OVERVIEW OF PROGRESS WITH MANAGEMENT STRATEGY EVALUATION (MSE) FOR GREENLAND HALIBUT

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This document summarises the results of the trials of four Candidate Management Procedures (CMPs) for Greenland Halibut under XSA- and SCAA-based Operating Models (OMs) for the resource, the details of which are specified in Butterworth and Rademeyer (2010a).

The four CMPs for which results are reported (the latter two were selected from trials of a number of variants to best illustrate the intents they are trying to achieve) are:

CMP1 (or **ctC**)
A constant future annual catch of 16 000 mt. This is reported to assist comparisons, not as a serious contender for final selection.

CMP2 (or **Base Case**)
This is the default control rule agreed (Butterworth and Rademeyer, 2010a) to be reported for comparative purposes. This control rule is:

$$TAC_{y+1} = \begin{cases} TAC_y \times (1+\lambda_u \times slope) & if \quad slope \geq 0 \\ TAC_y \times (1+\lambda_d \times slope) & if \quad slope < 0 \end{cases} \tag{1}$$

with λ_u=1.0 and λ_d=1.25.

Note that this rule is applied without any constraints imposed on inter-annual TAC changes.

CMP3
This control rule has the same form as that for the Base Case CMP2, but the control parameter λ is set to 0.7 (for both upward and downward TAC adjustments), and the TAC is constrained not to change by more than 15% each year.

CMP4
The details of this control rule are set out in Appendix I. Basically it adds an additional term to the right hand side of equation 1 which reduces or increases the TAC further according to the level of recent survey estimates compared to those for the resource at its 1975-1999 average abundance.

RESULTS

Fig. 1a-d shows past values and projections for annual catches and exploitable biomasses ($B^{5\text{-}9}$) under CMP1-4 respectively for the Base Case SCAA and XSA Operating Models (OMs). The projections constitute 100 realisations of trajectories under various stochastic effects, which are shown by the median and 95% probability intervals for the catch or exploitable biomass each year. Note that the resultant plots of these intervals are not themselves trajectories, but rather trajectory envelopes. Fig 2 shows actual trajectories by plotting 10 replicates of future projections under CMP4.

Fig. 3 contrasts the four CMPs by plotting each of their four projections for median catch and median and lower 2.5%-ile for exploitable biomass.

Fig. 4 shows summary performance plots for the four CMPs applied to both the Base Case SCAA and XSA OMs. Note that the statistic P>15% is non-zero for CMP3 and CMP4 even though these impose 15% constrains on TAC changes from one year to the next. The reasons is that these statistics include the year 2010 for which the catch is selected from a pre-specified set of possibilities (involving changes that may exceed 15%), rather than being set by the CMP.

The robustness tests considered for both SCAA and XSA Base Case OMs are listed in Table 1, totalling 13 tests in all. Fig 5a-d shows summary performance statistics for these 13 tests for CMP1-4 respectively. Fig 6a-d show the corresponding plots of median catch and exploitable biomass across the Base Case and robustness tests separately for SCAA and for XSA.

DISCUSSION

The rationale underlying the sequence of four CMPs for which results are presented is best explained by reference to Fig. 3.

The simplest CMP, the constant annual catch of 16 000 mt (CMP1) is not acceptable because it leads to extirpation of the resource under the XSA Base Case OM.

The default Base Case CMP2 avoids this extirpation, but leads to a large reduction in catch in the short term without subsequent increase under the SCAA Base Case OM.

Adjustment of the control parameter values of equation (1) for CMP2 to give CMP3 avoids this large catch reduction for the SCAA Base Case OM, but remains unsatisfactory because of a large probability of a continuing decline in exploitable biomass under the XSA Base Case OM.

Addition of a further term to the right hand side of equation (1) to give CMP4 (see Appendix I) resolves these problems. There is no longer a substantial initial drop in the catch under the SCAA Base Case OM, and this catch shows a subsequent increase; under the Base Case XSA OM, the lower 2.5%-ile of the exploitable biomass shows an increase from the present level.

<u>Note</u>

The projections for the XSA Base Case OM under a 16 000 mt constant catch (CMP1) differ from (being more optimistic than) those presented in an earlier report on MSE for this resource

(Butterworth and Rademeyer, 2010b). The reason for this is clear from reference to the stock-recruitment plots shown in Appendix II. Two forms have been considered for fitting the stock-recruitment data in this exercise: Beverton-Holt and segmented regression/hockey-stick. For the SCAA Base Case, these forms differ little and fit the data virtually equally well. However, for the XSA the difference is greater, and in particular under Beverton-Holt (used in Butterworth and Rademeyer, 2010b) the recruitment at the current spawning biomass is predicted to be appreciably less than under the segmented regression/hockey-stick option used for the computations reported here. This latter option also fits the data in this case notably better than the Beverton-Holt form does. It is this particular difference in the immediate recruitment predictions from the two models that leads to these differences in constant catch projections for the XSA Base Case OM.

REFERENCES

Butterworth DS and Rademeyer RA. 2010a. Candidate Management Procedures testing methodology.

Butterworth DS and Rademezer RA. 2010b. Co-operative industry/government project: 2+3KLMNO Greenland halibut – bridging the gap.

Table 1: List of the SCAA and XSA robustness tests in the order they are presented in the summary performance plots of Fig. 5.

1	SCAA0	Base Case
2	SCAA1	flat commercial selectivity, estimated
3	SCAA2	flat commercial selectivity, fixed
4	SCAA3	$M = 0.1$
5	SCAA4	M increasing at older ages
6	SCAA5	$h = 0.6$
7	SCAA6	Modified Ricker
8	XSA0	Base Case (*CAV*)
9	XSA1	M=0.1 (*LMV*)
10	XSA2	Declining commercial selectivity at older ages (*CAV_domed*)
11	XSA3	M increasing at older ages (*CAV_varM*)
12	XSA4	Depleted segmented regression (*CAV_dep*)
13	XSA5	Depleted segmented regression with M=0.1 (*LMV_dep*)

