CO-OPERATIVE INDUSTRY/GOVERNMENT PROJECT

2+3KLMNO GREENLAND HALIBUT – BRIDGING THE GAP

TECHNICAL ANNEX

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Specifications for the Proposed Candidate Management Procedures and Simulation Testing

The candidate MPs

The algorithm is empirical, increasing or decreasing the TAC in relation to the magnitude of recent trends in survey abundance estimates. The basis for the associated computations is set out below.

The formula for computing the TAC recommendation is as follows:

$$TAC_y = \begin{cases} TAC_{init}\left[1+\lambda\, s_y\right] & \text{if } y = 2010 \\ TAC_{y-1}\left[1+\lambda\, s_y\right] & \text{if } y > 2010 \end{cases} \tag{1}$$

where

TAC_y is the TAC recommended for year *y*,

TAC_{init} and λ are tuning parameters, and

s_y is a measure of the immediate past trend in the survey-based abundance indices as available to use for calculations for year *y*.

This trend measure is computed as follows from the Canadian Fall (I_y^1), EU (I_y^2) and Canadian Spring (I_y^3) survey indices:

- linearly regress $\ln I_y^1$, $\ln I_y^2$ and $\ln I_y^3$ *vs* year *y'* for $y' = y-6$ to $y' = y-2$, to yield three regression slope values s_y^1 , s_y^2 and s_y^3,

Then $$s_y = \sum_{i=1}^{3} s_y^i \Big/ 3 \tag{2}$$

Furthermore, the maximum allowable change in TAC from one year to the next is $\pm$ *x*%, i.e.:

$$\left|TAC_y - TAC_{y-1}\right| \le \frac{(100-x)}{100} TAC_{y-1} \tag{3}$$

where for the candidates put forward, a value for *x* of 20 was found to provide an appropriate trade-off between undue TAC fluctuations and reducing the risk of heavy depletion.

The process used to test the candidate MPs

Projection Methodology

Projections into the future under a specific OMP were evaluated using the following steps.

Step 1:

The components of the numbers-at-age vector at the start of 2008 ($N_{2008,a}$: a = 1,…, m) are obtained from the MLE of an assessment of the resource (SCAA2 or XSA). Error is included for ages 0 to 5 because these are poorly estimated in the assessment given limited information on these year-classes, i.e.:

$$N_{2008,a} \rightarrow N_{2008,a} e^{\varepsilon_a} \qquad \varepsilon_a \text{ from } N\left(0,\left(\sigma_R\right)^2\right) \tag{4}$$

where σ_R=0.25.

These numbers-at-age are projected to 2010 assuming catches in 2008 and 2009 of 21178 t in line with the assumptions made by the NAFO SC. This requires specification of how the catch is disaggregated by age to obtain the $C_{y,a}$, and how future recruitments are specified.

The $C_{y,a}$ values are obtained under the assumption that the commercial selectivity function remains unchanged from the average of 2003-2007, i.e. :

for SCAA2:

$$S_a = \sum_{y=2003}^{2007} S_{y,a} \Big/ 5 \text{, renormalized so that } \max(S_a) = 1 \tag{5}$$

and for XSA:

$$S_a = \sum_{y=2003}^{2007} F_{y,a} \Big/ 5 \text{, renormalized so that } \max(S_a) = 1 . \tag{6}$$

From this it follows that:

$$F_y = C_y \Big/ \sum_a w_a^{mid} N_{y,a}\, e^{-M_a/2} S_a \tag{7}$$

and hence that:

$$C_{y,a} = N_{y,a}\, e^{-M_a/2} S_a F_y \tag{8}$$

Future recruitments are provided by application of the stock-recruitment relationship in equation B4 of Butterworth and Rademeyer (2009). Future recruitments will not be exactly determined by the stock-recruitment relationship, but will be subject to fluctuation about the levels indicated by that relationship. Log-normal fluctuations are introduced by generating ς_y factors from $N\left(0,\sigma_R^2\right)$ where σ_R=0.25. For SCAA, h is fixed (0.9) and for XSA, h is estimated by fitting the Beverton-Holt stock-recruitment curve to the XSA spawning biomass and recruitment for years 1975 to 2007, with a resultant estimate of 0.95.

