, Table 1). For both the age and the year serial correlations, a series specific correlation parameter is warranted in terms of AIC. These two specifications provide the basis for a revised baseline assessment (Case 4, "New Baseline"). Fig. 1 compares the biomass trajectories estimated for Cases 1 to 4, while the standardised residual patterns for the fits to the survey catch proportions-at-age for these four cases are shown in Fig. 2.

Figs 3-5 show results for the New Baseline, respectively the survey and commercial (average) selectivities, the fit to the survey abundance indices and the corresponding survey standardised residuals. The estimated numbers-at-age and fishing mortalities matrices are shown in Tables 8 and 9 respectively.

As previous assessments presented in Rademeyer and Butterworth (2009a), the New Baseline includes serial correlation in the survey abundance indices. The serial correlation parameter is not series specific as it is not warranted in terms of AIC criteria (Case 5, Table 1). Introduction of serial correlation does improve the randomness of the residuals (see Fig.5).

Variation in assumptions concerning the stock-recruitment relationship

Table 2 shows sensitivities to a number of variations in the New Baseline assumptions of a Beverton-Holt stock recruitment function with steepness h = 0.9 and recruitment variability set on input to σ_R = 0.2. First lower values of h are considered. Next a refinement of the Ricker form is considered which can also produce shapes similar to Beverton-Holt, as described in Butterworth and Rademeyer (2009a). This is implemented estimating both h and γ. Finally σ_R is set to 0.3. The resulting stock-recruitment curves, and time series of standardised stock-recruitment residuals and recruitment are shown in Fig. 6, while the biomass trajectories are shown in Fig. 7.

Variation in assumptions concerning the annual catches and commercial selectivity

Table 3 shows sensitivities to the 1990-1994 annual catch assumptions, as well as assumptions concerning the commercial selectivity. Fig. 8 plots the biomass trajectories for these four sensitivities. Fig. 9 compares the commercial selectivity estimated for the New Baseline, the XSA assessment and Case 10 with flat selectivity from age 10. To coincide with known changes in the operation or regulation of the fishery, an alternative commercial selectivity is considered in Case 11. The selectivity is divided into four periods (1960-1987, 1989-1995, 1996-2003, 2007-2008), with linear trends between the periods. The selectivity estimated for each period is shown in Fig. 10.

Sensitivities on the extent of selectivity variation

Cases 12a-c in Table 4 investigate the effect of changing the extent of selectivity variation, first in the commercial selectivity (more and less variation allowed in 12a and 12b respectively) and then in the survey selectivities (σ_Ω increased to 1 in 12c). Fig. 11 compares the biomass trajectories and Fig. 12 the standardised residuals for the commercial and survey proportions-at-age.

Sensitivities on the extent of natural mortality

Case 13 fixes the natural mortality to 0.15 instead of 0.2 in the New Baseline assessment (Table 4). The biomass trajectories are shown in Fig. 13.

Start in 1975 with data as in XSA

Cases 14a-c use the same data in fitting as used in the current XSA, i.e. excluding the pre-1995 Canadian fall survey information (biomass index and catch-at-age data) and the pre-1995 EU survey index. In 14a, the model starts in 1960 assuming unexploited equilibrium (as in the New Baseline) and is brought forward under the annual catches. Stock-recruitment residuals are estimated from 1975 onwards. In 14b, the model starts in 1975 and θ and φ are estimated; while in 14c, the XSA estimated proportions-at-age in 1975 are used as input and θ is estimated. Results for these three sensitivities are shown in Table 4, while the biomass trajectories are compared in Fig. 14.

The estimated numbers-at-age and fishing mortalities matrices are shown in Tables 10 and 11 respectively for 14a.

Retrospective assessments

The results of retrospective assessments for the New Baseline are shown in Table 6 and Fig.16.

Production-type model

Table 7 gives results of two production-type models with no stock-recruitment variations and no variations in selectivities. These models nevertheless have to be age-structured as account has to be taken of the different age “ranges” to which catches and the various surveys correspond. Case 1 fits to both survey indices and commercial and survey proportions-at-age, and selectivities are estimated, though with *h* fixed at 0.9 as otherwise parameter estimation becomes confounded. The purpose of this exercise is merely to estimate the selectivities at values which can be fixed when *h* is freed. Case 2 fits to the survey indices only and the selectivities are fixed to the values estimated in Case 1. Fig. 15 compares the biomass trajectories for production-type model 2, the New Baseline and the XSA.

Key results are summarised for the XSA, the New Baseline and all the sensitivities to this assessment, and the Production-type Model 2 in Table 12.

Projections results

20-year biomass projections for the New Baseline are plotted in Fig.17 under a series of catch scenarios: three constant catch (0, 16000t and 22750t) and a F0.1 strategy. The constant catch projections of 16000t and 22750t are compared across four models in Fig. 18: the New Baseline, a more pessimistic SCAA (Case 14a, start in 1975), the Production-type Model 2 and XSA.

The catches expected under the F0.1 strategy for the New Baseline, Case 14a and the Production-type Model 2 are plotted in Fig. 19. The reason for the sharp initial peak in estimates of the F0.1 strategy TAC for the New Baseline SCAA and the production model 2 is that both these assessments estimate current biomass to be appreciably above the MSY level, so that TACs are set with the intent to decrease current abundance.

MCMC results

For the New Baseline and the Production-type Model 2, MCMC has been used to compute posterior distributions. The contribution from equations B25 and B27 in Rademeyer and Butterworth (2009b) then correspond to priors on the distribution of the recruitment and selectivity residuals respectively. Other priors on the parameters (K^{sp}, the serial correlation parameters and the selectivity parameters) are taken to be uniform over wide and/or feasible ranges with the intent that they be uninformative.

The initial parameter vector used to start the MCMC computational process was the mode of the posterior. The chain was “thinned” by taking every 1000th value in the chain, and the results of the first one million iterations were discarded to allow for a "burn-in" period. A chain of 10 million iterations (including the burn-in period) was run.

Tables 14 and 15 compare the Maximum Likelihood Estimate (MLE), the median and 90%-iles for the New Baseline and the Production-type Model 2 respectively. The simple approach of comparing results for the first and second halves of the parts of the chains retained showed little difference, broadly suggesting that the chain was sufficiently long to achieve convergence.

Note that the treatments of the SCAA and the production model in this assessment of estimation precision have differed. For the SCAA the steepness parameter *h* was fixed at 0.9, consistent with most other SCAA variants for which results are reported here, whereas *h* was treated as an estimable parameter (with an uninformative prior) for the production model MCMC Bayesian computations. In retrospect, it is evident that as the value of *h* has an important influence on values of some other quantities of importance to management, it might have been better to include *h* as an estimable parameter with a prior in the SCAA Bayesian computations, but there was insufficient time to do this.

Discussion

Some key features of the results are as follows.

In Table 1 the selection of the New Baseline assessment was determined by the best AIC. It is important though to note that taking account of further serial correlation has the effect of decreased precision (larger Hessian-based CVs) for the resultant estimates.

Table 2 shows that the negative log likelihood does not increase very much for lower values of steepness *h*, and these in turn reflect greater extents of depletion. Together with that, however, comes a poorer fit to the survey series. In contrast, if recruitment variability is increased, abundance estimates also increase.

Tables 3 and 4 show that a lower value of *M*, or a decrease in 1990-94 catches leads to greater extents of depletion estimates, but that the reverse holds if the extent permitted of variation permitted for selectivity is increased. Assuming asymptotically flat selectivity does not lead to an especially pessimistic appraisal as in earlier work, but this flat level estimated is rather low, and so still suggests a large cryptic component of the biomass.

Omission of pre-1975 data leads (Table 5) to much greater estimates for the extent of depletion. Additional analyses (not shown here) indicate that it is chiefly the inclusion or otherwise of the pre-1995 Canadian fall CAA that determines whether or not the estimated extent of depletion of the halibut resource is large. Although these Table 5 results for abundance are quite close to those from the XSA in absolute terms, they also show very different behaviour close to the end of the assessment period, with their estimated biomass trends more positive than for XSA.

Table 6 yields a preferred production model assessment (model 2) with results similar to those of the New Baseline SCAA assessment. However the Hessian-based CV's for the production model are rather high, probably because this model treats *h* as an estimable parameter, whereas the SCAA fixes *h*. This qualitative comparison is borne out by the corresponding Bayesian results shown in Tables 12 and 13.

For the retrospective analysis, aside from a more negative appraisal for the assessment with only the most recent year's data removed, the plots in Fig. 16 are very consistent and provide no indication of any systematic pattern

In summary

The most important (and problematic) feature of the assessment of this Greenland halibut resource is the conflict between trends in the survey indices of abundance (or equally the CPUE) and information contained in the catch-at-age proportions for the surveys. The former fit better with an appraisal of a relatively large resource which is not substantially depleted below its pre-exploitation level, while the latter suggest the opposite. It is very evident for all variants where the SCAA suggests a highly depleted resource that the –lnL contribution from the survey indices deteriorates to an important extent.

Our efforts have concentrated particularly on trying to take due account of serial correlation in these data to discover whether this removes this conflict, to provide more correct relative weighting of the contributions of these two data sources to the negative log likelihood, and to provide a more defensible basis for estimates of precision such as Bayesian probability intervals. In this regard (and these are matters of relevance also to VPA approaches) we have been only partially successful. Our sense is that we have adequately accounted for serial correlation in the time trends of the survey indices and the commercial catch-at-age proportions, but only partially so for the survey catch-at-age proportions. This then suggests that in a statistical context our computations reflect an over-weighting of the survey catch-at-age proportions, and with that results for resource status that are negatively biased to some extent.

It is unsurprising that there is a wide range of absolute biomass scale across the various SCAA variants reported, as the conflict indicated would contribute to such an effect. Our view is that for more reliable results priority in assessments should first be given to having models fit the trends in indices of overall abundance, provided due account is taken of serial correlation effects and attention given to possible non-comparability over time.

The most pessimistic (in stock status terms) of the SCAA variants reported produce biomass estimates that do not differ that greatly from those from XSA. Importantly however, even in those cases the SCAA assessments provide results for recent years more in line with survey index (and CPUE) trends, and give more positive projections for future abundance: for example all SCAA projections under a constant TAC of 22750 tons increase, whereas XSA indicates a decrease.

References

Butterworth DS and Rademeyer RA. 2009a. Further applications of Statistical Catch-at-Age Assessment methodology to the 2J3K-O Greenland Halibut resource.

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

Healey BP and Mahé J-C. 2008. An assessment of Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Subarea 2 and Divisions 3KLMNO. NAFO SRC Doc. 08/48, Ser. No N5550.

Table 1: Results of fits of various SCAA variants to the commercial catch and survey data compared to the Baseline assessment B2 of Butterworth and Rademeyer (2009a). Biomass units are ‘000t. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs. –lnL values in parenthesis are for repeating case 1) but fitting to the same number of data points as the sensitivity concerned (see text for details).

	Baseline B2 (Rademeyer and Butterworth, 2009a)			1) As B2 but max age = 20 and with extra -lnL^{CAA} summation			2) As 1) with serial correlation in age for the survey CAA				3) As 1) with serial correlation in year for the survey CAA				4) as 1) serial correlation by age and year for the survey CAA **New Baseline**				5) as New Baseline (NB) with a survey ρ for each series			
No of parameters	503			503			507				511				515				518			
No of data points	1024			1024			965				977				924				924			
'-lnL:overall	-500.4			-498.2			-573.2	-(516.8)			-525.3	-(476.0)			-602.2	-(497.4)			-603.2			
'-lnL:Survey	-49.3			-49.4			-49.0	-(47.3)			-46.9	-(49.9)			-47.1	-(48.1)			-49.4			
'-lnL:CAA	-225.0			-224.5			-216.3	-(223.1)			-226.4	-(227.5)			-220.2	-(226.5)			-220.3			
'-lnL:CAAsurv	-367.2			-367.8			-423.2	-(376.8)			-438.4	-(338.0)			-478.2	-(350.3)			-478.9			
'-lnL:RecRes	30.1			30.0			23.9	(26.2)			31.6	(29.8)			23.0	(26.0)			24.1			
'-lnL:SelPen	111.1			113.5			91.4	(104.3)			154.7	(109.6)			120.4	(101.5)			121.3			
h	**0.90**			**0.90**			**0.90**				**0.90**				**0.90**				**0.90**			
θ	**1**			**1**			**1**				**1**				**1**				**1**			
ϕ	**0**			**0**			**0**				**0**				**0**				**0**			
ρ - surveys	0.63			0.63			0.62				0.67				0.65				0.24	0.59	0.78	0.69
ρ_{CAAage}	**0**			**0**			0.64	0.14	0.15	0.30	**0**				0.70	0.24	0.24	0.38	0.70	0.25	0.23	0.37
ρ_{CAAyr}	**0**			**0**			**0**				-0.20	-0.78	-0.28	-0.51	-0.35	-0.73	-0.25	-0.53	-0.36	-0.73	-0.25	-0.54
K^{sp}	576	(0.19)		601	(0.20)		687	(0.29)			598	(0.23)			596	(0.27)			645	(0.29)		
$B^{sp}{}_{2008}$	372	(0.42)		402	(0.42)		497	(0.53)			371	(0.50)			353	(0.60)			412	(0.58)		
$B^{sp}{}_{2008}/K$	0.65	(0.24)		0.67	(0.23)		0.72	(0.25)			0.62	(0.28)			0.59	(0.34)			0.64	(0.30)		
MSYL^{sp}	0.17	(0.62)		0.17	(0.12)		0.17	(0.12)			0.17	(0.14)			0.17	(0.15)			0.17	(0.14)		
$B^{sp}{}_{MSY}$	100	(0.68)		101	(0.30)		115	(0.38)			100	(0.35)			100	(0.41)			108	(0.41)		
MSY	43	(0.18)		44	(0.19)		49	(0.28)			44	(0.22)			43	(0.26)			47	(0.28)		
σ_{comCAA}	0.07			0.07			0.07				0.07				0.07				0.07			
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}	$\sigma_{survCAA}$	
CanFall1	118	0.29	0.06	116	0.29	0.06	97	0.29	0.04		120	0.29	0.06		116	0.29	0.04		106	0.27	0.04	
CanFall2	197	0.15	0.05	189	0.15	0.05	176	0.15	0.03		199	0.18	0.03		213	0.17	0.02		196	0.17	0.02	
EU	69290	0.29	0.07	67058	0.29	0.07	56604	0.29	0.06		68255	0.29	0.06		67945	0.29	0.06		62109	0.29	0.06	
CanSpr	11	0.39	0.05	10	0.39	0.05	9	0.40	0.05		11	0.40	0.04		11	0.40	0.05		10	0.40	0.05	
σ_R_out	0.22			0.22			0.20				0.23				0.20				0.20			

Table 2: Results of fits of various SCAA variants related to aspects of the stock-recruitment relationship assumed (see text for details) to the commercial catch and survey data, compared to the New Baseline assessment. Biomass units are '000t. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs (note cases 6b and 8 have not fully converged so that Hessian-based CVs are not available).

