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Evaluations of Management strategies for Norway pout in the North Sea and Skagerrak

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DTU AQUA, Copenhagen, Denmark

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International Council for the Exploration of the Sea

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Summary

Request

On basis of a request from the EU Commission 8th February 2013 ICES is asked for additional evaluations of modified and alternative harvest control rules for the Norway pout stock in the North Sea and Skagerrak.

EU request to ICES on changing the TAC year for Norway pout.

In 2012, the EU and Norway submitted a request to ICES to evaluate various measures for the management of Norway pout. ICES responded to this request in October 2012.

The first option that ICES evaluated was a management strategy based on the existing ICES escapement strategy for Norway pout (catch should not exceed an amount that allows stock biomass to be above 150 000 tonnes at the beginning of the following year), modified to include absolute constraints on the annual TAC (a minimum TAC higher than zero and a ceiling on the TAC).

For this management strategy, ICES evaluated only the option whereby the September assessment is used for the TAC for the next calendar year (with an in-year update in May, but not in September). It was noted that this option, where the TAC for quarter 4 is set from the May assessment without knowing the recruitment indices from the third quarter, is less robust than the alternative, which has an additional in-year update in September.In the light of this, ICES is asked to again evaluate a management strategy based on the existing ICES escapement strategy, but where the TAC year is changed to 1 November – 31 October rather than 1 January – 31 December. In this case, the TAC for quarter 4 and for quarters 1 to 3 of the following year would be fixed on the basis of the September assessment, with no update in May.

This request is answered in June 2013

1 Basis for the advice: Analysis

1.1 Interpretation of the request

The request from the EU Commission is not clear. After consultation with the Commission (e-mail Gilles Doignon to ICES, 19 March 2013) ICES has interpreted the request in the following way:

It is requested to evaluate a Management Strategy (MS) on the basis on the existing ICES escapement strategy for the Norway pout stock; however with absolute TAC constraints that include a minimum TAC higher than zero and a ceiling of the TAC as included in the 2012 request. The TAC year is requested to be 1st November – 31st October rather than 1st January – 31st December. The advice is annually and will be based on the ICES assessment and advice in September-October.

The request specifies that the TAC should be set in accordance with the ICES escapement strategy, which targets a SSB at spawning time above the MSY $B_{escapement}$ after the fishery has taken place. For Norway pout it is assumed that spawning takes place in the beginning of quarter 1 which has been documented by Lambert *et al.* (2009) and Nielsen *et al.* (2012). The proposed TAC year, 1 November – 31 October, includes thereby one spawning period, but SSB in the following year is highly dependent on the fishery in January-October in the TAC year. By having a TAC year that does not align to the annual life-cycle for the species the default ICES escapement strategy cannot be used. We have, however, considered several alternative methods to set the TAC with the aim of having SSB above Blim at spawning time with a high (95%) probability (see the next section).

1.2 Data and methods

The proposed harvest control rules of a management plan for Norway pout in the North Sea and Skagerrak were evaluated using a simulation framework (SMS) in accordance with the ICES guidelines (ICES, 2008; ICES 2013) for management strategy evaluation. The SMS has previously been used for Management Strategy Evaluation (MSE) of the short lived species sandeel and Norway pout (ICES, 2007a,b; ICES, 2012c) and multispecies assessments (ICES, 2008). The SMS allows the use of quarterly time steps, which is not the case for the standard software packages used in ICES MSE.

The SMS does not include a full assessment cycle with an explicit stock assessment and a short term forecast using a Harvest Control Rule (HCR) to calculate the TAC. Instead, it is assumed that the true stock size can be "observed" with some bias and noise and it is this "perceived" stock that makes the basis for the use of a HCR and estimation of a TAC. The true stock size is assumed known in the first projection year and is later updated annually by recruitment and catches derived from application of the HCR on the "perceived" stock.

Risk to B_{lim} (the probability of real SSB being below B_{lim}) is calculated in both the short and long term. For the individual years 2014–2017 the risk to B_{lim} is calculated as the number of times, across 10000 iterations, that SSB in year y is below B_{lim} divided by number of iterations (10000). This is referred to as prob 1 (probability type 1 or risk type 1) in the ICES guidelines to MSE (ICES, 2013). Long term risk is defined as the maximum probability that SSB is below Blim, where the maximum (of the annual probabilities) is taken over the years 2017–2028 (Prob3, risk type 3 in the ICES MSE guidelines)

1.2.1 Implementation of the shifted TAC year

The assessment and MS model operates with quarterly time steps which do not fit to the TAC year, 1st November – 31st October. Technically it will be almost impossible (and require a lot of assumptions) to split the model time steps into months. Therefore, the Management Strategy Evaluation will be done with quarterly time steps. The model TAC year will accordingly follow the quarters, (Q4 plus Q1-Q3). By such an assumption it is ignored that the real TAC year (1st November – 31st October) is one month later than in the evaluation, however this will probably have a very limited effect on the overall evaluation results.

1.2.2 Implementation of the "escapement strategy"

By having a TAC year (1st November – 31st October), and spawning in the first quarter, the default ICES escapement strategy cannot be used. Several ways of redefining the "escapement strategy" in situations with unaligned TAC years can be outlined:

1. The TAC (Nov-Oct) is set such that SSB is above MSY $B_{escapement}$ the 1st Jan in both the TAC year and the 1st Jan in the TAC year +1. It is assumed that the exploitation pattern, Q4 & Q1-Q3 in the TAC year, follows the long term average. It is also assumed that the exploitation in Q4 of the TAC year +1 is set to zero, as no TAC has been set for this period yet. See elaboration on this assumption in relation to the description of the exploitation pattern below.
2. The TAC (Nov-Oct) is set such that SSB is above MSY $B_{escapement}$ only the 1st Jan in the TAC year. The same assumption on exploitation pattern as for option 1 is used.
3. The TAC (Nov-Oct) is set such that SSB is above MSY $B_{escapement}$ only the 1st Jan of the TAC year +1. The same assumption on exploitation pattern as for option 1 is used.
4. The default MSY $B_{escapement}$ refers by default to the SSB at spawning time, i.e. start of quarter 1 corresponding to 1st of January. A new management reference point can however be defined, which simply refers to the biomass after the end of the TAC year (here 1st November). This needs redefinition of reference points. For option 2 the TAC can be very low (too restrictive) regardless of a high stock biomass of immature fish the 1st January in the TAC year. With such an age distribution option 3 will provide a larger TAC, however with a risk of SSB below MSY $B_{escapement}$ in the TAC year. Option 1 combines the features of option 1 and 2.

The historical age composition of SSB (**Figure 1** and **Figure 2**) does not show a clear difference in age composition for low SSB (e.g. < 100,000 t) and high SSB years, which could be used to guide the choice of option. However, consecutive years with low SSB are naturally characterized by consecutive low recruitments (e.g. the period 2003-2006) or a very high F (e.g. 1986-1989). F in the recent years is relatively low and will probably remain low due to the present low fleet capacity and changes in the by-catch regulations (see also below). This indicates that it is the size of the recruitment that is the most relevant measure when the TAC is to be set such that option 3 become the most relevant criteria, if management based on the "escapement strategy" is chosen.

Option 4 will require a definition and value (at the 1st November) of a new biomass reference point for which there is a rather limited basis. Option 3 is quite similar to Option 4, but option 3 makes use of an existing reference point and an assumption of no fishing in November-December after the TAC year. Such approach is likely more robust than a new option 4 biomass reference point for use the 1st November. Therefore, ICES has only made a MSE of option 3.

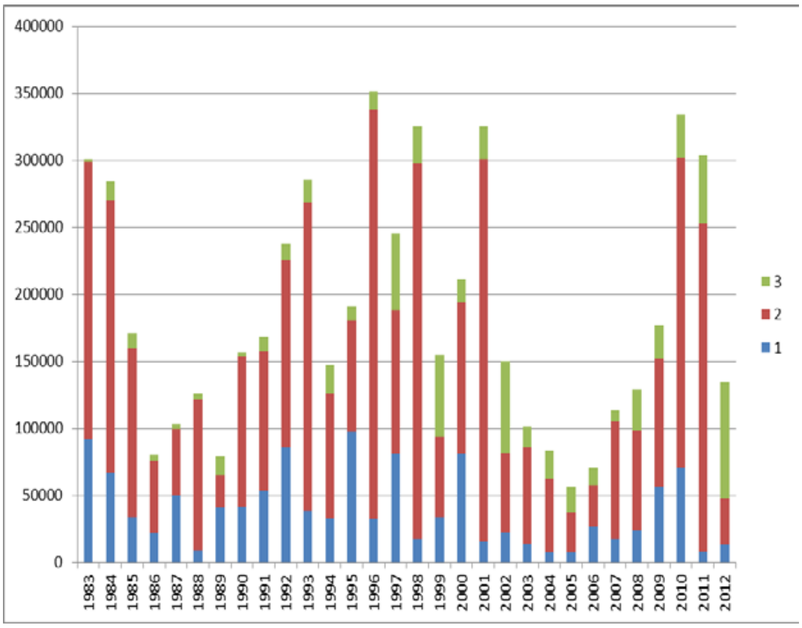

Figure 1. SSB (tonnes) of Norway pout by year and age. 20% of age 1 and 100% of older Norway pout are sexual mature. The colours indicate the age group.

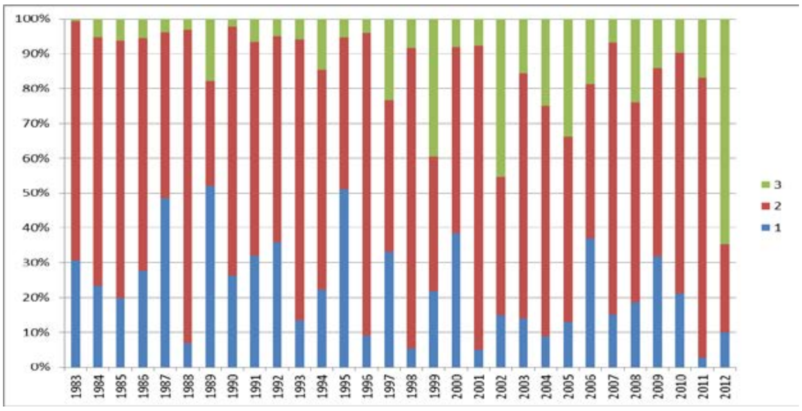

Figure 2. Relative SSB of Norway pout by year and age.

