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NEAFC request concerning long-term management strategy for herring in the Northeast Atlantic (Norwegian spring-spawning herring)

Advice summary

Please note: **The present advice has been updated to include the evaluation of the long-term management strategy options chosen by the Coastal States in October 2018.** ‡

ICES has evaluated the long-term management strategy (LTMS) for Norwegian Spring-Spawning (Atlanto-Scandian) Herring. The harvest control rule (HCR) proposed for the LTMS is found to be consistent with the precautionary approach. In addition, the HCR remains precautionary when constraints on interannual TAC change are added (-20%/+25%), and is also robust to 10% banking or borrowing of quota between years.

ICES has additionally evaluated the harvest control rules proposed for the Norwegian spring-spawning herring stock as requested by NEAFC. The options that are precautionary and maximize the long-term yield are identified in the tables. Comparing short-, medium-, and long-term results, for the HCRs without a constraint on the interannual variation of the TAC, a main conclusion is that, for any given [F_{target}, $B_{trigger}$] or [HR_{target}, $B_{trigger}$] combinations, the probability (P) of SSB falling below B_{lim} [P(SSB< B_{lim})] is highest for the medium term for all rules tested. This is as expected, given the current low stock size. Generally, the rules with two biomass trigger points ($B_{trigger}$ and B_{lim}; rules 2 and 4) have lower P(SSB< B_{lim}) than the rules with a single biomass trigger point ($B_{trigger}$ only; rules 1 and 3).

In general, higher [F_{target}, $B_{trigger}$] or [HR_{target}, $B_{trigger}$] combinations give the highest yields, although the differences are small for options with P(SSB< B_{lim}) less than 5%. When comparing the yields for the different rules in the medium term, a general pattern is that the yields are similar between F rules and biomass rules.

Increasing the F_{target}, HR_{target}, or the $B_{trigger}$ in the HCR leads to increased interannual variability in yield. The interannual variability in yield was generally lower for the biomass rules (rule 3 and 4) than for the F rules (rule 1 and 2), and also generally lower for the average TAC constraint than for the +25%/−20% TAC constraint. The lowest interannual variability was found for the biomass rule (rule 3) when an average constraint was included.

During this evaluation it became apparent that the fishing mortality reference points published in April (ICES, 2018a) were estimated incorrectly. These were re-estimated; F_{MSY} was revised from 0.108 to 0.157, F_{pa} was revised from 0.182 to 0.227, and F_{lim} was revised from 0.234 to 0.291.There was not enough time to evaluate the effect of allowing a maximum of 10% of the TAC to be banked or borrowed any year.

Request

Request to ICES concerning a long-term management strategy for Norwegian spring-spawning herring

In order to revise the long-term management plan for Norwegian spring-spawning herring consistent with the new stock assessment model (ICES 2016; 2017) and the corresponding updated reference points (ICES 2018a; 2018b), a Management Strategy Evaluation is needed. The objective is to ensure harvest of the stock within safe biological limits. The Parties therefore request ICES to evaluate the following harvest control rules.

Rule 1

- *A range of $B_{trigger}$ from 1 to 6 million tonnes with a range of target Fs from 0.05 to 0.25.*
- *The fishing mortality is the average for age groups 5 to 12+ weighted by stock numbers.*
- *Time of comparison for SSB is the same as used in the assessment.*

‡The harvest control rule selected by the Coastal States was initially not evaluated for robustness to the inclusion of TAC constraints and banking and borrowing by WKNSSHMSE. Following the Coastal States agreement for the long-term management strategy, which included TAC constraints (-20% to +25%) and 10% banking or borrowing, additional simulations were run to evaluate these additions to the HCR (Annex 9 in ICES, 2018c).

- *A harvest control rule with a fishing mortality equal to the target F when SSB is at or above $B_{trigger}$.*
- *In the case that the SSB is forecast to be less than $B_{trigger}$, the TAC shall be fixed consistently with a fishing mortality that is given by:*
  $F = F_{target} * SSB/B_{trigger}$
- *The following special case is to be evaluated: $B_{trigger}$=3.184 (=MSY $B_{trigger}$=B_{pa}) and the target fishing mortality of 0.102 (F_{MSY}).*

Rule 2

- *A range of $B_{trigger}$ from 2.5 to 6 million tonnes with a range of target Fs from 0.05 to 0.25.*
- *The fishing mortality is the average for age groups 5 to 12+ weighted by stock numbers.*
- *Time of comparison for SSB is the same as used in the assessment.*
- *A harvest control rule with a fishing mortality equal to the target F when SSB is at or above $B_{trigger}$.*
- *In the case that the SSB is forecast to be less than B_{lim}, the target F is 0.05.*
- *In the case that the SSB is forecast to be between B_{lim} and $B_{trigger}$, the target F will decrease linearly between those two points.*
- *The following special case is to be evaluated: $B_{trigger}$=3.184 (=MSY $B_{trigger}$=B_{pa}) and the target fishing mortality of 0.102 (F_{MSY}).*

Rule 3

- *A proxy for SSB (SSB_{proxy}) is defined as the biomass of herring aged 5 and older or an appropriate age range as identified by ICES.*
- *The reference biomass (B_{ref}) is defined as the biomass of herring aged 4 and older or an appropriate age range as identified by ICES.*
- *Time of comparison for SSB_{proxy} is the same as used for SSB in the assessment.*
- *A range of $B_{trigger}$ from 1 to 6 million tonnes with an approriate range of harvest rate (HR_{target}).*
- *A harvest control rule with $TAC=HR_{target} * B_{ref}$ when SSB_{proxy} is at or above $B_{trigger}$.*
- *In the case that the SSB_{proxy} is forecast to be less than $B_{trigger}$, the $TAC = HR_{target} * B_{ref} * (SSB_{proxy}/B_{trigger})$*
- *The following special case is to be evaluated: Btrigger=3.184 (=MSY $B_{trigger}$=B_{pa}) and a harvest rate equivalent to 0.102 (F_{MSY}).*

Rule 4

A biomass rule intended to be equivalent to Rule 2 with two levels of harvest rate: target harvest rate = HR_{target} when SSB_{proxy} is greater than $B_{trigger}$; harvest rate = HR_{lowest} when SSB_{proxy} is below B_{lim}; and harvest rate decreasing linearly between these bounds.

Evaluation and performance criteria

Starting point of the evaluations should be the current stock status as estimated by the most recent assessment and be consistent across time.

Each alternative shall be assessed in relation to how it performs in the short term (2019-2023), medium term (2024-2033) and long term (2034-2053) in relation to:

- *Average SSB*
- *Average yield*
- *Indicator for year to year variability in SSB and yield*
- *Risk of SSB falling below B_{lim}*

Evaluation of the management strategies shall be simulated:

- *With no constraint on the interannual variation of TAC.*
- *With a constraint on the interannual variation of TAC:*
  - *When the rules would lead to a TAC, which deviates by more than 20% below or 25% above the TAC of the preceding year, the TAC is to be set respectively no more than 20% less or 25% more than the TAC of the preceding year.*
  - *The TAC is to be set as the average of a) the current TAC and b) the TAC that would result from the application of the harvest control rule without constraint for the TAC year.*

- *The TAC constraint shall not apply if the SSB (rule 1 and 2) or SSB_{proxy} (rule 3 and 4) in the year for which the TAC is to be set is less or equal to Btrigger.*
- *Allowing a maximum of 10% to be banked or borrowed any year.*

ICES is also requested to assess what, if any, other measures in addition to those contained in the present Management Strategy might contribute to attaining the objectives of the strategy, and provide estimates of their efficiency.

Finally, it is expected that the Parties will, as appropriate, review and revise these management measures and strategies on the basis of any new advice provided by ICES.

Elaboration on the advice

Evaluation of the fishing mortality reference points

During these evaluations, two changes were made which impacted on the estimates of fishing mortality reference points. Ages 0–1 were included in the analysis and the number of iterations in the simulation model were increased to improve the stability of the estimates. These changes had a minor impact on the biomass reference points, which were kept unchanged, but fishing mortality reference points were different.

The estimation of fishing mortality reference points is sensitive to inputs and assumptions. The current management plan target of 0.125 has been used for nearly two decades without driving the stock below B_{lim}. The current analysis confirms that this fishing mortality is precautionary since it is below F_{MSY} (= F_{p05}).

