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Re-evaluation of the harvest control rule for Northeast Arctic saithe and long-term yield versus exploitation level using Prost

by

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INTRODUCTION

Strategy for the harvesting of Northeast Arctic saithe

Norwegian authorities has as aim that "The yearly Total Allowable Catch (TAC) for Northeast Arctic saithe shall, within safe biological limits, be determined so that the highest potential economical yield is realized both from the harvest of saithe and from the harvest of other species in interaction with saithe".

To achieve the abovementioned objective yearly Total Allowable Catch of Northeast Arctic saithe shall, when circumstances do not order otherwise, be determined as follows:

1) estimate the average TAC level for the coming 3 years based on F_{pa}, TAC for the next year will be set to this level as a starting value for the 3-year period.

2) the year after, the TAC calculation for the next 3 years is repeated based on the updated information about the stock development, however the TAC should not be changed by more than +/- 15% compared with the previous year's TAC.

3) if the spawning stock biomass (SSB) in the beginning of the year for which the quota is set (first year of prediction), is below B_{pa}, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from F_{pa} at SSB=B_{pa} to 0 at SSB equal to zero. At SSB-levels below B_{pa} in any of the operational years (current year and 3 years of prediction) there should be no limitations on the year-to-year variations in TAC."

The harvest control rule (HCR) was evaluated and implemented in 2007. At the benchmark assessment at WKROUND February 2010 (ICES CM 2010/ACOM:36) several changes were made to the saithe assessment:

- Expansion of the catch matrix from 3-11+ to 3-15+
- Base the Norwegian trawl CPUE on data from all quarters and from days with > 20% but < 80% saithe in the catches
- Split the two tuning series in 2002
- Reduce the shrinkage in the XSA and remove the time tapered weighting

More details and general information is given in (ICES CM 2010/ACOM:36) and the Stock Annex (Quality Handbook).

This WD describes new HCR evaluation runs made with the PROST software, based on the expanded age matrix and the new initial stock size from the latest (2010) XSA-assessment. In addition long-term runs with different exploitation levels were performed to investigate the potential long-term yield.

POPULATION MODEL USED

The population model used was the same as in 2007 (Mehl et. Al, WD 4 2010, ICES CM 2007/ACFM:16). In all cases, 1000 simulations for the period 2010-2130 were performed and the results for the last 100 years of this period were considered. This was done in order to exclude the effect of the initial values. The stock size for 2010 (initial data) was taken from the 2010 assessment.

The ‘default’ model was:

- A Beverton-Holt spawning stock-recruitment model with lognormal error distribution
- Assessment error and bias are estimated as age-dependent, normally distributed.
- Density-dependent weight at age in catch (average for 1981-2009 used for age groups where density-dependence was not found)
- Weight at age in stock is set equal to weight at age in catch
- Time series (1986-2009) average used for maturation at age without density-dependence
- No uncertainty in weight at age, maturity at age or natural mortality at age
- Exploitation pattern: 1998-2009 averages used for all age groups in all years
- Implementation of catch: First, the catch at age is calculated from the perceived stock using the fishing mortality derived from the harvest control rule and the given exploitation pattern. This catch at age is then applied to the actual stock.
- Implementation error and bias is estimated using the same percentage for all age groups

Recruitment

The Beverton-Holt stock-recruitment function with a log-normal error distribution is given by

$$R = \frac{a * SSB}{b + SSB} e^{\varepsilon}$$

where the stochastic term ε is normally distributed N(0,σ).

The fit was done using Solver in Excel spreadsheets described by Skagen and Aglen (2002). The following values of a, b and σ were estimated (units: tonnes and thousand of fish)

a=207703, b=49415, σ = 0.478

Growth (weight at age)

Growth is modelled as density dependent. We have used the time series of catch weights in 1990-2009 vs. total stock biomass in 1989-2008 to fit a density-dependent model for weight at age (kg) in the stock $ws_{a,y}$ for ages 3-10. The model is of the form

$$ws_{a,y} = -\alpha_a TSB_{y-1} + \beta_a \text{ , where}$$

TSB_y is the total stock biomass in year y, a is age and α_a and β_a are constants. The parameters in the regressions are given in the text table below.

