ECOREGION **Iceland and East Greenland**
SUBJECT **Request from Iceland to ICES to evaluate the long-term management plan and harvest control rule for Icelandic haddock**

Advice summary

ICES has evaluated the current biological precautionary reference points and considers that B_{lim} = 45 000 t is appropriate. ICES recommends that a precautionary harvest rate HR_{pa} = 0.46 replaces the current F_{pa}.

ICES concludes that the harvest control rule for Icelandic haddock in the request is precautionary and in accordance with the ICES MSY approach.

Request

ICES received the following request from Iceland.

> *"The Government of Iceland is in the process of formally adopting the following management plan for Icelandic saithe and haddock:*
>
> *The management strategy for Iceland saithe and haddock is to maintain the exploitation rate at the rate which is consistent with the precautionary approach and that generates maximum sustainable yield (MSY) in the long term.*
>
> *In accordance with this strategy the following harvest control rules are under consideration for implementation by Icelandic authorities:*
>
> ***Saithe***
>
> *The annual total allowable catch (TAC) will be set by applying the following harvest control rule (HCR):*
>
> *1. When spawning stock biomass in the assessment year (SSB_y) is equal to or greater than* $SSB_{trigger}$*:*
>
> $$TAC_{y/y+l} = (\alpha\ B_{4+,y} + TAC_{y-1/y}) / 2$$
>
> *2. When SBB_y is below* $_{SSBtrigger}$*:*
>
> $$TAC_{y/y+1} = \alpha\ (SSB_y/SSB_{trigger})\ B_{4+,y}$$
>
> *where*
> *y the assessment year*
> *y/y_{+1} the fishing year starting 1September in year y and ending 31 August in year y+1*
> *y-1/y the fishing year starting 1September in year y-1 and ending 31 August in year y*
> *$B_{4+,y}$ the biomass of 4-year and older saithe in the assessment year*
> *SSB_y the spawning stock biomass in the assessment year*
> *and were α=0,20 and $SSB_{trigger}$=65000 t.*
>
> ***Haddock***
>
> *The annual total allowable catch (TAC) will be set by applying the following harvest control rule (HCR):*
>
> *1. When spawing stock biomass in the year following the assessment year (SSB_{y+1}) is equal to or greater than $SSB_{trigger}$:*
>
> $$TAC_{y/y+1} = \alpha\ B_{45+,y+l}$$
>
> *2. When SSB_{y+1} is below $SSB_{trigger}$:*
>
> $$TAC_{y/y+1} = \alpha\ SSB_{y+1}/\ SSB_{trigger}\quad B_{45+,y+l}$$

Where:
y the assessment year,
y/y_{+1} the fishing year starting 1 September in year y and ending 31 August in year y+1
y_{-1}/y the fishing year starting 1 September in year y-1 and ending 31 August in year y
$B_{45+,y+1}$ the reference biomass of 45cm and larger haddock in the year following the assessment year
and were α=0.40 and $SSB_{trigger}$ =45000 t.

These HCR formulations are based on work of national experts and the NWWG and have been considered to be accordance with the ICES MSY advisory framework.

The Government of Iceland requests ICES to evaluate whether these harvest control rules are in accordance with its objectives.

For haddock the evaluation should also include review of input data and the applied assessment methodology (Benchmark). For both haddock and saithe the evaluation should also address the appropriateness of current ICES reference points.

ICES is also invited to propose alternative rules or modified rules on its own initiative and to evaluate these."

This advice deals with the management plan and harvest rule for haddock. The ICES advice to evaluate the management plan and harvest rule for Icelandic saithe is dealt with in Section 2.3.3.2.

Elaboration on the advice

Re-evaluation of reference points

ICES has evaluated the current biological precautionary reference points and considers that the current B_{lim} = 45 000 t based on B_{loss}, the lowest observed biomass (in 1987 as estimated in 2010), is appropriate.