1.3 Input data

The Norway pout assessment is made using the Seasonal eXtended Survivor Analysis (SXSA) with quarterly time steps (ICES, 2012a,b). SXSA is a deterministic assessment method with no assumption about stability in exploitation pattern, which is suitable for the variable fishing pattern used for Norway pout. As a deterministic method, SXSA does not provide any estimates of the uncertainties of output variables such as SSB. Uncertainties are, however, needed to estimate the "perceived" stock numbers from the true ones. The output variables from the SXSA and the SMS assessment methods are quite similar **(Figure 3**), such that uncertainties on SSB estimated by the SMS assessment can be used to guide the choice of uncertainties for the perceived stock.

Input to MSE (presented in Table 1)

- The mean weight at age and in the stock are fixed over time in the SXSA assessment and used directly in the MSE as provided from the inter-benchmark assessment on the stock in Apr-May 2012 and as used in the September 2012 assessment (ICES, 2012a,b).
- The mean weight at age in the catch is based on annual observations as provided from the SXSA assessment in September 2012 (ICES, 2012a). The mean over the whole assessment period (except 2012 due to very few observations this year) has been used as basis for MSE.
- The natural mortality by age are fixed over time in the assessment as used directly in the MSE (ICES, 2012a, b).
- The proportion mature by age in the first quarter (spawning season) are fixed over time in assessment as provided from the inter-benchmark assessment on the stock in Apr-May 2012 (ICES, 2012b).
- The exploitation pattern by age and quarter: The exploitation pattern, i.e. age and seasonal selection in the fishery, is assumed to be constant in the MSE. This is not the case in a SXSA assessment and the actual exploitation pattern has furthermore changed from year to year due to the high seasonality and different targeting in the industrial fishing fleets, and not least because of the various annual and seasonal closures of the Norway pout fishery. The exploitation pattern is estimated by SMS from a configuration with constant exploitation pattern in the full assessment period (excluding closed seasons).
- The initial stock number at age by 1st January 2012 are taken from the SMS output. The recruitment and SSB estimates show that the difference between the SMS and SXSA stock numbers is negligible (**Figure 3**).
- Catches in 2012 is set to the best available estimate of total catches in 2012. The long term exploitation pattern is assumed for this catch
- The TAC for Q1-Q3 of 2013 is set to 200 000 tonnes. This is an high TAC compared to the most recent annual catches, however the realized catch will be limited by the Cap F used (see text below)

Stock recruitment

There is no clear relationship between the recruitment and SSB for this stock (**Figure 4**). The fit to the "Hockey stick" model with the inflection point at B_{lim} (90000 tonnes), shows that observations are without extreme outliers and within the 95% confidence limits. The cumulated probabilities of historical and predicted recruitment (for SSB higher than the inflection point) show a pretty good overlap (**Figure 5**). However, it seems that the predicted recruitment will provide less small recruiting year classes and stronger year classes than the observed historical distribution. The noise function (NORM(0,1), see step 2 in Appendix, Chapter 6, Section 2.2) to produce predicted recruitment has been constrained to deliver factors within ± 2.0 times standard deviations to mimic that the observed recruitment is within the 95% confidence interval. Using the full range did not provide a better fit, but (as expected) a larger range of recruitments than the observed.

Assessment noise (observation error)

The estimated uncertainties from the SMS were used to guide the selection of observation noise, i.e. the noise factor used to link the true stock size to the "observed" or "perceived" stock size estimated by an assessment.

Based on input data 1983-2012, the SMS estimated a CV on the stock size at age, TSB, SSB and recruitment in the beginning of the quarter following the last assessment (Q3, 2012) to:

"September assessment, 1983-2012, 1st half-year" uncertainties:

Recruitment, age 0 (Q2, 2012): CV at 47%, from Q3 survey indices

Stock number, age 0 (Q3, 2012): CV at 47%
Stock number, age 1 (Q3, 2012): CV at 22%
Stock number, age 2 (Q3, 2012): CV at 24%
Stock number, age 3+(Q3, 2012): CV at 22%

SSB(Q3, 2012): CV at 18%

For comparison, the uncertainties from the "May assessment, 1983-2011" are:

Recruitment, age 0 (Q3, 2012): CV at 64%, from stock recruitment relationship

Stock number, age 1 (Q1, 2012): CV at 47%
Stock number, age 2 (Q1, 2012): CV at 28%
Stock number, age 3+(Q1, 2012): CV at 24%

SSB(Q1, 2012): CV at 20%

Previous MSEs of Norway pout (ICES 2012c) were done using a log-normal distributed observation errors for stock sizes at 20% with correlated errors for all age groups. This was equivalent to the CV estimated for the SSB. The uncertainties on stock numbers from the September assessment are slightly lower than the uncertainties from the May assessment, however for an easier comparison of results, the uncertainties from the previous MSE were maintained as default in this evaluation.

It is assumed that the assessment is unbiased which reflects the very stable quality of the assessments results over years and consistency in retrospective analyses (ICES, 2012a).

"Implementation uncertainties" are assumed negligible and not considered in the MSE.

Cap F

The upper limit on the fishing mortality (Cap F), i.e. the maximum F the fleet can exert with a given (maximum) effort level, is set to 0.6. This F-level is high compared to the latest years observed F-levels, and higher than all yearly Fs observed for the last 10 years period. In the years 2009 and 2010 where the fishery was open and based on the relatively strong 2008 and 2009 year classes the TACs and national quotas set have not been taken by the fishery, and the highest yearly F in this period (2010) was 0.43. Furthermore, the Danish and also the Norwegian fishing fleets targeting Norway pout have been reduced in capacity during the last 10 year period (ICES, 2012a).

The annual Cap F is divided into two periods (Q4 and Q1-Q3) to be able to calculate the maximum realized catch and SSB at spawning time (1st January). The division is done in accordance with the long-term exploitation pattern which shows 47% of the F in Q4 and 53% in Q1-Q3. This results in $CapF_{Q4}$=0.28 and $CapF_{Q1\text{-}Q3}$=0.32.

The historical relationship between yearly standardized effort and fishing mortality as estimated in the accepted SXSA assessment from May 2012 (ICES, 2012a) is shown in **Figure 6**. Here the correlation between the total standardized Danish and Norwegian fishing effort in fishing days for the Norway pout fishery and the total fishing mortality by year as estimated by the SXSA is given. Values for 2008 and 2010–2011 are not included because no Norwegian fishing effort data is available for these years. The high correlation between effort and F allows an implementation of an effort ceiling to avoid very high F-values in the future and as such to justify the Cap-F values chosen.

Implementation of a Cap F in the fishery (i.e. effort limits) might be problematic for this stock without an EU-Norway agreement on the management of the stock. As an alternative to effort regulation (Cap F), an HCR which set an upper limit on the Forecast F used to calculate the TAC was tried. A range of F [0.4; 0.8] in combination with minimum TAC at 20kt and Maximum TAC at 200 kt was evaluated.

1.4 Methods and implementation

This section gives a detailed description of the methods for the HCR as requested. A more general description of the methodology as implemented in the SMS program can be found in the ICES WKMAMPEL (ICES, 2009).

The request includes 1 assessment/advice in late September (Year, Y) which makes the basis for a TAC for the period 1st November – 30th October. TAC constraints (minimum and maximum TAC) should be evaluated.

The assessment made in September estimates the population size, including recruitment age 0 the 1st July (Year, Y) on the basis of historical catches (including first half-year catches of the terminal assessment year, year Y) and EGFS and SGFS Q3 research survey (part of the IBTS Q3 research survey) abundance indices for recruitment (including index from the terminal assessment year) back shifted to the 1st July.

Step 1, the initial stock size at start of year (Y-1)

The SMS MSE operates by annual cycles (including quarterly time steps) where the true stock is updated annually with the quarterly "true" F and M values and recruitments. This specific MSE, where the TAC year does not follow the calendar year, does not fit well into the overall structure of the model, so specific changes must be made to calculate F values for all quarters of 2012.

The "true" stock numbers at age, F and M are assumed known (from historical assessment) without errors in the start of year Y-1. Stock numbers (1st January 2012) and recruits (Q2, 2012) are taken from the SMS (September 2012) estimate.

Implementation: Use the best available estimates (by 9th April) of the total catch weight in 2012 of Norway pout (DK 22495 t and N 4588 t; total 27083 t) and MSE the exploitation pattern to calculate true F in 2012.

To simulate that the evaluated HCR was actually applied in 2012 in order to set a combined TAC for Q4 2012 and for Q1-Q3 of 2013 a (fixed) value for the remaining 2013 Q1-Q3 was set to 200 000 t. This is a high TAC but it reflects that the ICES advice allows an annual TAC at around 400 000 t. Such high catch will probably not be reached as landing in 2013 by 8th April is less than 1000 t (DK landings 59 tons and N landings 636 ton (https://www.sildelaget.no/no/tall-og-fakta/kvoteoversikt.aspx). However, due to the Cap F used for Q1-Q3 the realised catch will be lower (106 437 tons with Cap F Q1-Q3 at 0.32).

Step 2, calculate the real stock size at the start of the year Y:

Increment the year index by 1. This step projects the true stock forward one year using the F and M for year Y-1. This will produce the true stock for 1st January, year Y.

Recruitment (in quarter 2) is estimated from SSB at 1st January (Year ….), a specified stock recruitment relationship (f(x)) and a log normal distributed noise term with standard deviation, std.

$$R_{true} = f(x) * e^{(std * NORM(0,1))}$$

NORM(0,1) is a number drawn from a normal distribution with mean=0 and standard deviation 1.