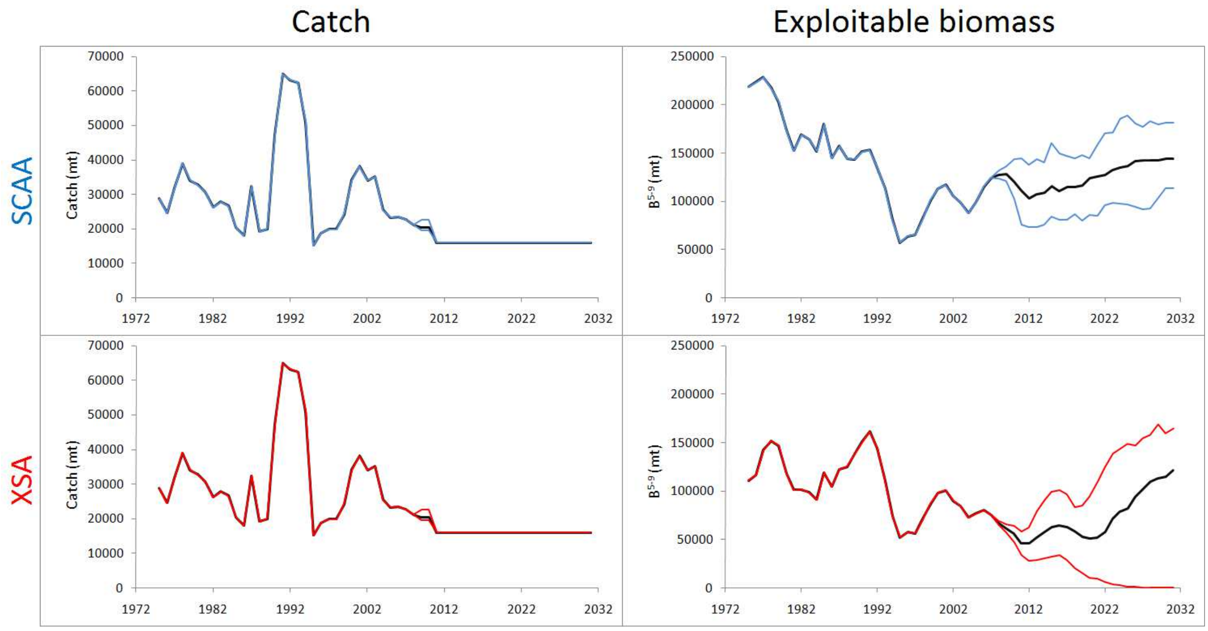


Fig. 1a: SCAA and XSA Base Cases projections under a constant catch of 16 000 mt (CMP1). The black line is the median and the 95%-iles are shown with the colored lines.

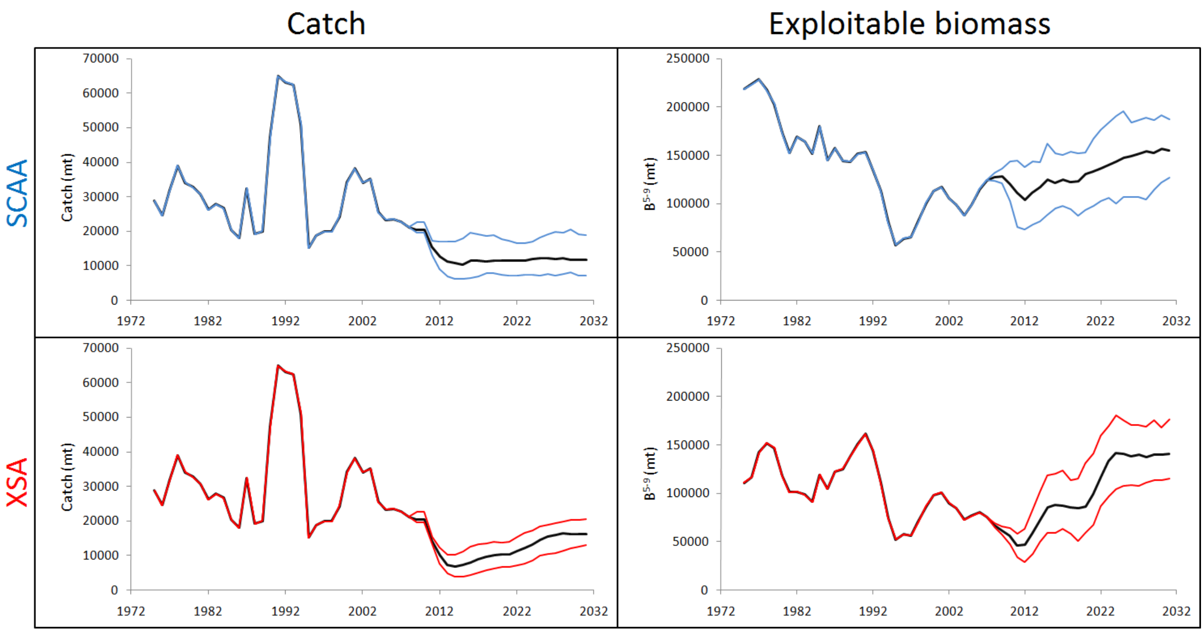


Fig. 1b: SCAA and XSA Base Cases projections under the Base Case CMP2. The black line is the median and the 95%-iles are shown with the colored lines.

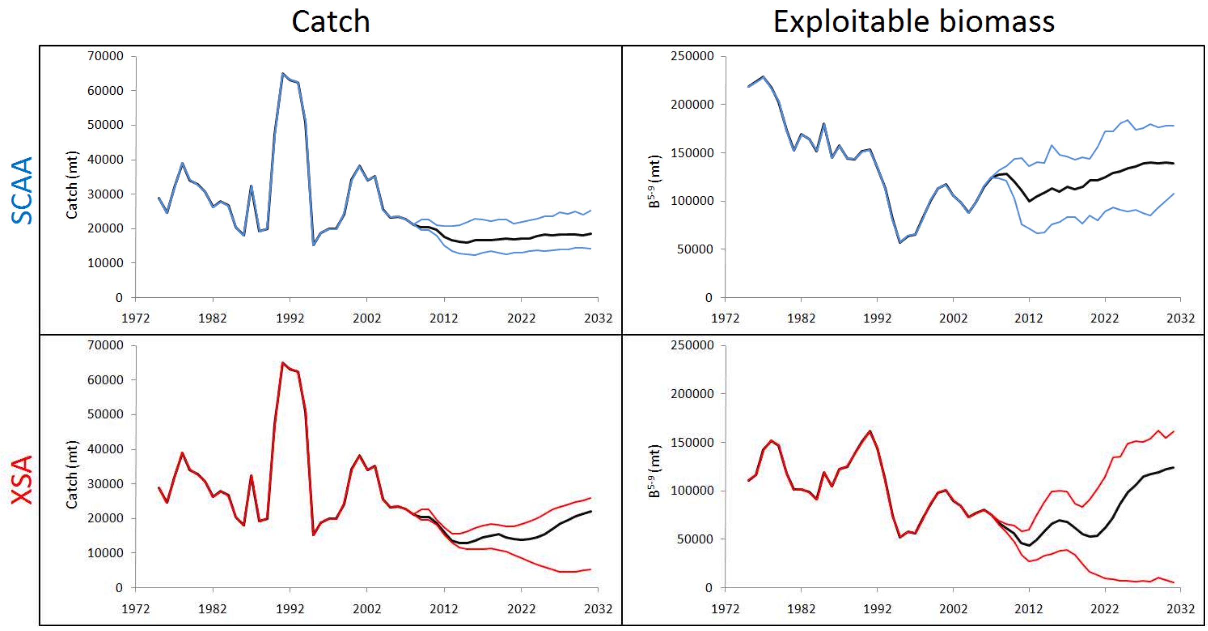


Fig. 1c: SCAA and XSA Base Cases projections under CMP3 (see text for details). The black line is the median and the 95%-iles are shown with the colored lines.