Evaluation of the four rules suggested for long-term management strategy

The target fishing mortality values evaluated are in the range of 0.10 to 0.20. These were used in combination with $B_{trigger}$ values in the range of 2.5–5 million tonnes, including MSY $B_{trigger}$ = 3.184 million t. The target harvest rate values evaluated range from 0.07 to 0.15. Comparing short-, medium-, and long-term tables for the HCRs without a constraint on the interannual variation of the TAC, a main result is that, for any given [F_{target}, $B_{trigger}$] or [HR_{target}, $B_{trigger}$] combination, the P(SSB< B_{lim}) is highest in the medium term (Tables 3 and 4). This is as expected, given the current low stock size.

For rule 1 (where F is reduced linearly below the biomass target), F_{target} values around 0.15 to 0.18 combined with $B_{trigger}$ values around 4.0 to 5.0 million t resulted in the highest median long-term yield (Table 5). Similar results were found for the medium term, although yield is generally lower in the medium term than in the long term. In the short term, the median yield is even lower because of the current low stock size. The highest yields were found at F_{target} values around 0.125 to 0.17 combined with $B_{trigger}$ values around 3.5 to 5 million t.

For rule 2 (where F is reduced to 0.05 below B_{lim} and reduced linearly below the biomass target), a higher number of [F_{target}, $B_{trigger}$] combinations were found precautionary compared to rule 1, likely because rule 2 has a steeper reduction in F below $B_{trigger}$. For rule 2, the highest median long-term yields were at F_{target} values around 0.17 to 0.20 combined with $B_{trigger}$ values around 4.0 to 5 million t (Table 5). In the medium term, the highest median yields were found at F_{target} values around 0.18 to 0.20 combined with $B_{trigger}$ values around 4 to 5 million t. In the short term, the highest median yields were found at F_{target} values around 0.16 to 0.20 combined with $B_{trigger}$ values around 3.5 to 4 million t.

For rule 3 (the biomass rule, with a linear decline in harvest rate), HR_{target} values around 0.12 to 0.14 in combination with $B_{trigger}$ values around 4.5 to 5 million t resulted in the highest median long-term yields. In the medium term this was achieved at HR_{target} values around 0.12 to 0.13 combined with $B_{trigger}$ values around 4.5 to 5 million t (Table 6). The short-term median yield was highest with combinations of HR_{target} values around 0.12 to 0.13 and $B_{trigger}$ values around 4.5 to 5 million t.

Similar to the F rules (rules 1 and 2) the biomass rule, with two changes in harvest rate (rule 4), had a higher number of precautionary combinations compared to rule 3. The highest median long-term yields for rule 4 were found at HR_{target} values around 0.13 to 0.15 combined with $B_{trigger}$values around 4 to 5 million t (Table 6). In the medium term the highest median yield was achieved at HR_{target} values around 0.14 to 0.15 combined with $B_{trigger}$ values around 4.5 to 5 million t. In the short term the highest median yield was achieved at HR_{target} values around 0.11 to 0.13 combined with $B_{trigger}$ values around 3.5 to 4 million t.

Increasing the F_{target}, HR_{target}, or the $B_{trigger}$ in the HCR leads to increased interannual variability (IAV, defined here as % change between any two consecutive years) in yield. When no constraint on TAC variation is included in the F rules, the interannual variability ranges from about 17% for [low F_{target}, low $B_{trigger}$] combinations to about 30% for [high F_{target}, high $B_{trigger}$] precautionary combinations (Table 7). When a TAC constraint based on an average TAC is included, the range is approximately 9–17%, and when a +25%/−20% TAC constraint is included the range is 19–21%. For the biomass rules (Table 8), the variability for rules without TAC constraint varied between 9% and 16%, for an averaging TAC constraint the variability was 7%–12%, and for the +25%/−20% TAC constraint the variability was 10−16%. Implementation of the TAC constraint for rules 1 and 3 had minor impact in terms of average yield.

It is important to note that [high F_{target}, high $B_{trigger}$] combinations result in actual Fs that can, on average, be substantially lower than the target F (Table 9). This is because the F used to set the catch according to the HCR is reduced below the F_{target} whenever the SSB is forecasted to be below $B_{trigger}$. So rules with higher target F do not necessarily result in overall higher Fs in reality, but will result in higher interannual changes in both F and yield.

For any given [F_{target}, $B_{trigger}$] or [HR_{target}, $B_{trigger}$] combination, the interannual yield variability range widens considerably with increases in either the F_{target}, HR_{target}, or the $B_{trigger}$. In such cases interannual yield variability values that are much higher than the medians reported in the tables cannot be ruled out (Figure 2).

Precautionary [F_{target}, $B_{trigger}$] combinations were identified (Table 1). There is a set of "borderline" combinations, corresponding to the 5% risk (i.e. probability of SSB falling below B_{lim}), in which larger values of F_{target} are associated with larger values of $B_{trigger}$ (for the same 5% risk) and vice versa. The precautionary F_{target} values associated with the lowest and the highest $B_{trigger}$ values and with MSY $B_{trigger}$ are shown in Table 1.

Table 1 Maximum precautionary F_{target}(≤ 5% risk) under the lowest, highest, and MSY $B_{trigger}$ values for rule 1 in the medium term.

	$B_{trigger}$ = 2.5 million t	$B_{trigger}$ = 5 million t	$B_{trigger}$ = MSY $B_{trigger}$ = 3.184 million t
No TAC change constraint	0.10	0.17	0.10
Average TAC constraint	0.10	0.17	0.12
+25%/−20% TAC constraint	0.10	0.17	0.12

There was not enough time to evaluate the last point in the request: to test the effect of allowing a maximum of 10% to be banked or borrowed any year.

Evaluation of the long-term management strategy chosen by the Coastal States[§]

The harvest control rule selected by the Coastal States was initially not evaluated for precautionarity to TAC constraints and banking and borrowing by WKNSSHMSE. Following the Coastal States agreement for the long-term management strategy, additional simulations were run to evaluate the LTMS. The results indicate that the LTMS is consistent with the precautionary approach (the maximum annual probability of SSB being below B_{lim} is less than 5% in any of the years simulated). In addition, the HCR remains precautionary when constraints on interannual TAC change and 10% banking or borrowing of quota between years are added. Full results are presented in Annex 2.

Basis of the advice

Background

The Norwegian spring-spawning herring (NSSH) was benchmarked in 2016 (ICES, 2016) and XSAM was accepted as the assessment model for this stock. The reference points were reevaluated in 2018 (ICES, 2018a). ICES advised that the current B_{lim} value of 2.5 million tonnes for the Norwegian spring-spawning herring (NSSH) should be retained while B_{pa} and MSY $B_{trigger}$ should be revised to 3.184 million tonnes. ICES furthermore advised that F_{MSY} should be set to 0.102, with F_{lim} being revised to 0.234 and F_{pa} revised to 0.182.

[§] Version 2: Section added.

In May 2018 NEAFC sent a request to ICES for an evaluation of a range of harvest control rules that could form the basis for a long-term management strategy for the stock. This request was dealt with by WKNSSHMSE (ICES Workshop on management strategy evaluation for the Norwegian spring spawning herring in subareas 1, 2 and 5, and in divisions 4.a and 14.a), meeting in 26–27 August 2018, and also working by correspondence (ICES, 2018c).

During WKNSSHMSE, because of issues related to the historical time-series of SSB/R pairs, the fishing mortality reference points established earlier in 2018 (ICES, 2018a) were revised, as explained above.

Results and conclusions

Results and conclusions are detailed in the elaboration on the advice section above, and in Annex 1.

In the present evaluation, the assessment was assumed to be unbiased, which may not be the case. A sensitivity analysis was carried out assuming 10% and 15% bias. This bias increased the probability of SSB falling below B_{lim}; however, the actual level of bias is currently unknown.

Methods

The simulations done are based on the assessment model (XSAM) used in ICES to conduct annual assessments for this stock. In the assessment, the model is run for ages 2–12+ and for the years 1988 to present (ICES, 2018d).