	New Baseline				6a) $h = 0.7$				6b) $h = 0.5$				7) Ricker like (h and γ estimated)				8) $\sigma_R = 0.3$			
No of parameters	515				515				515				517				515			
No of data points	924				924				924				924				924			
'-lnL:overall	-602.2				-601.4				-601.2				-605.1				-618.0			
'-lnL:Survey	-47.1				-47.7				-45.2				-41.6				-49.5			
'-lnL:CAA	-220.2				-220.2				-218.5				-215.1				-221.6			
'-lnL:CAAsurv	-478.2				-476.4				-479.2				-486.4				-482.7			
'-lnL:RecRes	23.0				22.9				23.4				23.4				16.1			
'-lnL:SelPen	120.4				120.0				118.4				114.6				119.8			
h	**0.90**				**0.70**				**0.50**				0.64				**0.90**			
θ	**1**				**1**				**1**				**1**				**1**			
ϕ	**0**				**0**				**0**				**0**				**0**			
ρ - surveys	0.65				0.64				0.65				0.65				0.63			
ρ_{CAAage}	0.70	0.24	0.24	0.38	0.70	0.25	0.24	0.38	0.69	0.24	0.24	0.37	0.68	0.24	0.24	0.35	0.71	0.23	0.22	0.37
ρ_{CAAyr}	-0.35	-0.73	-0.25	-0.53	-0.36	-0.73	-0.24	-0.53	-0.36	-0.73	-0.26	-0.54	-0.38	-0.74	-0.29	-0.55	-0.35	-0.74	-0.26	-0.54
K^{sp}	596	(0.27)			611	(0.27)			542	*			431	(0.10)			897	*		
B^{sp}_{2008}	353	(0.60)			342	(0.67)			169	*			44	(0.38)			703	*		
B^{sp}_{2008}/K	0.59	(0.34)			0.56	(0.40)			0.31	*			0.10	(0.33)			0.78	*		
MSYL^{sp}	0.17	(0.15)			0.28	(0.13)			0.37	*			0.26	(0.22)			0.17	*		
B^{sp}_{MSY}	100	(0.41)			170	(0.39)			202	*			113	(0.17)			150	*		
MSY	43	(0.26)			33	(0.26)			21	*			22	(0.13)			64	*		
σ_{comCAA}	0.07				0.07				0.07				0.07				0.07			
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}	$\sigma_{survCAA}$	
CanFall1	116	0.29	0.04		116	0.29	0.04		142	0.30	0.04		187	0.31	0.04		81	0.28	0.04	
CanFall2	213	0.17	0.02		228	0.16	0.02		334	0.15	0.02		450	0.15	0.02		137	0.16	0.02	
EU	67945	0.29	0.06		69465	0.30	0.06		96177	0.34	0.06		138111	0.39	0.06		44456	0.28	0.06	
CanSpr	11	0.40	0.05		12	0.39	0.05		17	0.39	0.05		22	0.40	0.05		7	0.40	0.05	
σ_R_out	0.20				0.20				0.20				0.20				0.25			

Table 3: Results of fits of various SCAA variants related to aspects of the commercial catches and selectivity (see text for details) to the commercial catch and survey data, compared to the New Baseline assessment. Biomass units are '000t. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs.

	New Baseline				9a) 1990-1994 catches increased by 10 000 t				9b) 1990-1994 catches decreased by 10 000 t				10) Flat commercial selectivity from age 10				11) Four commercial selectivity periods			
No of parameters	515				515				515				514				533			
No of data points	924				924				924				924				924			
'-lnL:overall	-602.2				-601.4				-608.7				-595.7				-616.7			
'-lnL:Survey	-47.1				-47.3				-41.6				-46.9				-49.0			
'-lnL:CAA	-220.2				-220.4				-215.1				-219.6				-233.2			
'-lnL:CAAsurv	-478.2				-477.9				-489.5				-478.6				-478.6			
'-lnL:RecRes	23.0				23.0				24.0				23.0				23.7			
'-lnL:SelPen	120.4				121.2				113.5				126.4				120.4			
h	**0.90**				**0.90**				**0.90**				**0.90**				**0.90**			
θ	**1**				**1**				**1**				**1**				**1**			
ϕ	**0**				**0**				**0**				**0**				**0**			
ρ - surveys	0.65				0.65				0.67				0.65				0.63			
ρ_{CAAage}	0.70	0.24	0.24	0.38	0.70	0.25	0.24	0.38	0.68	0.24	0.22	0.35	0.70	0.25	0.24	0.38	0.71	0.24	0.23	0.38
ρ_{CAAyr}	-0.35	-0.73	-0.25	-0.53	-0.36	-0.73	-0.25	-0.53	-0.36	-0.75	-0.31	-0.55	-0.36	-0.73	-0.25	-0.54	-0.34	-0.73	-0.25	-0.54
K^{sp}	596	(0.27)			725	(0.24)			334	(0.05)			529	(0.27)			801	(0.36)		
B^{sp}_{2008}	353	(0.60)			492	(0.46)			26	(0.42)			285	(0.66)			637	(0.60)		
B^{sp}_{2008}/K	0.59	(0.34)			0.68	(0.23)			0.08	(0.40)			0.54	(0.40)			0.80	(0.24)		
MSYL^{sp}	0.17	(0.15)			0.17	(0.11)			0.18	(0.18)			0.17	(0.18)			0.17	(0.12)		
B^{sp}_{MSY}	100	(0.41)			122	(0.33)			59	(0.20)			91	(0.44)			133	(0.45)		
MSY	43	(0.26)			52	(0.24)			27	(0.04)			39	(0.25)			57	(0.36)		
σ_{comCAA}	0.07				0.07				0.07				0.07				0.07			
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}	$\sigma_{survCAA}$	
CanFall1	116	0.29	0.04		94	0.29	0.04		226	0.32	0.04		132	0.30	0.04		84	0.29	0.04	
CanFall2	213	0.17	0.02		174	0.17	0.02		441	0.16	0.02		242	0.17	0.02		154	0.16	0.02	
EU	67945	0.29	0.06		54621	0.29	0.06		157491	0.37	0.06		77998	0.30	0.06		47307	0.28	0.06	
CanSpr	11	0.40	0.05		9	0.40	0.05		23	0.41	0.05		13	0.40	0.05		8	0.39	0.05	
σ_R_out	0.20				0.20				0.20				0.20				0.20			

Table 4: Results of fits of various SCAA variants related to the choice of the σ_Ω and *M* parameters (see text for details) to the commercial catch and survey data, compared to the New Baseline assessment. Biomass units are '000t. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs.

	New Baseline				12a) commercial $\sigma_\Omega = 4.0$				12b) commercial $\sigma_\Omega = 0.5$				12c) survey $\sigma_\Omega = 1.0$				13) M=0.15			
No of parameters	515				515				515				515				515			
No of data points	924				924				924				924				924			
'-lnL:overall	-602.2				-609.9				-558.3				-727.6				-604.0			
'-lnL:Survey	-47.1				-47.1				-40.0				-48.5				-39.2			
'-lnL:CAA	-220.2				-221.8				-186.9				-217.1				-213.5			
'-lnL:CAAsurv	-478.2				-478.2				-492.1				-560.9				-487.6			
'-lnL:RecRes	23.0				23.0				23.4				20.4				22.8			
'-lnL:SelPen	120.4				114.3				137.3				78.5				113.5			
h	**0.90**				**0.90**				**0.90**				**0.90**				**0.90**			
θ	**1**				**1**				**1**				**1**				**1**			
ϕ	**0**				**0**				**0**				**0**				**0**			
ρ - surveys	0.65				0.65				0.69				0.59				0.69			
ρ_{CAAage}	0.70	0.24	0.24	0.38	0.70	0.24	0.24	0.38	0.69	0.24	0.23	0.35	0.57	0.23	0.08	0.29	0.67	0.24	0.23	0.35
ρ_{CAAyr}	-0.35	-0.73	-0.25	-0.53	-0.35	-0.73	-0.25	-0.53	-0.37	-0.75	-0.32	-0.55	-0.54	-0.76	-0.45	-0.72	-0.38	-0.74	-0.30	-0.55
K^{sp}	596	(0.27)			610	(0.27)			353	(0.05)			888	(0.44)			572	(0.06)		
B^{sp}_{2008}	353	(0.60)			370	(0.57)			29	(0.27)			769	(0.67)			58	(0.41)		
B^{sp}_{2008}/K	0.59	(0.34)			0.61	(0.31)			0.08	(0.24)			0.87	(0.24)			0.10	(0.37)		
MSYL^{sp}	0.17	(0.15)			0.17	(0.15)			0.18	(0.13)			0.17	(0.11)			0.19	(0.17)		
B^{sp}_{MSY}	100	(0.41)			102	(0.40)			62	(0.15)			148	(0.53)			106	(0.20)		
MSY	43	(0.26)			44	(0.26)			28	(0.04)			63	(0.43)			28	(0.05)		
σ_{comCAA}	0.07				0.07				0.08				0.07				0.07			
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}	$\sigma_{survCAA}$	
CanFall1	116	0.29	0.04		113	0.29	0.04		204	0.32	0.04		82	0.29	0.03		232	0.32	0.04	
CanFall2	213	0.17	0.02		208	0.17	0.02		425	0.17	0.02		140	0.18	0.02		519	0.19	0.02	
EU	67945	0.29	0.06		66156	0.29	0.06		146929	0.38	0.06		43641	0.28	0.05		156148	0.38	0.06	
CanSpr	11	0.40	0.05		11	0.40	0.05		22	0.41	0.05		7	0.37	0.04		26	0.42	0.05	
σ_R_out	0.20				0.20				0.20				0.18				0.19			

Table 5: Results of fits of various SCAA variants starting in 1975 (see text for details) to the commercial catch and survey data, compared to the New Baseline assessment. Biomass units are '000t. Values fixed on input rather than estimated are shown in **bold**. –lnL values in parenthesis in the New Baseline column are for the data as the XSA data. Quantities shown in parenthesis are Hessian-based CVs.

	New Baseline				14a) XSA data only, start in 1975: unexploited equilibrium in 1960				14b) XSA data only, start in 1975: estimate θ and ζ				14c) XSA data only, start in 1975: estimate θ, start with XSA estimated proportions-at-age in 1975			
No of parameters	515				500				502				501			
No of data points	924				714				714				714			
'-lnL:overall	-602.2	-(381.6)			-444.4				-445.5				-447.4			
'-lnL:Survey	-47.1	-(31.9)			-31.0				-31.0				-31.0			
'-lnL:CAA	-220.2	-(220.2)			-210.5				-213.2				-223.6			
'-lnL:CAAsurv	-478.2	-(272.7)			-290.3				-290.1				-290.0			
'-lnL:RecRes	23.0	(23.0)			20.7				21.2				26.2			
'-lnL:SelPen	120.4	(120.4)			66.7				67.6				71.1			
h	**0.90**				**0.90**				**0.90**				**0.90**			
θ	**1**				**1**				0.34				0.04			
ϕ	**0**				**0**				0.27				**0**			
ρ - surveys	0.65				0.62				0.62		0.62	0.62	0.60			
ρ_{CAAage}	0.70	0.24	0.24	0.38	-0.02	0.24	0.16	0.35	0.00	0.24	0.16	0.36	0.12	0.24	0.16	0.35
ρ_{CAAyr}	-0.35	-0.73	-0.25	-0.53	-0.06	-0.75	-0.38	-0.57	0.00	-0.75	-0.38	-0.56	-0.03	-0.75	-0.38	-0.56
K^{sp}	596	(0.27)			350	(0.05)			339	(0.06)			357	(0.07)		
$B^{sp}{}_{2008}$	353	(0.60)			37	(0.42)			39	(0.45)			23	(0.48)		
$B^{sp}{}_{2008}/K$	0.59	(0.34)			0.10	(0.38)			0.12	(0.42)			0.06	(0.48)		
MSYL^{sp}	0.17	(0.15)			0.17	(0.16)			0.18	(0.17)			0.18	(0.19)		
$B^{sp}{}_{MSY}$	100	(0.41)			61	(0.19)			59	(0.19)			63	(0.20)		
MSY	43	(0.26)			28	(0.04)			27	(0.05)			29	(0.07)		
σ_{comCAA}	0.07				0.07				0.07				0.07			
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}	$\sigma_{survCAA}$	
CanFall1	116	0.29	0.04		178	0.31	0.14		167	0.30	0.13		182	0.31	0.13	
CanFall2	213	0.17	0.02		421	0.16	0.02		420	0.16	0.02		447	0.15	0.02	
EU	67945	0.29	0.06		215975	0.28	0.06		214345	0.28	0.06		235979	0.29	0.06	
CanSpr	11	0.40	0.05		22	0.41	0.05		22	0.41	0.05		23	0.40	0.05	
σ_R_out	0.20				0.22				0.23				0.26			

Table 6: Results of five retrospective on the New Baseline compared to the New Baseline assessment. Biomass units are '000t. Values fixed on input rather than estimated are shown in **bold**.

	New Baseline data to 2007				15a) data to 2006				15b) data to 2005				15c) data to 2004				15d) data to 2003				15e) data to 2002			
No of parameters	515				514				488				459				449				421			
No of data points	924				882				850				808				767				726			
'-lnL:overall	-602.2				-590.4				-562.4				-568.0				-533.1				-524.7			
'-lnL:Survey	-47.1				-42.6				-38.4				-38.1				-39.0				-37.5			
'-lnL:CAA	-220.2				-210.1				-201.7				-192.4				-184.0				-169.7			
'-lnL:CAAsurv	-478.2				-482.5				-456.6				-468.4				-433.4				-445.6			
'-lnL:RecRes	23.0				25.8				22.2				20.9				21.6				24.3			
'-lnL:SelPen	120.4				118.9				112.0				110.0				101.7				103.7			
h	**0.90**				**0.90**				**0.90**				**0.90**				**0.90**				**0.90**			
θ	**1**				**1**				**1**				**1**				**1**				**1**			
ϕ	**0**				**0**				**0**				**0**				**0**				**0**			
ρ - surveys	0.65				0.65				0.67				0.59				0.62				0.63			
ρ_{CAAage}	0.70	0.24	0.24	0.38	0.70	0.13	0.18	0.35	0.70	0.14	0.13	0.38	0.71	-0.08	0.10	0.04	0.70	-0.05	0.16	-0.03	0.70	-0.12	0.25	-0.23
ρ_{CAAyr}	-0.35	-0.73	-0.25	-0.53	-0.35	-0.84	-0.27	-0.66	-0.35	-0.91	-0.24	-0.68	-0.36	-0.77	-0.16	-0.83	-0.36	-0.78	-0.08	-0.81	-0.38	-0.73	-0.09	-0.96
K^{sp}	596				739				760				797				765				670			
$B^{sp}{}_{2008}$	353				536				549				613				590				510			
$B^{sp}{}_{2008}/K$	0.59				0.72				0.72				0.77				0.77				0.76			
MSYL^{sp}	0.17				0.17				0.17				0.17				0.17				0.17			
$B^{sp}{}_{MSY}$	100				126				130				137				132				116			
MSY	43				52				55				58				57				50			
σ_{comCAA}	0.07				0.07				0.07				0.07				0.07				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}	$\sigma_{survCAA}$	
CanFall1	116	0.29	0.04		92	0.29	0.04		89	0.29	0.04		86	0.29	0.04		90	0.29	0.04		106	0.29	0.04	
CanFall2	213	0.17	0.02		167	0.21	0.02		164	0.26	0.02		183	0.22	0.02		201	0.22	0.02		265	0.30	0.03	
EU	67945	0.29	0.06		53219	0.29	0.06		52381	0.30	0.06		48240	0.30	0.06		47364	0.25	0.06		54091	0.23	0.06	
CanSpr	11	0.40	0.05		9	0.40	0.04		9	0.38	0.04		9	0.37	0.02		10	0.37	0.03		12	0.27	0.00	
σ_R_out	0.20				0.21				0.20				0.19				0.20				0.22			

Table 7: Results of fits of various production model-type assessments to the commercial catch and survey data (see text for details). Biomass units are '000t. Values fixed on input rather than estimated are shown in **bold**. Quantities shown in parenthesis are Hessian-based CVs.