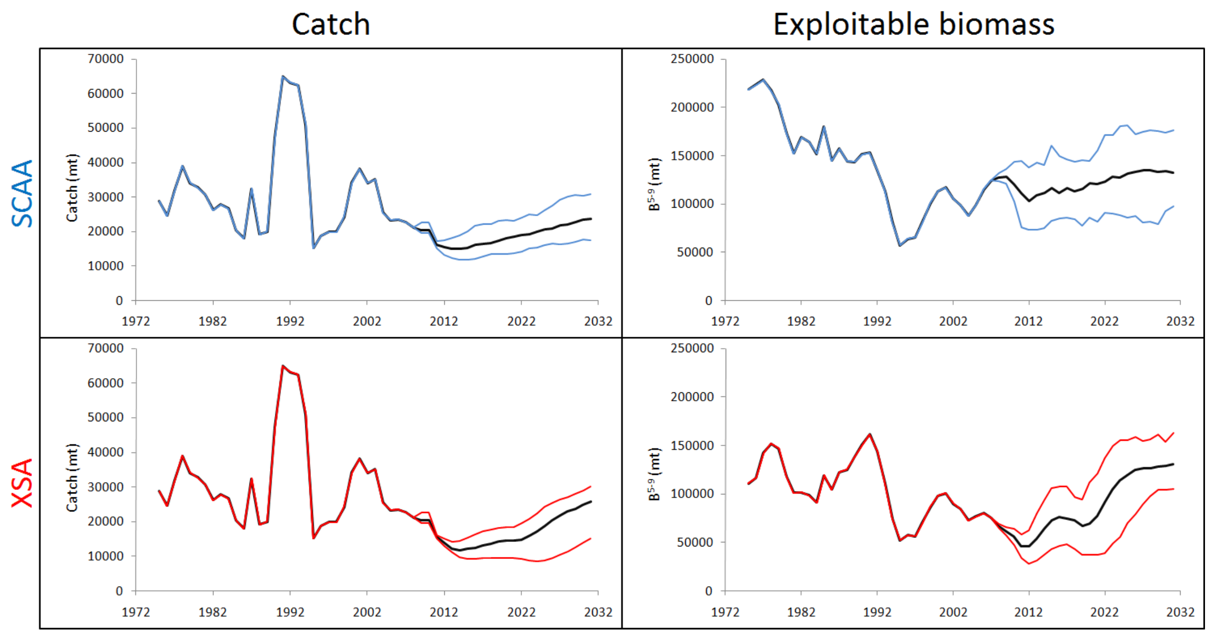


Fig. 1d: SCAA and XSA Base Cases projections under CMP4 (see text for details). The black line is the median and the 95%-iles are shown with the colored lines.

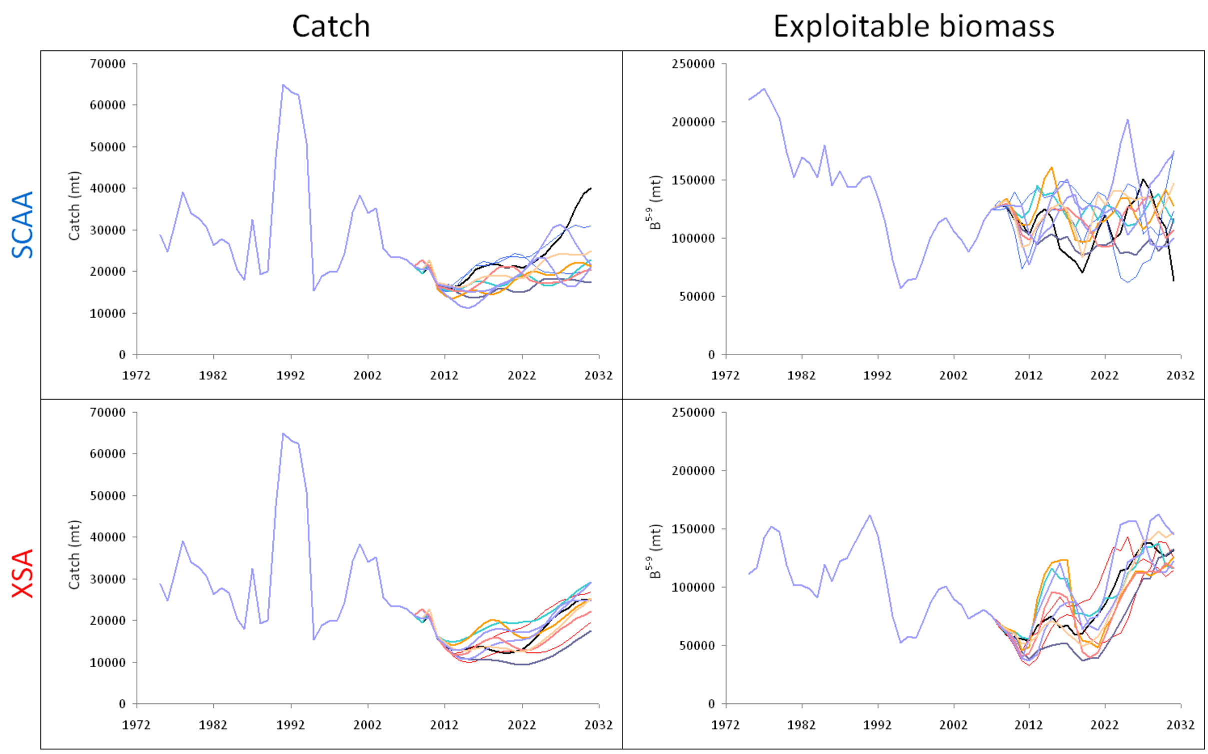


Fig.2: SCAA and XSA Base Cases worm projections (first 10 realisations) under CMP4.

Fig. 3: Comparison of SCAA and XSA Base Cases median projections under the constant catch ("ctC" or CMP1), the Base Case CMP2 ("BC"), CMP3 ("MP3") and CMP4 ("MP4"). The lower 2.5%-ile PIs are also shown for the exploitable biomass.