Step 2:

The information obtained in Step 1 is used to generate values of the abundance indices I_{2008}^i and I_{2009}^i . Indices of abundance in future years will not be exactly proportional to true abundance, but also subject to observation error. Log-normal observation error is therefore added to the expected value of the abundance index evaluated, taking account of the serial correlation estimated in the SCAA, i.e.:

$$I_y^i = q^i B_y^i e^{\lambda_y^i} \tag{9}$$

where

B_y^i is the biomass available to the survey as determined by equations B8-B10 Butterworth and Rademeyer (2009) as appropriate, with the survey selectivity being estimated for the SCAA2 assessment, and for the XSA taken as the catchability estimated in that assessment, renormalized so that $\max(S_a^i)=1$. For each survey, the selectivity is assumed to stay constant from the last age (13, 12 and 8 for the Canadian Fall, EU and Canadian Spring surveys respectively) to the plus group,

q^i is as estimated (using equation B19 (Butterworth and Rademeyer (2009)) for the assessment in question,

$$\lambda_y^i = \rho^i \lambda_{y-1}^i + \varepsilon_y^i \quad \text{, and} \tag{10}$$

$$\varepsilon_y^i \quad \text{from } N\left(0,\left(\sigma^i\right)^2\right) \ . \tag{11}$$

Furthermore, σ^i and ρ^i are as estimated in the SCAA2 assessment (equation B18, Butterworth and Rademeyer (2009)). These values are taken to apply also for the XSA projections, given that estimates of these quantities from the XSA assessment were not immediately available to the authors..

To commence this data generation process and compute I_{2008}^i, a value for λ_{2007}^i is required; this is given by:

$$\lambda_{2007}^i = \ell\text{n}\left(I_{2007}^i\right) - \ell\text{n}\left(q^i B_{2007}^i\right)$$

for the assessment concerned.

<u>Step 3</u>:

Given the new survey indices I_{2009}^i equations 1-3 above are used to compute TAC_{2010}.

<u>Step 4</u>:

The numbers-at-age $N_{2010,a}$ are projected forward under a catch TAC_{2010} by means of the operating model to determine $N_{y_1+1,a}$ (in this process, it is assumed that the recent commercial age-specific selectivity pattern estimated in step 1 remains unchanged).

Steps 1-4 are repeated for each future year in turn for as long a period as desired, and at the end of that period the performance of the candidate MP under review is assessed by considering statistics such as the average catch taken over the period and the final spawning biomass of the resource.

Additional Notes

The Namibian hake example of the application of a similar approach to another fishery is detailed in Butterworth and Geromont (2001).

The analysis in the main text does not pretend to be a complete evaluation of the MPs put forward, having been limited by availability of full results from other assessments and considerations of time. Such a fuller analysis would include:

- Testing the MPs against a wider set of "operating models", i.e. not only the XSA and SCAA2 assessments, but variants on these assessments (e.g. ones run with alternative input values for natural mortality *M*), as well as assessments based on other methodologies.
- Setting ("conditioning") the statistical structure (such as values for the quantities σ and ρ) for generating future survey values on values for the corresponding assessments rather than adopting the values from SCAA2 (which was done in the main text simply because this information was not available for other assessments).
- Taking account of parameter estimation uncertainty in the assessments by projecting forward from, for example, the Bayesian posterior for the current numbers-at-age vector, rather than from the maximum (penalised) likelihood estimate for this vector. While these Bayesian posterior results could have been produced for the SCAA2 assessment, this option was not immediately pursued as equivalent results for XSA could not have been developed quickly.
- Providing fuller reports for performance statistics (i.e. beyond catch and B5-9), in particular to allow a more thorough appraisal of the different trade-offs between catch, risk and catch variability for a fuller range of candidate MPs.
- The MPs proposed "rely" on defensible results from each of the three standard surveys becoming available each year. Rules would need to be developed and tested to cover situations where this did not eventuate (for example, if a survey failed to cover a major part of the standard survey area because of mechanical problems developing on the survey vessel). In other fisheries, simple approaches such as "substitute the value for the previous year's survey" have been shown to perform quite satisfactorily.