	New Baseline				1) Production-type model, fitting to survey and CAA (K and selectivity parameters estimated, h fixed)			2) Production-type model, fitting to survey indices only (K and h estimated, selectivity fixed to PM1)		
No of parameters	515				45			3		
No of data points	924				924			60		
'-lnL:overall	-602.2				99.1			-39.1		
'-lnL:Survey	-47.1				-39.1			-39.1		
'-lnL:CAA	-220.2				-35.4			-		
'-lnL:CAAsurv	-478.2				173.6			-		
'-lnL:RecRes	23.0				-			-		
'-lnL:SelPen	120.4				-			-		
h	**0.9**				**0.9**			0.89	(0.25)	
θ	**1**				**1**			**1**		
ϕ	**0**				**0**			**0**		
ρ - surveys	0.65				0.64			0.64		
ρ_{CAAage}	0.70	0.24	0.24	0.38	-			-		
ρ_{CAAyr}	-0.35	-0.73	-0.25	-0.53	-			-		
K^{sp}	596	(0.27)			507	(0.12)		500	(0.31)	
$B^{sp}{}_{2008}$	353	(0.60)			252	(0.27)		250	(0.78)	
$B^{sp}{}_{2008}/K$	0.59	(0.34)			0.50	(0.16)		0.50	(0.47)	
MSYL^{sp}	0.17	(0.15)			0.17	(0.10)		0.13	(0.01)	
$B^{sp}{}_{\text{MSY}}$	100	(0.41)			88	(0.21)		67	(0.31)	
MSY	43	(0.26)			38	(0.11)		41	(0.31)	
σ_{comCAA}	0.07				0.15			-		
Survey	q's x10^6	σ_{surv}	σ_{survCAA}		q's x10^6	σ_{surv}	σ_{survCAA}	q's x10^6	σ_{surv}	σ_{survCAA}
CanFall1	116	0.29	0.04		112	0.31	0.12	114	0.32	-
CanFall2	213	0.17	0.02		222	0.25	0.10	221	0.25	-
EU	67945	0.29	0.06		72049	0.31	0.16	72271	0.31	-
CanSpr	11	0.40	0.05		14	0.48	0.18	14	0.48	-
σ_R_out	0.20				-			-		

Table 8: Numbers-at-age (in millions) matrix for the New Baseline.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1960	318.7	260.9	213.6	174.9	143.2	117.2	96.0	78.6	64.3	52.7	43.1	35.3	28.9	23.7	19.4	15.9	13.0	10.6	8.7	7.1	32.2
1961	317.9	260.9	213.6	174.9	143.2	117.2	96.0	78.5	64.1	52.5	43.1	35.3	28.9	23.7	19.4	15.9	13.0	10.6	8.7	7.1	32.2
1962	320.2	260.3	213.6	174.9	143.2	117.2	96.0	78.5	64.1	52.4	42.9	35.2	28.9	23.6	19.4	15.9	13.0	10.6	8.7	7.1	32.2
1963	324.0	262.1	213.1	174.9	143.2	117.2	96.0	78.5	64.1	52.3	42.8	35.1	28.8	23.6	19.4	15.9	13.0	10.6	8.7	7.1	32.2
1964	330.3	265.2	214.6	174.5	143.2	117.2	95.9	78.3	63.9	52.2	42.7	35.0	28.7	23.6	19.3	15.8	13.0	10.6	8.7	7.1	32.2
1965	292.2	270.4	217.2	175.7	142.9	117.2	95.9	78.0	63.1	51.5	42.4	34.8	28.6	23.5	19.3	15.8	13.0	10.6	8.7	7.1	32.2
1966	346.9	239.2	221.4	177.8	143.9	116.9	95.8	77.1	61.4	49.9	41.4	34.4	28.3	23.3	19.2	15.8	12.9	10.6	8.7	7.1	32.2
1967	345.6	284.0	195.9	181.3	145.6	117.7	95.3	75.7	58.4	46.9	39.3	33.3	27.8	23.0	19.0	15.6	12.9	10.6	8.7	7.1	32.2
1968	389.4	282.9	232.5	160.4	148.4	119.1	95.8	74.2	55.4	43.3	36.4	31.4	26.8	22.5	18.7	15.4	12.7	10.5	8.6	7.1	32.1
1969	307.0	318.9	231.7	190.4	131.3	121.4	96.7	73.5	52.6	39.9	33.1	28.8	25.1	21.6	18.2	15.2	12.6	10.4	8.6	7.1	32.1
1970	302.4	251.4	261.1	189.7	155.8	107.4	98.4	73.3	50.6	36.9	30.0	26.0	23.0	20.2	17.5	14.8	12.4	10.3	8.5	7.0	32.0
1971	297.9	247.6	205.8	213.7	155.3	127.4	87.0	74.4	50.1	35.3	27.7	23.6	20.7	18.5	16.3	14.2	12.0	10.1	8.4	6.9	31.9
1972	390.5	243.9	202.7	168.5	175.0	127.0	103.6	67.4	53.9	36.8	27.2	22.0	19.0	16.8	15.0	13.3	11.6	9.8	8.2	6.8	31.8
1973	395.4	319.7	199.7	166.0	137.9	143.1	103.1	79.4	47.6	38.7	28.1	21.6	17.6	15.3	13.6	12.2	10.8	9.4	8.0	6.7	31.6
1974	345.2	323.7	261.8	163.5	135.9	112.8	116.3	79.3	56.5	34.4	29.6	22.3	17.3	14.2	12.4	11.0	9.9	8.8	7.7	6.6	31.4
1975	322.1	282.7	265.0	214.3	133.8	111.1	91.7	89.9	57.2	41.3	26.5	23.6	17.9	13.9	11.5	10.1	9.0	8.1	7.2	6.3	31.0
1976	308.8	263.7	231.4	217.0	175.4	109.4	90.8	73.2	68.8	42.2	30.1	19.9	18.7	14.3	11.3	9.4	8.2	7.3	6.6	5.9	30.5
1977	261.2	252.8	215.9	189.5	177.6	143.5	89.4	72.8	56.7	51.7	31.3	22.9	15.9	15.1	11.6	9.1	7.6	6.7	6.0	5.4	29.8
1978	304.2	213.9	207.0	176.8	155.1	145.3	116.0	68.7	51.4	40.1	39.7	24.8	18.4	12.8	12.2	9.4	7.5	6.2	5.5	4.9	28.8
1979	367.0	249.1	175.1	169.5	144.7	126.8	117.1	87.7	46.6	35.0	30.3	31.1	19.8	14.8	10.4	9.9	7.7	6.1	5.1	4.5	27.6
1980	303.3	300.5	203.9	143.3	138.7	118.4	102.7	91.2	63.9	33.4	25.6	22.4	25.0	16.0	12.0	8.4	8.1	6.3	5.0	4.2	26.2
1981	287.2	248.3	246.0	166.9	117.3	113.5	95.6	79.2	65.1	44.6	24.0	18.6	17.9	20.2	13.0	9.7	6.9	6.6	5.1	4.1	24.8
1982	286.9	235.2	203.3	201.4	136.7	96.0	92.5	75.1	57.1	44.8	32.7	18.4	14.8	14.4	16.3	10.5	7.9	5.6	5.4	4.2	23.6
1983	277.6	234.9	192.5	166.4	164.9	111.8	78.3	73.2	55.6	40.8	33.6	25.5	14.8	11.9	11.7	13.3	8.6	6.5	4.6	4.4	22.8
1984	311.2	227.3	192.3	157.6	136.2	134.9	91.0	61.7	52.8	39.0	30.5	26.6	20.5	12.0	9.7	9.5	10.8	7.0	5.3	3.7	22.2
1985	315.6	254.8	186.1	157.5	129.0	111.5	109.7	71.5	43.9	36.4	28.9	24.1	21.4	16.6	9.7	7.9	7.8	8.8	5.7	4.3	21.2
1986	283.9	258.4	208.6	152.4	128.9	105.6	90.1	86.1	53.3	32.3	28.4	23.2	19.5	17.4	13.5	7.9	6.5	6.3	7.2	4.7	20.9
1987	236.0	232.4	211.6	170.8	124.7	105.5	85.4	70.9	64.7	39.5	25.3	22.8	18.8	15.8	14.2	11.0	6.5	5.3	5.2	5.9	21.0
1988	220.9	193.2	190.3	173.2	139.8	102.0	86.1	66.6	47.4	44.6	30.2	20.0	18.3	15.1	12.8	11.5	9.0	5.3	4.3	4.2	22.0
1989	195.0	180.9	158.2	155.8	141.8	114.4	83.4	68.4	48.1	34.8	34.9	24.2	16.2	14.8	12.3	10.4	9.4	7.3	4.3	3.5	21.5
1990	232.5	159.7	148.1	129.5	127.5	116.0	93.4	66.1	50.1	36.0	27.1	27.5	19.4	13.0	12.0	10.0	8.5	7.7	6.0	3.5	20.4
1991	248.5	190.4	130.7	121.2	106.0	104.2	94.3	70.5	40.5	32.6	25.9	20.2	21.4	15.3	10.4	9.7	8.1	6.9	6.2	4.9	19.6
1992	249.5	203.4	155.9	107.0	99.2	86.5	81.8	68.9	43.6	24.3	21.1	18.5	15.4	16.6	12.1	8.3	7.8	6.6	5.6	5.1	20.0
1993	370.8	204.3	166.6	127.6	87.6	81.0	67.7	59.1	41.4	25.3	15.4	14.9	14.0	11.9	13.1	9.7	6.7	6.3	5.3	4.6	20.5
1994	463.0	303.6	167.2	136.4	104.4	71.5	51.6	39.2	32.7	24.6	17.3	11.4	11.4	10.9	9.4	10.5	7.8	5.4	5.1	4.3	20.4
1995	440.5	379.1	248.6	136.9	111.6	85.2	45.0	29.3	21.3	19.2	16.6	12.7	8.7	8.9	8.6	7.5	8.5	6.3	4.4	4.2	20.2
1996	265.7	360.7	310.4	203.5	112.1	91.2	68.5	34.4	20.5	15.6	14.6	13.1	10.0	6.9	7.2	7.0	6.1	6.9	5.1	3.6	20.0
1997	254.5	217.5	295.3	254.1	166.6	91.6	73.0	51.7	23.2	14.7	11.8	11.5	10.3	8.0	5.6	5.8	5.7	5.0	5.6	4.2	19.3
1998	298.3	208.4	178.1	241.8	208.0	136.2	72.7	55.0	35.7	16.4	10.9	9.1	9.1	8.2	6.4	4.5	4.7	4.6	4.1	4.6	19.2
1999	358.3	244.2	170.6	145.8	197.9	170.1	108.6	55.4	38.9	25.7	12.3	8.5	7.2	7.3	6.7	5.2	3.7	3.8	3.8	3.3	19.4
2000	412.4	293.3	199.9	139.7	119.4	161.7	137.3	82.5	36.2	28.5	19.7	9.6	6.7	5.7	5.9	5.4	4.2	3.0	3.1	3.1	18.6
2001	453.5	337.6	240.2	163.7	114.3	97.5	130.3	103.0	51.5	26.0	21.6	15.3	7.5	5.3	4.6	4.7	4.4	3.4	2.4	2.5	17.7
2002	361.9	371.3	276.4	196.6	134.0	93.5	77.8	95.4	64.5	37.3	20.4	17.2	12.2	6.0	4.3	3.7	3.8	3.6	2.8	2.0	16.6
2003	244.7	296.3	304.0	226.3	161.0	109.6	74.7	57.5	61.0	47.1	29.4	16.2	13.7	9.8	4.9	3.5	3.0	3.1	2.9	2.3	15.2
2004	251.1	200.3	242.6	248.9	185.3	131.6	85.2	52.4	33.6	43.1	37.0	23.6	13.0	11.0	7.9	4.0	2.8	2.5	2.6	2.4	14.3
2005	198.8	205.6	164.0	198.6	203.7	151.6	103.4	61.6	32.8	24.4	34.2	29.8	18.9	10.5	9.0	6.5	3.2	2.3	2.0	2.1	13.6
2006	333.2	162.7	168.3	134.3	162.6	166.7	122.3	79.4	41.3	23.2	18.8	27.4	24.1	15.4	8.5	7.3	5.3	2.6	1.9	1.7	12.9
2007	309.7	272.8	133.2	137.8	109.9	133.1	134.7	94.5	54.3	29.5	17.9	15.1	22.2	19.6	12.5	7.0	6.0	4.3	2.2	1.5	11.9
2008	311.0	253.5	223.3	109.1	112.8	90.0	108.4	106.9	66.6	39.6	23.1	14.3	12.2	18.1	15.9	10.2	5.7	4.9	3.5	1.8	11.0