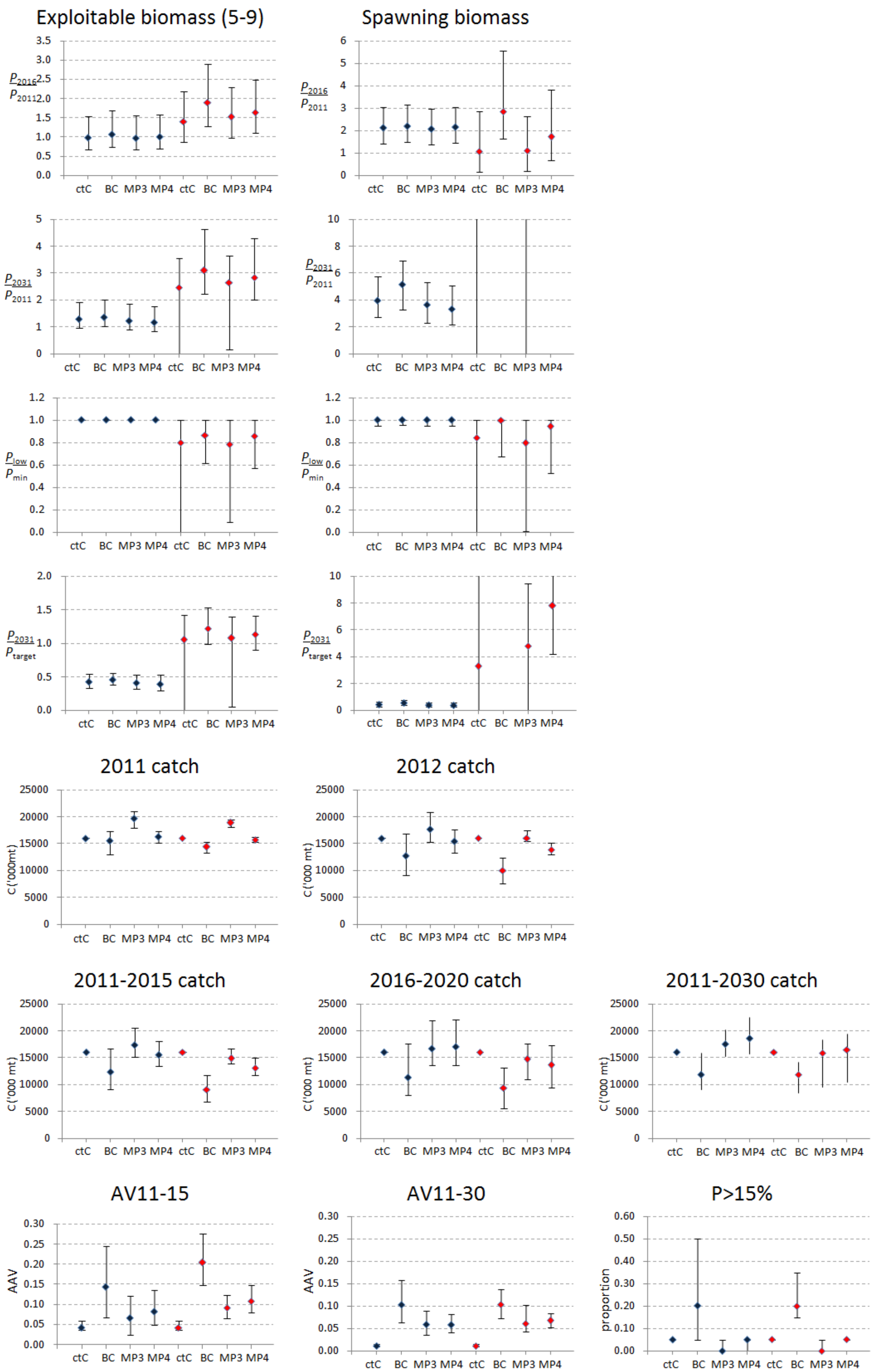


Fig. 4: Median and 95%-iles for a series of performance statistics for the SCAA (blue dots) and the XSA (red dots) Base Cases under a constant catch and three CMPs.

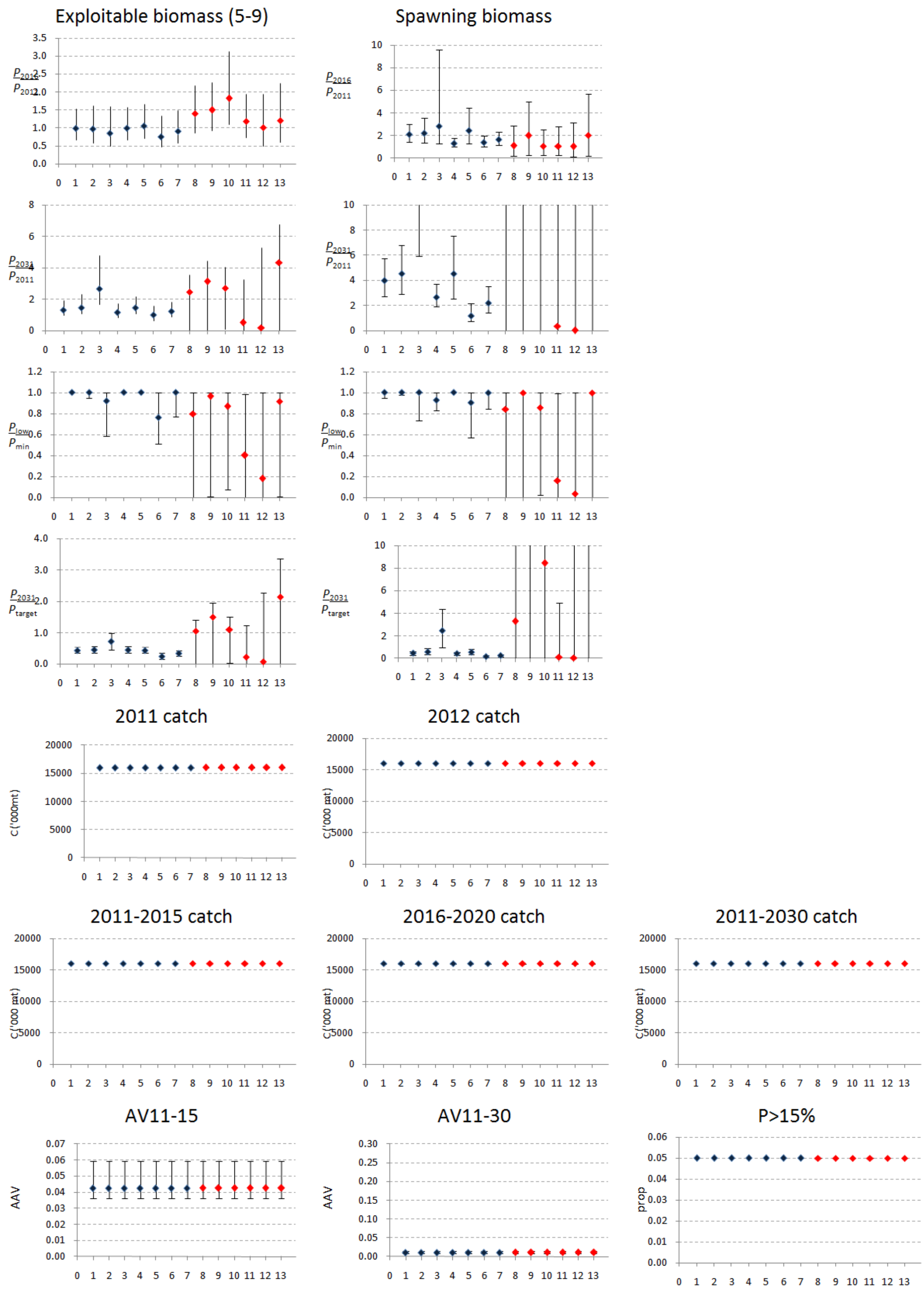


Fig. 5a: Median and 95%-iles for a series of performance statistics for the SCAA (blue dots) and the XSA (red dots) Base Cases and robustness tests under a constant catch strategy CMP1. See Table 1 to identify specific tests to the numbers on the horizontal axes.

