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

Advice summary

ICES has evaluated the current biological precautionary reference points and considers that B_{lim} = 61 000 t. B_{pa}, F_{lim}, and F_{pa} are not defined. HR_{MSY} is estimated to be in the range of 0.20 to 0.25; the higher values within this range are expected to result in probabilities greater than 0.05 that SSB< B_{lim}. No changes to the current MSY reference points are proposed.

ICES concludes that the harvest control rule for Icelandic saithe 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 $SSB_{trigger}$:*
>
> $$TAC_{y/y+1} = \alpha\ (SSB_y/SSB_{\text{trigger}})\ B_{4+,y}$$
>
> *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 $SSB_{trigger}$=65000t.*
>
> ***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 saithe. The ICES advice to evaluate the management plan and harvest rule for Icelandic haddock is dealt with in Section 2.3.3.1.

Elaboration on the advice

Re-evaluation of reference points

ICES has defined the biological precautionary reference points to be B_{lim} = 61 000 t based on B_{loss}, the lowest observed biomass (in 1997). This is in accordance with the previous methodology used for this stock, updated with current assessment values. No other PA reference or limit points are required to evaluate the management plan and are therefore not proposed.

Proposed management plan

The proposed management plan for Icelandic saithe fishery, setting a TAC based on a harvest rate (HR) of 0.20 of the biomass of B_{4+} in the assessment year, is considered to be precautionary. This approach is thought to have lower risks than a management plan using a short-term forecast and F because the HR approach is more robust to changes in selection pattern in the fishery. As the proposed plan is based on harvest rates, ICES expresses MSY exploitation rates in terms of a harvest rate ($TAC_{y/y+1}$ = 0.2 $B_{4+,y}$). Evaluations of HR_{MSY} give HR values between 0.20 and 0.25, depending on the assumptions. Exploitation at the higher end of these values is considered to result in increased probability of SSB< B_{lim} (Table 2.3.3.2.1 and Figure 2.3.3.2.1) with little gain in catch (Figure 2.3.3.2.2). Setting a TAC based on HR below 0.20 will result in a marginal decrease in the maximum long-term catch.

The inclusion of the management point $SSB_{trigger}$ (65 kt) in the proposed plan was considered necessary to reduce the probability of SSB< B_{lim} to 0.05.

Suggestions

The proposed HCR is discontinuous at $SSB_{trigger}$ because the catch stabilizer is removed below $SSB_{trigger}$. A continuous rule (see Annex 2.3.3.2.1) has two potential advantages. It stabilizes the catch over all biomasses, reducing interannual change in catch, and never creates a step change in catch across the stock status trigger point that occurs with the discontinuous rule. ICES considers that the continuous catch stabilizer should be preferred to the discontinuous catch stabilizer in the original proposal.

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 in the beginning of 2012. The objective of this 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. The rules investigated were similar to those initially tested in the ICES Benchmark Workshop in 2010 (ICES, 2010).

Last year ICES advised that a TAC should be set as 0.20 of the biomass of B_{4+}, the basis being ICES MSY framework.

There have been no previous evaluations of this proposed plan.

Results and conclusions

The results of simulation of HCR in terms of key population metrics (e.g. recruitment, catch, biomass, and exploitation rate) are given in Figure 2.3.3.2.3. The future dynamics are expected to be similar to those observed historically since the average historical mortality has been only marginally higher than the proposed rule.

The proposed HCR is discontinuous at $SSB_{trigger}$ because the catch stabilizer is removed below $SSB_{trigger}$. Two other options were tested (Figure 2.3.3.2.4): a version with no catch stabilizer or $SSB_{trigger}$, and a continuous version of the proposed HCR with a catch stabilizer throughout (see Annex 2.3.3.2.1).

The HCR rules were evaluated relative to:

- Probability of SSB being below B_{lim} expressed as a fraction (ICES considers that an HCR is precautionary if the maximum annual probability that SSB is below B_{lim} is ≤ 0.05).
- Long-term high yield. The median over the iterations is used.

The value of the harvest rate that results in the highest long-term yield is 0.23; however, this HR is associated with a higher than 0.05 probability of SSB< B_{lim} and would not be classed as precautionary.

The continuous and the discontinuous catch stabilizer rules are both considered precautionary for TACs set based on harvest rates less than or equal to 0.20 (Tables 2.3.3.2.1 and 2.3.3.2.2). At the proposed harvest rate of 0.20, it is expected that the spawning biomass has a probability of going below B_{lim} at least once in the first 10 years (Table 2.3.3.2.3).

Continuous stabilization has two potential advantages. It never creates a step change in the catch advice across the stock status trigger point as occurs with the discontinuous rule (Figure 2.3.3.2.4), but rather stabilizes the catch above and below $B_{trigger}$. This reduces the interannual change in catch from 18 kt without catch stabilization to 14 kt with stabilization (Figure 2.3.3.2.5).

The expected range of realized harvest rates when setting a TAC based on a 0.20 of the biomass of B_{4+} is 0.12 to 0.32 (Figure 2.3.3.2.6). The realized harvest rate will be higher than the estimated point value of $HR_{MSY} = 0.23$ in one third of the cases, but overall the rule is considered in accordance with MSY. The expected range of spawning biomass is 63 to 272 kt (Figures 2.3.3.2.3 and 2.3.3.2.7), with the median being around the highest observed historically. The expected range of the biomass of B_{4+} is 122–499 kt (Table 2.3.3.2.4), which is within the historical range. These distributions can in the future be used to check that realized ranges are in line with expectations. If future observed values were to go outside the range illustrated this would indicate that there were good reasons to re-evaluate the assumptions behind the simulations.