Table 9 fishing mortality-at-age matrix for the New Baseline.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	av5-10
1960	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0016	0.0035	0.0032	0.0018	0.0008	0.0006	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0019
1961	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0013	0.0028	0.0025	0.0014	0.0007	0.0005	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0015
1962	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0010	0.0022	0.0020	0.0011	0.0005	0.0004	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0012
1963	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0029	0.0061	0.0055	0.0031	0.0015	0.0010	0.0007	0.0005	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0032
1964	0.0000	0.0000	0.0000	0.0000	0.0001	0.0009	0.0075	0.0161	0.0145	0.0081	0.0038	0.0026	0.0018	0.0012	0.0009	0.0006	0.0004	0.0003	0.0002	0.0001	0.0001	0.0085
1965	0.0000	0.0000	0.0000	0.0000	0.0003	0.0022	0.0180	0.0388	0.0349	0.0195	0.0091	0.0063	0.0043	0.0030	0.0020	0.0014	0.0010	0.0007	0.0005	0.0003	0.0002	0.0204
1966	0.0000	0.0000	0.0000	0.0001	0.0005	0.0044	0.0354	0.0771	0.0691	0.0383	0.0179	0.0123	0.0084	0.0058	0.0040	0.0027	0.0019	0.0013	0.0009	0.0006	0.0004	0.0404
1967	0.0000	0.0000	0.0000	0.0001	0.0008	0.0062	0.0507	0.1113	0.0997	0.0548	0.0255	0.0175	0.0120	0.0082	0.0057	0.0039	0.0027	0.0018	0.0013	0.0009	0.0006	0.0580
1968	0.0000	0.0000	0.0000	0.0001	0.0010	0.0079	0.0648	0.1435	0.1283	0.0701	0.0325	0.0222	0.0153	0.0105	0.0072	0.0049	0.0034	0.0023	0.0016	0.0011	0.0008	0.0745
1969	0.0000	0.0000	0.0000	0.0001	0.0012	0.0094	0.0780	0.1741	0.1554	0.0844	0.0389	0.0266	0.0183	0.0125	0.0086	0.0059	0.0041	0.0028	0.0019	0.0013	0.0009	0.0900
1970	0.0000	0.0000	0.0000	0.0002	0.0012	0.0097	0.0801	0.1791	0.1598	0.0867	0.0400	0.0273	0.0187	0.0129	0.0088	0.0061	0.0042	0.0029	0.0020	0.0014	0.0009	0.0926
1971	0.0000	0.0000	0.0000	0.0001	0.0008	0.0067	0.0551	0.1213	0.1085	0.0595	0.0277	0.0190	0.0130	0.0089	0.0061	0.0042	0.0029	0.0020	0.0014	0.0009	0.0007	0.0631
1972	0.0000	0.0000	0.0000	0.0001	0.0010	0.0081	0.0666	0.1475	0.1318	0.0719	0.0333	0.0228	0.0156	0.0107	0.0074	0.0051	0.0035	0.0024	0.0017	0.0011	0.0008	0.0765
1973	0.0000	0.0000	0.0000	0.0001	0.0010	0.0077	0.0631	0.1395	0.1247	0.0682	0.0316	0.0216	0.0149	0.0102	0.0070	0.0048	0.0033	0.0023	0.0016	0.0011	0.0007	0.0725
1974	0.0000	0.0000	0.0000	0.0001	0.0009	0.0070	0.0574	0.1266	0.1132	0.0621	0.0288	0.0197	0.0136	0.0093	0.0064	0.0044	0.0030	0.0021	0.0014	0.0010	0.0007	0.0659
1975	0.0000	0.0000	0.0000	0.0002	0.0013	0.0021	0.0252	0.0667	0.1047	0.1169	0.0884	0.0292	0.0200	0.0137	0.0094	0.0065	0.0045	0.0031	0.0021	0.0015	0.0010	0.0673
1976	0.0000	0.0000	0.0000	0.0001	0.0011	0.0018	0.0210	0.0555	0.0867	0.0968	0.0733	0.0244	0.0167	0.0115	0.0079	0.0054	0.0037	0.0026	0.0018	0.0012	0.0008	0.0558
1977	0.0000	0.0000	0.0000	0.0001	0.0009	0.0125	0.0641	0.1482	0.1463	0.0647	0.0339	0.0214	0.0147	0.0101	0.0069	0.0048	0.0033	0.0023	0.0016	0.0011	0.0007	0.0783
1978	0.0000	0.0000	0.0000	0.0001	0.0012	0.0155	0.0800	0.1870	0.1846	0.0807	0.0422	0.0266	0.0182	0.0125	0.0086	0.0059	0.0041	0.0028	0.0019	0.0013	0.0009	0.0983
1979	0.0000	0.0000	0.0000	0.0001	0.0008	0.0115	0.0504	0.1162	0.1354	0.1106	0.1037	0.0181	0.0124	0.0086	0.0059	0.0040	0.0028	0.0019	0.0013	0.0009	0.0006	0.0880
1980	0.0000	0.0000	0.0000	0.0001	0.0009	0.0135	0.0590	0.1368	0.1596	0.1301	0.1220	0.0212	0.0145	0.0100	0.0069	0.0047	0.0032	0.0022	0.0015	0.0011	0.0007	0.1035
1981	0.0000	0.0000	0.0000	0.0001	0.0012	0.0048	0.0418	0.1270	0.1730	0.1109	0.0621	0.0270	0.0185	0.0127	0.0087	0.0060	0.0041	0.0028	0.0020	0.0013	0.0009	0.0866
1982	0.0000	0.0000	0.0000	0.0001	0.0010	0.0038	0.0333	0.1003	0.1360	0.0878	0.0494	0.0215	0.0148	0.0102	0.0070	0.0048	0.0033	0.0023	0.0016	0.0011	0.0007	0.0684
1983	0.0000	0.0000	0.0000	0.0001	0.0007	0.0058	0.0378	0.1267	0.1552	0.0907	0.0349	0.0154	0.0106	0.0073	0.0050	0.0034	0.0024	0.0016	0.0011	0.0008	0.0005	0.0752
1984	0.0000	0.0000	0.0000	0.0001	0.0008	0.0063	0.0416	0.1402	0.1720	0.1002	0.0385	0.0169	0.0116	0.0080	0.0055	0.0038	0.0026	0.0018	0.0012	0.0008	0.0006	0.0831
1985	0.0000	0.0000	0.0000	0.0001	0.0005	0.0131	0.0422	0.0924	0.1067	0.0485	0.0193	0.0119	0.0082	0.0056	0.0039	0.0027	0.0018	0.0013	0.0009	0.0006	0.0004	0.0537
1986	0.0000	0.0000	0.0000	0.0001	0.0005	0.0124	0.0398	0.0870	0.1003	0.0457	0.0182	0.0113	0.0077	0.0053	0.0037	0.0025	0.0017	0.0012	0.0008	0.0006	0.0004	0.0506
1987	0.0000	0.0000	0.0000	0.0001	0.0010	0.0026	0.0479	0.2029	0.1713	0.0696	0.0330	0.0226	0.0155	0.0107	0.0073	0.0050	0.0035	0.0024	0.0016	0.0011	0.0008	0.0879
1988	0.0000	0.0000	0.0000	0.0001	0.0006	0.0017	0.0306	0.1259	0.1069	0.0443	0.0212	0.0145	0.0100	0.0069	0.0047	0.0032	0.0022	0.0015	0.0011	0.0007	0.0005	0.0551
1989	0.0000	0.0000	0.0000	0.0001	0.0010	0.0030	0.0326	0.1104	0.0899	0.0524	0.0381	0.0220	0.0151	0.0104	0.0071	0.0049	0.0034	0.0023	0.0016	0.0011	0.0008	0.0544
1990	0.0000	0.0000	0.0000	0.0003	0.0024	0.0072	0.0803	0.2894	0.2314	0.1310	0.0942	0.0538	0.0367	0.0251	0.0172	0.0118	0.0081	0.0056	0.0038	0.0026	0.0018	0.1389
1991	0.0000	0.0000	0.0000	0.0004	0.0032	0.0418	0.1138	0.2814	0.3105	0.2328	0.1344	0.0732	0.0498	0.0340	0.0233	0.0160	0.0110	0.0075	0.0052	0.0036	0.0025	0.1858
1992	0.0000	0.0000	0.0001	0.0004	0.0034	0.0455	0.1243	0.3098	0.3423	0.2556	0.1468	0.0798	0.0542	0.0370	0.0253	0.0174	0.0119	0.0082	0.0056	0.0039	0.0027	0.2040
1993	0.0000	0.0000	0.0000	0.0004	0.0030	0.2511	0.3459	0.3913	0.3196	0.1825	0.1036	0.0696	0.0474	0.0324	0.0222	0.0152	0.0105	0.0072	0.0049	0.0034	0.0023	0.2657
1994	0.0000	0.0000	0.0000	0.0004	0.0031	0.2634	0.3637	0.4120	0.3358	0.1911	0.1083	0.0727	0.0495	0.0338	0.0231	0.0159	0.0109	0.0075	0.0052	0.0035	0.0024	0.2791
1995	0.0000	0.0000	0.0000	0.0002	0.0016	0.0193	0.0688	0.1607	0.1108	0.0692	0.0369	0.0354	0.0243	0.0166	0.0114	0.0078	0.0054	0.0037	0.0026	0.0018	0.0012	0.0776
1996	0.0000	0.0000	0.0000	0.0002	0.0018	0.0227	0.0813	0.1915	0.1313	0.0817	0.0435	0.0417	0.0285	0.0195	0.0134	0.0092	0.0063	0.0044	0.0030	0.0021	0.0014	0.0920
1997	0.0000	0.0000	0.0000	0.0002	0.0015	0.0307	0.0839	0.1701	0.1500	0.1007	0.0600	0.0347	0.0237	0.0163	0.0112	0.0077	0.0053	0.0036	0.0025	0.0017	0.0012	0.0992
1998	0.0000	0.0000	0.0000	0.0002	0.0013	0.0264	0.0717	0.1445	0.1277	0.0860	0.0514	0.0298	0.0204	0.0140	0.0096	0.0066	0.0045	0.0031	0.0021	0.0015	0.0010	0.0846
1999	0.0000	0.0000	0.0000	0.0002	0.0017	0.0138	0.0741	0.2257	0.1110	0.0643	0.0448	0.0395	0.0270	0.0185	0.0127	0.0087	0.0060	0.0041	0.0028	0.0020	0.0013	0.0890
2000	0.0000	0.0000	0.0000	0.0003	0.0020	0.0163	0.0880	0.2721	0.1322	0.0763	0.0530	0.0467	0.0319	0.0219	0.0150	0.0103	0.0071	0.0049	0.0033	0.0023	0.0016	0.1063
2001	0.0000	0.0000	0.0000	0.0002	0.0013	0.0257	0.1122	0.2685	0.1234	0.0411	0.0314	0.0286	0.0196	0.0134	0.0092	0.0064	0.0044	0.0030	0.0021	0.0014	0.0010	0.1004
2002	0.0000	0.0000	0.0000	0.0001	0.0012	0.0238	0.1034	0.2460	0.1138	0.0380	0.0290	0.0265	0.0181	0.0124	0.0086	0.0059	0.0040	0.0028	0.0019	0.0013	0.0009	0.0923
2003	0.0000	0.0000	0.0000	0.0001	0.0010	0.0513	0.1552	0.3378	0.1470	0.0410	0.0202	0.0229	0.0157	0.0108	0.0074	0.0051	0.0035	0.0024	0.0017	0.0011	0.0008	0.1254
2004	0.0000	0.0000	0.0000	0.0001	0.0008	0.0417	0.1250	0.2670	0.1185	0.0334	0.0165	0.0187	0.0128	0.0088	0.0061	0.0042	0.0029	0.0020	0.0014	0.0009	0.0006	0.1004
2005	0.0000	0.0000	0.0000	0.0001	0.0006	0.0143	0.0636	0.1988	0.1493	0.0629	0.0189	0.0125	0.0086	0.0059	0.0041	0.0028	0.0019	0.0013	0.0009	0.0006	0.0004	0.0846
2006	0.0000	0.0000	0.0000	0.0001	0.0005	0.0131	0.0581	0.1804	0.1358	0.0575	0.0173	0.0114	0.0078	0.0054	0.0037	0.0026	0.0018	0.0012	0.0008	0.0006	0.0004	0.0770
2007	0.0000	0.0000	0.0000	0.0001	0.0005	0.0049	0.0314	0.1499	0.1154	0.0466	0.0277	0.0112	0.0077	0.0053	0.0037	0.0025	0.0017	0.0012	0.0008	0.0006	0.0004	0.0627
2008	0.0000	0.0000	0.0000	0.0000	0.0004	0.0035	0.0223	0.1042	0.0807	0.0329	0.0196	0.0080	0.0055	0.0038	0.0026	0.0018	0.0012	0.0008	0.0006	0.0004	0.0003	0.0439

Table 10: Numbers-at-age (in millions) matrix for case 14a – starting in 1975 assuming equilibrium in 1960.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1960	187.1	153.2	125.4	102.7	84.1	68.8	56.4	46.1	37.8	30.9	25.3	20.7	17.0	13.9	11.4	9.3	7.6	6.2	5.1	4.2	18.9
1961	187.1	153.2	125.4	102.7	84.1	68.8	56.3	46.1	37.6	30.8	25.2	20.7	17.0	13.9	11.4	9.3	7.6	6.2	5.1	4.2	18.9
1962	187.1	153.2	125.4	102.7	84.1	68.8	56.3	46.1	37.6	30.7	25.1	20.6	16.9	13.9	11.4	9.3	7.6	6.2	5.1	4.2	18.9
1963	187.1	153.2	125.4	102.7	84.1	68.8	56.3	46.1	37.6	30.7	25.1	20.6	16.9	13.8	11.3	9.3	7.6	6.2	5.1	4.2	18.9
1964	187.1	153.2	125.4	102.7	84.1	68.8	56.3	46.0	37.4	30.5	25.0	20.4	16.8	13.8	11.3	9.3	7.6	6.2	5.1	4.2	18.9
1965	187.1	153.2	125.4	102.7	84.1	68.8	56.3	45.8	36.9	30.0	24.6	20.2	16.6	13.7	11.3	9.2	7.6	6.2	5.1	4.2	18.9
1966	187.1	153.2	125.4	102.7	84.1	68.8	56.2	45.3	35.7	28.7	23.6	19.7	16.3	13.5	11.1	9.2	7.5	6.2	5.1	4.2	18.9
1967	187.0	153.2	125.4	102.7	84.1	68.8	56.1	44.5	33.6	26.3	21.7	18.5	15.6	13.1	10.8	9.0	7.4	6.1	5.1	4.2	18.8
1968	186.9	153.1	125.4	102.7	84.1	68.8	55.9	43.6	31.4	23.5	19.1	16.6	14.4	12.4	10.5	8.7	7.3	6.0	5.0	4.1	18.8
1969	186.8	153.0	125.4	102.7	84.0	68.7	55.8	42.8	29.4	20.8	16.5	14.4	12.8	11.3	9.8	8.4	7.0	5.9	4.9	4.1	18.7
1970	186.5	152.9	125.3	102.6	84.0	68.7	55.6	42.0	27.4	18.4	14.0	12.1	10.9	9.9	8.9	7.8	6.7	5.7	4.8	4.0	18.6
1971	186.2	152.7	125.2	102.6	84.0	68.7	55.5	41.7	26.3	16.7	12.2	10.2	9.1	8.4	7.8	7.1	6.3	5.4	4.6	3.9	18.4
1972	185.8	152.5	125.0	102.5	84.0	68.7	55.7	42.7	28.3	17.6	11.8	9.2	7.9	7.2	6.7	6.3	5.7	5.1	4.4	3.8	18.2
1973	185.3	152.1	124.8	102.4	83.9	68.6	55.6	42.2	27.8	18.1	12.0	8.8	7.0	6.2	5.7	5.4	5.1	4.6	4.1	3.6	17.9
1974	184.7	151.7	124.5	102.2	83.8	68.6	55.6	42.2	27.6	17.8	12.4	8.9	6.7	5.5	4.9	4.5	4.3	4.1	3.8	3.4	17.6
1975	189.4	151.3	124.2	102.0	83.7	68.5	55.6	42.3	27.8	17.8	12.3	9.2	6.8	5.2	4.3	3.9	3.7	3.5	3.3	3.1	17.1
1976	195.1	155.0	123.8	101.7	83.5	68.4	55.9	43.7	30.5	18.0	11.0	8.0	7.0	5.3	4.1	3.5	3.1	3.0	2.8	2.7	16.4
1977	153.5	159.7	126.9	101.4	83.2	68.2	55.8	44.2	32.0	20.5	11.6	7.4	6.1	5.5	4.2	3.3	2.8	2.5	2.4	2.3	15.6
1978	184.7	125.6	130.7	103.9	83.0	68.1	54.6	40.8	27.9	19.8	14.4	8.7	5.7	4.8	4.4	3.4	2.7	2.3	2.1	2.0	14.6
1979	222.6	151.2	102.9	107.0	85.1	67.8	54.1	38.5	23.6	15.7	13.3	10.5	6.6	4.4	3.8	3.5	2.7	2.2	1.8	1.7	13.5
1980	187.4	182.3	123.8	84.2	87.6	69.6	54.4	39.9	24.6	14.1	9.8	8.2	8.1	5.2	3.5	3.0	2.8	2.2	1.8	1.5	12.4
1981	184.5	153.4	149.2	101.4	68.9	71.6	55.5	39.0	23.5	13.2	8.1	5.6	6.3	6.3	4.1	2.8	2.5	2.3	1.8	1.4	11.4
1982	201.3	151.0	125.6	122.2	83.0	56.3	58.2	42.4	24.6	11.8	7.0	5.0	4.2	4.8	4.9	3.3	2.3	2.0	1.8	1.5	10.4
1983	178.2	164.8	123.7	102.8	100.0	67.8	45.8	45.2	28.5	13.9	6.9	4.6	3.8	3.2	3.8	4.0	2.6	1.8	1.6	1.5	9.7
1984	198.1	145.9	135.0	101.2	84.2	81.7	55.0	35.1	29.3	16.8	8.8	4.9	3.5	3.0	2.6	3.0	3.2	2.1	1.5	1.3	9.1
1985	220.0	162.2	119.4	110.5	82.9	68.8	66.3	42.1	22.6	17.1	10.5	6.2	3.7	2.7	2.4	2.0	2.4	2.6	1.7	1.2	8.5
1986	199.0	180.1	132.8	97.8	90.5	67.8	55.1	50.4	29.2	14.9	12.5	8.2	4.9	3.0	2.2	1.9	1.7	2.0	2.1	1.4	7.9
1987	165.4	163.0	147.5	108.7	80.0	74.0	54.4	42.3	35.5	19.7	11.0	9.8	6.4	3.9	2.4	1.8	1.5	1.3	1.6	1.7	7.6
1988	150.7	135.4	133.4	120.7	89.0	65.4	60.3	41.6	24.1	20.4	13.8	8.4	7.5	5.0	3.1	1.9	1.4	1.2	1.1	1.3	7.6
1989	137.7	123.4	110.8	109.2	98.8	72.8	53.4	47.2	27.4	15.9	15.2	10.8	6.6	6.0	4.0	2.5	1.5	1.2	1.0	0.9	7.3
1990	106.1	112.7	101.0	90.7	89.4	80.8	59.3	41.6	32.4	19.1	11.7	11.3	8.4	5.2	4.8	3.2	2.0	1.3	0.9	0.8	6.7
1991	106.4	86.9	92.3	82.7	74.3	73.0	65.5	42.9	21.2	17.5	11.9	7.6	8.1	6.2	4.0	3.7	2.6	1.6	1.0	0.8	6.1
1992	122.1	87.1	71.1	75.6	67.7	60.5	56.6	46.0	22.8	9.1	8.1	6.8	5.0	5.7	4.6	3.0	2.9	2.0	1.3	0.8	5.6
1993	187.8	100.0	71.3	58.2	61.8	55.1	46.5	38.6	22.2	8.3	3.7	4.3	4.3	3.5	4.2	3.5	2.3	2.3	1.6	1.0	5.2
1994	234.0	153.7	81.9	58.4	47.6	50.3	30.3	22.3	16.1	9.1	3.5	1.8	2.7	3.0	2.5	3.1	2.7	1.8	1.8	1.3	5.0
1995	230.2	191.6	125.9	67.0	47.8	38.8	25.8	13.1	8.1	5.7	3.4	1.6	1.1	1.8	2.1	1.9	2.4	2.1	1.5	1.4	5.1
1996	139.8	188.5	156.9	103.0	54.8	38.9	30.4	18.2	7.5	4.8	3.6	2.3	1.0	0.8	1.4	1.6	1.5	1.9	1.7	1.2	5.3
1997	137.5	114.5	154.3	128.4	84.3	44.7	30.4	20.9	9.6	4.2	2.9	2.4	1.5	0.7	0.6	1.0	1.3	1.1	1.5	1.3	5.3
1998	158.3	112.6	93.7	126.3	105.1	68.7	34.5	20.6	10.3	4.8	2.3	1.8	1.6	1.1	0.5	0.4	0.8	1.0	0.9	1.2	5.4
1999	184.1	129.6	92.1	76.7	103.4	85.7	53.3	23.7	10.6	5.3	2.8	1.5	1.2	1.2	0.8	0.4	0.3	0.6	0.8	0.7	5.3
2000	206.4	150.7	106.1	75.4	62.8	84.2	68.3	37.0	10.6	5.3	2.9	1.8	1.0	0.9	0.9	0.6	0.3	0.3	0.5	0.6	4.9
2001	223.8	169.0	123.4	86.8	61.7	51.1	66.8	45.9	14.1	4.7	2.6	1.8	1.1	0.7	0.6	0.6	0.5	0.3	0.2	0.4	4.5
2002	176.9	183.3	138.3	101.0	71.1	50.3	40.1	43.6	16.8	6.6	3.0	1.7	1.2	0.8	0.5	0.5	0.5	0.4	0.2	0.2	4.0
2003	119.7	144.8	150.0	113.3	82.7	57.9	39.6	26.7	17.3	8.3	4.4	2.0	1.2	0.9	0.6	0.4	0.4	0.4	0.3	0.2	3.4
2004	121.3	98.0	118.6	122.8	92.7	67.4	43.2	23.7	9.5	7.1	4.9	3.0	1.3	0.8	0.6	0.4	0.3	0.3	0.3	0.2	2.9
2005	96.3	99.3	80.2	97.1	100.5	75.6	51.0	27.3	10.1	4.5	4.5	3.5	2.0	1.0	0.6	0.5	0.3	0.2	0.2	0.3	2.5
2006	160.2	78.8	81.3	65.7	79.4	82.1	60.2	36.5	13.3	4.6	2.5	3.1	2.5	1.5	0.7	0.5	0.4	0.3	0.2	0.2	2.3
2007	144.1	131.2	64.5	66.6	53.7	64.9	65.5	43.7	19.1	6.6	2.7	1.8	2.3	1.9	1.2	0.6	0.4	0.3	0.2	0.2	2.0
2008	148.1	118.0	107.4	52.8	54.5	43.9	52.6	50.1	24.7	10.7	4.3	1.8	1.3	1.8	1.5	0.9	0.5	0.3	0.3	0.2	1.8