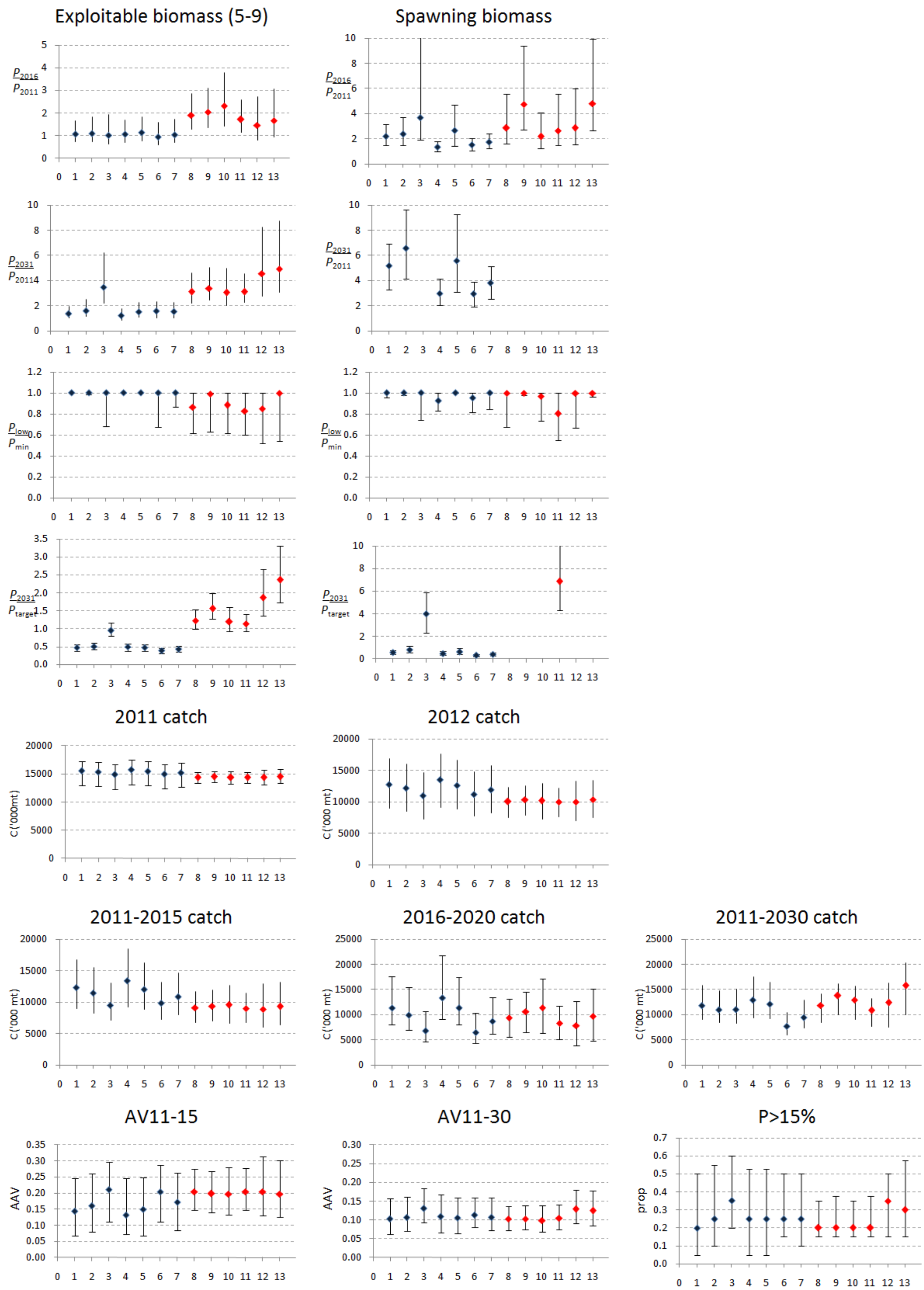


Fig. 5b: Median and 95%-iles for a series of performance statistics for the SCAA (blue dots) and the XSA (red dots) Base Cases and robustness tests under the Base Case CMP2. See Table 1 to identify specific tests to the numbers on the horizontal axes.

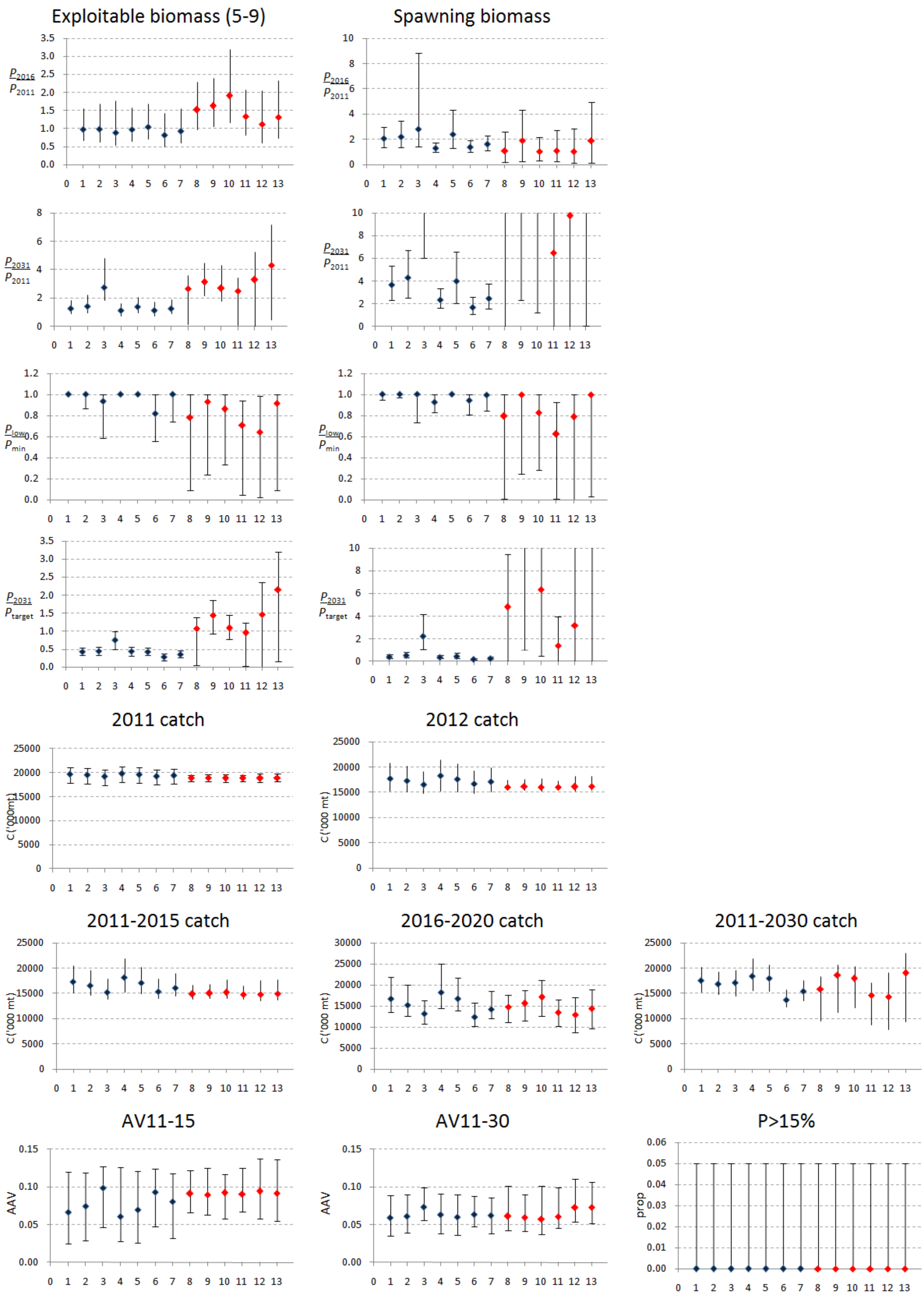


Fig. 5c: Median and 95%-iles for a series of performance statistics for the SCAA (blue dots) and the XSA (red dots) Base Cases and robustness tests under the CMP3. See Table 1 to identify specific tests to the numbers on the horizontal axes.