A sensitivity analysis shows that the proposed plan leads to stock recovery if the spawning-stock biomass is reduced to half of the B_{lim} (Figure 2.3.3.2.9), assuming a linear reduction in mean recruitment below the breakpoint in the S–R function (65 kt).

Methods

A Management Strategy Evaluation (MSE) was conducted for the Icelandic saithe stock using a specifically developed code (http://www.hafro.is/~einarhj/ices_2013_hcr_evaluation.html). 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 recent average, this being close to the long-term mean. The selection pattern used was the same as the one currently 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. No short-term forecast is required when applying the HCR, the TAC being based on the harvest rate as a proportion of the biomass of B_{4+} in the assessment year. The spawning-stock biomass in the assessment year is used as a trigger to modify the harvest rate.

The analyses were based on 2500 iterations for each harvest rate or HCR rule.

Sources

ICES. 2010. Report of the Benchmark Workshop on Roundfish (WKROUND), 9–16 February 2010, Copenhagen, Denmark. ICES CM 2010/ACOM:36. 183 pp.

Hjörleifsson, E. and Björnsson, H. 2013. Report of the evaluation of the Icelandic saithe management plan. ICES CM 2013/ACOM:61.

Source code for simulations

http://www.hafro.is/~einarhj/ices_2013_hcr_evaluation.html

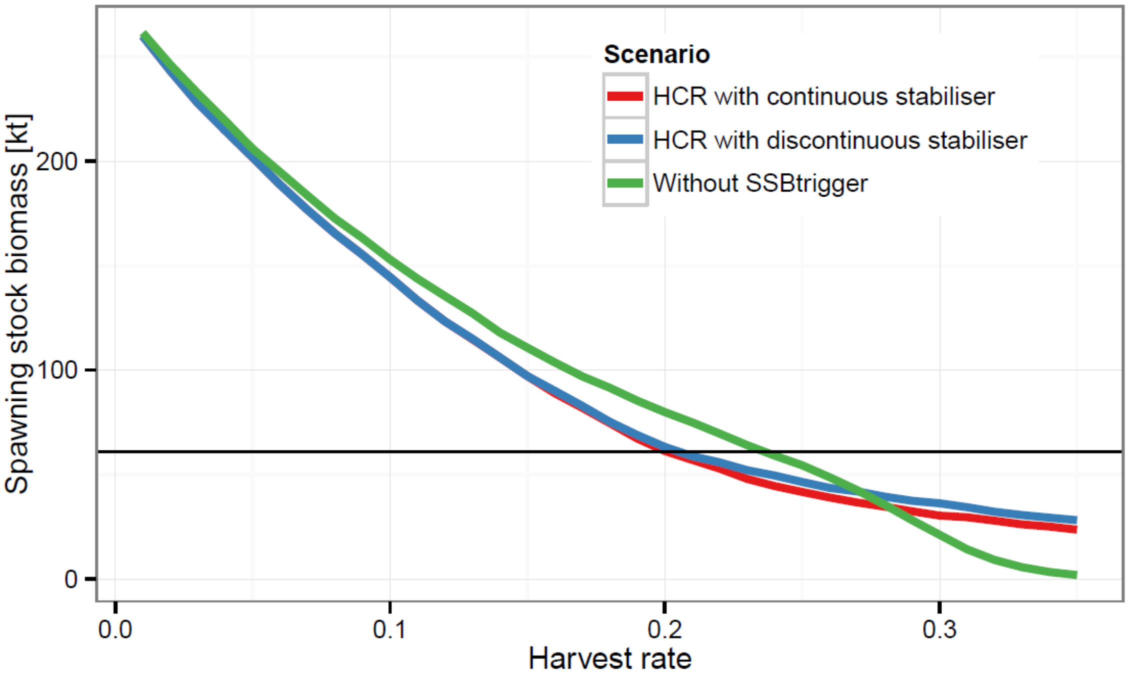

Figure 2.3.3.2.1 The 5th percentile of the spawning-stock biomass as a function of setting different harvest rates in the HCR. The blue line is for the HCR with discontinuous catch stabilizer, the red line the HCR with continuous catch stabilizer, and the green line when no catch stabilizer or $B_{trigger}$ is set in the rule. The horizontal line represents B_{lim}. See Figure 2.3.3.2.4 for a visual description of these rules.