Step 3, calculate the realised TAC in Q1-Q3 and update the true stock size to 1st July:

This step mimics that the TAC uptake in Q1-Q3 will actually depend on the size of the stock. It is not realistic that effort (F) will increase significantly above the values within the last 10 years to actually take the TAC, if it is set too high relative to the real stock size. The input exploitation pattern for the first three quarters is assumed fixed.

Implementation: Use the true stock numbers 1st January, the true recruitment 1st July, the exploitation pattern, and the (remaining) TAC to calculate true F for the first 3 quarters of year Y. Don't let the true F exceed Cap F_{Q1Q3}. Update the true stock numbers to 1st July (and 1st October) by true F and recruitment.

Step 4, simulate the September assessment:

This step simulates the assessment made in September.

Implementation: The "observed" or perceived stock the 1st July in year Y is obtained from the true stock and an observation noise and bias:

$$N(a)_{obs} = N(a)_{true} * Bias * e^{(std * NORM(0,1))} * e^{(-(std^2/2))}$$

The bias factor (default=1) and the standard deviation (std) are given as input. The same random number drawn from NORM(0,1) are used for all ages (correlated observation errors).

The result is observed stock numbers for all ages at 1st July.

Step 5, calculate the observed F for Q3 and update the observed stock size to 1st October:

This step mimics the short term forecast for the period between assessment and new TAC year.

The TAC year is 1 November - 31 October. However, for technical reasons (use of quarterly time steps in the model), the TAC year in the MSE is set for 1 October- 30 September (Q4 within the year and Q1-Q3 in the following year).

Implementation: Use the observed stock numbers 1st July, the Q3 exploitation pattern and the realised Q3 catch to calculate observed F for Q3 and the observed stock number 1st October. This reflects the fact that the assessment working group will have a good estimate of the realised catches in August-September and the expected fishery in October.

Update the observed stock numbers to the 1st October using the observed F.

Step 6, calculate TAC for 1 November - 31 October (implemented as Q4 & Q1-Q3):

This step mimics the forecast done at the September assessment to set the TAC:

Implementation: Scale the observed (long-term) exploitation pattern for Q4 & Q1-Q3 and set $Q4_{y+1}$ to zero such that observed SSB at spawning time in the year after the TAC year becomes Bpa (the "escapement strategy"). Calculate yield from such F and adjust the TAC (if needed), such that the TAC is within the TAC constrains.

Step 7, calculate the true F for Q4 and adjust the "true" TAC for Q4:

This step mimics that the TAC uptake in Q4 will actually depend on the size of the stock. In cases with rather low stock sizes, it is not realistic that effort (F) will increase significantly to actually take the TAC.

Implementation: Use the true stock numbers 1st October, the Q4 & Q1-Q3 exploitation pattern to calculate the true F necessary to take the TAC. Adjust the TAC (if necessary) from step 6 if the true F to take this TAC exceeds the input cap F. Recalculate true F_{Q4} and adjust the (realised) catch and remaining TAC if needed.

Step 10, make a new simulation loop:

Start a new simulation loop from step 2.

Table 1. Input to the MSE

Mean weight at age in the stock (kg):

	Age 0	Age 1	Age 2	Age 3+
Q1:	0.000	0.009	0.025	0.040
Q2:	0.000	0.012	0.025	0.050
Q3:	0.004	0.025	0.040	0.060
Q4:	0.006	0.025	0.040	0.058

Mean weight at age in the catch (kg):

	Age 0	Age 1	Age 2	Age 3+
Q1:	0.0	0.0098	0.0256	0.0408
Q2:	0.0	0.0136	0.0283	0.0418
Q3:	0.0066	0.0264	0.0380	0.0497
Q4:	0.0080	0.0273	0.0398	0.0519

Proportion mature at age:

	Age 0	Age 1	Age 2	Age 3+
Q2:	0.00	0.20	1.0	1.0

Natural mortality at age:

	Age 0	Age 1	Age 2	Age 3+
Q1:	0.00	0.29	0.39	0.44
Q2:	0.00	0.29	0.39	0.44
Q3:	0.29	0.29	0.39	0.44
Q4:	0.29	0.29	0.39	0.44

Exploitation pattern scaled to mean F_{1-2} at 1.0:

	Age 0	Age 1	Age 2	Age 3+
Q1:	0.000	0.073	0.153	0.153
Q2:	0.000	0.070	0.148	0.148
Q3:	0.005	0.197	0.415	0.415
Q4:	0.053	0.304	0.639	0.639

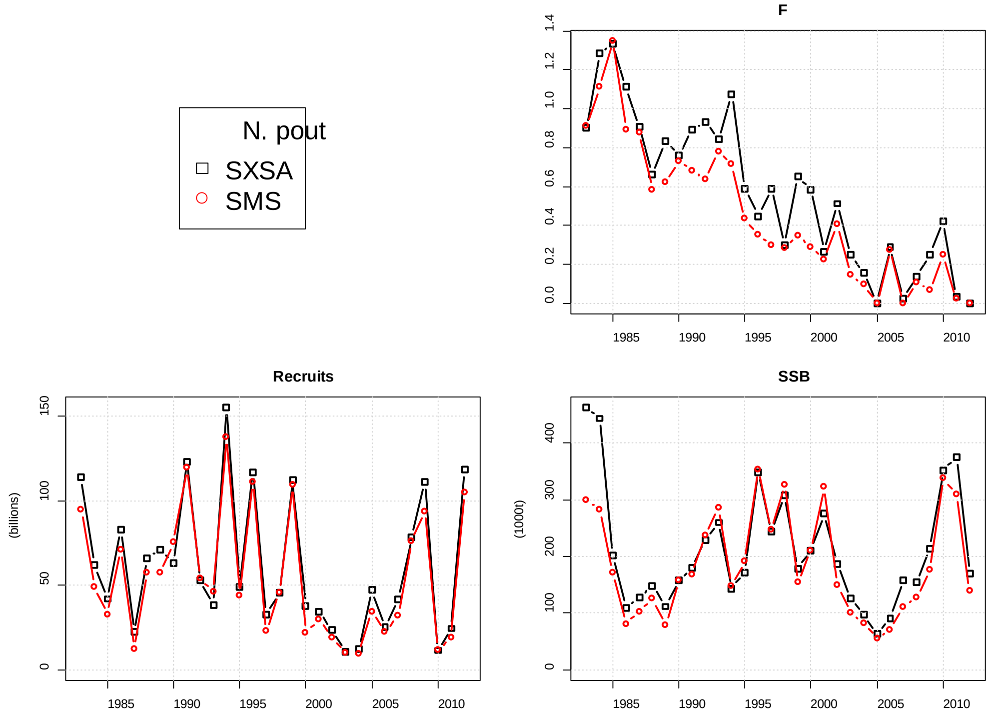

Figure 3 Comparison of output from the default XSA method (September assessment) and the SMS. The mean F values are calculated as the mean of the sum of quarterly F at ages 1 and 2.

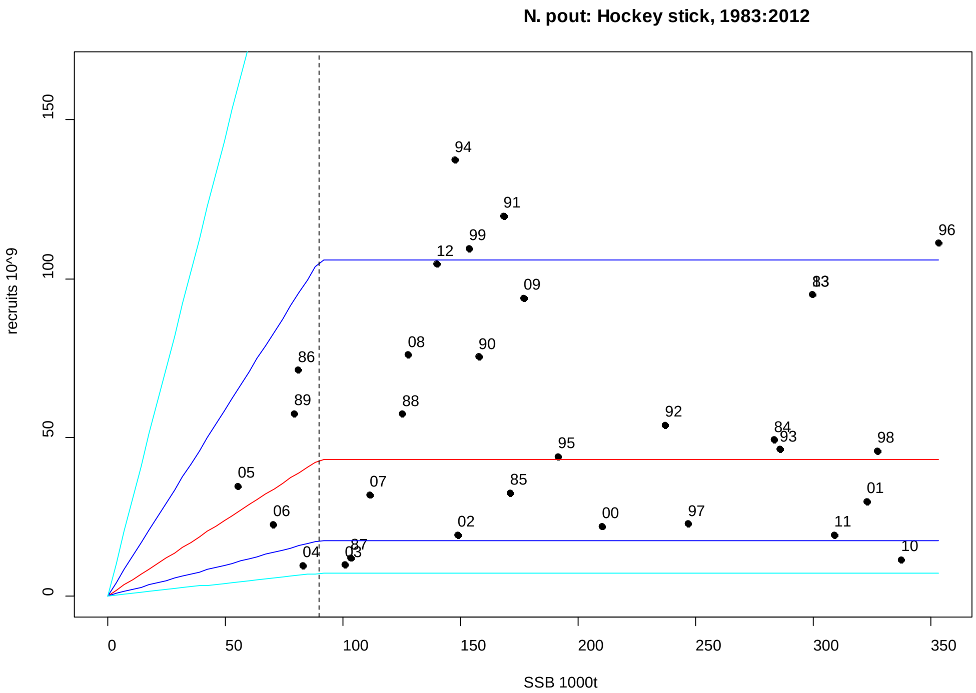

Figure 4 Stock recruitment relationship as estimated by the SMS using the "Hockey stick" model and a fixed inflection point at 90.000 tonnes (B_{lim}). The median (red line) and the one and two time standard deviations lines are shown.