Table 11: Fishing mortality-at-age matrix for case 14a – starting in 1975 assuming equilibrium in 1960.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	av5-10
1960	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0016	0.0044	0.0047	0.0035	0.0021	0.0015	0.0010	0.0007	0.0005	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001	0.0028
1961	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0013	0.0035	0.0037	0.0028	0.0016	0.0012	0.0008	0.0006	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0022
1962	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0010	0.0028	0.0030	0.0022	0.0013	0.0009	0.0006	0.0005	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0017
1963	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0028	0.0076	0.0082	0.0062	0.0036	0.0025	0.0018	0.0013	0.0009	0.0006	0.0005	0.0003	0.0002	0.0002	0.0001	0.0048
1964	0.0000	0.0000	0.0000	0.0000	0.0002	0.0011	0.0073	0.0202	0.0218	0.0163	0.0094	0.0067	0.0047	0.0033	0.0024	0.0017	0.0012	0.0008	0.0006	0.0004	0.0003	0.0127
1965	0.0000	0.0000	0.0000	0.0001	0.0004	0.0026	0.0175	0.0491	0.0530	0.0394	0.0227	0.0160	0.0113	0.0080	0.0057	0.0040	0.0029	0.0020	0.0014	0.0010	0.0007	0.0307
1966	0.0000	0.0000	0.0000	0.0001	0.0007	0.0050	0.0347	0.0989	0.1070	0.0789	0.0451	0.0318	0.0224	0.0158	0.0112	0.0079	0.0056	0.0040	0.0028	0.0020	0.0014	0.0616
1967	0.0000	0.0000	0.0000	0.0002	0.0011	0.0073	0.0505	0.1462	0.1585	0.1162	0.0658	0.0462	0.0325	0.0230	0.0162	0.0115	0.0081	0.0058	0.0041	0.0029	0.0020	0.0907
1968	0.0000	0.0000	0.0000	0.0002	0.0014	0.0095	0.0662	0.1949	0.2117	0.1540	0.0865	0.0606	0.0426	0.0300	0.0212	0.0150	0.0106	0.0075	0.0053	0.0038	0.0027	0.1205
1969	0.0000	0.0000	0.0000	0.0003	0.0017	0.0117	0.0826	0.2475	0.2695	0.1945	0.1083	0.0756	0.0530	0.0373	0.0263	0.0186	0.0131	0.0093	0.0066	0.0047	0.0033	0.1524
1970	0.0000	0.0000	0.0000	0.0003	0.0018	0.0126	0.0889	0.2681	0.2922	0.2102	0.1166	0.0813	0.0569	0.0400	0.0282	0.0199	0.0141	0.0100	0.0071	0.0050	0.0035	0.1648
1971	0.0000	0.0000	0.0000	0.0002	0.0013	0.0090	0.0632	0.1854	0.2013	0.1467	0.0825	0.0578	0.0406	0.0287	0.0202	0.0143	0.0101	0.0072	0.0051	0.0036	0.0025	0.1147
1972	0.0000	0.0000	0.0000	0.0002	0.0016	0.0109	0.0769	0.2288	0.2489	0.1802	0.1006	0.0703	0.0493	0.0347	0.0245	0.0173	0.0122	0.0087	0.0061	0.0043	0.0031	0.1411
1973	0.0000	0.0000	0.0000	0.0002	0.0016	0.0108	0.0762	0.2266	0.2465	0.1785	0.0997	0.0697	0.0489	0.0344	0.0243	0.0172	0.0121	0.0086	0.0061	0.0043	0.0031	0.1397
1974	0.0000	0.0000	0.0000	0.0002	0.0015	0.0104	0.0732	0.2170	0.2360	0.1711	0.0958	0.0670	0.0470	0.0331	0.0234	0.0165	0.0117	0.0083	0.0059	0.0041	0.0029	0.1339
1975	0.0000	0.0000	0.0000	0.0002	0.0017	0.0034	0.0411	0.1286	0.2335	0.2825	0.2319	0.0736	0.0516	0.0363	0.0256	0.0181	0.0128	0.0091	0.0064	0.0045	0.0032	0.1535
1976	0.0000	0.0000	0.0000	0.0002	0.0014	0.0029	0.0353	0.1097	0.1976	0.2381	0.1963	0.0631	0.0443	0.0312	0.0220	0.0156	0.0110	0.0078	0.0055	0.0039	0.0028	0.1300
1977	0.0000	0.0000	0.0000	0.0002	0.0013	0.0233	0.1142	0.2588	0.2814	0.1538	0.0908	0.0589	0.0414	0.0292	0.0206	0.0146	0.0103	0.0073	0.0052	0.0037	0.0026	0.1537
1978	0.0000	0.0000	0.0000	0.0003	0.0017	0.0299	0.1485	0.3448	0.3765	0.2013	0.1176	0.0760	0.0533	0.0375	0.0264	0.0187	0.0132	0.0093	0.0066	0.0047	0.0033	0.2031
1979	0.0000	0.0000	0.0000	0.0002	0.0012	0.0208	0.1042	0.2491	0.3168	0.2659	0.2812	0.0543	0.0382	0.0269	0.0190	0.0134	0.0095	0.0067	0.0048	0.0034	0.0024	0.2063
1980	0.0000	0.0000	0.0000	0.0002	0.0016	0.0264	0.1339	0.3272	0.4211	0.3503	0.3714	0.0692	0.0486	0.0342	0.0241	0.0170	0.0121	0.0085	0.0060	0.0043	0.0030	0.2717
1981	0.0000	0.0000	0.0000	0.0003	0.0021	0.0073	0.0684	0.2584	0.4942	0.4365	0.2819	0.0921	0.0644	0.0453	0.0319	0.0225	0.0159	0.0112	0.0080	0.0056	0.0040	0.2578
1982	0.0000	0.0000	0.0000	0.0002	0.0016	0.0058	0.0537	0.1985	0.3686	0.3280	0.2160	0.0721	0.0506	0.0356	0.0251	0.0177	0.0125	0.0089	0.0063	0.0045	0.0032	0.1951
1983	0.0000	0.0000	0.0000	0.0002	0.0015	0.0093	0.0660	0.2330	0.3258	0.2578	0.1458	0.0680	0.0477	0.0336	0.0237	0.0168	0.0119	0.0084	0.0059	0.0042	0.0030	0.1730
1984	0.0000	0.0000	0.0000	0.0002	0.0016	0.0096	0.0682	0.2416	0.3385	0.2675	0.1509	0.0703	0.0493	0.0347	0.0245	0.0173	0.0122	0.0087	0.0061	0.0043	0.0031	0.1794
1985	0.0000	0.0000	0.0000	0.0002	0.0011	0.0211	0.0733	0.1664	0.2153	0.1108	0.0509	0.0461	0.0325	0.0229	0.0162	0.0115	0.0081	0.0057	0.0041	0.0029	0.0020	0.1063
1986	0.0000	0.0000	0.0000	0.0001	0.0010	0.0192	0.0663	0.1498	0.1934	0.1000	0.0461	0.0418	0.0294	0.0208	0.0147	0.0104	0.0074	0.0052	0.0037	0.0026	0.0019	0.0958
1987	0.0000	0.0000	0.0000	0.0002	0.0015	0.0040	0.0698	0.3613	0.3554	0.1521	0.0769	0.0659	0.0463	0.0326	0.0230	0.0163	0.0115	0.0081	0.0058	0.0041	0.0029	0.1699
1988	0.0000	0.0000	0.0000	0.0001	0.0010	0.0025	0.0445	0.2176	0.2142	0.0954	0.0489	0.0420	0.0296	0.0209	0.0148	0.0104	0.0074	0.0052	0.0037	0.0026	0.0019	0.1039
1989	0.0000	0.0000	0.0000	0.0002	0.0013	0.0044	0.0515	0.1765	0.1586	0.1098	0.0909	0.0559	0.0393	0.0277	0.0196	0.0138	0.0098	0.0069	0.0049	0.0035	0.0025	0.0986
1990	0.0000	0.0000	0.0001	0.0004	0.0030	0.0103	0.1246	0.4741	0.4189	0.2779	0.2266	0.1357	0.0943	0.0659	0.0463	0.0326	0.0230	0.0163	0.0115	0.0081	0.0058	0.2554
1991	0.0000	0.0000	0.0001	0.0007	0.0046	0.0549	0.1540	0.4322	0.6459	0.5695	0.3544	0.2148	0.1474	0.1022	0.0714	0.0501	0.0353	0.0249	0.0176	0.0124	0.0088	0.3685
1992	0.0000	0.0000	0.0001	0.0008	0.0053	0.0645	0.1825	0.5280	0.8123	0.7083	0.4290	0.2561	0.1746	0.1206	0.0840	0.0588	0.0413	0.0291	0.0206	0.0145	0.0103	0.4541
1993	0.0000	0.0000	0.0001	0.0008	0.0054	0.3985	0.5345	0.6709	0.6916	0.6530	0.5185	0.2591	0.1766	0.1219	0.0849	0.0594	0.0418	0.0294	0.0208	0.0147	0.0104	0.5778
1994	0.0000	0.0000	0.0001	0.0009	0.0062	0.4702	0.6398	0.8161	0.8436	0.7925	0.6196	0.3018	0.2043	0.1404	0.0975	0.0681	0.0478	0.0337	0.0238	0.0168	0.0119	0.6970
1995	0.0000	0.0000	0.0001	0.0006	0.0042	0.0413	0.1471	0.3579	0.3176	0.2454	0.1751	0.1964	0.1352	0.0940	0.0657	0.0461	0.0325	0.0229	0.0162	0.0115	0.0081	0.2141
1996	0.0000	0.0000	0.0001	0.0007	0.0050	0.0491	0.1763	0.4394	0.3880	0.2973	0.2105	0.2367	0.1619	0.1120	0.0781	0.0548	0.0385	0.0272	0.0192	0.0136	0.0096	0.2601
1997	0.0000	0.0000	0.0001	0.0006	0.0041	0.0585	0.1896	0.5056	0.4982	0.3721	0.2752	0.1933	0.1331	0.0925	0.0647	0.0455	0.0320	0.0226	0.0160	0.0113	0.0080	0.3165
1998	0.0000	0.0000	0.0001	0.0006	0.0039	0.0547	0.1763	0.4642	0.4576	0.3436	0.2551	0.1798	0.1240	0.0863	0.0604	0.0425	0.0299	0.0211	0.0149	0.0106	0.0075	0.2919
1999	0.0000	0.0000	0.0001	0.0007	0.0049	0.0272	0.1634	0.6012	0.4963	0.3958	0.2505	0.2347	0.1605	0.1111	0.0775	0.0543	0.0382	0.0269	0.0190	0.0135	0.0095	0.3224
2000	0.0000	0.0000	0.0001	0.0009	0.0058	0.0322	0.1965	0.7647	0.6214	0.4888	0.3040	0.2842	0.1929	0.1328	0.0923	0.0646	0.0454	0.0320	0.0225	0.0159	0.0113	0.4013
2001	0.0000	0.0000	0.0001	0.0006	0.0044	0.0420	0.2255	0.8076	0.5610	0.2323	0.2196	0.2041	0.1403	0.0974	0.0681	0.0478	0.0337	0.0237	0.0168	0.0119	0.0084	0.3480
2002	0.0000	0.0000	0.0001	0.0006	0.0040	0.0389	0.2078	0.7235	0.5092	0.2140	0.2024	0.1882	0.1297	0.0902	0.0631	0.0443	0.0312	0.0220	0.0156	0.0110	0.0078	0.3160
2003	0.0000	0.0000	0.0001	0.0007	0.0047	0.0925	0.3147	0.8372	0.6882	0.3206	0.1766	0.2211	0.1516	0.1051	0.0733	0.0514	0.0362	0.0255	0.0180	0.0128	0.0090	0.4050
2004	0.0000	0.0000	0.0001	0.0006	0.0040	0.0777	0.2593	0.6534	0.5463	0.2640	0.1473	0.1837	0.1267	0.0881	0.0617	0.0433	0.0305	0.0216	0.0152	0.0108	0.0076	0.3247
2005	0.0000	0.0000	0.0001	0.0004	0.0028	0.0280	0.1355	0.5167	0.5853	0.3691	0.1733	0.1260	0.0877	0.0614	0.0431	0.0304	0.0214	0.0152	0.0107	0.0076	0.0054	0.3013
2006	0.0000	0.0000	0.0001	0.0004	0.0025	0.0249	0.1200	0.4463	0.5030	0.3221	0.1531	0.1116	0.0778	0.0546	0.0384	0.0271	0.0191	0.0135	0.0096	0.0068	0.0048	0.2616
2007	0.0000	0.0000	0.0000	0.0003	0.0018	0.0102	0.0683	0.3706	0.3761	0.2298	0.1894	0.0792	0.0555	0.0390	0.0275	0.0194	0.0137	0.0097	0.0069	0.0049	0.0035	0.2074
2008	0.0000	0.0000	0.0000	0.0002	0.0016	0.0090	0.0597	0.3173	0.3219	0.1988	0.1643	0.0692	0.0486	0.0342	0.0241	0.0170	0.0121	0.0085	0.0060	0.0043	0.0030	0.1785