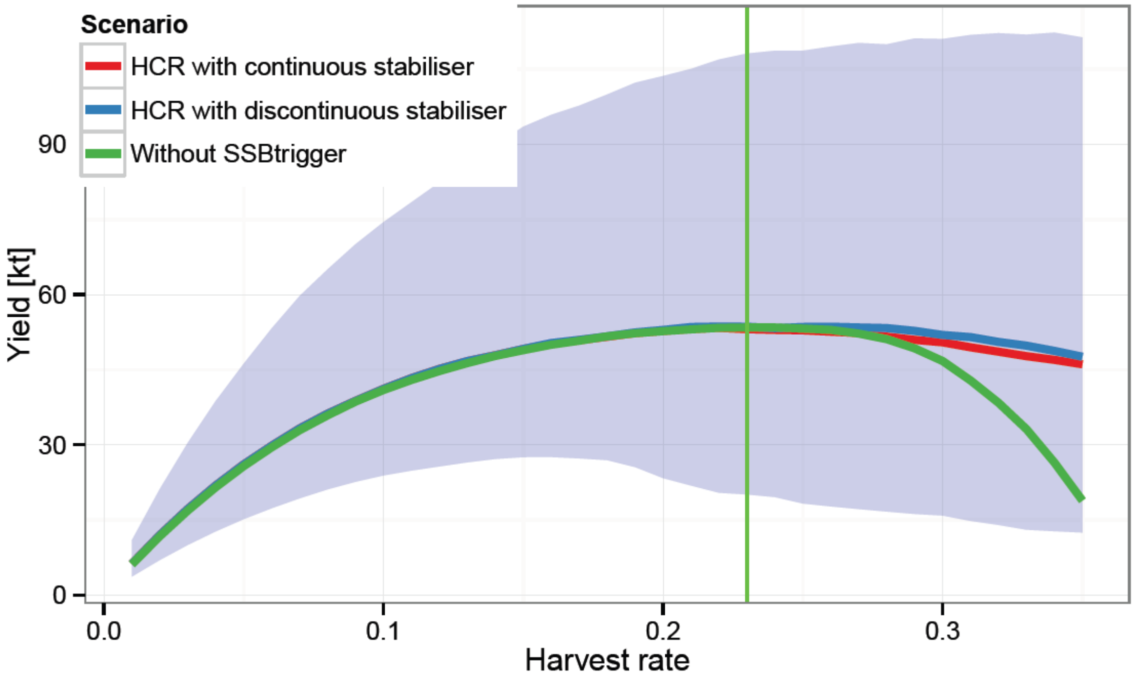

Figure 2.3.3.2.2 Catch as a function of setting different harvest rates in the HCR. The blue line and the shaded area show the median and the 5th and 95th percentiles of catch for the discontinuous HCR, the red line shows the median for the continuous rule, and the green line when no catch stabilizer or $SSB_{trigger}$ is set in the rule. The vertical line indicates the point value of the harvest rate that results in maximum catch.

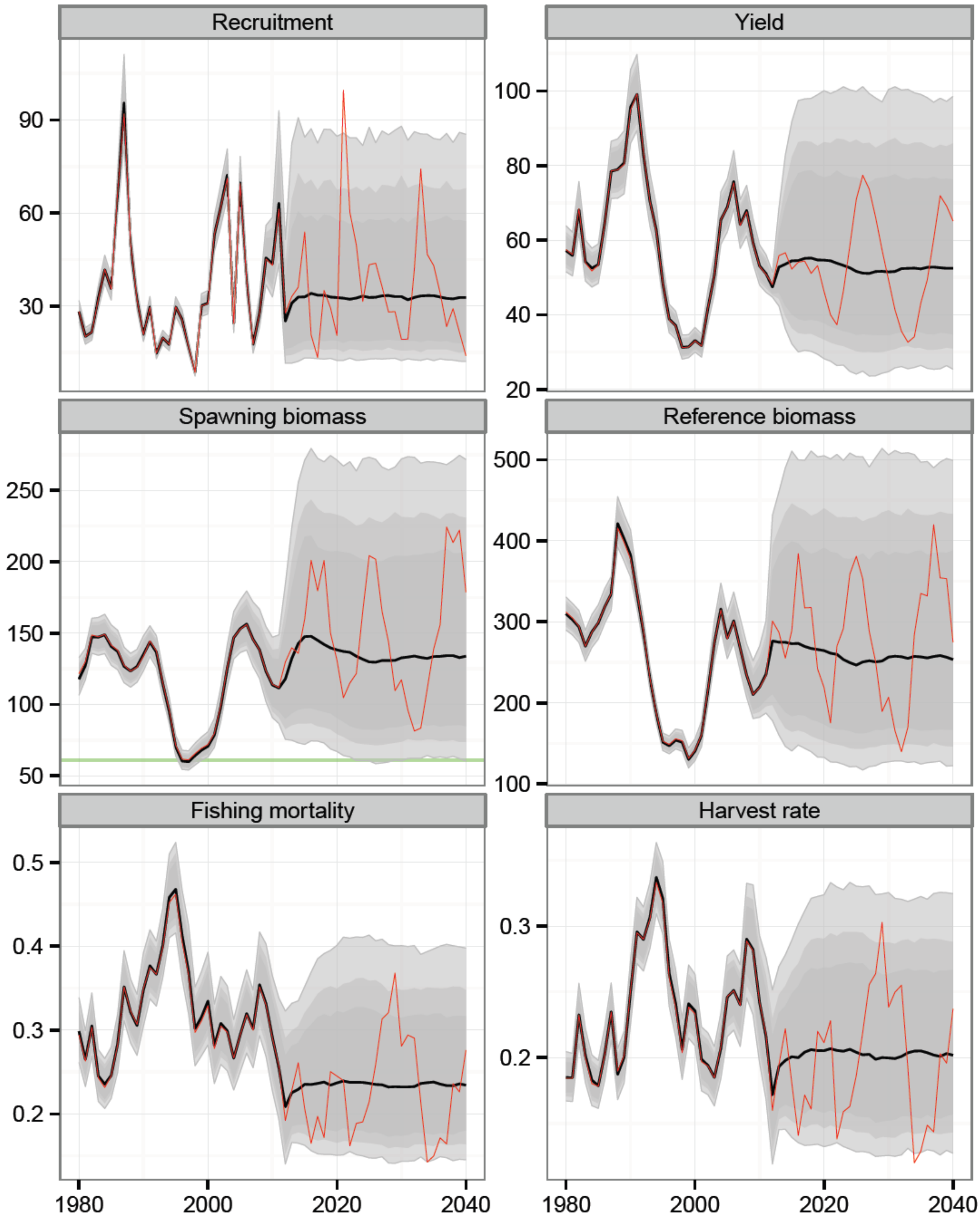

Figure 2.3.3.2.3 Time-series plots of historical assessment and simulations based on a harvest rate of 0.20 for the HCR with continuous catch stabilizer. The shading shows the 90%, 80%, and 50% range of values with the median depicted in black. One random draw is displayed in red. The horizontal line in the spawning-stock biomass panel refers to B_{lim}. The upper scale of the y-axis is set to the 99.5 percentiles of observations.