Currently, ICES advice for this stock is based on the precautionary approach F_{pa} = 0.47, evaluated in 2000. In 2010 F_{pa} was changed to 0.35 to account for slow growth and this value has been used as the basis for ICES advice since then. The new proposed precautionary harvest rate (HR_{pa}) = 0.46, which is based not on F but on a Harvest Rate (HR), leads on average to $F_{4–7}$ = 0.45, close to the value of 0.47 proposed in 2000. Modification of this HR_{pa} for slow growth is not required because the reference biomass B_{45+} used in the HR calculation is a function of fish size, both length and weight. Thus, at a constant HR the fishing mortality-at-age decreases automatically when growth is slower. This takes into account growth changes accounted for in the provision of advice in recent years, when F_{pa} was lowered to 0.35 in a period of poor growth.

If the probability of SSB< B_{lim} under certain conditions does not exceed 0.05, ICES classifies such conditions as precautionary (ICES, 2013). In the proposed management plan HR = 0.4 the probability of SSB< B_{lim} does not exceed 0.05 (see Table 2.3.3.1.1), which is considered precautionary. In the long term, and under equilibrium conditions, HR = 0.52 maximizes yield (Figure 2.3.3.1.1). However, this exceeds HR_{pa} = 0.46 and the probability of SSB< B_{lim} at this HR exceeds 0.05, therefore HR=0.52 is not considered precautionary.

Proposed management plan

The proposed management plan for the Icelandic haddock fishery, setting a TAC based on a harvest rate (HR) of 0.40 of the reference biomass (B_{45cm+}) in the year following the assessment year (i.e. the advisory year), modified by the ratio $\frac{SSB_{y+1}}{SSB_{trigger}}$ when $SSB_{y+1} < SSB_{trigger}$ is considered to be precautionary and in accordance with the ICES MSY approach.

A TAC stabilizer was not considered appropriate for this stock as there is large variability in stock size and relatively reliable estimates of stock and recruitment.

Basis of the advice

Background

The request is based on the work of an *ad hoc* group of managers, stakeholders, and scientists from the Marine Research Institute (MRI), initiated by the Icelandic Ministry of Industries and Innovation at the beginning of 2012. The objective of the group was to investigate harvest control rules for saithe, haddock, and golden redfish that would be in conformity with the precautionary approach and ICES MSY framework, and to maintain a long-term high sustainable yield. For haddock, stability of catches in terms of lower fifth and tenth percentile of catches was also one of the criteria looked at. The work on haddock has been conducted over the last year.

In 2012, ICES advised that the TAC should be set based on F_{pa} = 0.35, the value applicable to a slow-growth period. The proposed management plan would have given the same catch advice in that year.

There have been no previous evaluations of the proposed plan.

The proposed plan is based on a harvest rate (HR) approach using a reference biomass for haddock at 45 cm and above (B_{45+}).

Results and conclusions

The results of simulations of the proposed harvest control rule in terms of key population metrics (recruitment, yield, spawning biomass, reference biomass (B_{45+}), fishing mortality, and harvest rate) are given in Figure 2.3.3.1.2. The future dynamics are expected to be similar to those observed historically; however, past exploitation rates have been higher than those anticipated under the proposed plan. Mean and fifth percentiles of catch for a range of harvest rates, along with the fifth percentile of SSB that is used to define precautionary reference points, are shown in Figure 2.3.3.1.1. The peak in catch occurs at an HR of 0.52, but this implies >0.05 probability of SSB< B_{lim}.

Annual probabilities of SSB< B_{lim} that do not exceed 0.05 in all years occur at HRs with a target lower than or equal to 0.4 (Table 2.3.3.1.1). In the longer term higher HRs of up to 0.46 may be possible without the probability of SSB< B_{lim} exceeding 0.05. However, there is only a marginal gain in mean catch (2%) by increasing the HR from 0.40 to 0.46. There may be other benefits to reducing the HR; the fifth percentile in catch (Figure 2.3.3.1.1) shows a maximum at a lower HR than 0.46, the peak in the mean catch. This indicates that at a lower HR, it would be expected that there would be slightly higher catches in periods of low productivity than when exploiting at HRs above 0.40. ICES considers that the proposed plan is precautionary as the maximum annual probability that SSB is below B_{lim} is $\leq$ 0.05 at the proposed harvest rate of 0.40. However, over a number of years the annual probabilities combine, and it is expected that the spawning biomass will have a probability of around 0.16 of going below B_{lim} at least once in the first ten years; this probability reduces to 0.09 in the longer term (Table 2.3.3.1.2).