	$B^{sp}{}_{2008}$	$B^{sp}{}_{2008}/K$	$B^{exp}{}_{2008}$	MSYL^{sp}	MSY
XSA	15		68		
New Baseline	353 (0.60)	0.59 (0.34)	326	0.17 (0.15)	43 (0.26)
5) as New Baseline (NB) with a survey ρ for each series	412 (0.58)	0.64 (0.30)	328	0.17 (0.14)	47 (0.28)
6a) h = 0.7	342 (0.67)	0.56 (0.40)	296	0.28 (0.13)	33 (0.26)
6b) h = 0.5	169 *	0.31 *	181	0.37 *	21 *
7) Ricker like (h and γ estimated)	44 (0.38)	0.10 (0.33)	120	0.26 (0.22)	22 (0.13)
8) $\sigma_R = 0.3$	703 *	0.78 *	548	0.17 *	64 *
9a) 1990-1994 catches increased by 10 000 t	492 (0.46)	0.68 (0.23)	412	0.17 (0.11)	52 (0.24)
9b) 1990-1994 catches decreased by 10 000 t	26 (0.42)	0.08 (0.40)	126	0.18 (0.18)	27 (0.04)
10) Flat commercial selectivity from age 10	285 (0.66)	0.54 (0.40)	282	0.17 (0.18)	39 (0.25)
11) Four commercial selectivity periods	637 (0.60)	0.80 (0.24)	465	0.17 (0.12)	57 (0.36)
12a) commercial $\sigma_\Omega = 4.0$	370 (0.57)	0.61 (0.31)	335	0.17 (0.15)	44 (0.26)
12b) commercial $\sigma_\Omega = 0.5$	29 (0.27)	0.08 (0.24)	136	0.18 (0.13)	28 (0.04)
12c) survey σ_Ω = 1.0	769 (0.67)	0.87 (0.24)	498	0.17 (0.11)	63 (0.43)
13) M=0.15	58 (0.41)	0.10 (0.37)	133	0.19 (0.17)	28 (0.05)
14a) start in 1975: unexploited equilibrium in 1960	37 (0.42)	0.10 (0.38)	135	0.17 (0.16)	28 (0.04)
14b) start in 1975: estimate θ and ζ	39 (0.45)	0.12 (0.42)	135	0.18 (0.17)	27 (0.05)
14c) start in 1975: estimate θ, start with XSA estimated proportions-at-age in 1975	23 (0.48)	0.06 (0.48)	122	0.18 (0.19)	29 (0.07)

Table 12: Summary key statistics for XSA and all the SCAA sensitivities (4 to 14 and Production-type model 2)

	Median	lower 5%-ile	upper 5%-ile	Median	lower5%-ile	upper5%-ile	Median	lower5%-ile	upper5%-ile	Median	lower5%-ile	upper5%-ile
B^{sp}_{2008}	263	132	491	263	132	491	263	132	491	263	132	491
B^{sp}_{2008}/K	0.51	0.32	0.71	0.51	0.32	0.71	0.51	0.32	0.71	0.51	0.32	0.71
B^{sp}_{2013}	338	195	590	338	195	590	338	195	590	266	143	483
B^{sp}_{2013}/K	0.66	0.47	0.85	0.66	0.47	0.85	0.66	0.47	0.85	0.52	0.34	0.70
B^{sp}_{2018}	433	295	674	433	295	674	433	295	674	181	111	302
B^{sp}_{2018}/K	0.84	0.70	0.98	0.84	0.70	0.98	0.84	0.70	0.98	0.35	0.27	0.44
B^{sp}_{2028}	549	421	769	549	421	769	549	421	769	132	100	189
B^{sp}_{2028}/K	1.06	1.02	1.10	1.06	1.02	1.10	1.06	1.02	1.10	0.26	0.24	0.27
F0.1	0.43	0.37	0.48	0.43	0.37	0.48	0.43	0.37	0.48	0.43	0.37	0.48
C_{2008}	24175	24175	24175	24175	24175	24175	24175	24175	24175	24175	24175	24175
C_{2009}	0	0	0	16000	16000	16000	22750	22750	22750	66560	44719	102391
C_{2010}	0	0	0	16000	16000	16000	22750	22750	22750	47236	33886	69586
C_{2011}	0	0	0	16000	16000	16000	22750	22750	22750	38723	28284	56606
C_{2012}	0	0	0	16000	16000	16000	22750	22750	22750	34807	25605	50873
C_{2013}	0	0	0	16000	16000	16000	22750	22750	22750	37899	27537	55590
C_{2018}	0	0	0	16000	16000	16000	22750	22750	22750	40001	31318	54924
C_{2028}	0	0	0	16000	16000	16000	22750	22750	22750	38944	31023	53115

Table 13: MCMC medians and 90% probability intervals of projected spawning biomass (in absolute terms and relative to pre-exploitation level) in 2008, 2013, 2018 and 2018 under a series of catch scenarios. The expected catches are also shown for a series of years.

	Total			
	MLE	Median	lower5%-ile	upper5%-ile
K^{sp}	576	516	410	708
h	0.90	0.90	0.90	0.90
B^{sp}_{2008}	372	262	132	494
B^{sp}_{2008}/K	0.65	0.51	0.32	0.71
MSYL^{sp}	0.17	0.17	0.17	0.17
MSY	43	38	31	51

Table 14: Maximum likelihood estimates (MLE) and MCMC medians and 90% probability intervals for New Baseline SCAA assessment. Note that *h* was fixed at 0.9 for the MCMC computations.

	Total			
	MLE	Median	lower5%-ile	upper5%-ile
K^{sp}	500	1003	483	2827
h	0.89	0.72	0.37	0.93
B^{sp}_{2008}	250	813	197	2964
B^{sp}_{2008}/K	0.50	0.82	0.40	1.05
MSYL^{sp}	0.13	0.27	0.15	0.45
MSY	41	53	25	167

Table 15: Maximum likelihood estimates (MLE) and MCMC medians and 90% probability intervals for the Production-type Model 2.

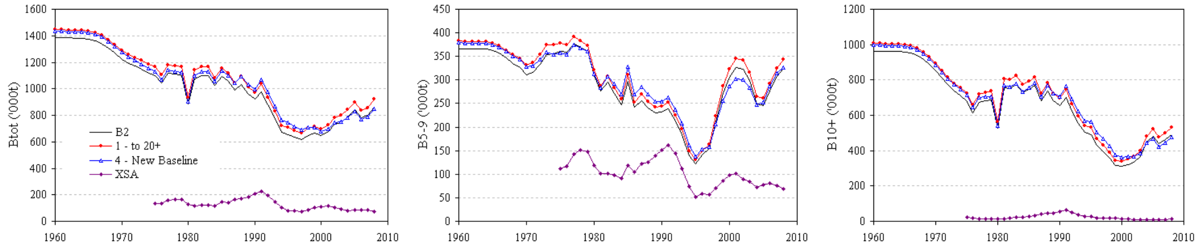

Fig. 1: Total, exploitable (5-9) and spawning (10+) biomass trajectories for the Baseline B2 of Butterworth and Rademeyer (2009a) cases 1 and 4 (New Baseline), and XSA (Healey and Mahé, 2008) assessments.

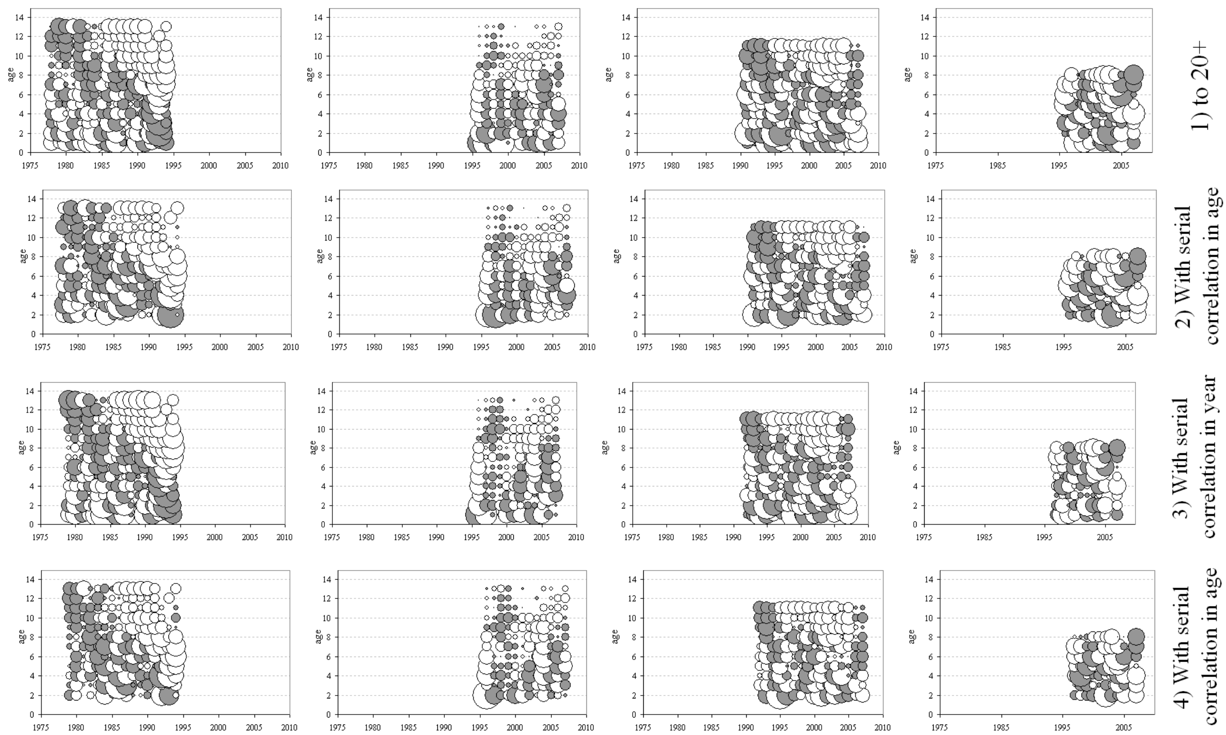

Fig. 2: Standardised residual plots for the survey proportions-at-age data for a series of SCAA assessments.

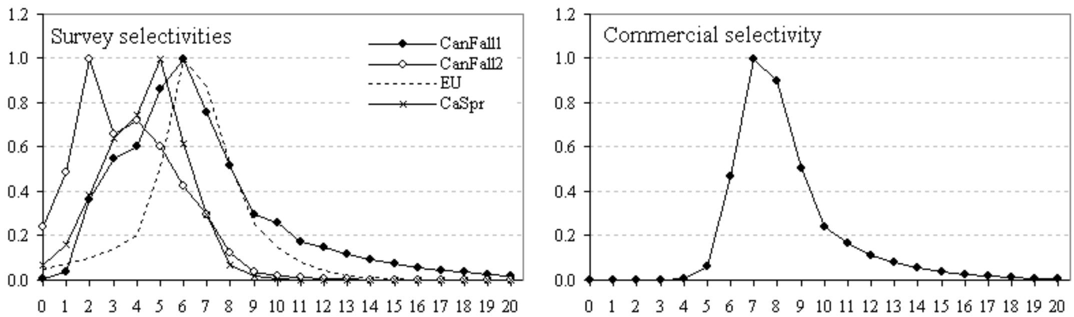

Fig. 3: Survey and commercial fishing selectivities-at-age estimated for the New Baseline assessment.

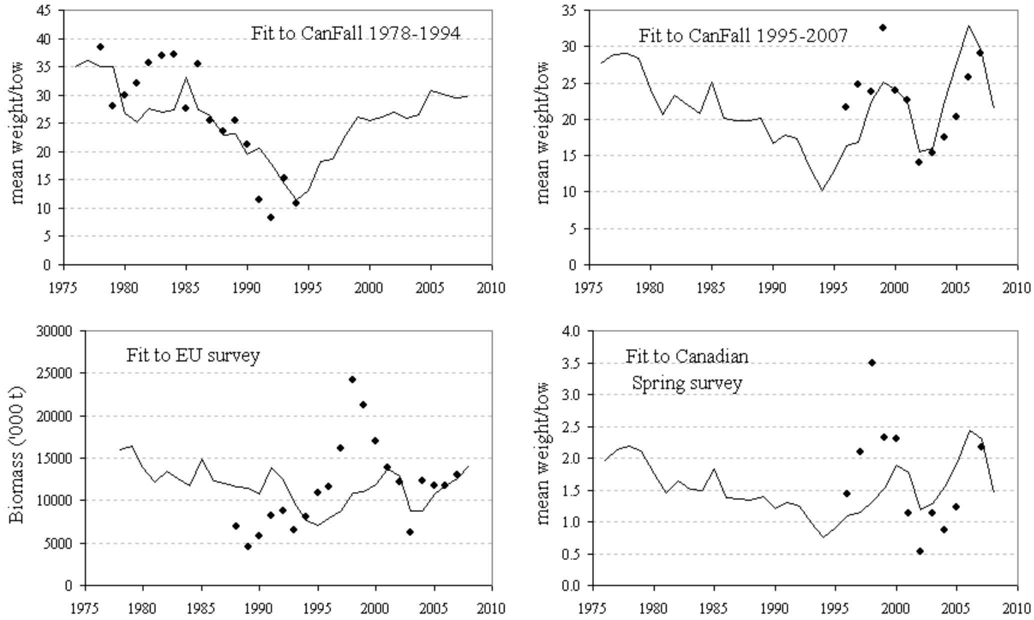

Fig. 4: Fits of the New Baseline assessment to the abundance indices provided by the survey series.