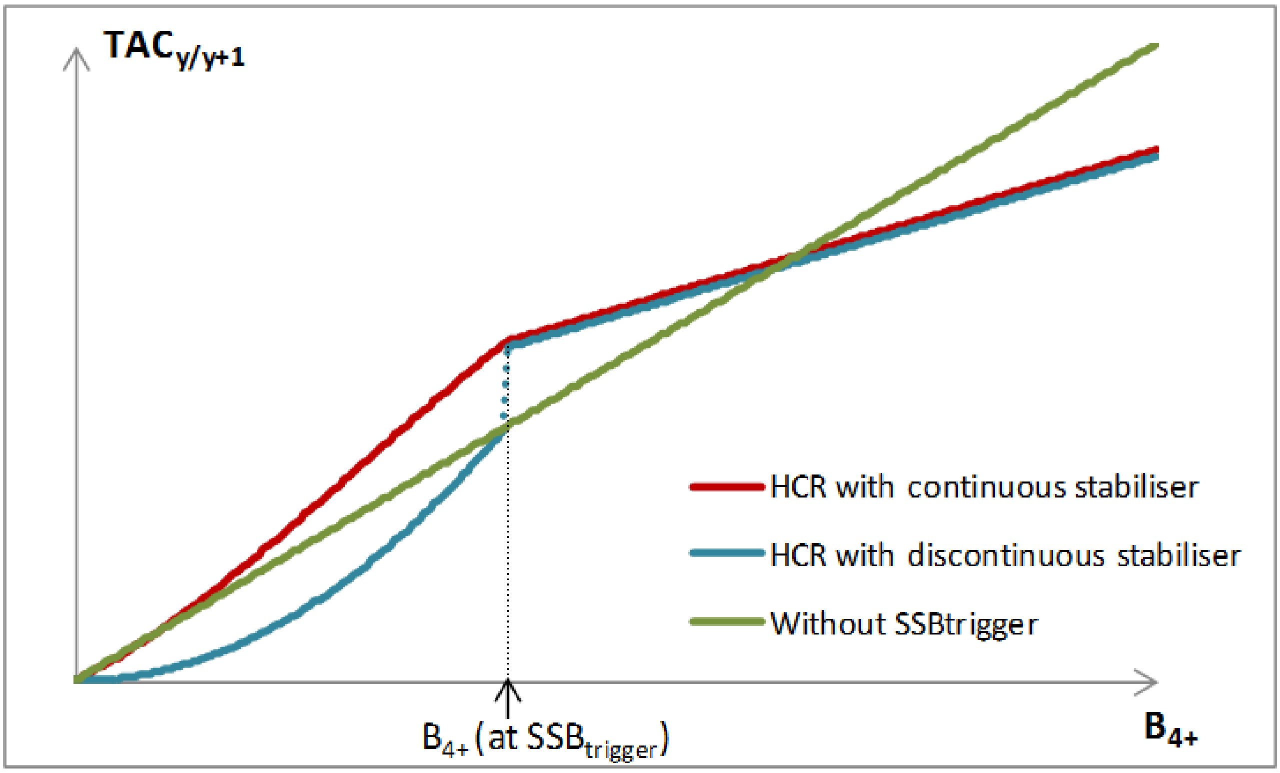

Figure 2.3.3.2.4 Visual description of the Icelandic saithe harvest control rules: HCR with continuous stabilizer (red); HCR with discontinuous stabilizer (blue; the discontinuity is indicated by a dotted line); Rule without $SSB_{trigger}$ or stabilizer (green). An offset has been added to the discontinuous HCR above the trigger to make the rules distinguishable (otherwise the continuous and discontinuous rules overlap above the trigger). [Note, for illustrative purposes, the discontinuity shown may be larger than would be realized in practice.]