The distribution of biomass, exploitation rates, catches, and interannual changes in catch are summarized in Figure 2.3.3.1.3 and Table 2.3.3.1.3. These distributions should be used, in the future, to check that realised ranges are compatible with expectations. If future observed values were to go outside the range illustrated, this would indicate that there is a need to re-evaluate the assumptions of the simulations. In the simulations the assumed assessment error is not bias corrected, resulting in an average "realised" harvest ratio a little higher than the target value of 0.4.

The inclusion of the $SSB_{trigger}$ in the proposed management plan provides two useful attributes. It is considered necessary to reduce the risk of depletion of the stock in the long periods of poor recruitment that are characteristic of haddock stocks. If the SSB does decline below B_{lim}, the rate of recovery is improved if the HR is reduced below $SSB_{trigger}$ (Figure 2.3.3.1.4). Under normal circumstances this $SSB_{trigger}$ (set at B_{lim}) should not be encountered often (Figure 2.3.3.1.3).

Methods

A Management Strategy Evaluation (MSE) was conducted for the Icelandic haddock stock. The operating model (which generates the "true" future populations in the simulations) was the same as used in the annual assessment. Mean weights-at-age and maturity were based on the same procedures used in the assessment and described in detail in Annex 2.3.3.1. The selection pattern used is a function of stock weights and is the same as observed in the fisheries. Recruitment and weights were simulated stochastically, with autocorrelated noise.

The assessment error of the reference and spawning biomass in the assessment year were based on estimates from empirical and analytical retrospective patterns. The error was autocorrelated in time to emulate observed sequential periods of over- or underestimation of stock biomass. A short-term forecast is required when applying the HCR, the TAC being based on the harvest rate as a proportion of the B_{45+} biomass (biomass of haddock at 45 cm and larger) in the advice year. The spawning-stock biomass in the advice year is used as a trigger to modify the harvest rate.

Sources

ICES. 2013. Report of the Workshop on Guidelines for Management Strategy Evaluations (WKGMSE), 21–23 January 2013, ICES HQ, Denmark. ICES CM 2013/ACOM:39.

Björnsson, H. 2013. Report of the evaluation of the Icelandic haddock management plan. ICES CM 2013/ACOM:59.

Source code for simulations:
http://www.hafro.is/~einarhj/ices_2013_hcr_evaluation.html