The effect on the simulation output of the variability in biological parameters (weights and proportion fish mature-at-age) has been evaluated for the F rules and found to be very small relative to the effect of the very high variability in recruitment. Therefore, long-term unweighted means (1988–2017) were used for the future mean weights-at-age and proportion mature-at-age in the simulations.

The recruitment model was a combination of the Beverton–Holt, Ricker, and segmented regression stock and recruitment functions.

The variation of the selection pattern in the simulation were generated using the same time-series model as in the assessment.

To establish the basis for MSE, the model is run from 1950 to present to obtain a sufficiently long time-series to estimate an appropriate stock–recruitment relationship. The assessment provides the approximated simultaneous distribution of all parameters and stock sizes such that initial values can be sampled from this approximated distribution. The catch in 2018 is set as the quota for 2018. For 2019 onwards catches are given by the proposed management strategies tested.

One replicate is obtained as follows: Sample one realization of stock sizes-at-age for 1st January 2018 from the assessment made in 2017 and parameters specifying the model for fishing mortality from their simultaneous distribution. Sample one set of parameters for the spawning-stock recruitment model independently from stock sizes. For one set of initial values, parameters for F, and parameters for spawning-stock recruitment, the stock is projected forward for a given management strategy using assessment and prediction errors until 2053. The performance statistics as a function of sample size (number of replicates) were found to have stabilized after 3000 replicates.

Sources and references

ICES. 2016. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA), 29 February–4 March 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM 2016/ACOM:34. 106 pp.

ICES. 2017. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 30 August–5 September 2017, ICES Headquarters, Copenhagen, Denmark. ICES CM 2017/ACOM:23. 994 pp.

ICES. 2018a. Report of the Workshop on the determination of reference points for Norwegian Spring Spawning herring (WKNSSHREF), 10–11 April 2018, ICES Headquarters, Copenhagen, Denmark. ICES CM 2018/ACOM:45. 83 pp.

ICES. 2018b. Coastal States request for ICES to re-evaluate the reference points for Norwegian spring-spawning herring. *In* Report of ICES Advisory Committee, 2018. ICES Advice 2018, sr.2018.06. Issued 26 April 2018.

ICES. 2018c. Report of the Workshop on a long-term management strategy for Norwegian Spring-spawning herring (WKNSSHMSE), 26-27 August 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM:53. 113pp. ICES. 2018d. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 28 August–3 September 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM: 23. 488 pp.

Annex 1

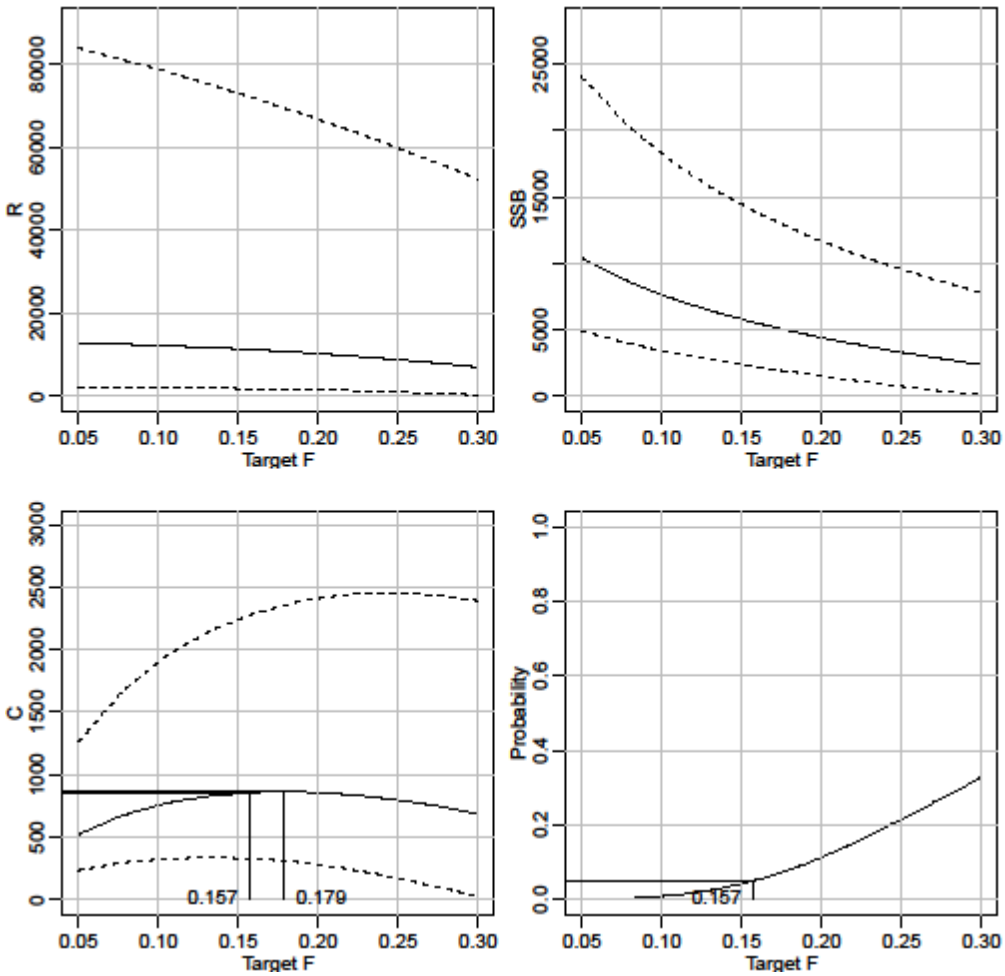

Figure 1 Median recruitment, SSB, and catch when fishing with constant target F without MSY $B_{trigger}$, including prediction error, and the probability of falling below B_{lim} in any year using the MSY approach with MSY $B_{trigger}$ = B_{pa} (lower right panel). The corresponding 5th and 95th percentiles are shown with dashed lines. The F_{MSY} point and the F_{p05} value are indicated with vertical lines.

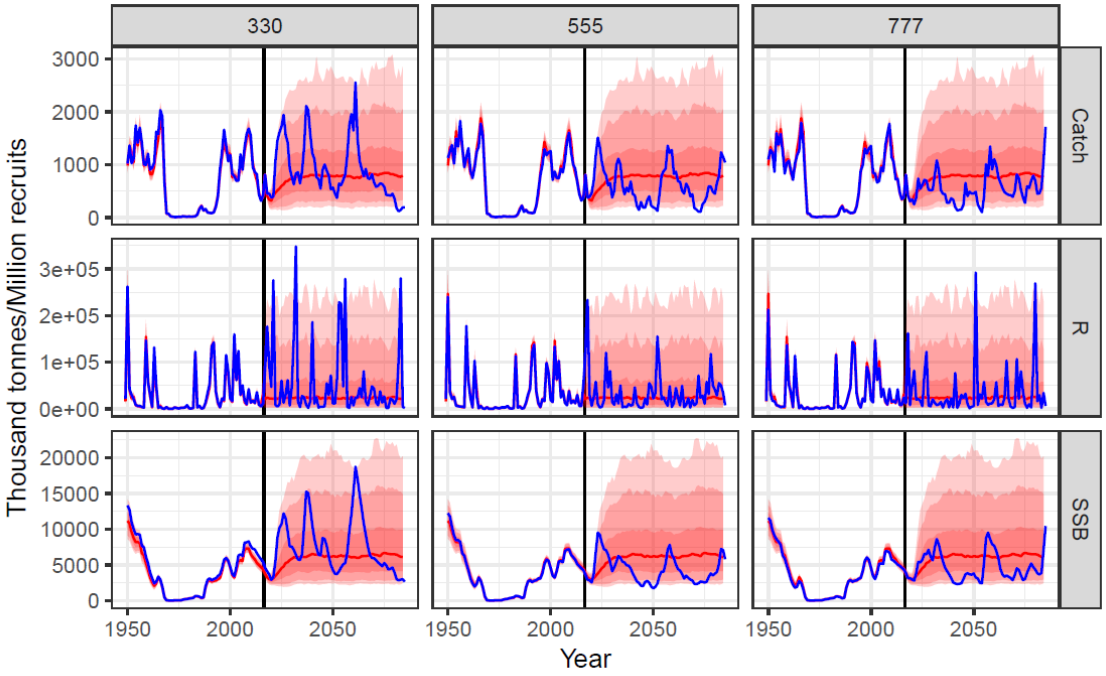

Figure 2 Simulation results for 2019–2053 together with the historical assessment, for Rule 1 ($B_{trigger}$ = 3184 thousand tonnes, F_{target} = 0.125). The three rows correspond to the realised catch, recruitment, and SSB, and show the 5th, 25th, 50th, 75th, and 95th percentiles of their distribution. The columns correspond to three particular realisations (numbered on top, selected semi-randomly).