Age	α_a	β_a	R^2	p
3	-0.0448	0.69897	0.0140	> 0.05
4	-0.1949	1.14477	0.0962	> 0.05
5	-0.5252	1.91847	0.2551	< 0.05
6	-0.7741	2.63698	0.3742	< 0.05
7	-1.2776	3.62272	0.4396	< 0.05
8	-1.7335	4.57018	0.5024	< 0.05
9	-2.1127	5.48202	0.4971	< 0.05
10	-2.5946	6.53315	0.5113	< 0.05
11	-3.4026	7.82010	0.4943	< 0.05
12	-2.78	8.01669	0.3731	< 0.05
13	-2.6663	8.78736	0.2339	> 0.05
14	-3.3689	10.07782	0.3230	< 0.05
15	-0.7306	10.07433	0.0104	> 0.05

The relationship for ages 3-4, 13 and 15 is insignificant. For those ages TSB could not be used as predictor and we use average values for these age groups. For age 14 we also use the historic average.

Maturity

Maturity at age was analysed for density dependence in the 2007 analyses, but no significant results were found. Therefore the time series (1985-2009) average was used for maturation at age.

Fishing mortality/fishing pattern

The exploitation pattern has improved over the last fifteen years with much lower catches of 2 and 3 year old fish, while the element of larger fish has been increasing. The minimum landing size was increased in 1999, but the improvement started even before this, partly due to regulations and partly due to better prices for larger saithe. There is no reason to include periods when the pattern was significantly different from what it can be expected to be in the future, due to different regulations. We have therefore used the 1998-2009 averages by age for all years

Assessment and implementation error

Assessment and implementation error and bias are estimated explicitly as percentages of stock over/under estimation and over/under fishing. The assessment bias and error are modelled as age-dependent, with no correlation between age groups. The pattern used is based on an historical analysis. Retrospective XSA-runs were compared to the assessment in 2010, to estimate the bias. Due to the split of the tuning series in 2002, only data from 2006 to 2009 could be used to calculate the relative bias and corresponding standard deviations. It was decided to apply for all age groups normal distributed errors around the mean values for the age group with the largest σ, truncated at ± 2.5σ. The results were:

AGE	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**
Bias	-0.03	-0.05	0.05	0.08	0.14	0.09	0.08	0.21	0.21	0.37	0.32	0.24	0.25
St. dev	0.37	0.24	0.09	0.11	0.06	0.06	0.07	0.31	0.43	0.46	0.84	0.35	0.35

Implementation error and bias is modelled using the same percentage for all age groups. To explore the amount of bias and error to introduce, the relation between catch and quota for the period 1989-2009 was fitted to a normal distribution. The fit was considered acceptably good for the purpose and the estimated parameters were $\mu = 0.997$ and $\sigma = 0.12$. Thus, it was decided to include a bias of -0.3% with normally distributed error and with a CV of 0.12 truncated at $\pm 2.5\sigma$ for all age groups.

Software used

The simulations were carried out using the PROST software for stochastic projections (Åsnes 2007).

Reality check

A reality check of the 'default' model was made with $F_{4\text{-}7} = 0.37$ for all SSB levels, 50% maximum year-to-year-change in TAC and with and without assessment and implementation error. $F_{4\text{-}7} = 0.37$ is equal to the average fishing mortality for the period 1960-2009. Two runs were performed, one with no assessment and implementation error (option 1) and one with assessment and implementation error estimates (option 2).

For option 1 the realised F is the same as the XSA-average of 0.37. Recruitment and TSB are also both close to the XSA-average, while the SSB is somewhat lower. This is partly due to a higher SSB prior to 1985, when a fixed maturity ogive is applied. The stock sizes are slightly lower for option 2 with a negative retrospective trend in assessment error, while the catch is the same as the historic average. The runs indicate that the model performs reasonably well at this level of fishing mortality.

	$F_{4\text{-}7}$	Recruitment (million)	TSB (1000 t)	SSB (1000 t)	Catch (1000 t)
XSA average 1960-2009	0.37	188	698	353	162
Simulation result opt. 1	0.37	188	653	248	160
Simulation result opt. 2	0.38	187	647	240	160

LONG-TERM SIMULATIONS

The various settings used in three long-term simulations are described in Table 1, and the results of the simulations are described in Table 2.

Table 1. Settings for each run

Run No.	F	3-year rule	Assessment/ implement-tation error	Percent change TAC	F below Bpa
1	0.35	No	1 (no error)	15	Flat
2	0.35	Yes	1 (no error)	15	Linear
3	0.35	Yes	2 (error)	15	Linear

Table 2. Results of long-term simulations. Catch, TSB and SSB in 1000 tonnes, recruits in millions.