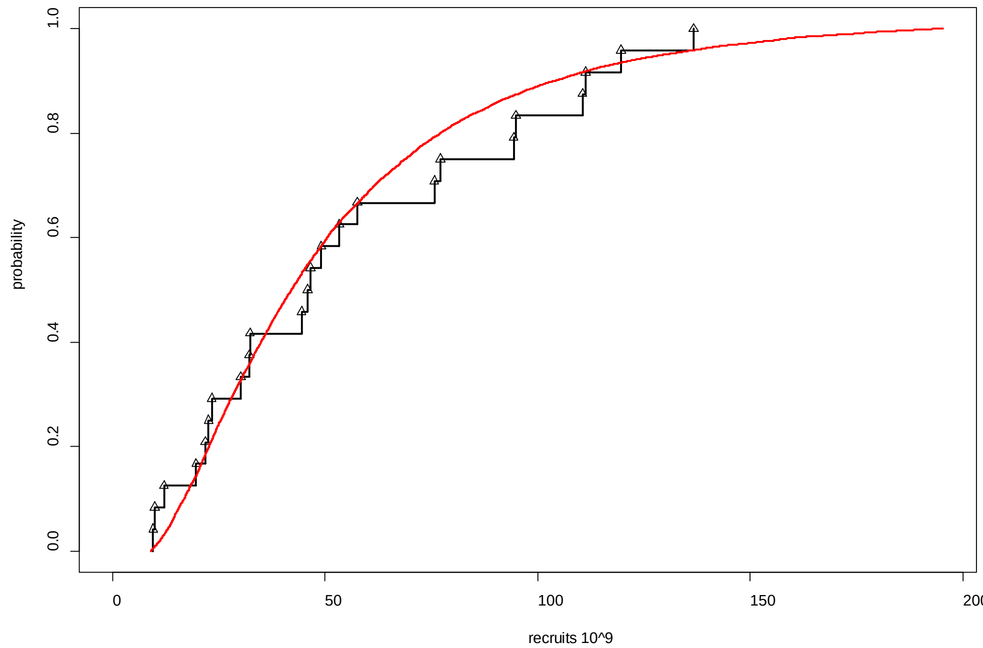

Figure 5. Cumulated probability of historical recruitment and recruitments produced by the estimated stock recruitment relationship.

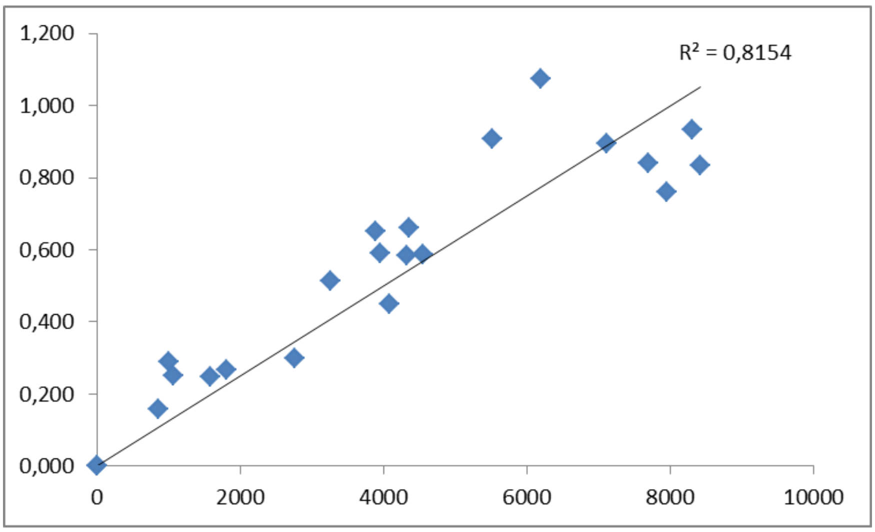

Figure 6. Correlation between the standardized fishing effort and the fishing mortality.

2 Results

The results will focus on the sensitivity of the chosen range for the absolute TAC constraints and the sensitivity to the assumption of a Cap F.

The sensitivity of the choice of minimum TAC is shown in **Figure 7**. Given a maximum TAC at 200 kt and a Cap F at 0.6, the long term performance of the scenario is robust to the choice of minimum TAC. The probability of a SSB below B_{lim} is in the range 0–12% for fixed TACs in the range 0–50 kt. A higher than 5% probability for SSB below B_{lim} in the long-term is estimated for a minimum TAC of around 20 kt.

Due to the high recruitment in 2012 (observed as age 0 in Q3 surveys in 2012 and in Q1 survey in 2013) the short term risk for the scenarios shows a low (zero) risk for SSB in 2013 (not shown in the figure) and a low risk in in 2014. The probability of SSB below B_{lim} in a year increases in the period 2015-2017. The long term probability ("Prob 3 (2018-27)") follows the annual risk in 2017, which indicates that a fast stationary (equilibrium) situation develops rather quickly after the effect of the initial stock numbers has disappeared. The 5%, percentiles of SSB by year from the run with minimum TAC at 20000 t (Figure 8) confirms a fast development to a stationary situation.

Given a minimum TAC at 20 kt, the actual choice of maximum TAC affect the long-term Prob(SSB<B_{lim}) very little and is less than 5% for the range 50–250 kt of maximum TAC (**Figure 9**). The highest long-term yield is obtained with a maximum TAC at around 150 kt. Mean F increase with increasing maximum TAC, but more steeply in the range 50-150 kt maximum TAC. Median SSB is quite robust to the choice of maximum TAC, and becomes almost stable just below Bpa (150 kt) for maximum TAC at 150 kt or higher.

The risk levels by minimum TAC are hardly influenced by choosing a maximum TAC at 150 kt (Figure 10). Correspondingly, the minimum TAC can just be raised by 1-2 kt (to around 22k t) given a maximum TAC at 150 kt and a long term prob(SSB<Blim) at 5%.

Figure 7 to **Figure 10** present the median values over numerous individual simulations. The actual variation within each simulation run is shown in **Figure 11** (min TAC at 20 kt and max TAC at 100 kt) and **Figure 12** (min TAC at 20 kt max at TAC 200 kt).

With max TAC at 100 kt (**Figure 11**) the yield is rather evenly distributed within the range 20-120 kt (median 80 kt, mean 76 kt). The yield presented is yield by calendar year and can therefore exceed the maximum TAC (at 100 kt given for the Quarter 4 and Quarter 1- Quarter 3). The distribution of (calendar year) F is rather symmetrical with median at 0.32. Less than 5% of the simulation is restricted by the Cap F at 0.6.

For the max TAC at 200 kt scenario (**Figure 12**) the median (94 kt) and mean (100 kt) yield are higher than for the max 100 kt TAC scenario. F is likewise higher (median 0.45) and has a rather skewed distribution where Cap F is reached in around 35% of the cases.

The sensitivity plots of long term prob(SSB<B_{lim}) to Cap F for a maximum TAC at 100 kt (**Figure 13**) and 200 kt (**Figure 14**) show that the 200 kt option is very sensitive to the assumption of Cap F, while the 100 kt maximum TAC option is robust. Having a maximum TAC at 200 kt will therefore require a strictly enforced effort ceiling.

If an effort ceiling cannot be implemented or enforced, an upper limit on the intended F (or effort) can be included in the HCR. This is an upper limit on the F used to set the TAC from the escapement strategy. **Figure 15** present the result where there is no upper limit for the realised F (Cap F) , but a limit on the forecast F, and an upper limit on the TAC at 100 kt. For the shown range of forecast F [0.4;0.8] the prob(SSB<Blim) is less than 5%. Median yield (around 75 kt) from the run with max forecast F at 0.6 is is close to the median yield (around 80 kt) from for a run with Cap F at 0.6 and max TAC at 100 kt (**Figure 9**) the yield.

Given a max TAC at 200 kt, forecast F can maximum be 0.62 to obtain a prob(SSB<Blim) of less than 5% **(Figure 16)**. Such F will give a median yield of around 80 kt which is close to the yield form a scenario with max TAC at 200 kt and a Cap F at 0.6 **(Figure 9)**.

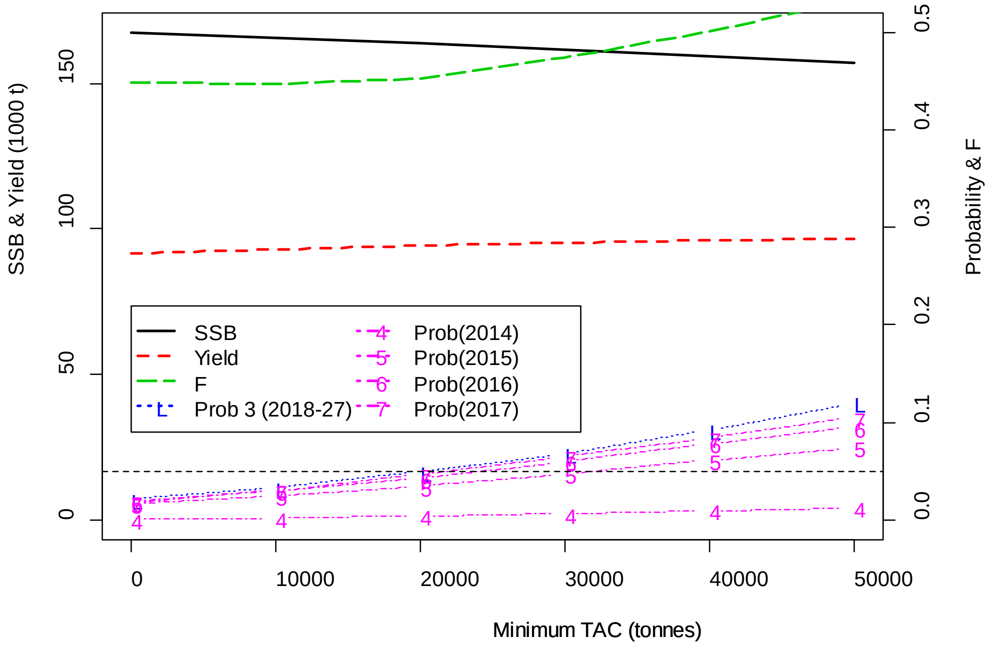

Figure 7. Sensitivity analysis: Minimum TAC. The graph shows the median value of SSB, yield and F in the years 2018-2027 from 10000 iterations for each value of minimum TAC shown on the X axis. The probabilities (Prob) of SSB below B_{lim} are shown for individual years and a long-term period. Maximum TAC is fixed to 200 kt.