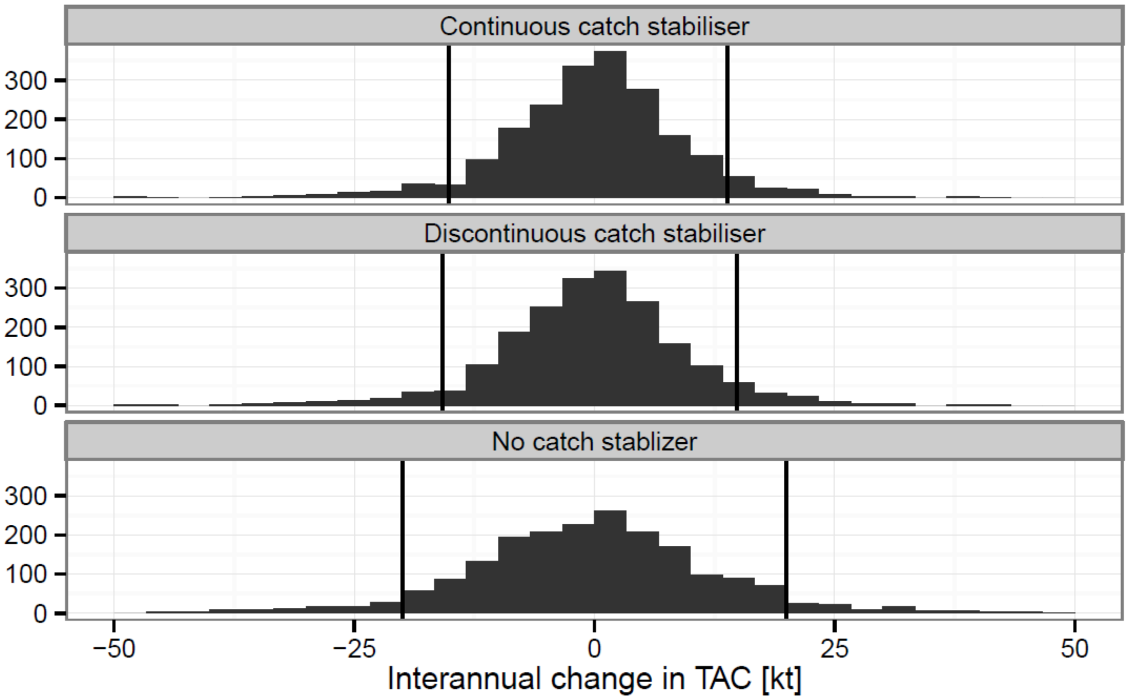

Figure 2.3.3.2.5 Interannual changes in TAC (in thousand tonnes) for HCR with no catch stabilizer, with a discontinuous catch stabilizer (off below $B_{trigger}$), and with a continuous catch stabilizer when a TAC is set based on 0.20 of the biomass of B_{4+}. Grey vertical lines represent the 5^{th} and 95^{th} percentiles of the distribution, B_{lim} being represented by a black line.

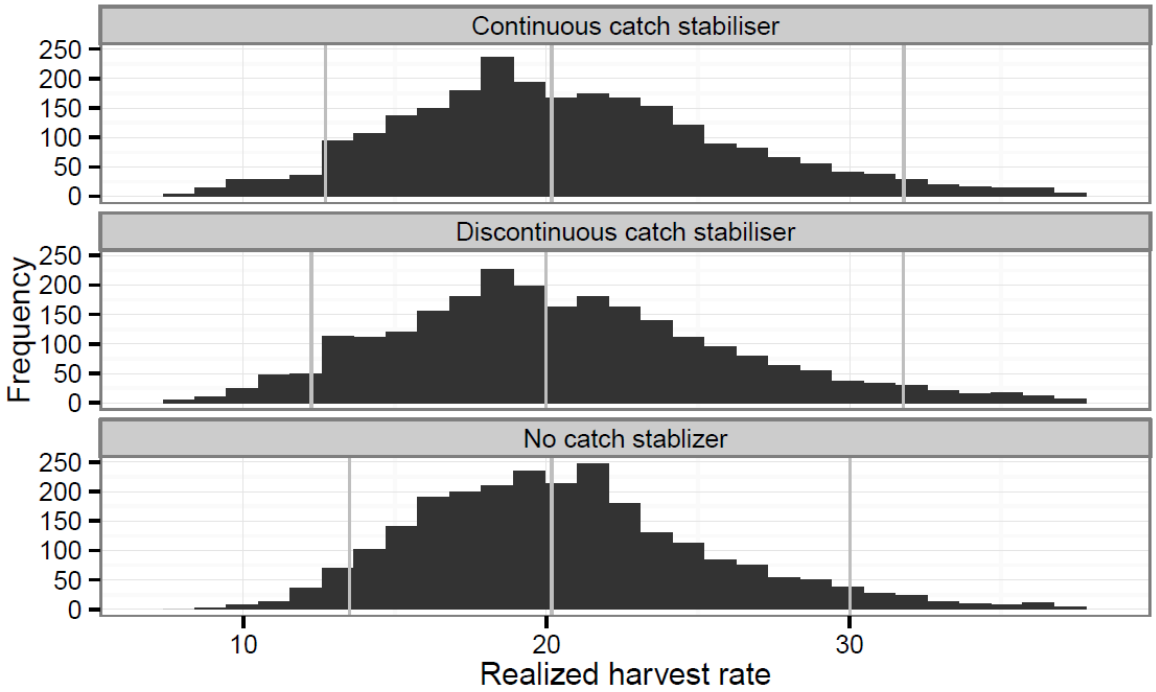

Figure 2.3.3.2.6 Distribution of the resulting harvest rate for HCR with no catch stabilizer, with a discontinuous catch stabilizer (off below $B_{trigger}$), and with a continuous catch stabilizer when a TAC is set based on 0.20 of the biomass of B_{4+}. Grey lines represent the 5^{th}, median, and 95^{th} percentiles of the distribution.