Table 3 Risk, with P(SSB< B_{lim}), expressed as % in the short, medium, and long term for F rules without and with constraint in interannual TAC change. Unshaded cells correspond to the precautionary [F_{target}, $B_{trigger}$] combinations [P(SSB< B_{lim})< 5%].

Risk3 tables for F-rules

Rule 1 - F-rule through 0,0

shortterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	4.2	4.4	6.2	6.7	8.7	9.8	11.0	11.7	13.0	14.9	18.6
3184	3.2	3.4	5.3	5.7	7.1	8.2	8.9	9.3	10.8	12.0	15.4
3500	2.7	2.9	4.5	4.9	6.3	7.3	7.9	8.1	9.2	10.4	13.2
4000	2.1	2.2	3.0	3.5	4.8	5.6	6.3	6.6	7.4	8.2	10.2
4500	1.7	1.8	2.5	2.7	3.5	4.4	4.8	4.9	5.9	6.7	8.1
5000	1.6	1.6	2.0	2.1	2.7	3.0	3.6	3.9	4.5	5.1	6.7

mediumterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	4.2	4.4	6.3	7.0	9.2	10.8	11.9	12.2	14.0	15.7	19.1
3184	3.3	3.5	5.2	5.8	7.5	8.9	9.7	10.2	11.4	12.9	16.2
3500	2.8	3.0	4.5	4.9	6.6	7.5	8.4	8.8	10.1	11.3	14.2
4000	2.3	2.3	3.3	3.7	5.2	6.1	6.8	6.9	8.1	9.2	11.4
4500	1.7	1.8	2.6	2.9	3.7	4.7	5.2	5.5	6.3	7.2	9.1
5000	1.3	1.4	2.0	2.3	3.0	3.5	3.9	4.1	4.8	5.7	7.2

longterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	2.5	2.7	4.7	5.1	6.6	8.0	9.2	9.8	11.7	13.2	17.1
3184	2.0	2.1	3.4	4.0	5.4	6.3	7.3	7.7	9.0	10.7	13.8
3500	1.6	1.7	2.9	3.3	4.5	5.4	6.2	6.5	7.9	9.2	12.1
4000	1.3	1.4	2.3	2.5	3.5	4.3	4.8	4.9	5.9	7.1	9.7
4500	1.1	1.1	1.6	1.8	2.5	3.2	3.7	4.0	4.6	5.4	7.3
5000	0.9	0.9	1.3	1.4	2.0	2.4	2.8	3.0	3.6	4.2	5.4

Rule 1 with average constraint

shortterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	5.0	5.1	6.4	6.7	8.3	9.4	10.3	10.7	12.1	13.2	16.1
3184	3.1	3.3	5.2	5.4	6.3	7.7	8.2	8.5	9.5	11.1	13.5
3500	2.6	2.8	4.2	4.7	5.9	6.7	7.4	7.7	8.6	9.7	12.1
4000	2.1	2.2	3.0	3.4	4.7	5.5	6.1	6.4	7.1	8.0	9.9
4500	1.7	1.8	2.5	2.7	3.5	4.4	4.8	4.9	5.9	6.5	8.0
5000	1.6	1.6	2.0	2.1	2.7	3.0	3.6	3.9	4.5	5.1	6.7

mediumterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	4.5	4.6	6.3	7.1	9.0	10.4	11.4	11.8	13.2	15.0	18.4
3184	3.3	3.4	4.9	5.5	7.0	8.2	9.1	9.5	10.7	12.2	15.0
3500	2.7	2.9	4.3	4.7	6.3	7.1	8.0	8.3	9.5	10.8	13.4
4000	2.3	2.3	3.2	3.6	5.0	5.9	6.5	6.7	7.7	8.8	11.0
4500	1.6	1.7	2.5	2.9	3.7	4.6	5.1	5.3	6.2	7.0	8.9
5000	1.3	1.4	2.0	2.3	3.0	3.4	3.9	4.0	4.8	5.6	7.1

longterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	2.6	2.8	4.8	5.3	7.1	8.6	9.6	10.1	11.8	13.6	18.0
3184	1.9	2.0	3.3	3.7	5.2	6.3	7.2	7.6	9.2	10.7	13.9
3500	1.6	1.7	2.8	3.2	4.4	5.3	6.1	6.4	7.6	9.1	11.8
4000	1.3	1.4	2.2	2.5	3.5	4.2	4.7	4.8	5.9	6.8	9.7
4500	1.1	1.1	1.5	1.7	2.6	3.3	3.7	3.8	4.6	5.2	7.2
5000	0.9	0.9	1.3	1.4	1.9	2.4	2.8	3.0	3.6	4.2	5.4

Rule 1 with 25/20% TAC-constraint

shortterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	4.3	4.5	6.2	6.7	8.4	9.9	10.6	10.9	12.2	13.6	15.7
3184	3.1	3.3	5.1	5.6	6.9	7.7	8.4	8.6	9.6	11.1	13.1
3500	2.7	2.8	4.4	4.8	6.1	6.8	7.4	7.7	8.5	9.5	11.8
4000	2.1	2.2	3.0	3.4	4.7	5.5	6.1	6.3	7.1	7.9	9.8
4500	1.7	1.8	2.5	2.7	3.5	4.4	4.8	4.9	5.8	6.5	7.9
5000	1.6	1.6	2.0	2.1	2.7	3.0	3.6	3.9	4.5	5.1	6.7

mediumterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	4.1	4.3	6.2	6.7	8.9	10.2	11.2	11.5	13.0	14.5	17.5
3184	3.3	3.4	4.9	5.4	7.0	8.2	9.0	9.3	10.6	11.7	14.5
3500	2.7	2.9	4.3	4.7	6.2	7.1	7.9	8.2	9.4	10.5	12.8
4000	2.3	2.3	3.2	3.7	4.9	5.8	6.4	6.6	7.6	8.6	10.8
4500	1.6	1.7	2.5	2.8	3.7	4.5	5.0	5.2	6.1	7.0	8.7
5000	1.3	1.4	2.0	2.3	3.0	3.4	3.9	4.0	4.8	5.6	7.1

longterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	2.4	2.6	4.4	5.0	6.5	7.7	8.7	9.1	10.8	12.3	16.0
3184	1.7	1.9	3.1	3.6	5.1	6.0	6.8	7.1	8.5	9.8	12.8
3500	1.5	1.6	2.7	3.1	4.2	5.2	5.8	6.1	7.2	8.5	11.3
4000	1.3	1.4	2.2	2.4	3.3	4.0	4.5	4.7	5.4	6.6	8.9
4500	1.1	1.1	1.5	1.7	2.5	3.2	3.6	3.7	4.5	5.0	6.9
5000	0.8	0.9	1.3	1.4	1.8	2.4	2.7	2.9	3.4	4.2	5.3