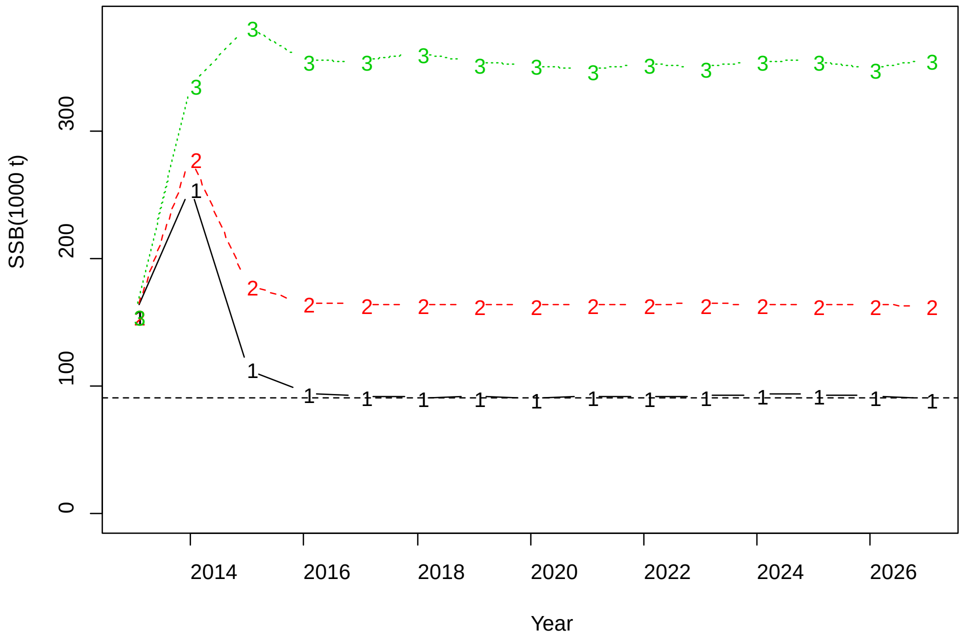

Figure 8. 5%, 50% and 95% percentiles of SSB, for scenario presented in Figure 7 with minimum TAC at 200 kt. The vertical line shows Blim (90 kt).

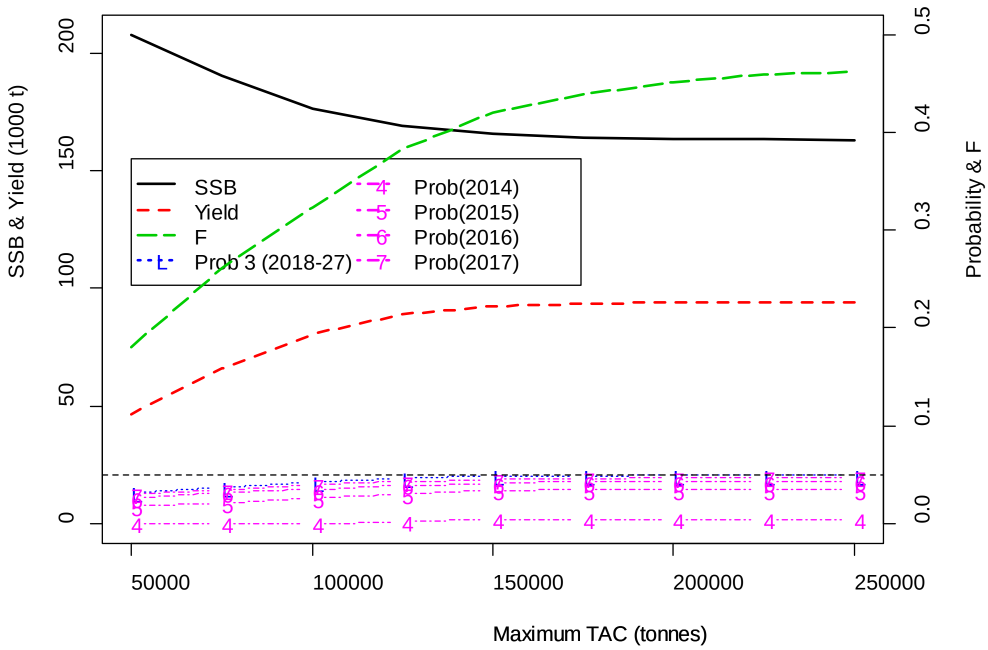

Figure 9. Sensitivity analysis: Maximum TAC. Minimum TAC is fixed at 20 kt.

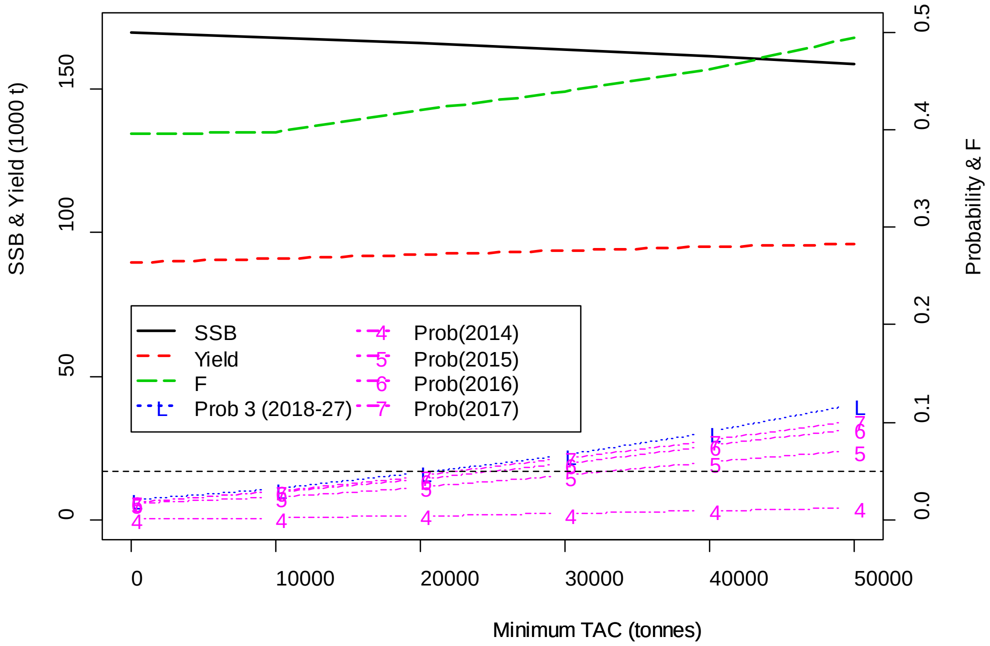

Figure 10. Sensitivity analysis: Minimum TAC. Maximum TAC is fixed at 150 kt.

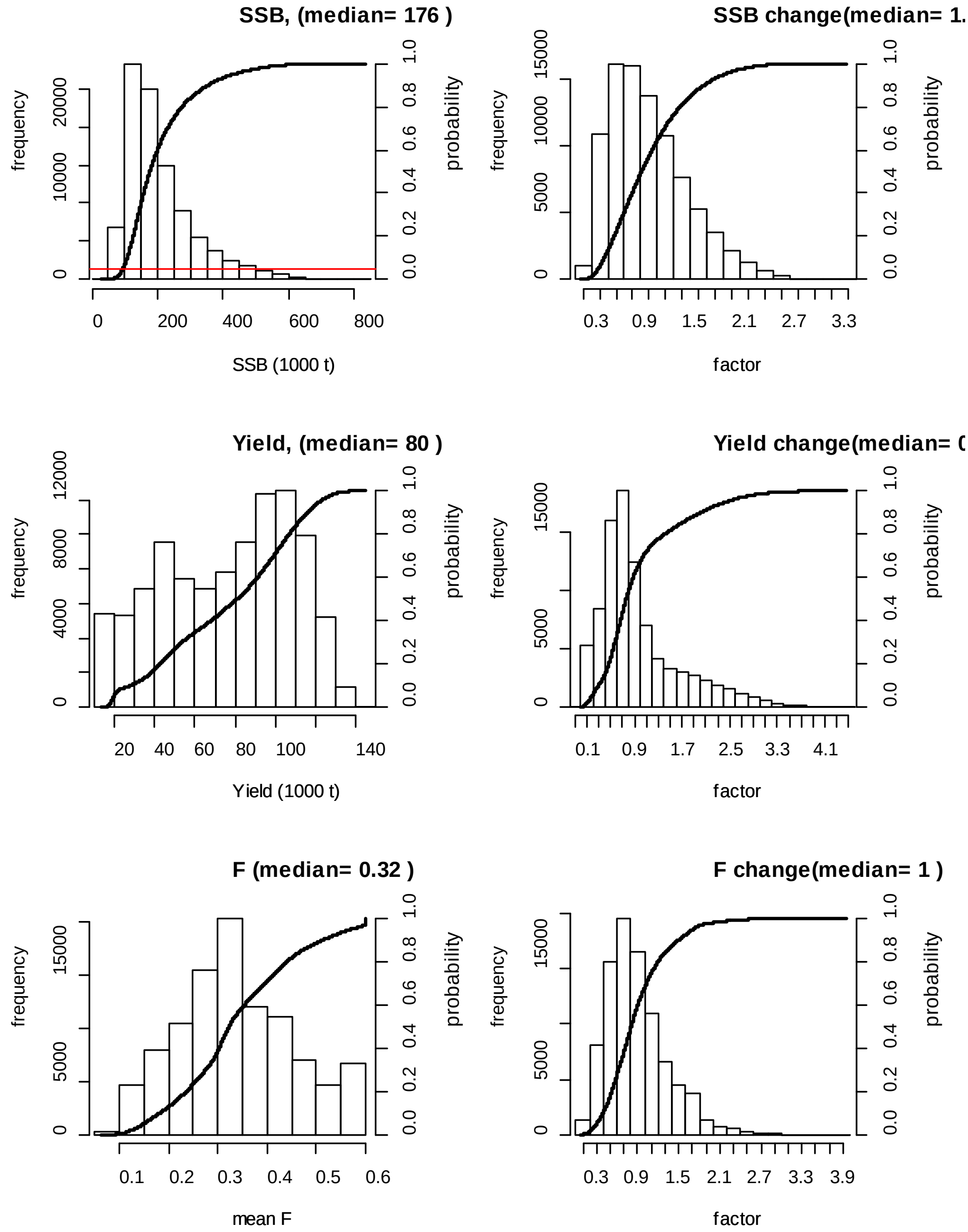

Figure 11. Distribution of SSB, yield and F, including cumulative probability in the years 2018-2027 from 10000 iterations (left column). The relative change from one year to the next is shown in the right column. Minimum TAC at 20 kt and maximum TAC at 100 kt.