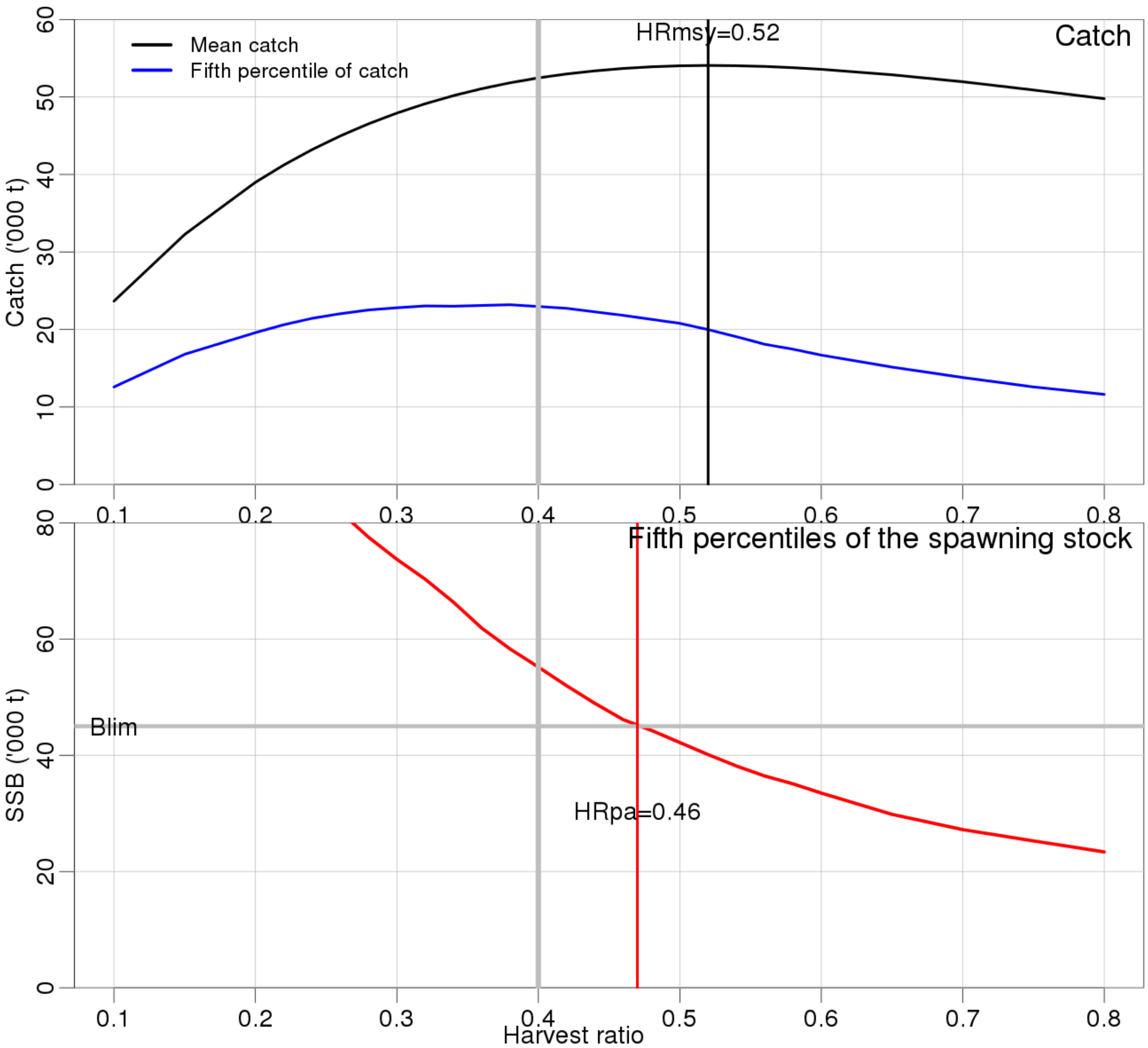

Figure 2.3.3.1.1 Upper panel: Mean catch and fifth percentile of catch against target harvest ratio (HR). Lower panel: Fifth percentile of SSB against harvest ratio. Vertical lines show proposed HR = 0.4, proposed HR_{pa} = 0.46 based on a probability of SSB< B_{lim} = 0.05, and HR_{MSY} = 0.52. The fifth percentile in catch has a maximum at lower HR than the mean, indicating that a lower HR would be expected to give slightly higher catches in low productivity periods.