Rule 2 - F-rule with Fmin = 0.05

shortterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	3.2	3.4	5.0	5.5	6.7	7.7	8.3	8.6	9.4	10.9	13.3
3184	2.4	2.4	3.2	3.5	4.3	5.1	5.4	5.5	6.2	6.9	8.1
3500	2.1	2.1	2.5	2.6	3.3	3.9	4.2	4.4	4.8	5.4	6.3
4000	1.8	1.8	2.1	2.2	2.4	2.6	2.8	2.9	3.3	3.5	4.4
4500	1.6	1.6	1.9	1.9	2.1	2.3	2.3	2.3	2.5	2.6	3.0
5000	1.6	1.6	1.6	1.7	1.9	2.0	2.1	2.1	2.2	2.3	2.5

mediumterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	3.3	3.4	4.9	5.2	7.0	8.2	8.8	8.9	10.1	11.2	13.5
3184	2.4	2.5	3.4	3.7	4.6	5.3	5.8	6.0	6.7	7.2	8.6
3500	2.1	2.1	2.9	3.0	3.9	4.4	4.8	4.9	5.3	6.1	7.0
4000	1.8	1.8	2.3	2.4	2.8	3.2	3.4	3.5	4.0	4.4	5.1
4500	1.5	1.6	1.8	2.0	2.4	2.5	2.7	2.8	3.0	3.4	3.8
5000	1.3	1.4	1.6	1.6	1.9	2.1	2.2	2.3	2.5	2.7	3.1

longterm risk

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	2.0	2.1	3.5	3.7	4.8	5.5	6.2	6.4	7.6	8.8	10.7
3184	1.5	1.5	2.2	2.5	3.2	3.6	4.0	4.1	4.9	5.6	6.7
3500	1.3	1.3	1.7	1.9	2.6	3.0	3.3	3.4	3.8	4.4	5.6
4000	1.1	1.2	1.4	1.5	1.9	2.2	2.4	2.5	2.9	3.2	3.9
4500	1.0	1.1	1.3	1.3	1.5	1.7	1.9	2.0	2.2	2.4	3.0
5000	0.9	0.9	1.1	1.1	1.3	1.4	1.5	1.5	1.9	2.0	2.3

Table 4 Risk, with P(SSB< B_{lim}), expressed as % in the short, medium, and long term for biomass rules without and with constraint in interannual TAC change. Unshaded cells correspond to the precautionary [F_{target}, $B_{trigger}$] combinations [P(SSB< B_{lim})< 5%].

Risk3 tables for biomass rules

Rule 3 - biomass rule going through 0,0

shortterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	2.9	4.1	5.3	6.5	8.3	10.6	12.7	15.3	17.6
3184	2.5	3.4	4.8	5.8	7.3	9.2	11.2	13.3	15.6
3500	2.2	2.9	4.1	5.1	6.2	7.8	10.0	11.7	13.7
4000	1.7	2.3	2.9	4.0	5.0	6.1	7.3	9.0	10.9
4500	1.6	1.8	2.3	2.9	3.7	4.9	5.5	6.5	8.0
5000	1.6	1.6	1.8	2.3	2.8	3.4	4.6	5.3	6.2

mediumterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	2.8	3.7	5.0	6.6	8.6	10.8	12.8	15.2	18.0
3184	2.4	3.1	4.0	5.4	7.4	9.1	11.2	12.9	15.2
3500	2.0	2.7	3.6	4.7	6.0	7.8	9.8	11.6	13.3
4000	1.5	2.1	2.8	3.7	4.5	6.0	7.2	8.8	10.7
4500	1.1	1.5	2.1	2.8	3.6	4.3	5.6	6.8	8.1
5000	0.9	1.2	1.6	2.2	2.7	3.5	4.1	5.2	6.6

longterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	1.4	2.0	3.1	4.4	6.0	7.7	10.0	12.1	14.8
3184	1.1	1.6	2.7	3.5	4.9	6.4	8.3	10.4	12.4
3500	1.0	1.4	2.3	3.1	4.2	5.6	7.2	9.1	11.2
4000	0.8	1.1	1.7	2.4	3.3	4.3	5.5	7.1	9.0
4500	0.6	1.0	1.3	1.8	2.6	3.2	4.2	5.2	6.7
5000	0.5	0.7	1.0	1.3	1.8	2.5	3.3	4.1	5.1

Rule 3 with average constraint

shortterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	4.0	4.9	5.9	7.1	8.8	10.4	12.1	14.2	15.8
3184	2.8	3.9	5.0	5.8	7.1	8.9	10.7	12.6	14.3
3500	2.3	3.1	4.2	5.1	6.1	7.5	9.4	11.3	12.9
4000	1.7	2.3	2.9	3.9	5.0	6.0	7.1	8.7	10.8
4500	1.6	1.8	2.3	2.9	3.7	4.9	5.5	6.5	7.8
5000	1.6	1.6	1.8	2.3	2.8	3.4	4.6	5.3	6.2

mediumterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	3.4	4.3	5.5	7.1	9.0	10.9	12.7	14.6	16.7
3184	2.7	3.2	4.2	5.5	7.4	9.0	10.7	12.4	14.5
3500	2.2	2.8	3.6	4.6	6.0	7.6	9.6	11.1	13.1
4000	1.5	2.2	2.8	3.7	4.4	6.0	7.2	8.8	10.5
4500	1.1	1.5	2.1	2.8	3.6	4.3	5.6	6.8	8.0
5000	0.9	1.2	1.6	2.1	2.7	3.5	4.1	5.1	6.5

longterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	1.6	2.4	3.6	5.1	6.6	8.9	11.1	13.6	16.7
3184	1.2	1.9	2.8	3.9	5.3	6.9	9.3	11.4	13.7
3500	1.1	1.6	2.4	3.4	4.5	5.9	8.0	9.9	12.1
4000	0.8	1.3	1.7	2.6	3.3	4.6	5.9	7.7	9.7
4500	0.6	1.0	1.3	1.9	2.6	3.4	4.4	5.8	7.3
5000	0.5	0.7	1.0	1.4	2.0	2.6	3.4	4.3	5.7

Rule 3 with25&20% TAC-constraint

shortterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	3.3	4.2	5.3	6.4	8.3	10.5	12.5	14.3	16.1
3184	2.5	3.5	4.8	5.7	7.2	9.1	11.0	12.6	14.3
3500	2.2	2.9	4.1	5.1	6.2	7.7	9.6	11.2	12.7
4000	1.7	2.3	2.9	4.0	5.0	6.0	7.1	8.7	10.5
4500	1.6	1.8	2.3	2.9	3.7	4.9	5.5	6.5	7.8
5000	1.6	1.6	1.8	2.3	2.8	3.4	4.6	5.3	6.2

mediumterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	2.9	3.8	5.1	6.6	8.5	10.7	12.6	14.5	16.9
3184	2.5	3.1	4.0	5.4	7.3	9.1	10.9	12.5	14.4
3500	2.1	2.7	3.5	4.6	5.9	7.8	9.7	11.1	12.9
4000	1.5	2.1	2.8	3.7	4.4	6.0	7.1	8.7	10.5
4500	1.1	1.5	2.1	2.8	3.6	4.2	5.5	6.8	8.0
5000	0.9	1.2	1.6	2.1	2.7	3.5	4.1	5.1	6.5

longterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	1.4	2.0	3.0	4.2	5.9	7.5	9.6	11.7	14.2
3184	1.1	1.6	2.6	3.5	4.6	6.3	7.9	10.1	12.0
3500	1.0	1.4	2.2	3.0	4.2	5.5	7.1	9.0	10.9
4000	0.8	1.1	1.7	2.3	3.2	4.3	5.5	6.9	8.9
4500	0.6	1.0	1.3	1.8	2.5	3.2	4.1	5.3	6.6
5000	0.5	0.7	1.0	1.3	1.8	2.5	3.2	4.0	5.1

Rule 4 - biomass rule with HRmin = 0.05

shortterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	2.7	3.9	5.0	6.1	7.7	9.6	11.4	13.8	15.7
3184	2.2	3.1	3.9	4.8	5.7	6.8	8.4	9.9	12.0
3500	2.2	2.6	3.2	4.1	4.8	5.7	6.5	7.8	9.2
4000	2.0	2.3	2.6	2.9	3.6	4.3	4.8	5.2	6.2
4500	1.8	2.0	2.3	2.5	2.8	3.1	3.7	4.2	4.5
5000	1.8	1.9	2.1	2.3	2.5	2.7	2.9	3.2	3.7

mediumterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	2.6	3.4	4.5	5.8	7.5	9.1	10.8	12.5	14.5
3184	2.2	2.7	3.3	4.2	5.3	6.3	7.9	8.9	10.1
3500	2.0	2.4	2.9	3.5	4.3	5.5	6.3	7.3	8.4
4000	1.6	2.1	2.4	2.9	3.4	3.8	4.7	5.7	6.6
4500	1.5	1.7	2.1	2.3	2.7	3.2	3.5	4.2	4.9
5000	1.4	1.6	1.7	2.1	2.3	2.6	3.0	3.4	3.9

longterm risk

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	1.2	1.8	2.7	3.6	4.6	6.0	7.6	9.1	10.8
3184	1.1	1.4	2.2	2.7	3.5	4.5	5.5	6.6	8.1
3500	1.0	1.3	1.8	2.4	3.0	3.8	4.6	5.7	6.8
4000	1.0	1.1	1.4	1.9	2.4	3.0	3.6	4.2	5.3
4500	0.9	1.0	1.3	1.6	2.0	2.4	2.9	3.3	4.0
5000	0.8	1.0	1.2	1.4	1.6	2.1	2.4	2.7	3.0

Table 5 Yield, expressed as median catch (kt), in the short, medium, and long term for F rules without and with a constraint in interannual TAC change. Red cells correspond to the non-precautionary [F_{target}, $B_{trigger}$] combinations [P(SSB< B_{lim})< 5%]. Cells shaded in green colours indicate the combinations that result in yield ≥95% of the maximum yield among the precautionary combinations.