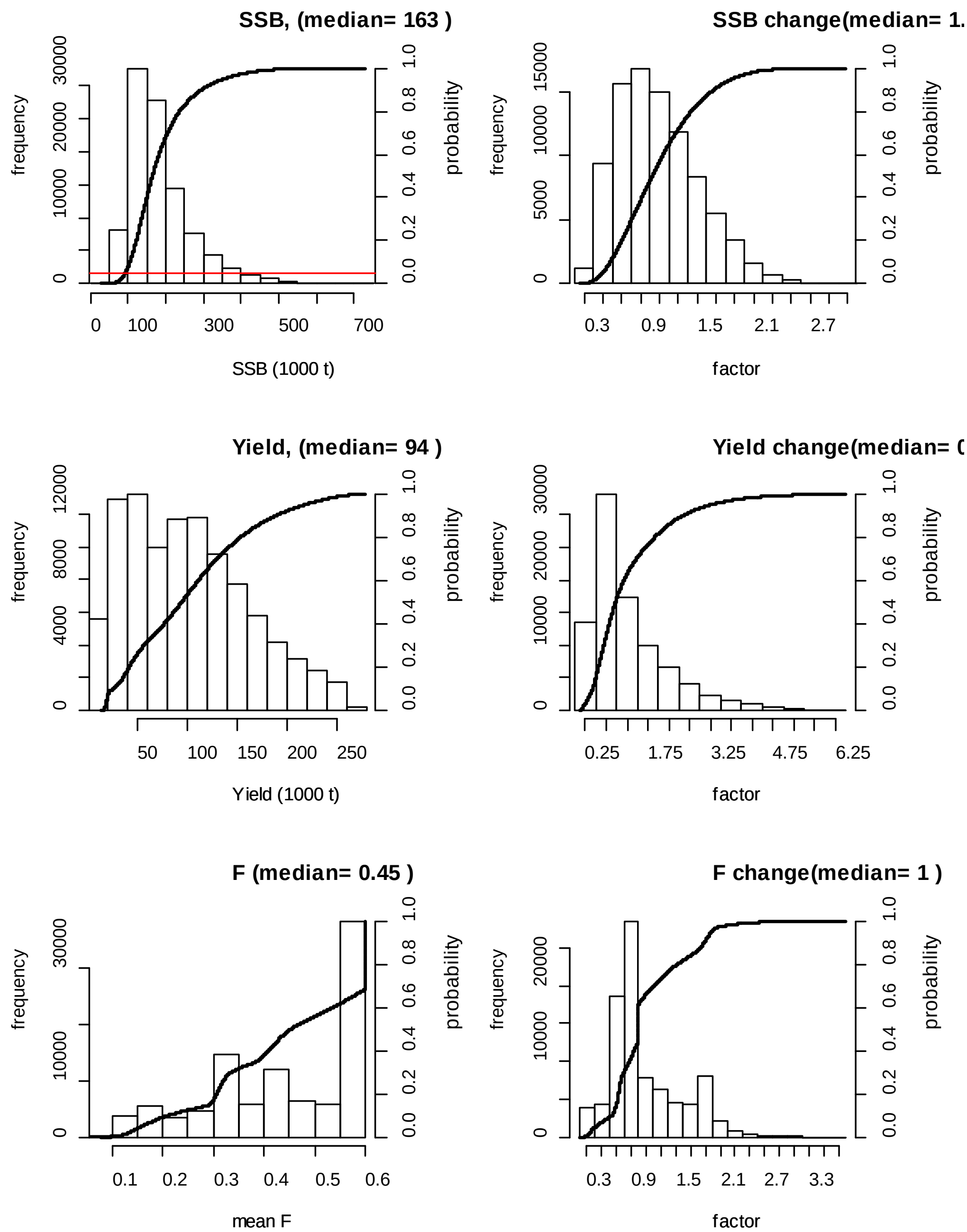

Figure 12. Distribution of SSB, yield and F, including cumulative probability in the years 2018-2027 from 10000 iterations (left column). The relative change from one year to the next is shown in the right column. Minimum TAC at 20 kt and maximum TAC at 200 kt.

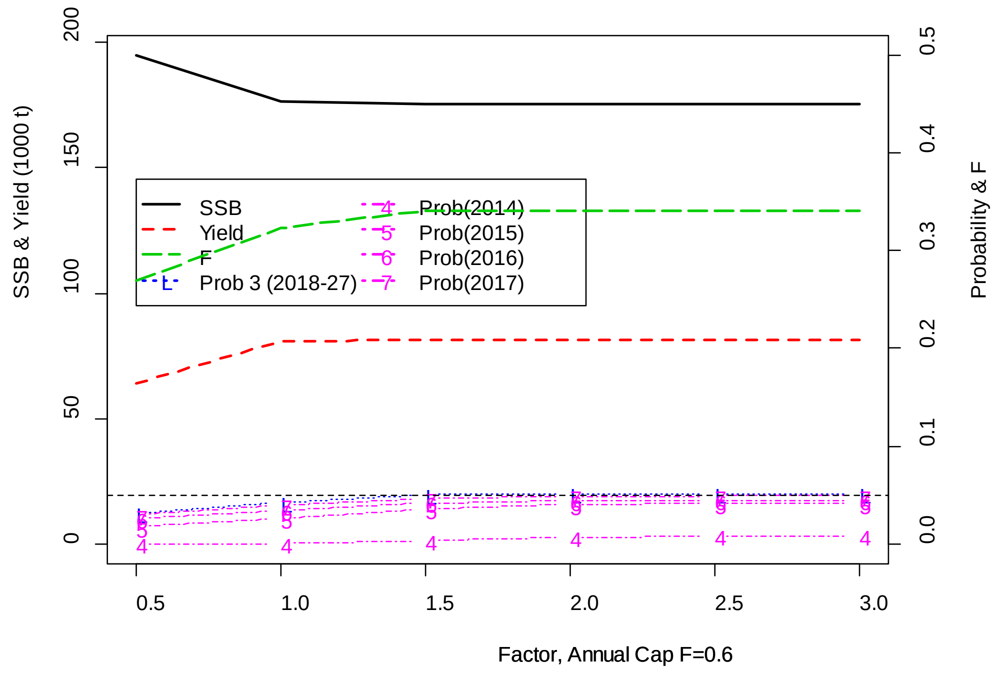

Figure 13. Sensitivity analysis: Cap F. As default a cap F at 0.60 for the whole year is used. The x-axis shows the given factor used to multiply the default Cap F values. Minimum TAC is fixed at 20 kt and maximum TAC is fixed at 100 kt.

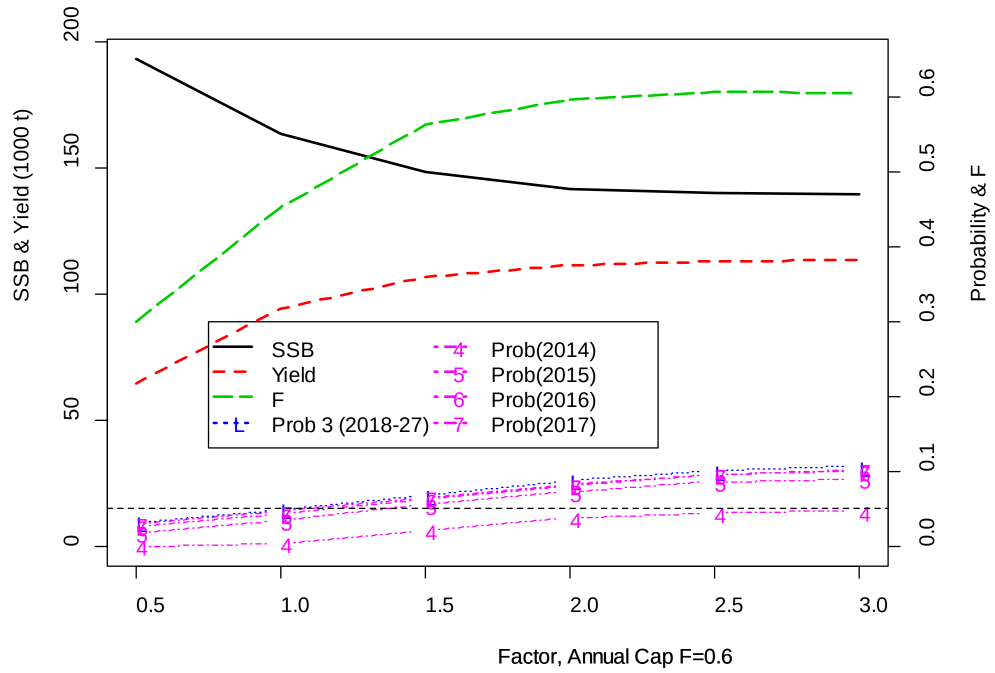

Figure 14. Sensitivity analysis: Cap F. Minimum TAC is fixed at 20 kt and maximum TAC is fixed at 200 kt.