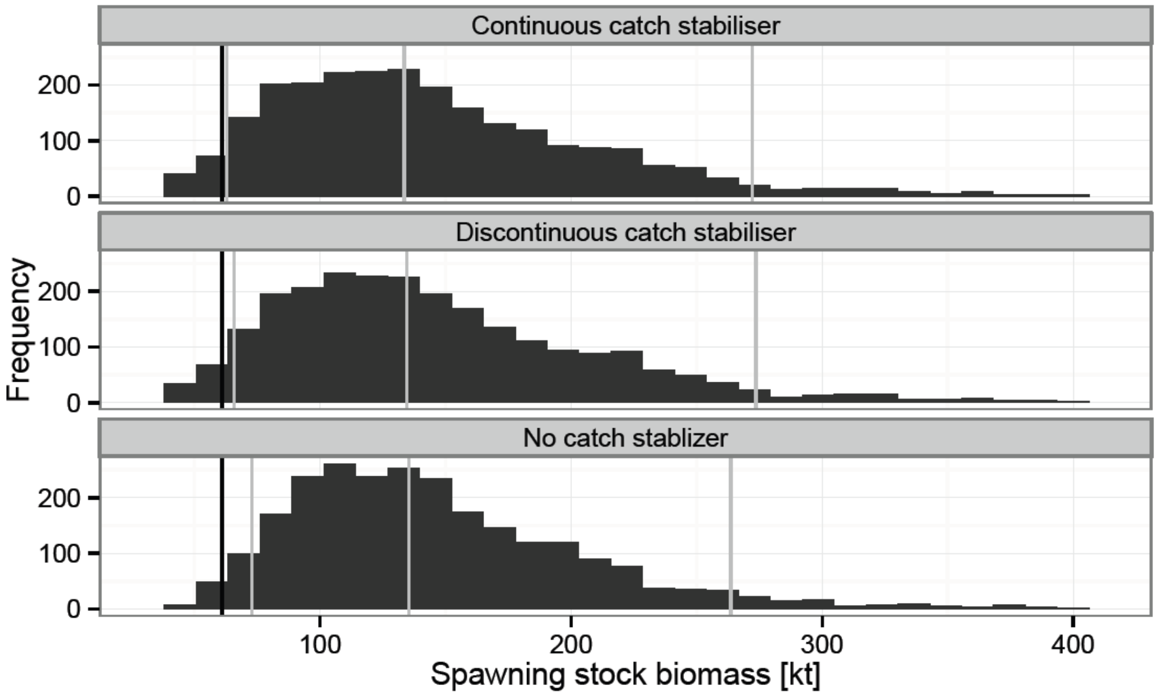

Figure 2.3.3.2.7 Distribution of spawning-stock biomass (SSB) for HCR with no catch stabilizer, with a discontinuous catch stabilizer (off below $B_{trigger}$), and with a continuous catch stabilizer when a TAC is set based on 0.20 of the biomass of B_{4+}. Grey vertical lines represent the 5^{th}, median, and 95^{th} percentiles of the distribution, B_{lim} being represented by a black line.

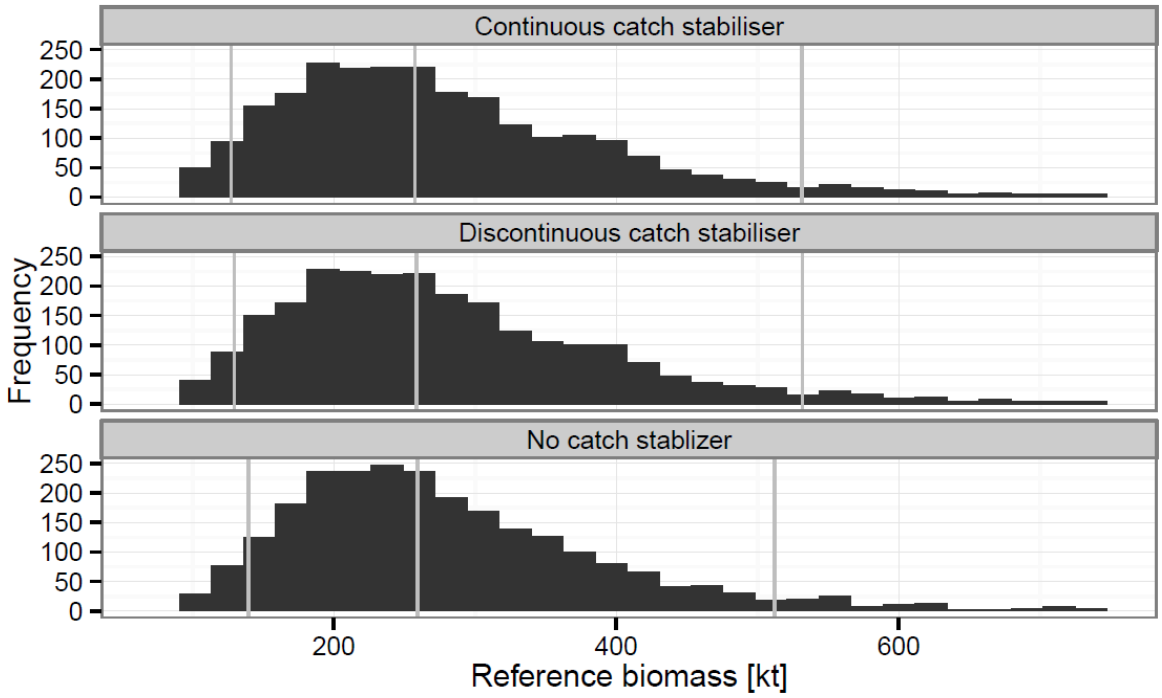

Figure 2.3.3.2.8 Distribution of biomass of B_{4+} for HCR with no catch stabilizer, with a discontinuous catch stabilizer (off below $B_{trigger}$), and with a continuous catch stabilizer when a TAC is set based on 0.20 of the biomass of B_{4+}. Grey vertical lines represent the 5^{th}, median, and 95^{th} percentiles of the distribution.