Yield tables for F-rules with Risk3

Rule 1 - F-rule through 0.0

shortterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	381	387	442	456	499	527	545	553	578	603	651
3184	381	387	442	456	499	526	545	552	578	602	649
3500	381	387	441	455	495	521	539	546	570	593	636
4000	365	370	418	430	466	488	503	509	531	550	589
4500	333	338	383	394	428	449	463	469	489	507	544
5000	307	311	353	364	396	416	430	436	454	472	507

mediumterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	579	586	640	652	688	708	720	725	742	757	782
3184	581	588	642	656	692	713	727	733	750	766	793
3500	583	590	645	658	696	718	732	738	755	772	799
4000	587	594	650	665	703	726	741	747	765	782	808
4500	592	598	657	671	710	733	747	752	769	782	798
5000	596	603	661	676	712	732	743	747	757	764	771

longterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	704	710	757	768	795	808	816	819	827	833	841
3184	706	712	760	771	800	814	823	827	838	846	858
3500	708	713	762	774	803	818	828	832	843	853	866
4000	711	716	767	778	809	826	836	841	854	864	880
4500	714	720	771	784	816	834	846	851	864	875	888
5000	717	724	778	790	824	843	854	859	871	879	880

Rule 1 with average constraint

shortterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	377	382	424	435	468	491	506	512	533	554	593
3184	375	379	421	433	467	489	504	510	532	552	591
3500	371	376	419	431	465	488	503	510	531	552	591
4000	356	362	411	423	458	481	496	502	523	543	581
4500	333	338	383	395	429	451	465	471	491	510	547
5000	307	312	353	364	396	416	430	436	456	473	508

mediumterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	579	586	644	659	700	723	739	745	765	782	815
3184	582	589	649	663	704	728	743	749	770	789	820
3500	584	591	651	666	707	731	747	753	774	791	821
4000	587	594	655	670	711	735	750	756	775	791	814
4500	590	597	658	673	713	735	748	753	767	779	797
5000	592	599	659	673	706	725	735	740	753	764	779

longterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	718	724	773	784	812	826	835	838	847	855	864
3184	721	727	777	789	819	834	844	848	859	868	881
3500	722	728	780	792	822	839	849	853	865	875	887
4000	725	731	785	797	829	847	858	862	874	883	892
4500	729	735	789	802	835	854	864	868	876	882	881
5000	732	739	794	807	841	855	862	864	869	870	870

Rule 1 with 25/20% TAC-constraint

shortterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	375	381	433	448	480	480	499	504	528	551	598
3184	368	373	427	442	480	480	493	491	514	536	580
3500	362	368	420	434	475	480	489	485	507	530	572
4000	345	351	399	412	448	472	479	480	496	516	554
4500	323	328	373	385	419	441	455	463	480	494	530
5000	301	306	349	360	392	412	426	432	450	469	502

mediumterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	564	571	626	640	677	699	714	720	740	758	793
3184	565	571	626	639	678	701	717	723	742	761	793
3500	565	572	626	641	679	702	718	725	744	761	791
4000	566	573	630	644	683	705	719	725	744	760	788
4500	568	574	631	645	683	705	719	724	741	756	779
5000	568	575	632	646	680	702	714	719	733	746	765

longterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	701	707	756	767	795	810	818	822	832	840	852
3184	703	709	759	770	800	815	826	830	841	850	864
3500	705	710	761	773	803	819	829	833	845	855	868
4000	707	713	764	776	807	824	835	839	851	860	872
4500	709	715	767	779	811	829	838	842	853	863	871
5000	711	717	770	783	815	831	841	845	855	861	865

Rule 2 - F-rule with Fmin = 0.05

shortterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	381	388	443	457	501	528	547	555	581	605	655
3184	382	388	444	459	502	529	548	556	582	606	655
3500	381	387	442	456	497	523	541	549	572	595	636
4000	361	366	409	420	450	469	481	487	503	517	546
4500	328	332	366	375	401	417	427	431	445	459	484
5000	307	310	339	346	369	384	393	397	409	421	444

mediumterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	581	587	642	655	692	715	729	735	754	771	801
3184	584	590	646	661	701	724	740	747	767	785	820
3500	586	593	650	665	705	730	746	753	773	794	829
4000	589	596	656	672	713	739	756	763	785	806	841
4500	593	600	662	678	721	746	763	770	790	807	832
5000	596	603	666	681	722	745	758	763	777	788	792

longterm yield

Btrigger \ Ftarget	0.1	0.102	0.12	0.125	0.14	0.15	0.157	0.16	0.17	0.18	0.2
2500	706	712	760	772	801	817	827	830	842	852	869
3184	708	714	764	776	807	824	835	840	853	866	888
3500	710	716	767	779	810	829	840	845	860	873	897
4000	712	718	770	783	817	836	849	854	871	886	912
4500	715	721	775	788	824	845	858	864	880	897	920
5000	717	724	780	794	831	852	866	872	888	900	912

Table 6 Yield, expressed as median catch (kt), in the short, medium, and long term for biomass rules without and with a constraint in interannual TAC change. Red shaded cells correspond to the non-precautionary [F_{target}, $B_{trigger}$] combinations [P(SSB< B_{lim})< 5%]. Cells shaded in green colours indicate the combinations that result in yield ≥95% of the maximum yield among the precautionary combinations.

Yield tables for biomass rules with Risk3

Rule 3 - biomass rule going through 0.0

shortterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	293	333	372	411	449	486	524	561	598
3184	292	331	370	408	446	483	520	556	591
3500	289	328	366	403	440	477	512	548	582
4000	270	305	339	372	404	435	466	496	526
4500	243	274	305	335	364	392	420	448	474
5000	220	249	277	305	332	358	383	409	434

mediumterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	493	541	584	623	657	687	714	737	758
3184	494	542	586	626	661	692	721	745	766
3500	496	545	589	629	664	696	725	750	773
4000	499	549	594	635	672	706	736	762	784
4500	502	553	600	642	679	714	743	769	791
5000	506	557	604	646	683	717	745	767	781

longterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	633	680	720	751	778	799	814	825	833
3184	634	682	722	755	783	805	822	836	846
3500	635	683	724	758	786	809	828	842	853
4000	637	686	727	762	792	817	837	852	865
4500	639	689	731	767	797	824	845	861	875
5000	641	692	735	771	803	830	851	868	880

Rule 3 with average constraint

shortterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	318	346	374	402	430	459	489	518	547
3184	317	346	374	402	431	459	488	517	545
3500	310	344	372	400	427	454	481	510	539
4000	269	305	339	372	405	437	467	495	523
4500	242	274	305	335	364	393	421	448	475
5000	220	249	277	305	332	358	383	409	434

mediumterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	478	528	574	617	655	691	724	752	778
3184	480	531	578	621	660	697	730	760	787
3500	483	534	581	624	664	701	735	765	791
4000	488	539	587	631	672	710	743	772	796
4500	492	545	594	639	680	717	749	775	792
5000	497	550	600	645	685	718	746	762	773

longterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	638	686	727	761	788	810	825	837	846
3184	639	688	730	765	794	818	837	852	864
3500	641	690	732	768	798	822	843	860	873
4000	643	693	736	773	805	832	855	874	886
4500	646	697	741	779	813	841	865	883	892
5000	649	701	747	787	821	850	872	882	879