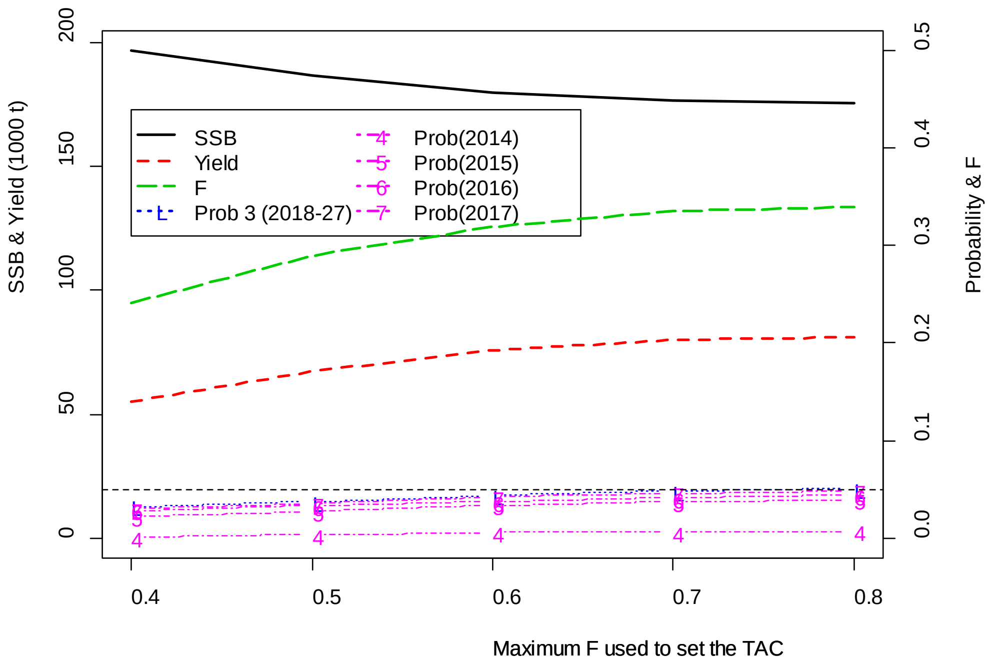

Figure 15. Maximum F used for TAC scenario. The x-axis shows the maximum F used in setting the TAC from the escapement strategy. Minimum TAC is fixed at 20 kt and maximum TAC is fixed at 100 kt. Cap F is not applied.

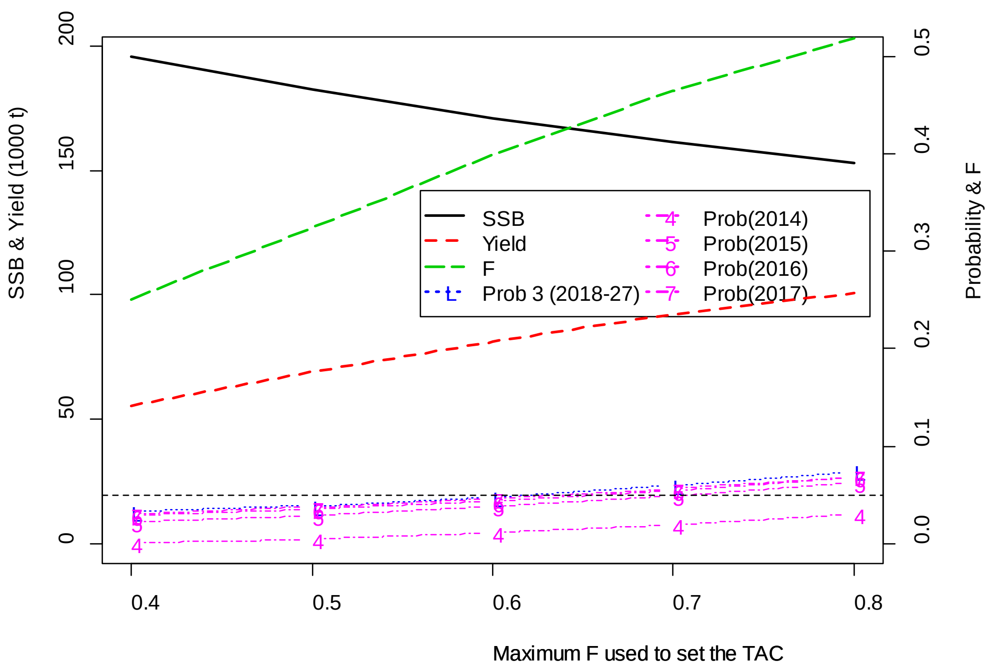

Figure 16. Maximum F used for TAC scenario. The x-axis shows the maximum F used in setting the TAC from the escapement strategy. Minimum TAC is fixed at 20 kt and maximum TAC is fixed at 200 kt. Cap F is not applied.

3 Discussion and conclusion

The MSE simulations presented are based on a long row of assumptions of constant values for key parameters such as the fishing pattern, mean weights, maturity and natural mortality at age. Some of the assumptions have been investigated in Lambert *et al.* (2009) and Nielsen *et al.* (2012). Likewise, it is assumed that the estimated stock recruitment relationship is valid for future recruitments. However, this represents the normal ICES procedure to MSE and we have not made additional sensitivity analyses. Given these assumptions the presented scenario results should be regarded more as a sensitivity analysis than as absolute performance in relation to e.g. the probability of SSB above B_{lim}.

Some general conclusion from the evaluation of the options can, however, be made in relation to sustainability according to the precautionary approach for the different management strategies. The applicability of the fixed TAC within the precautionary framework depends on the assumption on when the fishery will actually cease due to low catch rates (and stock size). This is implemented as a Cap F option in the MSE scenarios. The sensitivity to the value of CAP F is in general low for the different presented options, but it is obvious that if the fleet makes a determined attempt to catch the full minimum TAC even though the catch rates are low and the state of the stock is poor, then the MS will not be precautionary.

Norway pout is a semi-pelagic species which is widely and rather evenly distributed in the Northern North Sea (Lambert *et al.*, 2009; Nielsen *et al.*, 2012; Spartholt *et al.*, 2002a,b; ICES, 2012a incl. Stock Annex) and it does not show very dense schooling behaviour. The fact that the stock does not occur in large, very dense schools lower the risk for continuation of the fishery at low stock size, i.e. it is likely impossible to maintain high catch rates at low stock size. This indicates that the fishery will stop at low stock size.

The present fishery regulation will also contribute to maintain a low fishing mortality at low stock sizes. The Norway pout box in the North-Western part of the North Sea (closure to reduce by-catch rates of other gadoids) contains a significant proportion of the Norway pout stock which is out of reach of the fishery. In addition, the present by-catch regulation to protect other species including maximum by-catch rates of other gadoids will be difficult to obey with low stock size of Norway pout and probably bring the fishery to an end in such situations. Furthermore, selective devices have been made mandatory in the Danish fishery and (partly in the Norwegian) to reduce by-catches of other species (Eigaard *et al.*, 2012)

The main fishery for Norway pout is a targeted fishery where Norway pout constitutes the main catch (ICES, 2012a, incl. Stock Annex). Even though Norway pout is caught together with blue whiting in deep waters in some years in the Norwegian fishery, the by-catches of Norway pout has not been high in the Blue whiting fishery historically (including years when the Norway pout fishery has been closed) (ICES, 2012a). By-catch of Norway pout can therefore be ignored.

The sensitivity analyses presented show in general that SSB is maintained above B_{lim} with a high (95%) probability. This is partly because the assumed assessment uncertainty is lower than the uncertainty used to set B_{pa} from B_{lim}. The ratio between B_{lim} and B_{pa} reflects that given a CV at 30% of the estimate of SSB, there will be less than 5% risk that the real SSB is below B_{lim} for an assessment estimate of SSB at Bpa. This is a rather high uncertainty margin given the very stable assessment with limited retrospective noise (ICES, 2012a). Assessment results using the SMS models shows that SSB in the first year after the terminal year can be estimated with a CV at 18-20%. This value was used in the simulations and is lower than the assumed 30% CV.

The limited time gap, 3 months, between the most recent assessment estimates and the TAC period contributes also to the robustness of the scenarios. Most TAC advices from ICES make use of one so-called "intermediate year", which is the time period between the last assessment year and the TAC year. For Norway pout the TAC advice is mainly given with a shorter delay between the terminal year of the assessment and the TAC period.

Comparison with the 2012 MSE

The results from the scenarios presented in this paper follow the results from the MSE evaluations made in the Autumn 2012 (ICES, 2012c). The minimum sustainable TAC in the most recent evaluation is around 20 kt whereas the minimum TAC in the 2012 evaluation was around 27 kt for comparable options. The difference is probably due to the shift in the TAC year and the fact that the SSB at the 1st January (after fishing in November-December on the TAC for Nov-October) is not used in setting the TAC. This might increase the risk to Blim, such that a decrease in the minimum TAC becomes necessary. Using the SSB after having taken the TAC in the second calendar year (January-October) as target in the escapement strategy seems however to work quite well.

Advice summary

The proposed Management Strategy is in accordance with the sustainability criteria under the precautionary approach given a minimum TAC of maximum 20 kt and an assumption about future fishing mortality (and fishing effort) stays within the range of the values observed [0.0; 0.6] for the last decade.

A maximum TAC can be set at levels up to around 200 kt. Such high maximum TAC is however very sensitive to the assumption of an upper limit on realised fishing mortality (Cap F at 0.6) and will require a strict effort control, especially if the present effort level is increased significantly.

A maximum on F used in setting the TAC from the escapement strategy might be an alternative to effort control. Such maximum F should be around 0.6 for an HCR with maximum TAC at 200 kt or up to 0.8 if a maximum TAC at 100 kt is chosen. Median yield is almost the same for the two options.

The changes in the TAC year to 1st November - 31th October could not be implemented fully in the Management Strategy Evaluation. However the present evaluation (using a TAC year 1st October-30th September) is considered sufficient to show that the suggested shift in TAC year has a very limited influence on long-term yield, stock sizes and risk to Blim.