Run No.	Error option	In-put F	Realised F	Catch	TSB	SSB	Recr.	% years SSB< B_{lim}	% years SSB< B_{pa}	Average year-to-year change in TAC
1	1	0.35	0.35	162	685	268	191	0	13	6
2	1	0.35	0.35	162	685	270	190	0	12	5
3	2	0.35	0.36	161	679	262	190	0	21	11

The results of the simulations are quite similar. In none of the years is there any risk of falling below B_{lim}. The highest average year-to-year change in TAC of 11 % was found in run 3 (with assessment and implementation error). The part of the HCR limiting the annual change in TAC to 15 % is therefore probably not too restrictive and it was large enough to maintain SSB above B_{lim} in all the simulations.

LONG-TERM YIELD VERSUS EXPLOITATION LEVEL

Long-term runs were made with the same settings as in run 2 above (no assessment and implementation error) for exploitation levels from 0.1 to 0.4. The highest long-term yield of 169,292 t was obtained for F = 0.20, but the curve is rather flat and the maximum is poorly defined (Figure 1).

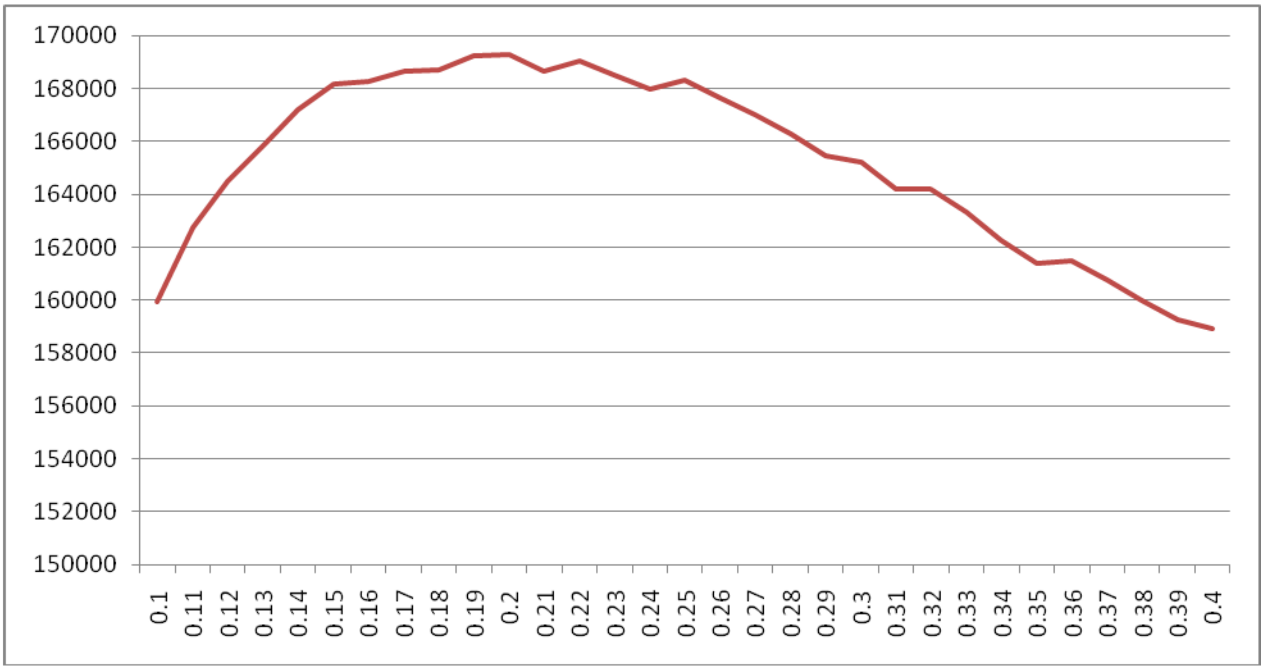

Figure 1. Long-term yield versus exploitation level.

CONCLUSIONS

The analyses presented indicate that the HCR still is in agreement with the precautionary approach, provided that the assessment uncertainty, assessment error and implementation error are not greater than those calculated from historic data and used in the evaluation.

The highest long-term yield of 169,292 t was obtained for F = 0.20, but the curve is almost flat between F=0.15 and F=0.25 and the decrease in long-term yield going from F=0.25 to F=0.35 is rather small (about 5%).

It should be noted that the conclusions drawn here is based on a risk level of 5 %. They will also hold for higher risk levels. The risk level to use should be decided by managers. If lower risk levels than 5 % is preferred, the harvest control rule should be evaluated against that level.

12. REFERENCES

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