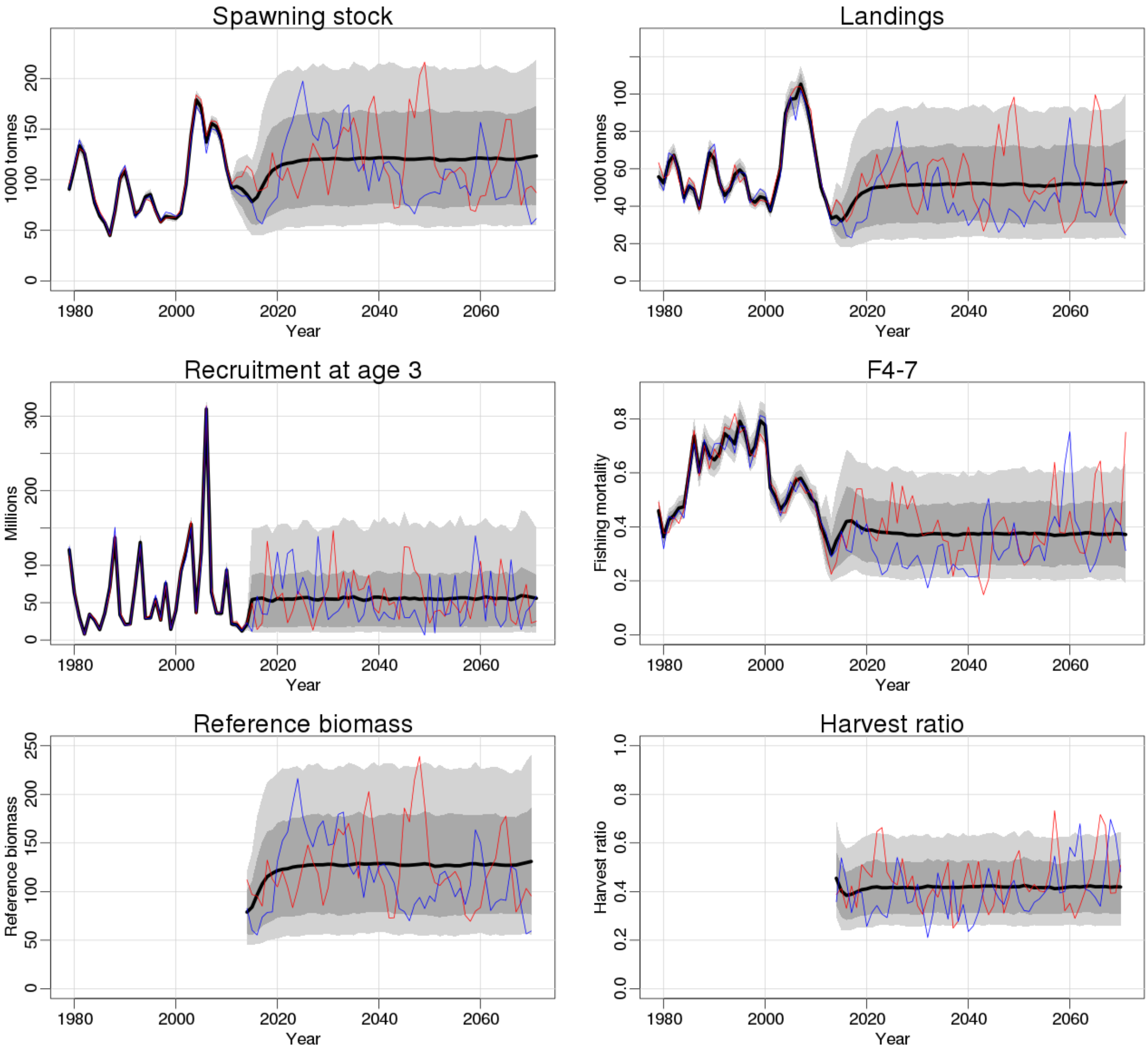

Figure 2.3.3.1.2 Time-series of historical assessment and simulations based on the proposed management plan. The shaded area corresponds to the 68% and 90% range of values. The mean is depicted as a black line. Two random draws are displayed, in red and blue.