4 Appendix 1. Summary table of the HCR evaluation

Stock: Norway Pout in the North Sea and Skagerrak

Background		
Motive/ initiative/ background	EU request to ICES for evaluating an HCR based one annual assessment (September), a minimum TAC larger than zero and a TAC estimated from the escapement strategy, however with a TAC year 1st November-31th October.	
Main objectives	Precautionary, timely to reflect larges changes in the stock abundance and a minimum TAC.	
Formal framework	ICES on request from The EU	
Who did the evaluation work	DTU Aqua, with review from WGNSSK 2013	
Method		
Software Name, brief outline include ref. or documentation	SMS-simulation programme, available from the author (mv@aqua.dtu.dk) Age structured operating model with quarterly time steps, no full assessment in the loop.	
Type of stock	Short lived, demersal	
Knowledge base *	Analytic assessment	
Type of regulation	TAC	
Operating model conditioning		
	Function, source of data	Stochastic? - how (distribution, source of variability)
Recruitment	Hockey stick using the full available time series,1983-2012, and inflection point at Blim	Log-normal, CV adjusted to resemble that of the observed recruitment.
Growth & maturity	Weight in catch, Weight in stock and Maturity ogive: average over the full time series	No
Natural mortality	Fixed in assessment and MSE	No
Selectivity	Long term average, by age and quarter.	No
Initial stock numbers	From assessment	No, The 2012 year class is (confirmed) high and dominates the stock for the near future.
Decision basis **	Escapemt strategy. SSB in the year after the TAC	
Number of iterations	10000	
Projection time	20 years	
Observation and implementation models		
Type of noise	Correlated noise on stock size	Log-normal, CV from the 2012 assessment.
***** Comparison with ordinary assessment?**	Year factor scaled to give CV of SSB resembling the observed.	
Projection: If yes - how?	Projection through intermediate “quarter” (quarter 3) based on a knowledge on the catch and the fixed exploitation pattern	
Projection: Deviations from WG practice?		
Implementation	The TAC (Q4 and Q1-Q3) is set from the “observed” stock size and the objective of SSB at Bpa after the TAC has been taken. The TAC year does not follow the	Uncertanties (log-normal) on the “observed” stock size. No bias.

	calendar year, The catch in Q4 after the TAC year is assumed zero when the escapement strategy is applied. • Realized F in Q4 cannot exceed a Cap F (0.28). Realized F in Q1-Q3 cannot exceed 0.32.	
Harvest rule		
Harvest rule design	TAC year includes 1st November-31 October. The TAC is set from the Escapement strategy, such that SSB is abobe Bpa the 1 January after the TAC year. For TAC setting, it assumed that catches in the period 1 Novenber – 31 December is zero (however will be recalculated by the next TAC year). A minimum TAC at 20 kt is used in combination with a maximumTAC at 100 kt (alternatively 200 kt). The above HCR assumes the use of effort within the range of the observed value inthe last decade. Alternatively, the esacpement strategy (as outlined above) is used with a maximum F in the range 0.6 to 0.8, depending on the maximum TAC value applied (100-200 kt)	
Stabilizers	Minimum and maximum TAC	
Duration of decisions	Annual	
Revision clause		
Presentation of results		
Interest parameters	• Median catch, F and SSB and their interannual variability. Risk to Blim	
****** Risk type and time interval**	Risk to Blim. The probability of the (true in the model) SSB falling below B_{lim} by year, 2014-2017 and long-term 2018-2027 (risk type 3 as defined by WKGMSE 2013)	
Precautionary risk level	5% of risk type 3.	
Experiences and comments		
Review, acceptance:	Several HCR were evaluated by ICES in September 2012. The present request is a follow up on those.	
Experiences and comments	The proposed management strategy is in accordance with the pre-cautionary approach and lead to sustainable yields, under certain constraints. The minimum TAC should be at 20 000 tonnes or lower. A main constraint in the suggested management strategy is that future fishing effort should not exceed the range of the values observed in the last decade. This constraint is not critical if a maximum annual TAC of around 100 000 tonnes or less is applied. Higher maximum TAC (e.g. 200 000 tonnes) should be complemented with effort management to ensure that fishing mortality remains within the range of values observed for the last decade. Alternative to effort control, application of a maximum value for F for setting the TAC from the escapement strategy could be used. Such maximum F should be below 0.8 for a maximum TAC at 100 000 tonnes or below 0.6 for a maximum TAC at 200 000 tonnes.	

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Annex 1 – Review Group comments

The RG asked for clarification about some points:

- Introduction of assessment in the MSE – This was taken as 20% CV (based on an approximation to the uncertainty in SSB in the terminal year, in the SMS assessment), assuming all ages have that CV. However, the uncertainty associated with a TAC derived from an escapement strategy, is strongly dependent on the uncertainty in the projected SSB after the fishery takes place. That SSB is almost entirely dominated by the population at age 0 in the terminal assessment year and by the incoming recruitment in the following year. The estimated population abundance at age 0 in the terminal assessment year has a 47% CV, which is substantially higher than 20%. This suggests that uncertainty has been underestimated in the MSE, which could lead to an underestimation of the risks associated with the HCR.

- The RG notes, however, that the results (in terms of the probability that SSB goes below Blim) are not very sensitive to the different settings of the HCRs, i.e different values of Fcap, minimum TAC and ceiling on TAC. Ceiling on TAC and Fcap are to large extent the same measure, avoiding too high catches when the escapement strategy gives very high TAC and F. Ceiling on TAC and/or Fcap can also help in compensating for the lack of sufficient "uncertainty " built in the simulations which is most profound when a large 0-group is measured. Ceiling on TAC and/or Fcap also helps with a minimum TAC strategy, by leaving a significant amount of age 3 abundance from strong year classes in the spawning stock.

  These points are best demonstrated by recent examples for the Norway pout stock. One example is that the age 3 (2009 cohort) makes up more than 50% of the spawning stock in 2012, whereas the SSB would have been well below Blim if that year class had been fished harder. Another example is the catch advice for 2013 based on a "standard" escapement strategy, which is more than 400 kt. This advice is obtained from 0 group indices in the autumn 2012 that have an estimated CV of 0.45. With no fishery in 2013 the spawning stock from this cohort might be close to, say, 500 kt in 2014, with CV of 0.45 or standard deviation around 225 kt (500x0.45). Removing catches from this cohort, leaving just 150 kt of SSB in 2014, will give 150 kt of SSB in 2014 with standard deviation of (still) 225 kt! A TAC ceiling of 150-200 kt would have taken care of this problem.

- After discussion with experts doing the MSE work, the RG understands that the assumptions done in the MSE to set the TAC (i.e. short-term projection part of the MSE, to set the annual TAC based on the assessed population) are probably less conservative than those used for the actual ICES advice. In the MSE, the TAC is set based on the assumption that recruitment in the following year follows exactly the hockey-stick model that was fitted as part of the historic SMS assessment. For practical purposes, this is not too dissimilar from assuming GM for this recruitment. On the other hand, the ICES WGNSSK (which produces the catch advice for the stock) assumes that this recruitment follows the 25 percentile of the estimated recruitments for the historic period, which is a more conservative assumption. Therefore, if the MSE finds that the HCR is precautionary, the same should apply to the more conservative procedure followed in the actual ICES advice.

- Taking all these aspects into consideration, the fact that they act in different directions (concerning whether the conclusions from MSE analysis to establish that the HCR is precautionary should be interpreted as optimistic or pessimistic), and given the time constraints, the RG considers the MSE evaluation to be acceptable. This is based on the understanding that the ICES procedure to provide catch advice will continue to be based on the assumption that the recruitment during the fishery year is the 25 percentile of the estimated historic time series.

- Accepting the current work done, the RG nevertheless envisages that this type of MSE evaluation could be done in the future considering higher CV values, as well as a recruitment assumption for the incoming recruitment (during the fishery year) that matches the way the short-term forecast is conducted in the ICES WGNSSK (for the annual catch advice).

- The RG also considers that the "standard escapement strategy" currently used for this stock should be examined a bit more in-depth. This "standard escapement strategy" does not impose a ceiling on the TAC or on F, and the RG considers it important to have a good understanding of its performance. It is understood from the experts' explanations that there are a number of reasons why the Norway pout stock is unlikely to be depleted even if the catch advice was too high, and that the full TAC is very unlikely to be taken in such cases, but a good understanding of the performance of the method used for the current ICES advice is considered very relevant.

- An alternative way forward for the advice of this stock could be using a stochastic projection framework: with a stochastic short term forecast starting with appropriate CV of the different age groups at assessment time, then projecting with a specified TAC and getting the probability distribution of SSB after the fishery for different TACs. For example, this is what is done for anchovy in the Bay of Biscay and capelin.

Further points/questions

- The option for Effort management, where F corresponding to the TAC can be very high but not considered to be fished, was explored as part of the MSE for Norway pout but the RG thinks this is not a very plausible idea for catch advice. Advising a TAC that is known to be too high just because it is very unlikely to be caught is not considered a good idea. The escapement strategy with a ceiling on TAC and a ceiling on F in the HCR of the management plan seems like a more relevant option, which is now drafted as the advice basis for the special request.

- The timing of comparison of SSB with reference points was also discussed during the RG:

  The method put forward by experts is to compare SSB on the 1st Jan after TAC year (no fishing in Nov/Dec) with Bpa. Another option could be to compare SSB at 1st Nov (e.g. with a 'back shifted Bpa', based on both M and F; or try to come up with a reference point based on the historic stock on November 1st), instead of Jan 1st after the TAC year (with current Bpa) but this one is not chosen. Additional exploration of these issues would be useful to check that the assumption made in the MSE is OK.
- ICES could provide catch options splitting between the first months of the TAC year (Nov/Dec), based on comparing SSB in the TAC year with Bpa, and separately for the last 10 months of the TAC year. This option is not included in the MSE as is considered less relevant to the request. This approach makes the HCR more precautionary as the fisheries in Nov-Dec in the assessment year can be closed if the predicted spawning stock is approaching Blim. It is on the other hand somewhat counteracting the minimum TAC in the request.