Notwithstanding the above, the MPs put forward in the main text are consider to be reasonably close to the probable outcome from a fuller investigation.

References

Butterworth DS and Geromont HF. 2001. Evaluation of a class of possible simple interim management procedures for the Namibian hake fishery. *S. Afr. J. mar. Sci*. 23:357-374.

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

Appendix

In the interests of brevity, projections for future survey results were shown only for the Canadian Fall survey in the main text. The full set of projections for all three surveys are shown below.

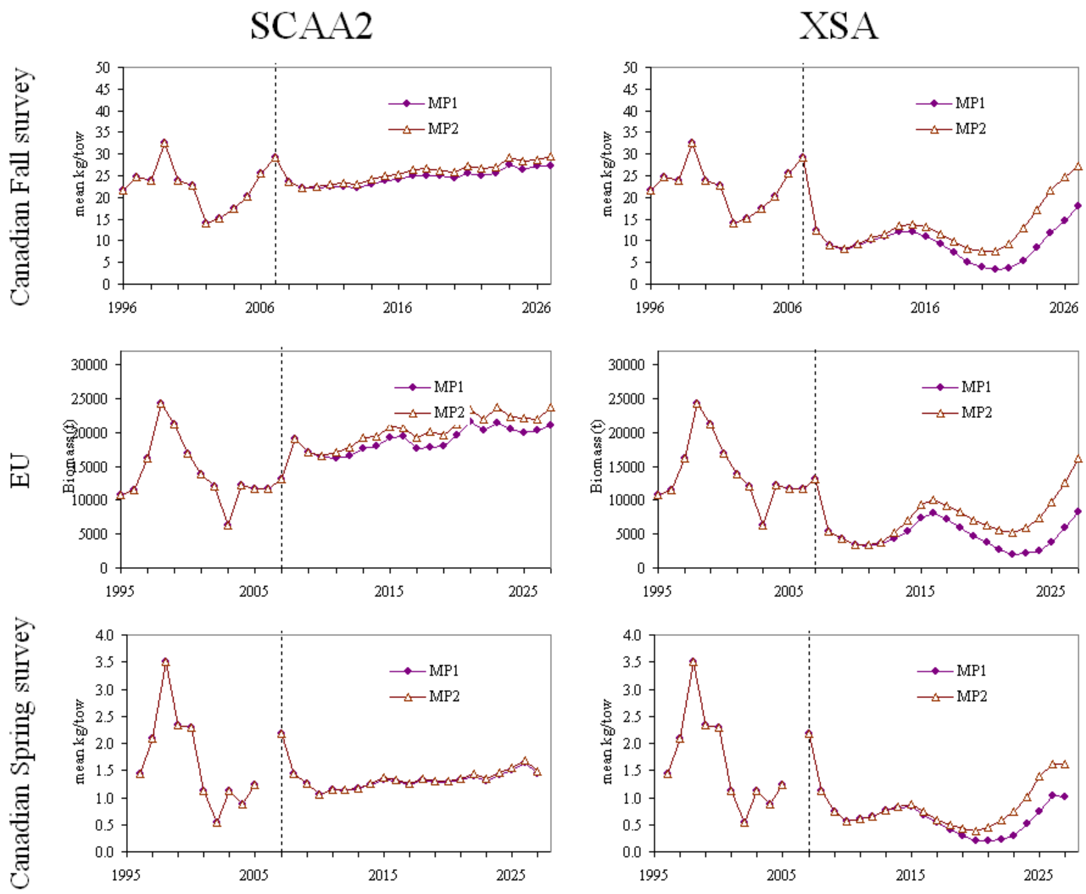

Fig. A1: Past values and future projections for the results from the Canadian Fall, EU and Canadian Spring surveys for the MP1 and MP2 approaches depending on whether the SCAA2 or the XSA assessment is that which reflects the underlying situation.