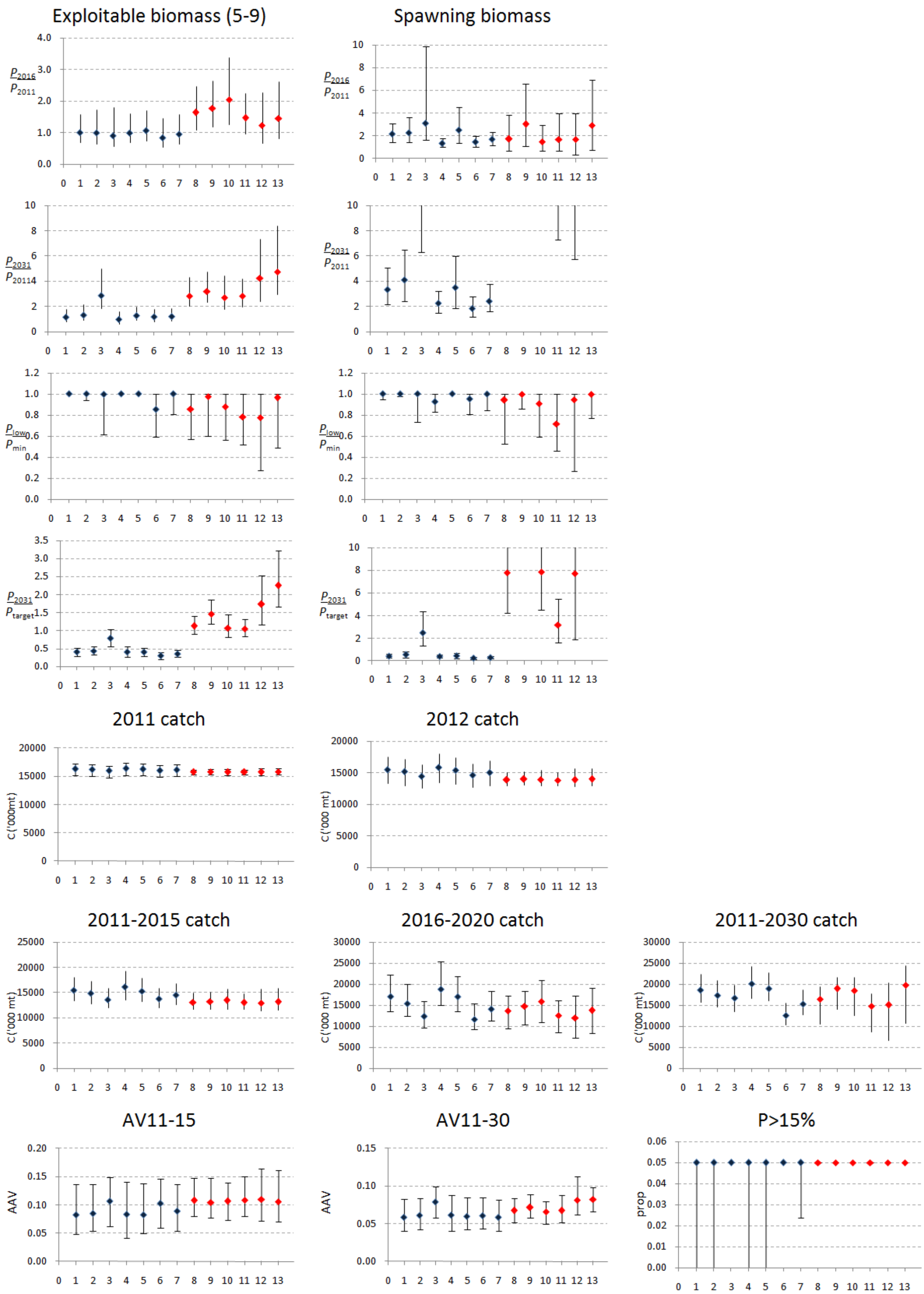


Fig. 5d: Median and 95%-iles for a series of performance statistics for the SCAA (blue dots) and the XSA (red dots) Base Cases and robustness tests under the CMP4. See Table 1 to identify specific tests to the numbers on the horizontal axes.

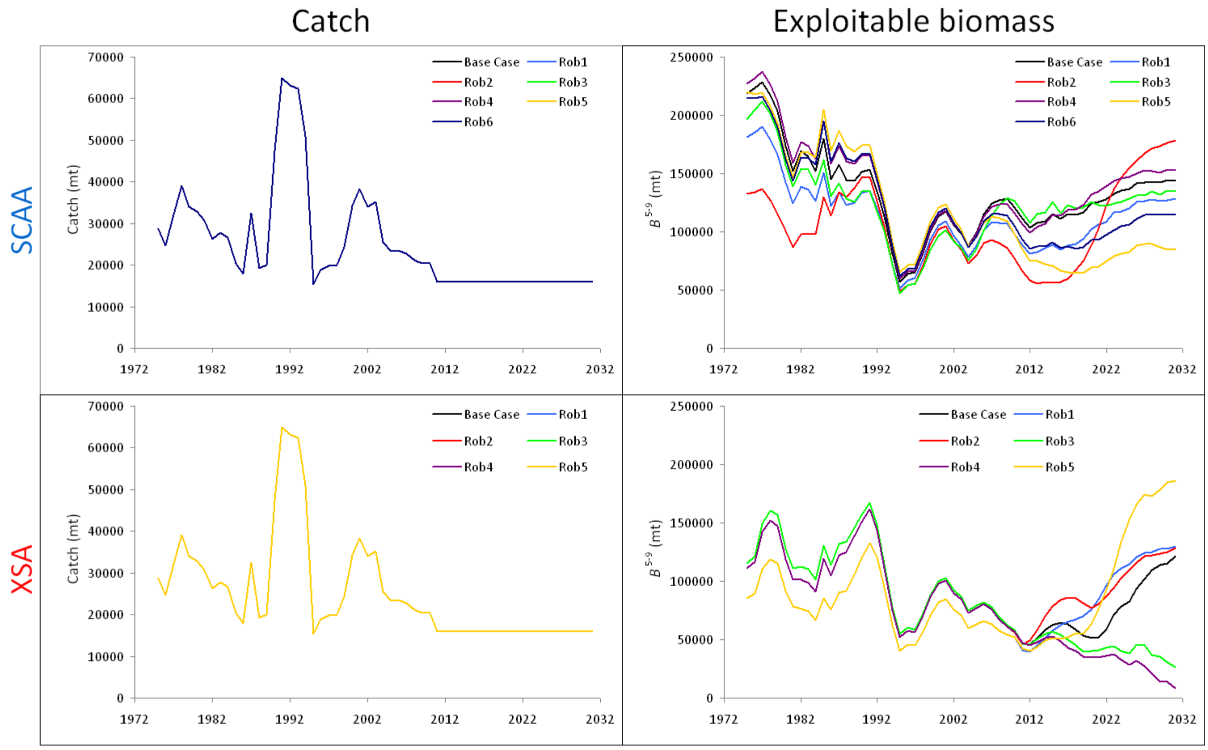


Fig. 6a: Comparison of SCAA and XSA Base Case and robustness tests projections under the constant catch strategy CMP1. Rob 1 under SCAA is “SCAA1” in Table 1, etc.