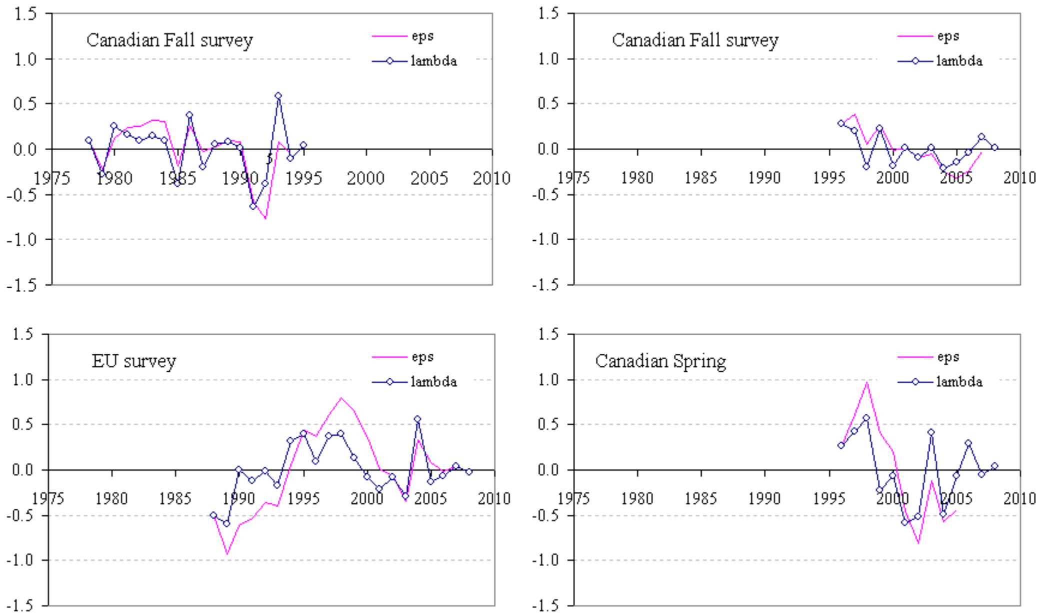

Fig. 5: Survey standardised residuals for the New Baseline assessment. Residuals are shown both before ("eps") and after ("lambda") adjustment for serial correlation.

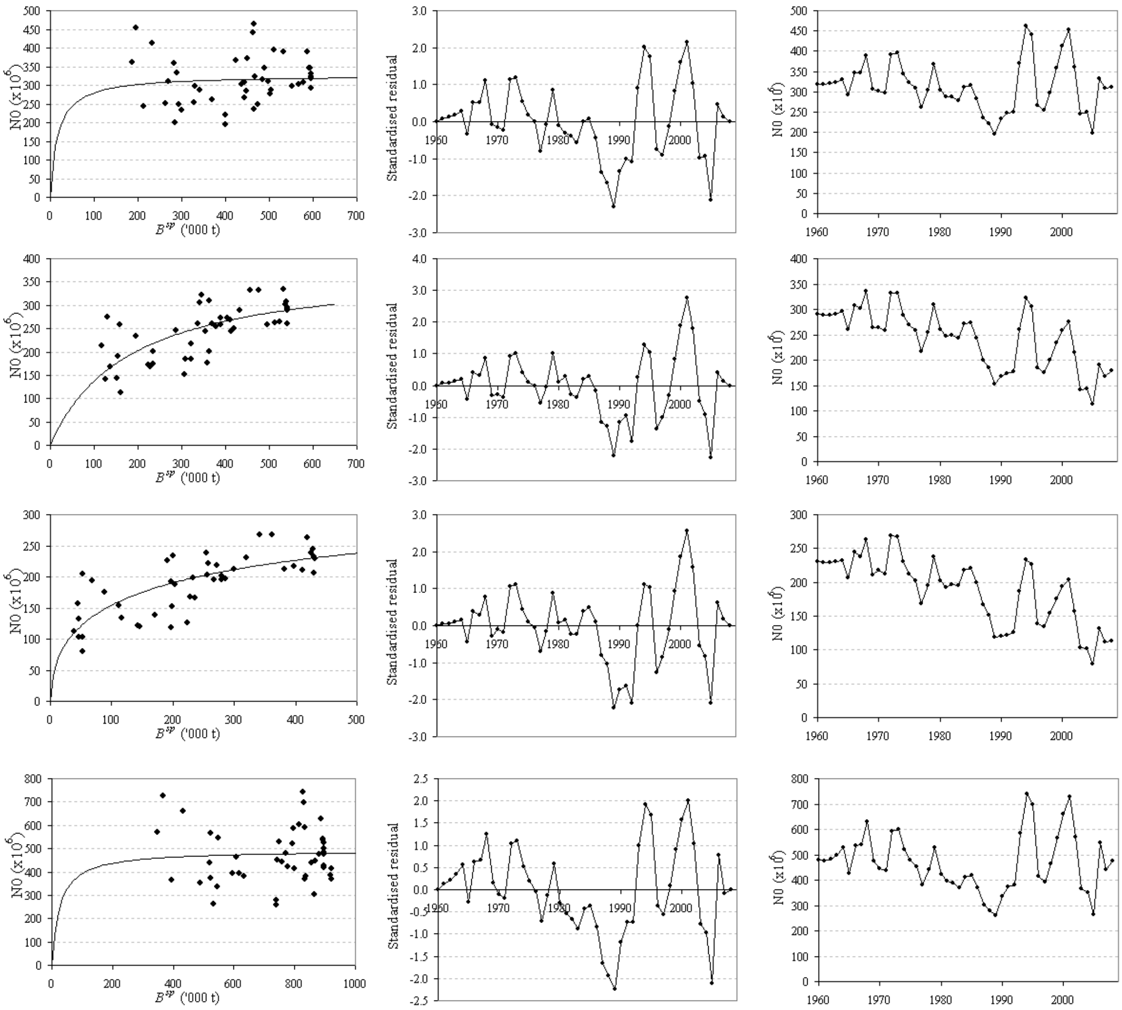

Fig. 6: Stock-recruitment curve and time series of standardised stock-recruitment residuals and recruitments for the New Baseline model (σ_R=0.25, h=0.9, top row), variant 6b (h=0.5, second row), variant 7 (Ricker-type, third row) and variant 8 (σ_R=0.3, bottom row).

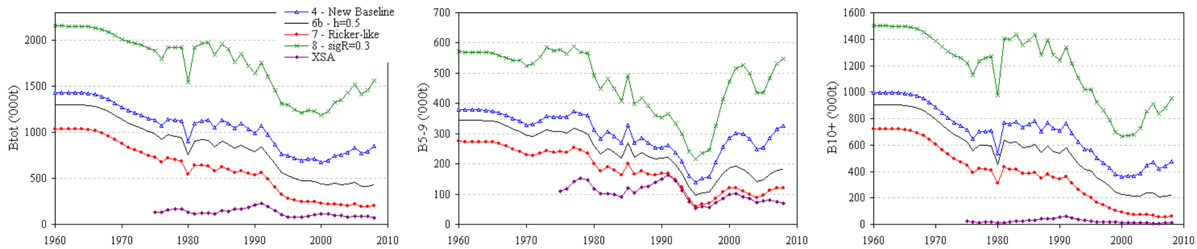

Fig. 7: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories for the New Baseline, alternative assumptions regarding the stock-recruitment relationship and XSA (Healey and Mahé, 2008) assessments.

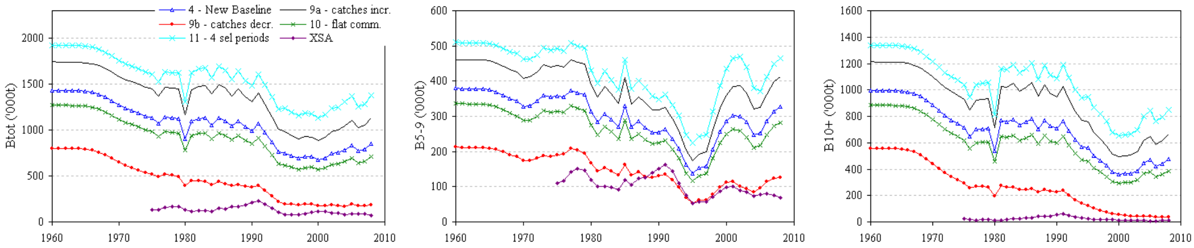

Fig. 8: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories for the New Baseline, alternative assumptions regarding the total catches and commercial selectivity and XSA (Healey and Mahé, 2008) assessments.

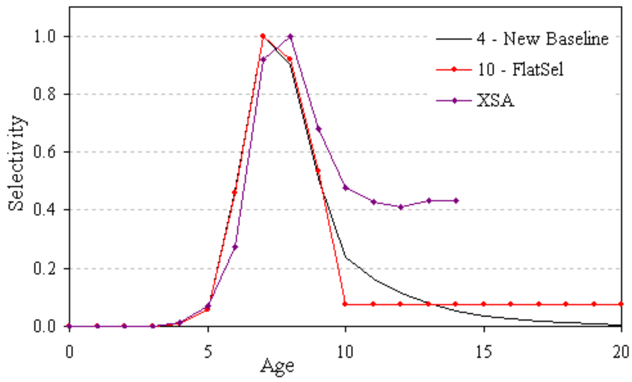

Fig. 9: Commercial selectivity for the New Baseline, sensitivity 10 with flat selectivity from age 10 and XSA.

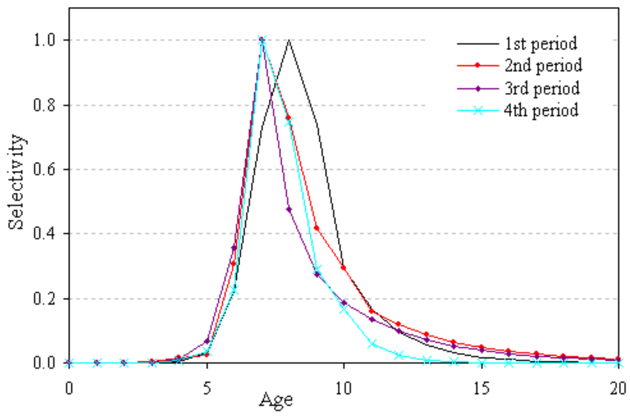

Fig. 10: Commercial selectivity for each of the four periods for sensitivity 11.

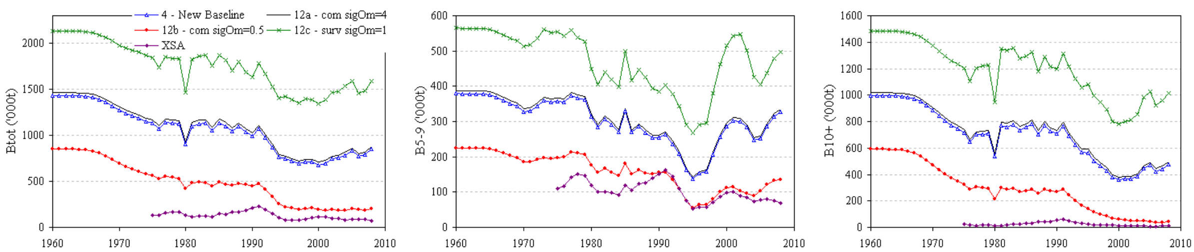

Fig. 11: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories for the New Baseline, sensitivities with alternative σ_Ω, and XSA assessments.

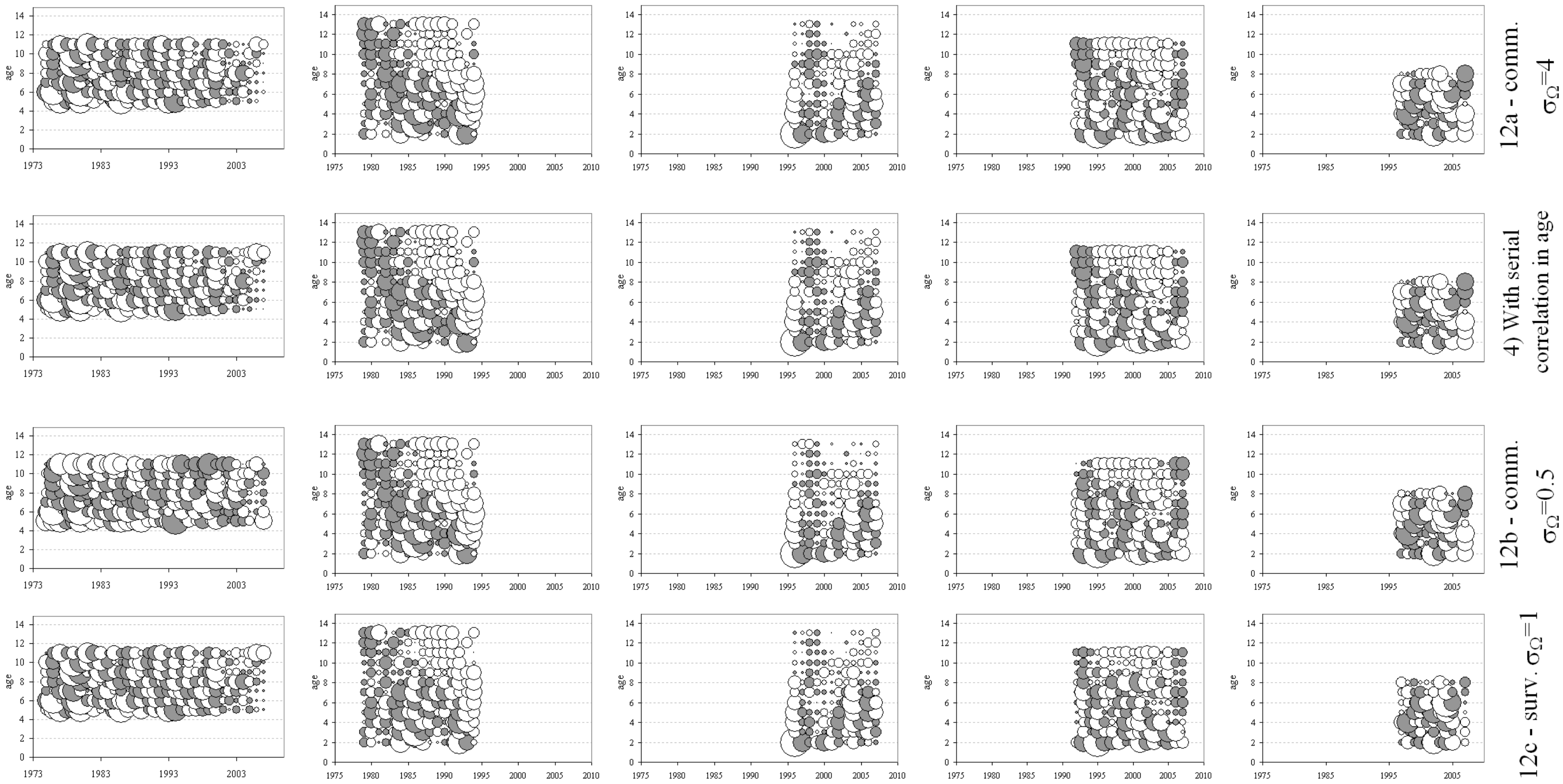

Fig. 12: Standardised residual plots for the commercial and survey proportions-at-age data for a series of SCAA assessments.