Rule 3 with25/20% TAC-constraint

shortterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	307	331	370	408	447	480	491	526	562
3184	307	330	369	407	445	480	482	515	550
3500	303	327	365	402	439	477	480	499	531
4000	270	305	338	371	404	436	468	480	506
4500	242	274	304	335	364	392	421	448	475
5000	220	249	277	305	332	358	383	409	434

mediumterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	475	522	565	603	639	670	700	726	751
3184	478	526	570	609	645	678	707	735	760
3500	480	529	574	613	649	683	713	741	766
4000	485	534	579	620	659	693	723	749	773
4500	490	540	585	627	665	698	729	754	775
5000	493	543	589	631	669	702	730	755	770

longterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	622	669	708	741	767	788	805	819	829
3184	624	671	711	746	774	797	816	831	844
3500	625	672	714	748	777	802	821	838	852
4000	628	676	718	754	784	810	831	848	862
4500	631	680	723	759	791	817	839	856	871
5000	633	684	727	765	796	822	845	862	874

Rule 4 - biomass rule with HRmin = 0.05

shortterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	293	332	372	410	448	486	523	560	596
3184	292	330	368	406	443	480	516	552	586
3500	289	327	364	401	436	471	505	537	570
4000	274	304	332	357	383	407	428	449	469
4500	258	281	303	324	343	362	380	398	414
5000	249	267	285	302	319	335	350	365	380

mediumterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	493	542	585	625	660	692	722	748	773
3184	495	544	589	630	667	702	734	762	789
3500	496	546	592	634	672	708	740	770	798
4000	498	549	596	640	680	717	751	781	809
4500	499	552	600	645	686	724	756	787	814
5000	500	554	602	646	687	725	757	782	802

longterm yield

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	634	681	722	755	784	807	827	843	856
3184	634	683	724	759	789	815	837	855	872
3500	635	684	726	761	792	819	842	861	878
4000	636	686	728	765	797	826	849	870	888
4500	637	687	731	769	802	831	855	877	895
5000	638	689	733	771	805	835	860	881	897

Table 7 Median interannual variability (IAV, expressed as a %) in yield in the medium term for F rules without and with a constraint in interannual TAC change. Unshaded cells correspond to the precautionary [F_{target}, $B_{trigger}$] combinations [$P(SSB < B_{lim}) \leq 5\%$].

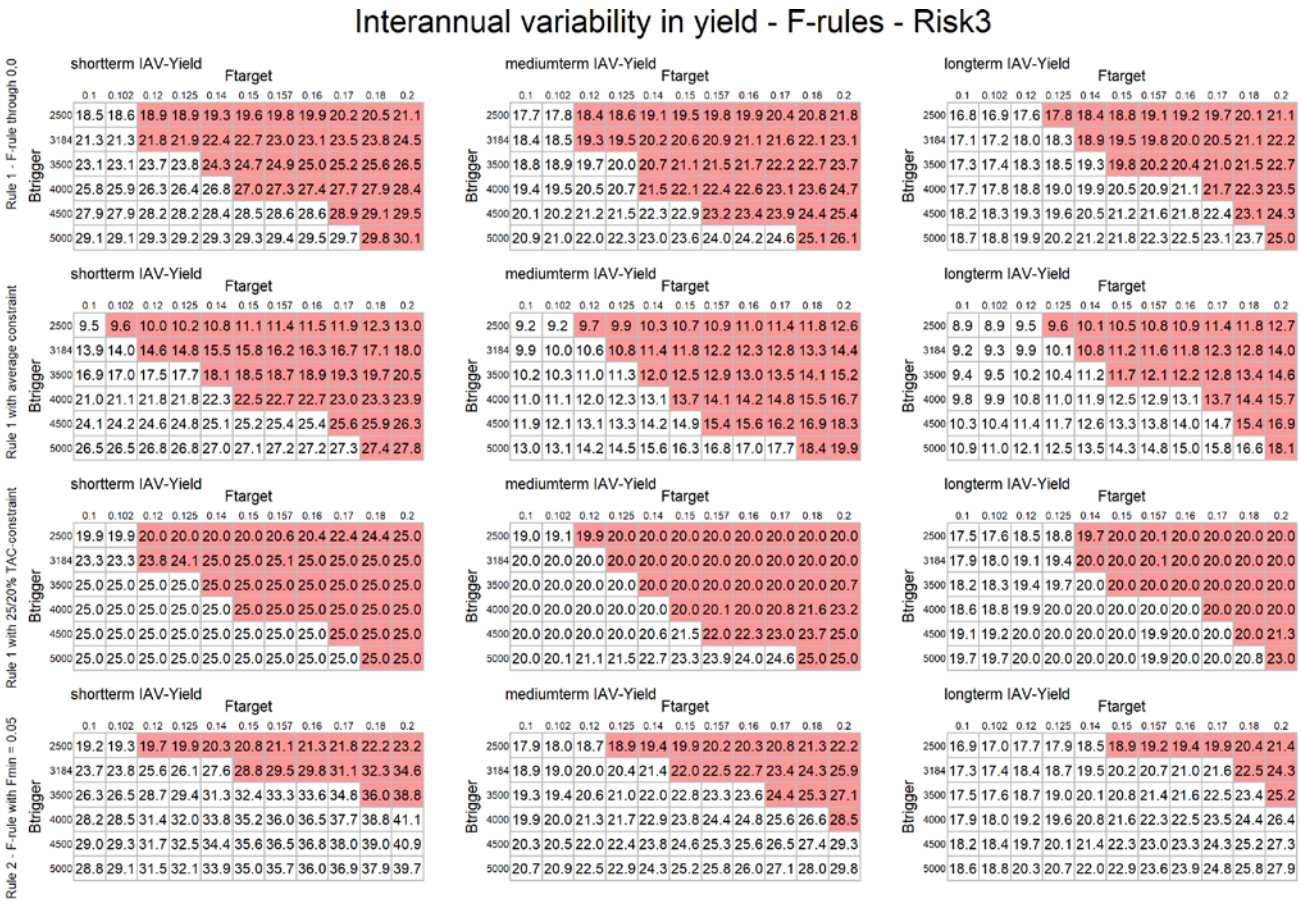

Table 8 Median interannual variability (IAV, expressed as a %) in yield in the medium term for biomass rules without and with constraint in interannual TAC change. Unshaded cells correspond to the precautionary [F_{target}, $B_{trigger}$] combinations [P(SSB< B_{lim})≤ 5%].

Interannual variability in yield - biomass rules - Risk3

Rule 3 - biomass rule going through 0.0

shortterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	7.6	7.8	8.0	8.2	8.4	8.7	9.0	9.3	9.7
3184	8.6	8.8	9.1	9.4	9.7	10.1	10.4	10.8	11.3
3500	10.0	10.2	10.5	10.8	11.1	11.5	12.0	12.4	13.0
4000	12.4	12.6	12.8	13.1	13.4	13.5	13.9	14.2	14.7
4500	13.6	13.7	13.8	14.0	14.2	14.4	14.6	14.7	15.0
5000	14.1	14.1	14.2	14.3	14.4	14.6	14.7	14.9	15.0

mediumterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	7.9	8.3	8.9	9.4	10.0	10.6	11.3	12.0	12.7
3184	8.1	8.7	9.2	9.9	10.5	11.2	11.9	12.7	13.5
3500	8.3	8.9	9.5	10.1	10.8	11.5	12.3	13.0	13.9
4000	8.6	9.2	9.8	10.5	11.2	12.0	12.8	13.6	14.4
4500	8.9	9.5	10.2	11.0	11.7	12.4	13.2	14.1	14.9
5000	9.2	9.9	10.6	11.3	12.1	12.9	13.7	14.5	15.4

longterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	8.2	8.7	9.2	9.7	10.3	10.8	11.4	12.1	12.8
3184	8.3	8.8	9.3	9.9	10.5	11.2	11.9	12.6	13.4
3500	8.4	8.9	9.5	10.1	10.7	11.4	12.1	12.9	13.8
4000	8.5	9.1	9.7	10.3	11.0	11.8	12.6	13.4	14.3
4500	8.6	9.3	9.9	10.6	11.4	12.2	13.1	13.9	14.8
5000	8.8	9.5	10.2	11.0	11.8	12.6	13.5	14.4	15.3