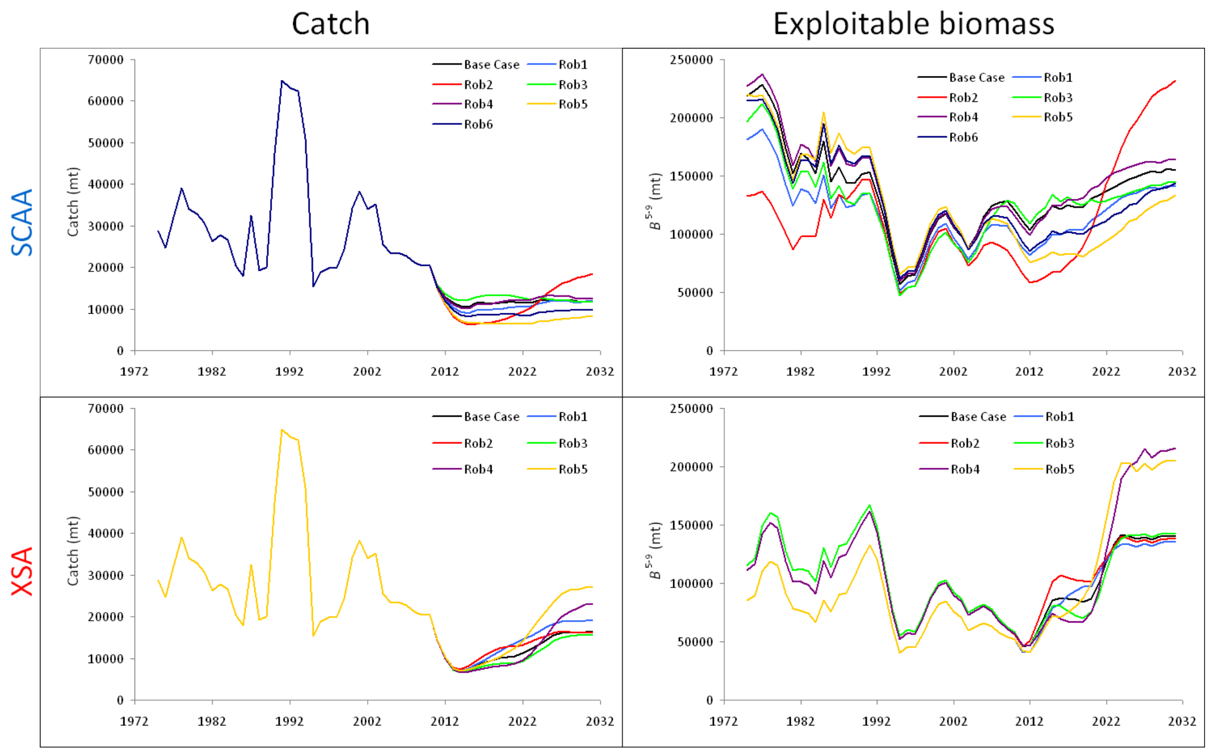


Fig. 6b: Comparison of SCAA and XSA Base Case and robustness tests projections under the Base Case CMP2. Rob 1 under SCAA is “SCAA1” in Table 1, etc.

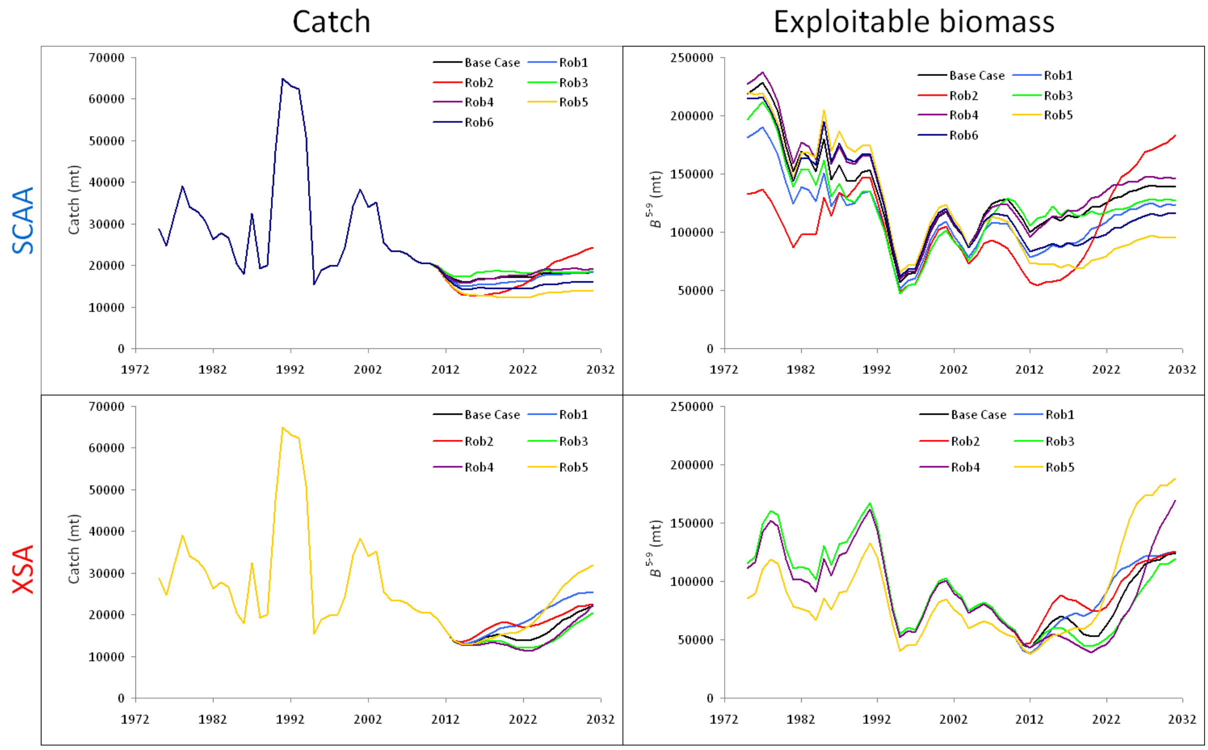


Fig. 6c: Comparison of SCAA and XSA Base Case and robustness tests projections under the CMP3. Rob 1 under SCAA is “SCAA1” in Table 1, etc.

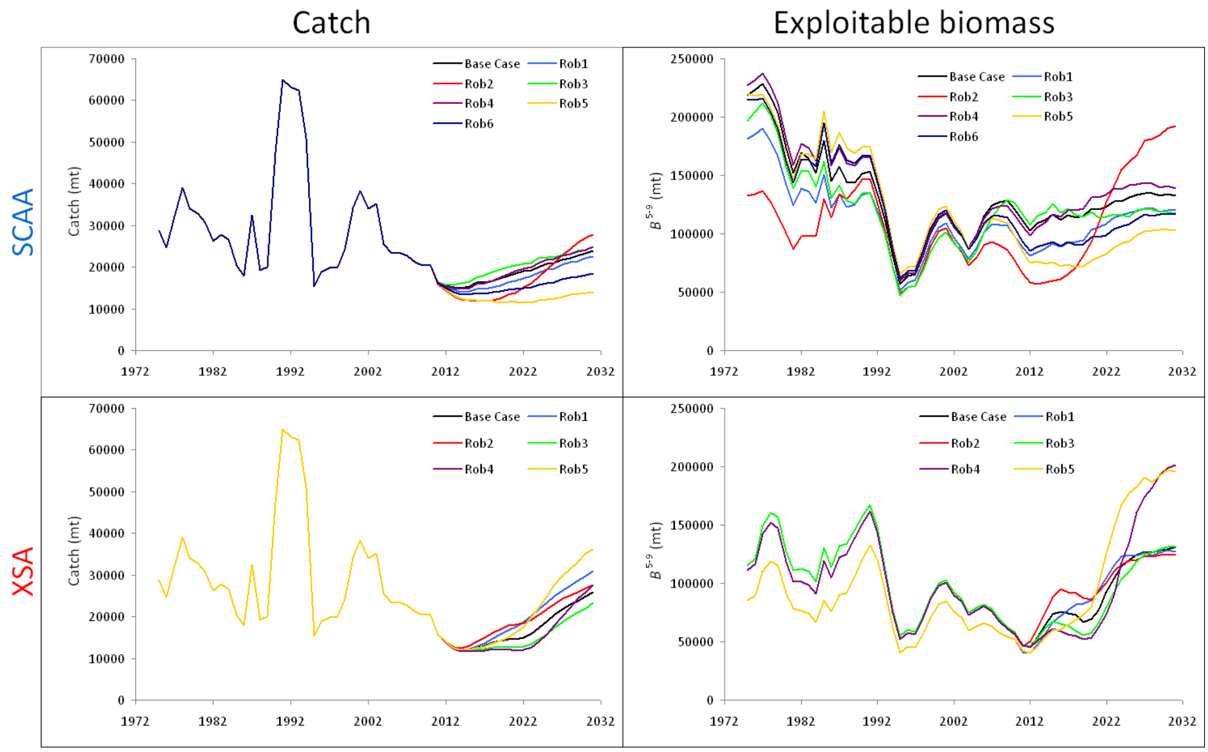


Fig. 6d: Comparison of SCAA and XSA Base Case and robustness tests projections under the CMP4. Rob 1 under SCAA is “SCAA1” in Table 1, etc.