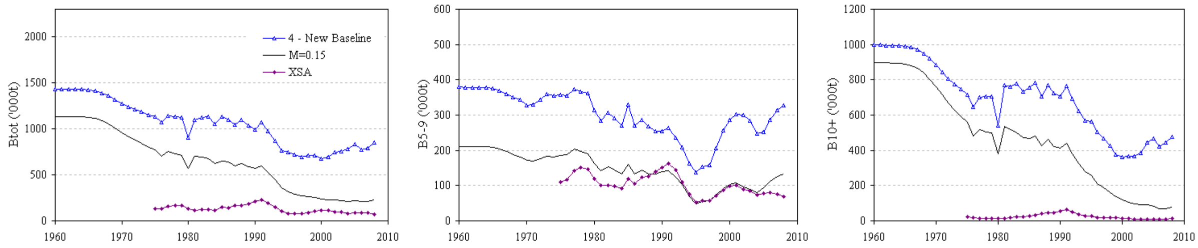

Fig. 13: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories for the New Baseline, sensitivity 13 with *M*=0.15 and XSA assessments.

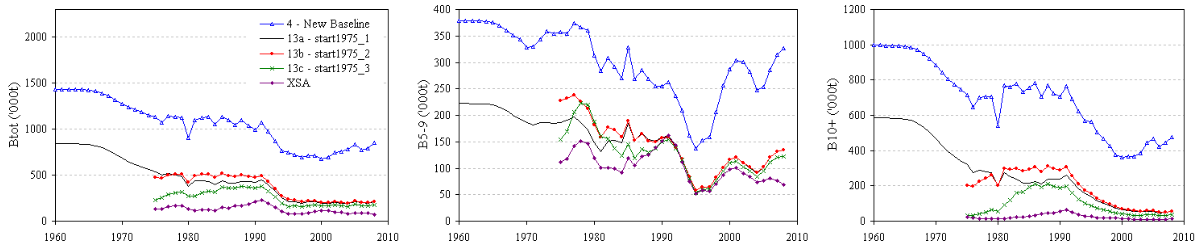

Fig. 14: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories for the New Baseline, sensitivities starting in 1975 and XSA assessments.

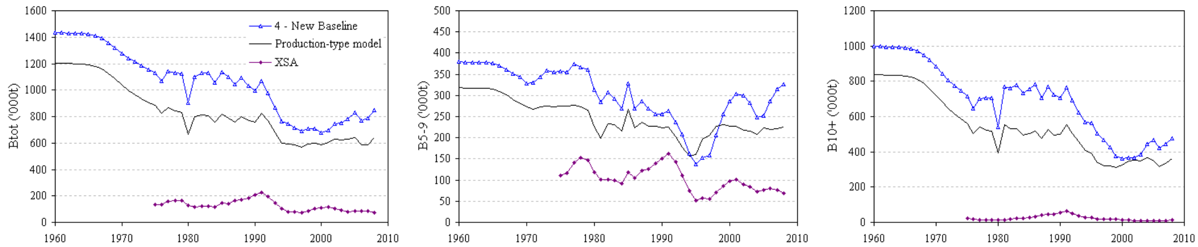

Fig. 15: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories for the New Baseline, the production-type model 2) and XSA assessments.

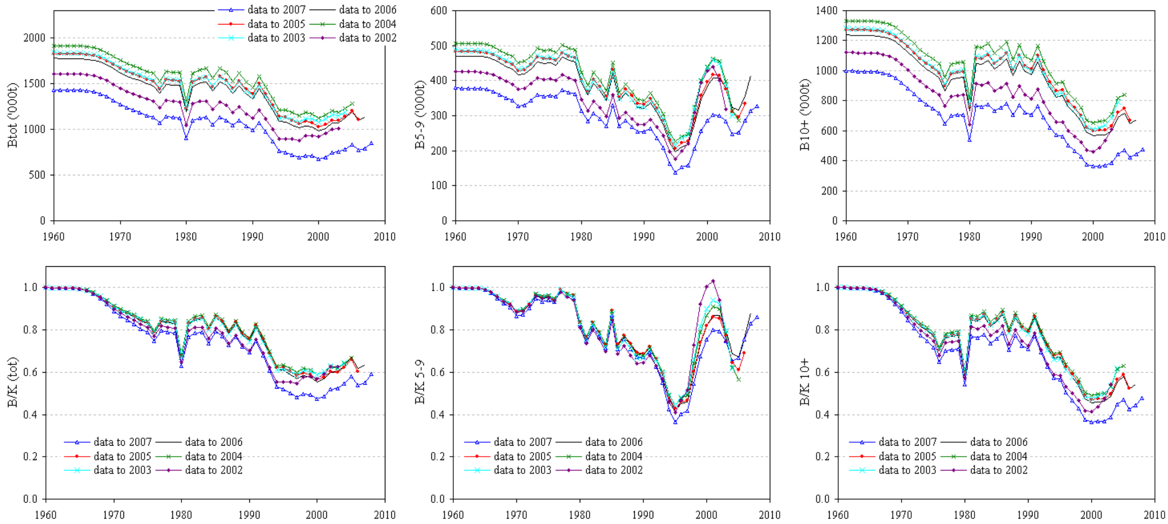

Fig. 16: Comparison of total (1+), exploitable (5-9) and spawning (10+) biomass trajectories (in absolute terms and relative to pre-exploitation level) for the New Baseline and five retrospective assessments.

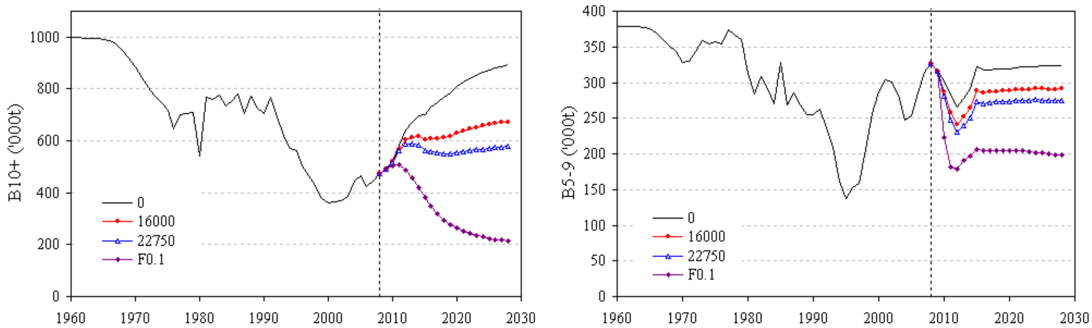

Fig. 17: Spawning (10+) and exploitable (5-9) biomass trajectories for the New Baseline assessment projected for a 20-year period under a series of catch scenarios.

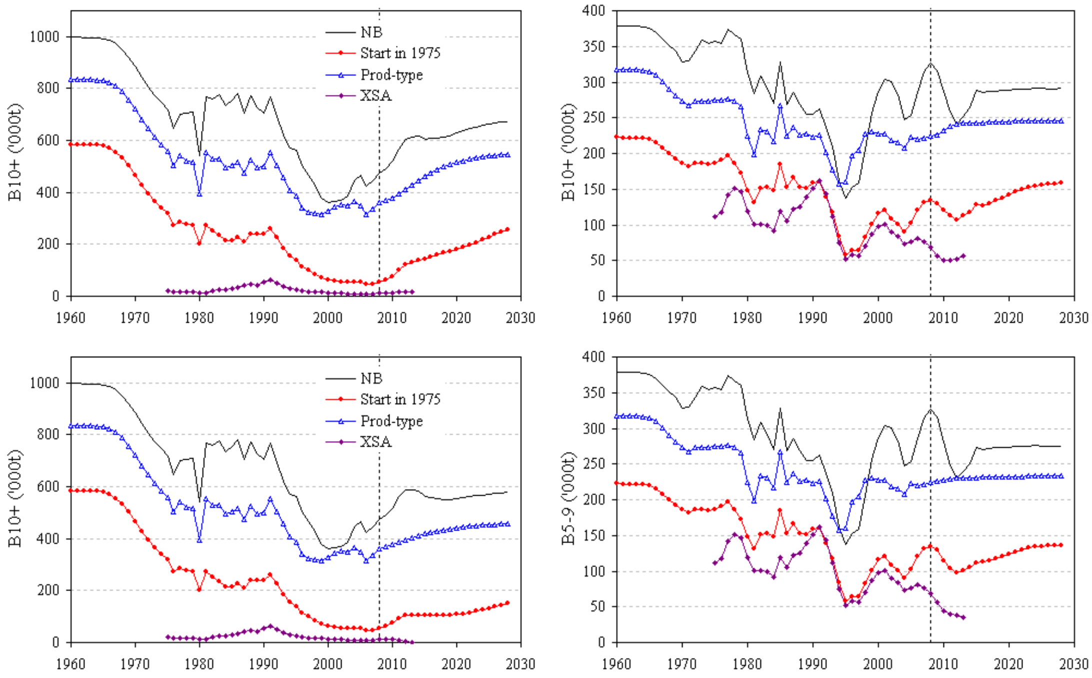

Fig. 18: Comparison of spawning (10+) and exploitable (5-9) biomass trajectories for the New Baseline, Case 14a (starting in 1975), the production-type model 2 and XSA assessments, projected for a 20-year period under a constant catch of 16000t (top row) and 22750t (bottom row).

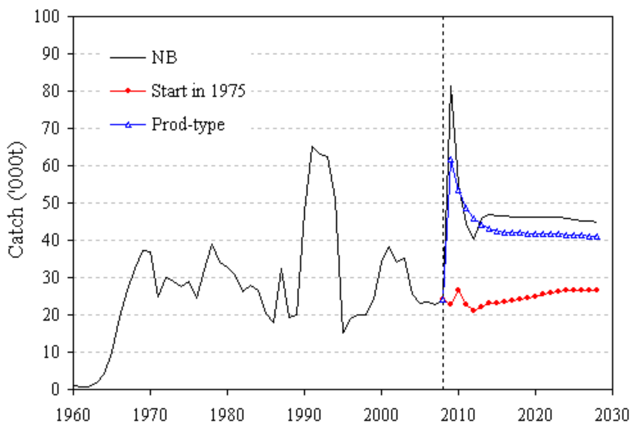

Fig. 19: Historic and projected catch under a F0.1 strategy for the New Baseline, Case 14a (starting in 1975) and the Production-type Model 2 assessments.

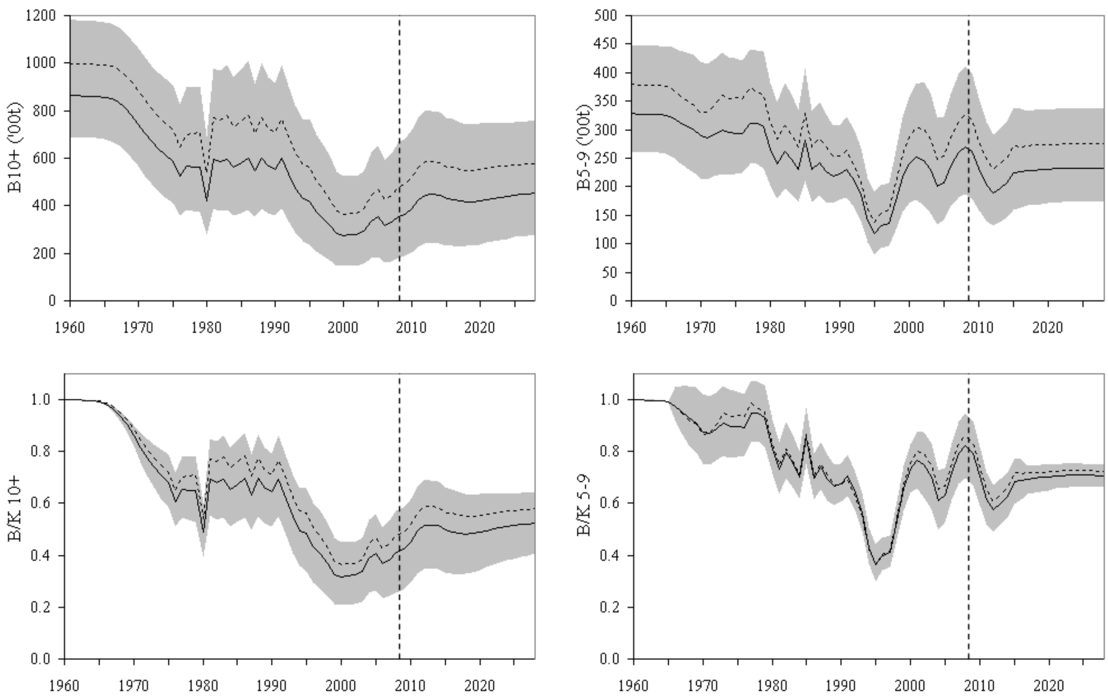

Fig. 20: Median (thick line) and 90% probability envelope (shaded area) spawning (10+) and exploitable (5-9) biomass trajectories (in absolute terms and relative to pre-exploitation level) for the New Baseline SCAA assessment. The MLE are also shown (dotted line). The projections are for a constant annual catch of 27500t.

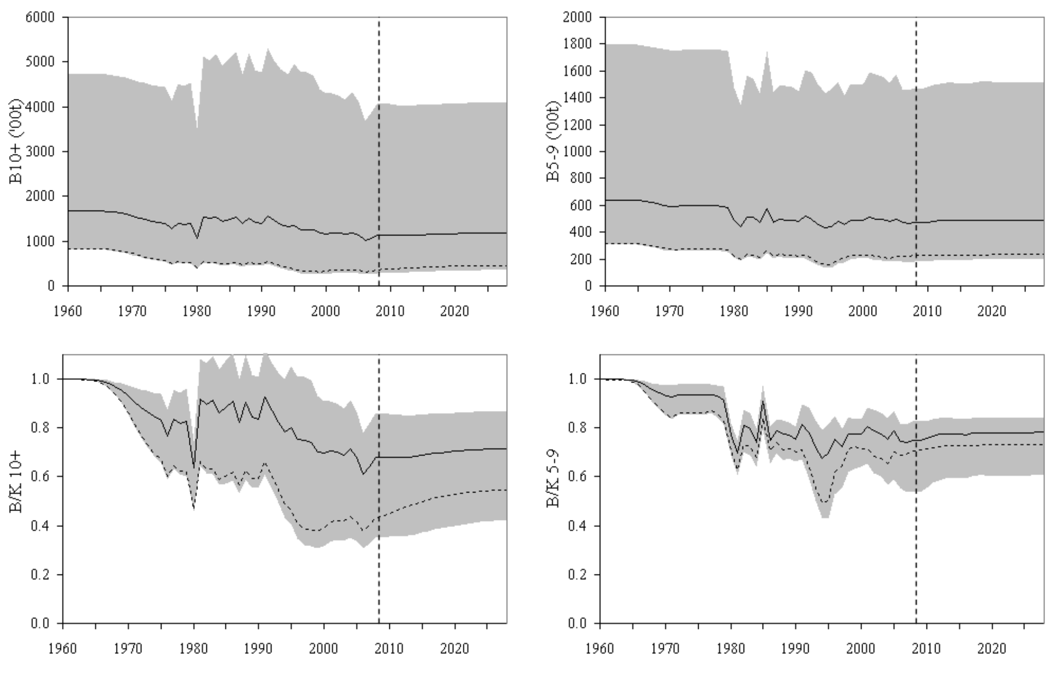

Fig. 21: Median (thick line) and 90% probability envelopes (shaded area) spawning (10+) and exploitable (5-9) biomass trajectories (in absolute terms and relative to pre-exploitation level) for the Production-type Model 2 assessment. The MLE are also shown (dotted line). The projections are for a constant annual catch of 27500t.