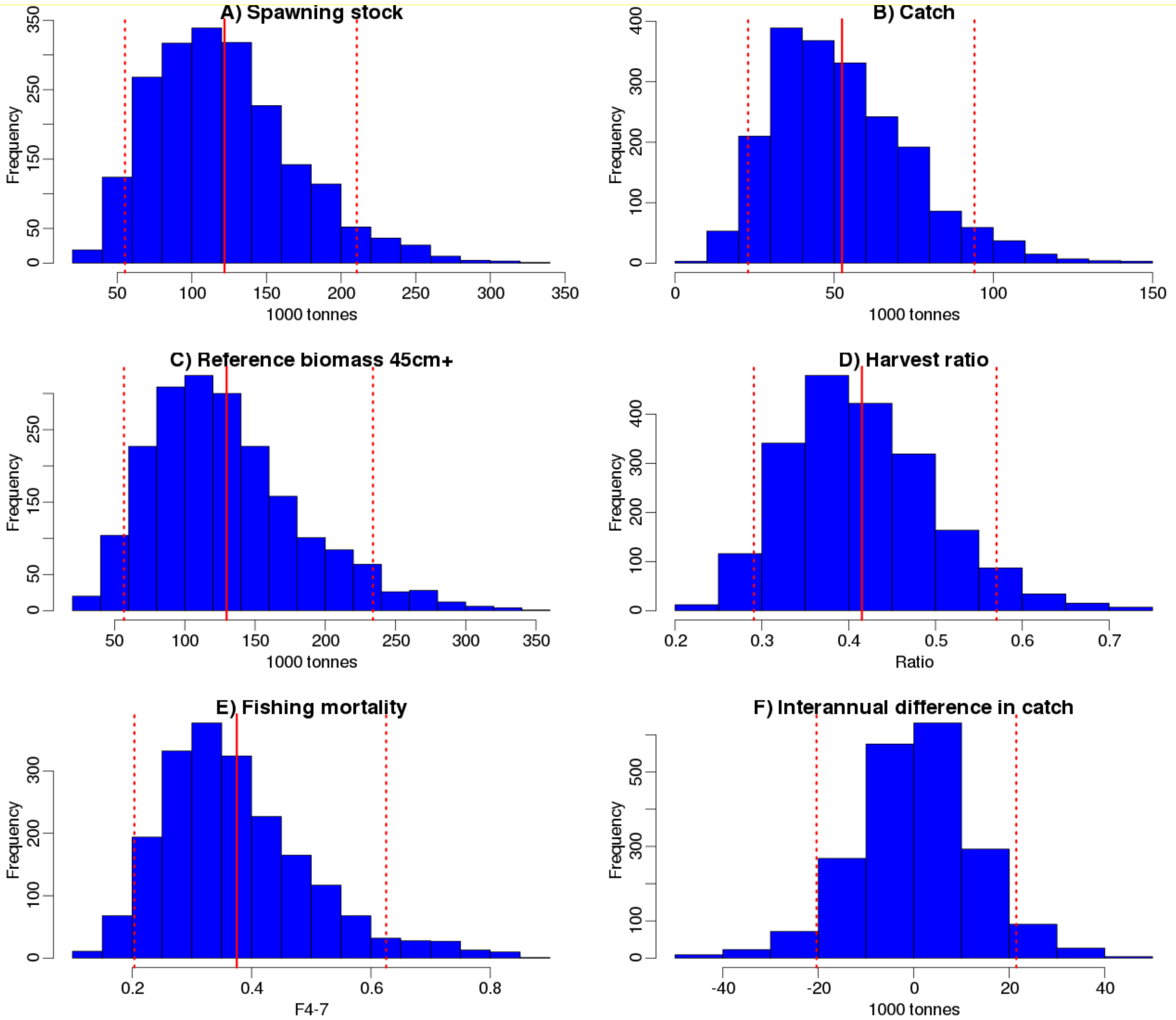

Figure 2.3.3.1.3 Distribution of predicted biomass (panels A and C), catch (panel B), measures of exploitation rate (panels D and E), and interannual difference in catch (panel F). Key metrics in this figure are summarized in Table 2.3.3.1.3.