APPENDIX I – Details of the control rule for CMP4

The CMP4 control rule includes a term which intends to adjust TACs up or down in relation n to the difference between the current resource abundance and the currently chosen target abundance, which is the average over the period 1975 to 1999. To be able to implement this in practice, where only the annual indices from surveys are available, it is first necessary to scale each survey to its average value over this period. However the surveys do not go as far back in time as 1975. Thus the operating model fits are used to rescale the survey averages over the years for which they are available, to what would have been their averages over the full 1975-1999 period.

First a target for each survey index *I*: $I^i_{t\arg}$ is calculated as follow:

$$I^i_{t\arg} = \frac{\sum_{y=1996}^{1999} I^i_y}{4} \cdot ratio^i \qquad \text{for Canadian Fall and Canadian spring surveys} \qquad \text{(App.I.1)}$$

$$I^i_{t\arg} = \frac{\sum_{y=1995}^{1999} I^i_y}{5} \cdot ratio^i \qquad \text{for EU survey} \qquad \text{(App.I.2)}$$

where $ratio^i$ is computed as:

$$ratio^i = \sum_{OM} \left(\frac{\sum_{y=1975}^{1999} B_y^{i,OM} q^{i,OM}}{\sum_{y=y1}^{1999} B_y^{i,OM} q^{i,OM}} \right) \Bigg/ \sum_{OM} 1 \qquad \text{(App.I.3)}$$

where *y*1=1996 for the Canadian fall and spring surveys and *y*1=1995 for the EU survey, and OM represents the 13 Operating Models over which an average is taken (see Table 1). Table App.I.1 shows how $ratio^i$ was computed.

Table App.I.1

	CanFall	EU	CanSpr
SCAA0	1.4	2.1	1.5
SCAA1	1.3	1.9	1.4
SCAA2	1.1	1.8	1.3
SCAA3	1.5	2.1	1.6
SCAA4	1.5	2.1	1.5
SCAA5	1.4	1.9	1.5
SCAA6	1.4	1.9	1.5
XSA0	1.7	1.8	1.6
XSA1	1.6	1.7	1.5
XSA2	1.7	1.8	1.6
XSA3	1.7	1.8	1.6
XSA4	1.7	1.8	1.6
XSA5	1.6	1.7	1.5
$ratio^i$	1.5	1.9	1.5

The current survey index is taken as the average of the last 3 years (or less if data are missing):

$$I^i_{y,av} = \frac{\sum_{y'=y-3}^{y-1} I^i_{y'}}{3} \qquad \text{(App.I.4)}$$

Then

$$I_y = \left(\frac{I^1_{y,av}}{I^1_{y,av}} + \frac{I^2_{y,av}}{I^2_{y,av}} + \frac{I^3_{y,av}}{I^3_{y,av}} \right) / 3 \qquad \text{(App.I.5)}$$

The general CMP formula on which CMP4 is based is then:

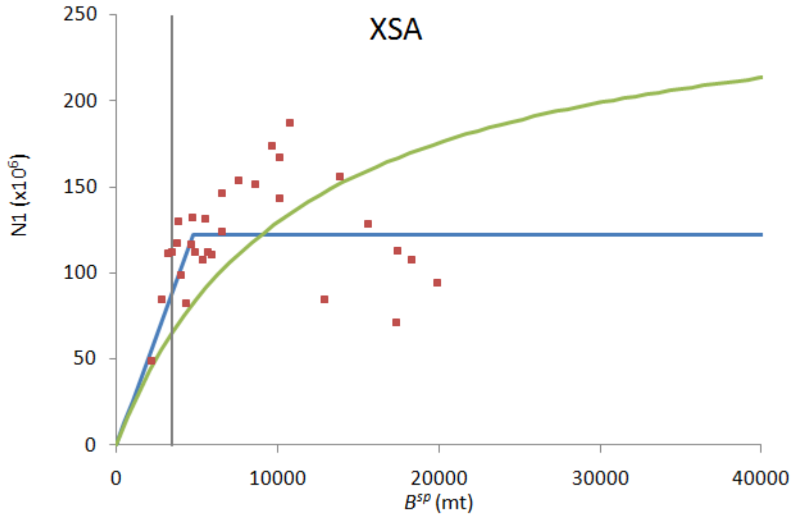
$$TAC_{y+1} = \begin{cases} TAC_y\left(1+\lambda s_y\right) + a\left(b - \left(I_y - 1\right)^2\right) & \text{if } I_y < 1 \\ TAC_y\left(1+\lambda s_y\right) + a\left(b + \left(I_y - 1\right)^2\right) & \text{if } I_y \geq 1 \end{cases} \qquad \text{(App.I.6)}$$

with 15% constraint on annual TAC change. The purpose of the second term on the right hand side is to further decrease the TAC if the surveys drop to low values, but also to increase the TAC if the surveys give high results, particularly ones higher than correspond to the target level.

For CMP4 the selected control parameter values are:

λ = 0.5
a = 2000
b = 0.5

APPENDIX II – Stock-recruitment relationships for Base Cases



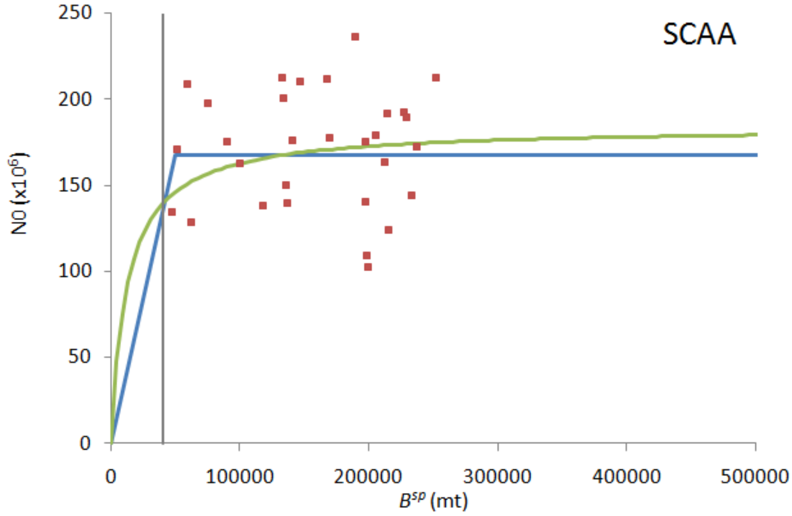


Fig. App.II.1: Fit of the segmented regression/hockey-stick (blue) and Beverton-Holt (green) stock-recruitment relationship to the XSA and SCAA Base Cases estimated recruitments for 1975 to 2004 (red dots). The grey line shows the 2008 estimated spawning biomass. Note the different scales for the spawning biomass. The steepnesses (*h*) of the Beverton-Holt fits are 0.95 for the XSA and 0.90 for the SCAA.