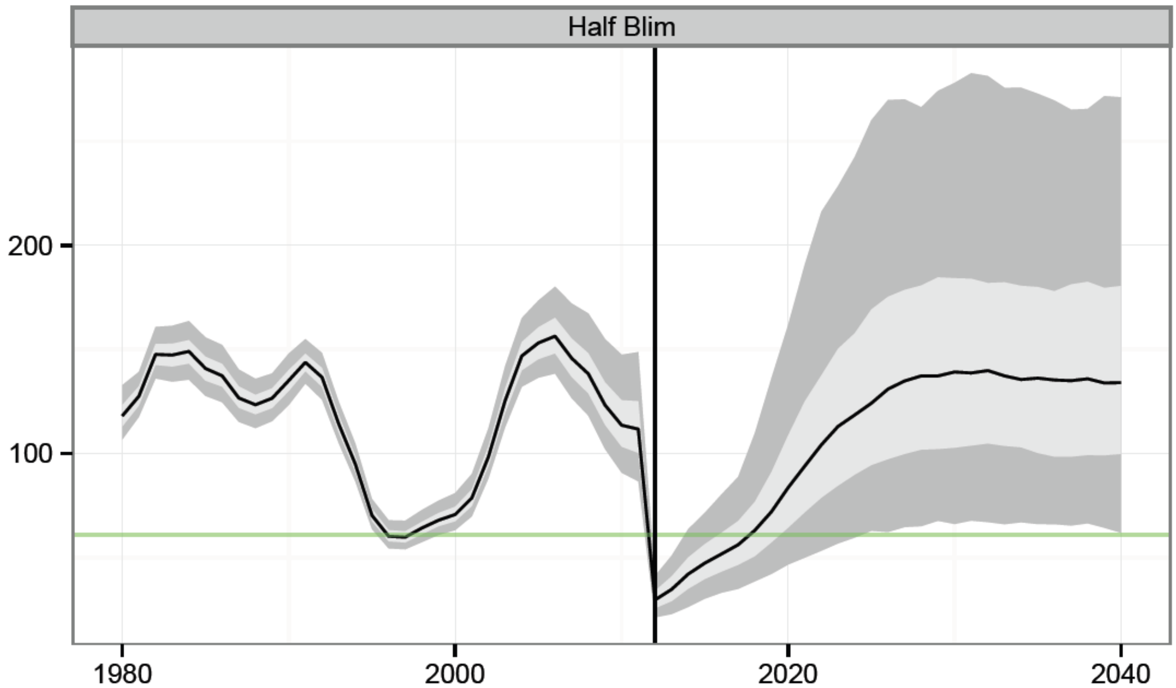

Figure 2.3.3.2.9 Spawning-stock biomass trajectory (5^{th}, 25^{th}, median, 75^{th}, and 95^{th} percentiles) when the starting biomass in 2012 is set to half of B_{lim}. The projections are based on the 0.20 harvest rate in the HCR with discontinuous catch stabilizer.

Table 2.3.3.2.1 Proposed HCR with discontinuous catch stabilizer. The probability of SSB< B_{lim} when a TAC is set based on a harvest rate of 0.15–0.25. Shown are annual probabilities for the first ten years of the simulation, the last ten years of the simulation, and the average annual probabilities for the last ten years (2061:2070).

year	15	16	17	18	19	20	21	22	23	24	25
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
2015	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03
2016	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.05
2017	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.06	0.08
2018	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.08	0.11
2019	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.05	0.07	0.10	0.13
2020	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.07	0.09	0.12	0.15
2021	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.12	0.14
2022	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.12	0.15
2061	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.07	0.09	0.11	0.13
2062	0.00	0.01	0.01	0.02	0.02	0.04	0.05	0.07	0.09	0.12	0.14
2063	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.07	0.10	0.12	0.14
2064	0.00	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.10	0.12	0.15
2065	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.12	0.15
2066	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.08	0.10	0.12	0.15
2067	0.00	0.01	0.01	0.02	0.02	0.04	0.05	0.07	0.10	0.12	0.15
2068	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.07	0.10	0.12	0.15
2069	0.00	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.10	0.11	0.14
2070	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.07	0.09	0.11	0.14
2061:2070	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.07	0.10	0.12	0.14

Table 2.3.3.2.2 HCR with continuous catch stabilizer. The probability of SSB< B_{lim} when TAC is set based on a harvest rate of 0.15–0.25. Shown are annual probabilities for the first ten years of the simulation, the last ten years of the simulation, and the average annual probabilities for the last 10 years (2061:2070).

year	15	16	17	18	19	20	21	22	23	24	25
2013	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
2014	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03
2015	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.05
2016	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.04	0.05	0.06
2017	0.00	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.05	0.07	0.09
2018	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.12
2019	0.00	0.00	0.01	0.01	0.01	0.03	0.04	0.06	0.09	0.12	0.15
2020	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.08	0.10	0.14	0.18
2021	0.00	0.00	0.01	0.01	0.02	0.04	0.06	0.09	0.11	0.14	0.18
2022	0.00	0.00	0.01	0.02	0.03	0.04	0.06	0.09	0.12	0.16	0.19
2061	0.01	0.01	0.02	0.02	0.03	0.04	0.06	0.08	0.11	0.13	0.16
2062	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.09	0.11	0.13	0.17
2063	0.01	0.01	0.01	0.02	0.03	0.05	0.06	0.09	0.11	0.14	0.17
2064	0.01	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.12	0.14	0.17
2065	0.01	0.01	0.02	0.02	0.03	0.04	0.07	0.09	0.11	0.15	0.17
2066	0.00	0.01	0.01	0.02	0.04	0.05	0.07	0.09	0.11	0.14	0.17
2067	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.09	0.12	0.15	0.17
2068	0.00	0.00	0.01	0.02	0.03	0.05	0.06	0.09	0.12	0.15	0.17
2069	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.09	0.11	0.14	0.16
2070	0.00	0.01	0.01	0.02	0.03	0.04	0.06	0.08	0.11	0.13	0.16
2061:2070	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.09	0.11	0.14	0.17