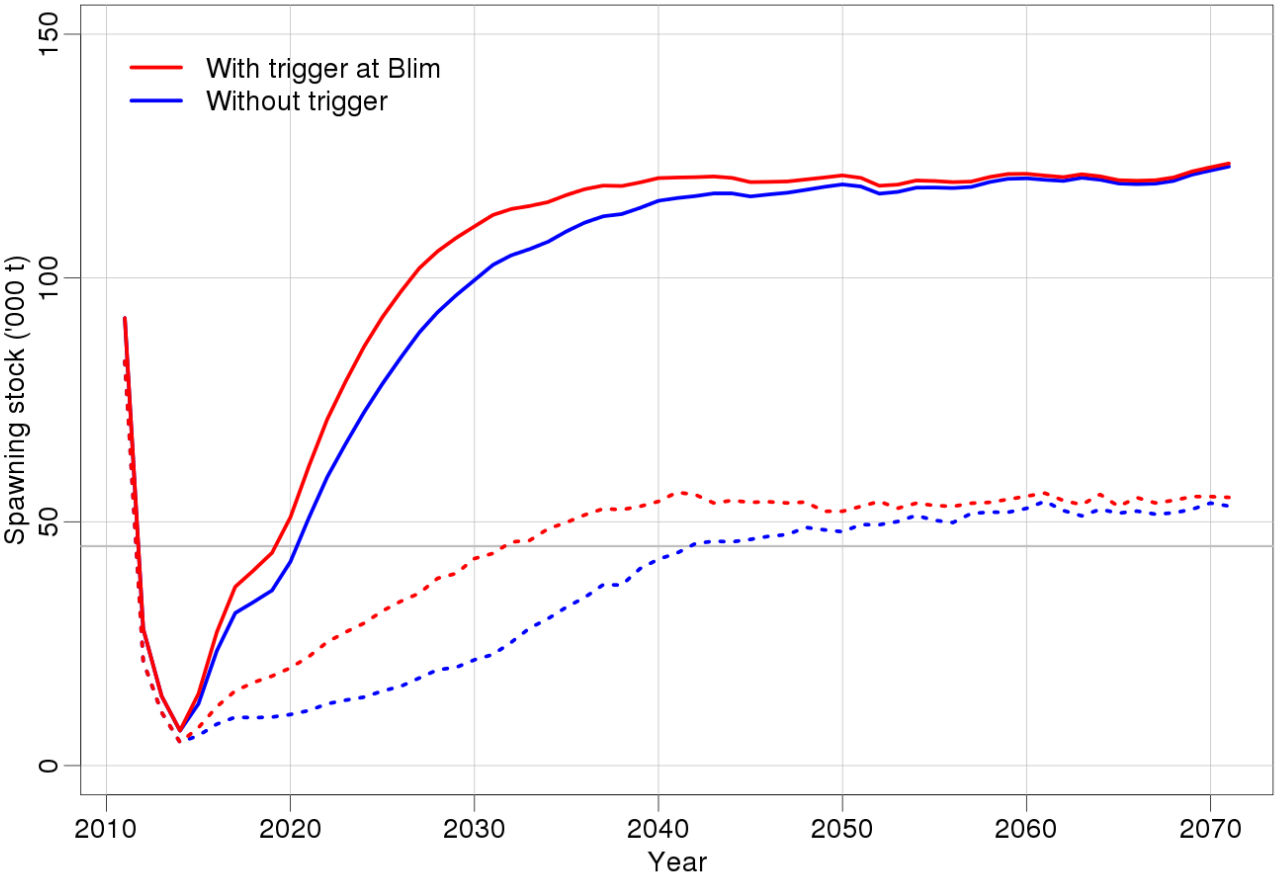

Figure 2.3.3.1.4 Recovery from low biomass. Spawning-stock biomass trajectory (5^{th} percentiles and mean) when the starting biomass in the beginning of the simulations is set at a very low level (20% of B_{lim}). Two harvest control rules are tested with reduced HR below $B_{trigger}$ (red) and without reduction (blue). For the harvest control rule without a reduction below $B_{trigger}$ it takes ten years longer before the 5^{th} percentile recovers above B_{lim}.

Table 2.3.3.1.1 Probability of spawning stock being below B_{lim} for different harvest ratios in a management plan based on biomass of haddock at 45 cm or larger in the advisory year.

	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50
2013	0	0	0	0	0	0	0	0	0	0
2014	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2015	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.1
2016	0.02	0.02	0.03	0.03	0.05	0.06	0.07	0.09	0.11	0.12
2017	0.02	0.02	0.02	0.04	0.05	0.06	0.07	0.08	0.09	0.1
2018	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.08	0.09
2019	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.08
2020	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.07
2021	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.08
2022	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07
2023	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07
2024	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.08
2025 on	0	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07

Table 2.3.3.1.2 The proportion of simulations that go below B_{lim} in the coming decade (2014–2013) and in a later decade (2051–2060) when the simulations have stabilized. The results are shown for different harvest ratios.

Harvest ratio	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50
2014–2023	0.07	0.09	0.10	0.13	0.16	0.19	0.22	0.25	0.28	0.31
2051–2060	0.02	0.04	0.05	0.07	0.09	0.12	0.14	0.17	0.20	0.25

Table 2.3.3.1.3 Key metrics from the histograms shown in Figure 2.3.3.1.3.

	5^{th} percentile	95^{th} percentile	Mean
SSB (in thousand tonnes)	55	210	121
Refbio 45 cm and larger (in thousand tonnes)	56	233	129
Catch (in thousand tonnes)	23	94	52
Harvest ratio	0.29	0.57	0.42
Fishing mortality (F_{4-7})	0.21	0.62	0.37
Mean absolute interannual change in catch is 9.9 thousand tonnes.			

Annex

Annex 2.3.3.1 Basis of the calculation of TAC for the proposed plan

Stock weights for the assessment year (y) by age (a) are available at the time of the assessment from a survey in March. Numbers-at-age are available from the assessment. The advice is based on SSB and B_{45cm+} in the advisory year (y+1). For those calculations catch, catch weights, and selection in the assessment year and stock weights and proportion mature in the advisory year are required. The calculations can then be done by spreadsheet or R scripts used for prediction.

Catch weights in the assessment year (y) by age (a) are predicted from stock weights by

$$cW_{a,y} = 8.65813 sW_{a,y}^{0.7388}$$ **Equation 2.3.3.1.1**

Selection pattern in the assessment year is a function of stock weights:

$$S_{a,y} = \frac{1}{1+e^{-\beta \log(\frac{sW_y}{sW_{50}})}}$$ **Equation 2.3.3.1.2**

where the current parameter estimates are β =2.07 and $sW_{50} = 1424$

Catch in the assessment year (C_y) is predicted as the remaining TAC in the current fishing year (y−1/y) + 1/3 of the predicted TAC for the next fishing year (y/y+1).

Knowledge of $N_{a,y}, cW_{a,y}, S_{a,y}$ for all ages and C_y is sufficient to calculate $N_{a,y+1}$

Stock weights (sW) in the advisory year (y+1) of age 3 and older are predicted from stock weights in the assessment year by

$$\log \frac{sW_{a+1,y+1}}{sW_{a,y}} = 2.646 - 0.30648 sW_{a,y} + \delta_{year}$$ **Equation 2.3.3.1.3**

The growth factor δ_{year} for the assessment year (y) has, in short-term predictions, been assumed to be unchanged from the year before the assessment year. In the long-term simulations δ_{year} was linked to stock size.

Contribution of age 2 to reference biomass 45 cm and larger and spawning stock is very small, so accurate prediction of mean weight-at-age is not needed. The approach used in the long-term simulations is recommended.

$$sW_{2,y+1} = 198 - 0.115(N_{2,y+1} + N_{3,y+1})$$ **Equation 2.3.3.1.4**

Proportion of mature fish by age (a) in the advisory year (y+1) is calculated from

$$P_{a,y+1} = \frac{1}{1+e^{12.642-1.933\log(sW_{a,y+1})}}$$ **Equation 2.3.3.1.5**

Reference biomass of haddock at 45 cm and larger in the advisory year (y+1) is calculated from

$$B_{45+,y+1} = \sum_a N_{a,y+1} sW_{a,y+1} \frac{1}{1+e^{-25.224-5.307\log\frac{sW_{y+1,a}}{44.5^3}}}$$ **Equation 2.3.3.1.6**

The sum is over all age groups but the contribution of age 3 and younger is small.

Spawning-stock biomass (SSB) in the advisory year (y+1) is calculated from

$$SSB_{y+1} = \sum_a N_{a,y+1} sW_{a,y+1} P_{a,y+1}$$ **Equation 2.3.3.1.7**

$$TAC_{y/y+1} = \min(1, \frac{SSB_{y+1}}{SSB_{trigger}})0.4B_{45+,y+1}$$ **Equation 2.3.3.1.8**

As $\frac{1}{3}$ of $TAC_{y/y+1}$ is assumed to be taken in the assessment year the procedure has to be repeated if the original estimate of $TAC_{y/y+1}$ is not close to the initial estimate.