Table 2.3.3.2.3 HCR with discontinuous catch stabilizer. The cumulative proportion of iterations that have gone below B_{loss} when a TAC is set based on a harvest rate of 0.15–0.25.

year	15	16	17	18	19	20	21	22	23	24	25
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
2015	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.03
2016	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06
2017	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.10
2018	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.07	0.09	0.12	0.16
2019	0.01	0.01	0.01	0.02	0.03	0.05	0.07	0.10	0.13	0.16	0.21
2020	0.01	0.01	0.02	0.03	0.04	0.06	0.09	0.12	0.16	0.21	0.26
2021	0.01	0.01	0.02	0.03	0.05	0.07	0.11	0.15	0.19	0.25	0.30
2022	0.01	0.01	0.02	0.04	0.06	0.09	0.13	0.17	0.22	0.29	0.34
2023	0.01	0.02	0.03	0.05	0.07	0.10	0.15	0.20	0.25	0.32	0.38
2024	0.01	0.02	0.03	0.05	0.08	0.12	0.17	0.23	0.28	0.36	0.42
2025	0.01	0.03	0.04	0.06	0.09	0.13	0.19	0.25	0.31	0.39	0.46
2026	0.02	0.03	0.04	0.07	0.11	0.15	0.21	0.28	0.34	0.42	0.49
2027	0.02	0.03	0.05	0.08	0.12	0.17	0.23	0.30	0.37	0.45	0.52
2028	0.02	0.04	0.06	0.09	0.13	0.18	0.25	0.32	0.39	0.48	0.54
2029	0.02	0.04	0.06	0.09	0.14	0.19	0.26	0.34	0.41	0.50	0.57
2030	0.02	0.04	0.07	0.10	0.15	0.21	0.28	0.35	0.43	0.53	0.60
2031	0.02	0.04	0.07	0.11	0.16	0.22	0.29	0.37	0.45	0.55	0.62
2032	0.02	0.05	0.08	0.12	0.17	0.23	0.31	0.39	0.47	0.57	0.64
2033	0.03	0.05	0.08	0.12	0.18	0.25	0.32	0.41	0.49	0.59	0.66
2034	0.03	0.05	0.09	0.13	0.19	0.26	0.34	0.42	0.51	0.61	0.68
2035	0.03	0.05	0.09	0.13	0.20	0.27	0.35	0.44	0.53	0.63	0.70
2036	0.03	0.06	0.09	0.14	0.20	0.28	0.37	0.46	0.55	0.65	0.72
2037	0.03	0.06	0.10	0.15	0.21	0.29	0.38	0.47	0.56	0.66	0.74
2038	0.03	0.06	0.10	0.15	0.22	0.30	0.39	0.49	0.58	0.68	0.75
2039	0.04	0.07	0.11	0.16	0.23	0.32	0.41	0.50	0.60	0.69	0.77
2040	0.04	0.07	0.11	0.17	0.24	0.33	0.42	0.52	0.61	0.71	0.78
2041	0.04	0.07	0.12	0.17	0.25	0.34	0.44	0.53	0.62	0.72	0.79
2042	0.04	0.07	0.12	0.17	0.26	0.35	0.45	0.55	0.64	0.74	0.81

Table 2.3.3.2.4 5^{th}, median, and 95^{th} percentiles of the key metrics for HCR with continuous catch stabilizer.

	5^{th} percentile	95^{th} percentile	Median
SSB (in thousand tonnes)	63	272	134
Refbio (in thousand tonnes)	122	499	253
Catch 1000 tonnes	25	103	53
Harvest ratio	0.12	0.32	0.20
Mean absolute interannual change in catch is 14 thousand tonnes.			

Annexes

Annex 2.3.3.2.1 HCR with continuous catch stablizer

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 $B_{trigger}$:

$$TAC_{y/y+1} = (1\text{-}\beta)\alpha\tilde{B}_{4+,y} + \beta TAC_{y-1/y}$$

2. When SBB_y is below $B_{trigger}$:

$$TAC_{y/y+1} = (1\text{-}\beta\frac{S\tilde{S}B_y}{B_{trigger}})\alpha\frac{S\tilde{S}B_y}{B_{trigger}}\tilde{B}_{4+,y} + \beta\frac{S\tilde{S}B_y}{B_{trigger}}TAC_{y-1/y}$$

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 where α=0,20, β=0.5 and $B_{trigger}$=65000 t.

Annex 2.3.3.2.2 Basis of the calculation of TAC for the proposed plan

The TAC for the fishing year is calculated based on biomass of 4 years and older fish (B_{4+}) in the assessment year. The biomass is calculated as the sum of products of the estimated stock in numbers-at-age in the assessment year, estimated with a separable model tuned with spring survey indices that include the spring survey measurement and the catch weight-at-age in the assessment year. The latter is predicted using the following model:

$$\log({}_{C}W_{t,a}) = \beta_0 + \beta_1 \log({}_{C}W_{t-1,a-1}) + \beta_2 \log({}_{S}W_{t,a})$$

where ${}_{C}W_{t,a}$ is catch weights from the current year, ${}_{C}W_{t-1,a-1}$ catch weights from the previous year, and ${}_{S}W_{t,a}$ survey weights from the current year.

The weights in the spawning-stock biomass in the assessment year are the same as those used in the biomass of B_{4+}. The maturity-at-age is obtained from the spring survey measurements using the following smoother:

$$\text{logit}(P_{a,t}) = \alpha + \beta\ age + \text{ns}(year, \text{df} = 6)$$

where *P* is the proportion mature-at-age *a* in year *t*, and ns are smoothing splines.