Rule 3 with average constraint

shortterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	7.9	6.8	6.0	5.6	5.8	6.3	7.0	7.8	8.6
3184	8.9	8.0	7.5	7.8	8.1	8.6	9.3	10.1	11.0
3500	10.3	10.1	9.9	9.9	10.1	10.5	11.3	12.1	13.0
4000	12.6	12.4	12.4	12.6	12.8	13.2	13.5	14.0	14.6
4500	13.6	13.6	13.7	13.8	14.0	14.3	14.6	14.8	15.0
5000	14.3	14.3	14.3	14.5	14.6	14.8	14.9	15.1	15.2

mediumterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	6.3	6.6	6.9	7.2	7.6	8.0	8.4	8.9	9.4
3184	6.5	6.9	7.2	7.6	8.1	8.6	9.2	9.8	10.4
3500	6.7	7.1	7.5	8.0	8.5	9.0	9.6	10.2	10.9
4000	7.1	7.5	7.9	8.4	8.9	9.5	10.3	10.9	11.7
4500	7.5	7.9	8.4	9.0	9.6	10.2	10.9	11.7	12.4
5000	7.9	8.4	8.9	9.5	10.2	10.8	11.6	12.3	13.1

longterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	6.3	6.7	7.1	7.5	7.9	8.3	8.8	9.4	9.9
3184	6.5	6.8	7.3	7.7	8.2	8.7	9.3	10.0	10.6
3500	6.5	6.9	7.4	7.9	8.4	9.0	9.6	10.3	11.0
4000	6.6	7.1	7.6	8.1	8.8	9.4	10.1	10.9	11.7
4500	6.8	7.3	7.9	8.5	9.2	9.9	10.7	11.4	12.3
5000	7.0	7.6	8.2	8.9	9.6	10.4	11.2	12.0	12.9

Rule 3 with25/20% TAC-constraint

shortterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	11.0	9.3	8.9	9.1	9.4	10.1	11.5	13.1	15.6
3184	11.5	10.0	10.0	10.3	10.8	11.7	13.2	15.2	17.7
3500	12.1	11.1	11.3	11.7	12.2	13.2	14.5	16.0	17.9
4000	13.6	13.6	13.8	14.0	14.4	14.8	15.5	16.3	17.0
4500	14.8	14.8	14.9	15.0	15.1	15.4	15.7	16.0	16.3
5000	15.2	15.1	15.1	15.2	15.3	15.5	15.6	15.7	15.9

mediumterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	9.6	10.1	10.7	11.3	11.9	12.6	13.4	14.2	14.9
3184	9.8	10.4	11.0	11.7	12.4	13.2	14.0	14.9	15.9
3500	9.9	10.5	11.2	12.0	12.7	13.5	14.4	15.3	16.2
4000	10.3	10.9	11.7	12.5	13.3	14.0	14.9	15.8	16.7
4500	10.6	11.3	12.1	12.9	13.7	14.5	15.4	16.3	17.1
5000	11.0	11.7	12.5	13.3	14.1	14.9	15.7	16.6	17.4

longterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	9.1	9.7	10.3	11.0	11.6	12.3	13.1	13.9	14.7
3184	9.2	9.8	10.5	11.1	11.9	12.6	13.5	14.4	15.4
3500	9.3	9.9	10.5	11.3	12.0	12.8	13.7	14.7	15.7
4000	9.4	10.0	10.7	11.5	12.3	13.2	14.1	15.1	16.1
4500	9.5	10.2	11.0	11.8	12.7	13.6	14.6	15.5	16.6
5000	9.7	10.5	11.3	12.2	13.1	14.0	14.9	16.0	17.0

Rule 4 - biomass rule with HRmin = 0.05

shortterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	7.8	8.0	8.2	8.4	8.7	9.0	9.3	9.7	10.1
3184	8.9	9.6	10.2	10.8	11.5	12.4	13.4	14.3	15.4
3500	10.1	11.1	12.2	13.4	14.7	16.0	17.4	18.7	20.2
4000	11.2	12.8	14.2	15.5	16.9	18.1	19.4	20.5	21.8
4500	11.2	12.6	13.9	15.2	16.4	17.4	18.4	19.3	20.3
5000	10.9	12.1	13.3	14.4	15.4	16.4	17.3	18.2	18.9

mediumterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	7.9	8.3	8.9	9.4	10.0	10.6	11.2	11.9	12.5
3184	8.1	8.7	9.4	10.1	10.7	11.5	12.3	13.1	14.0
3500	8.2	8.9	9.6	10.3	11.1	11.9	12.8	13.6	14.6
4000	8.4	9.1	9.9	10.7	11.6	12.4	13.4	14.4	15.5
4500	8.6	9.4	10.2	11.0	11.9	12.9	13.9	14.9	16.0
5000	8.7	9.5	10.4	11.3	12.2	13.2	14.2	15.3	16.4

longterm IAV

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	8.2	8.7	9.2	9.7	10.2	10.8	11.4	12.0	12.7
3184	8.3	8.8	9.4	10.0	10.7	11.4	12.1	12.9	13.8
3500	8.3	8.9	9.5	10.2	10.9	11.6	12.5	13.3	14.3
4000	8.4	9.1	9.7	10.4	11.2	12.1	13.0	14.0	15.1
4500	8.5	9.2	9.9	10.7	11.5	12.5	13.5	14.6	15.7
5000	8.6	9.3	10.1	11.0	11.9	12.8	13.9	15.0	16.1

Table 9 Median of the real F in the medium term for HCRs without and with a constraint in interannual TAC change. Unshaded cells correspond to the precautionary [F_{target}, $B_{trigger}$] or [HR_{target}, $B_{trigger}$] combinations [P(SSB< B_{lim})< 5%]. Note: The values for the biomass options are also shown as real F – not harvest rate.

Realised F for all tested rules with Risk3

Rule 1 - F-rule through 0,0

Btrigger \ Ftarget	0.1	0.12	0.125	0.14	0.15	0.16	0.17	0.18	0.2
2500	0.10	0.12	0.12	0.14	0.15	0.15	0.16	0.17	0.19
3184	0.10	0.12	0.12	0.13	0.14	0.15	0.16	0.17	0.19
3500	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18
4000	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.18
4500	0.09	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17
5000	0.09	0.11	0.11	0.13	0.13	0.14	0.15	0.15	0.17

Rule 3 - biomass rule going through 0,0

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.17	0.18
3184	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.17
3500	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17
4000	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17
4500	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
5000	0.07	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.15

Rule 1 with average constraint

Btrigger \ Ftarget	0.1	0.12	0.125	0.14	0.15	0.16	0.17	0.18	0.2
2500	0.10	0.12	0.12	0.14	0.15	0.15	0.16	0.17	0.19
3184	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18
3500	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.18
4000	0.09	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17
4500	0.09	0.11	0.11	0.12	0.13	0.14	0.15	0.15	0.17
5000	0.09	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.16

Rule 3 with average constraint

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	0.07	0.09	0.10	0.11	0.12	0.13	0.15	0.16	0.17
3184	0.07	0.08	0.10	0.11	0.12	0.13	0.14	0.15	0.16
3500	0.07	0.08	0.10	0.11	0.12	0.13	0.14	0.15	0.16
4000	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.15
4500	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
5000	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.14

Rule 1 with 25/20% TAC-constraint

Btrigger \ Ftarget	0.1	0.12	0.125	0.14	0.15	0.16	0.17	0.18	0.2
2500	0.09	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18
3184	0.09	0.11	0.11	0.13	0.14	0.14	0.15	0.16	0.17
3500	0.09	0.11	0.11	0.13	0.13	0.14	0.15	0.16	0.17
4000	0.09	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.16
4500	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.15	0.16
5000	0.09	0.10	0.11	0.12	0.12	0.13	0.14	0.14	0.15

Rule 3 with25/20% TAC-constraint

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17
3184	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17
3500	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
4000	0.07	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
4500	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
5000	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.14

Rule 2 - F-rule with Fmin = 0.05

Btrigger \ Ftarget	0.1	0.12	0.125	0.14	0.15	0.16	0.17	0.18	0.2
2500	0.10	0.12	0.12	0.14	0.15	0.15	0.16	0.17	0.19
3184	0.10	0.12	0.12	0.13	0.14	0.15	0.16	0.17	0.19
3500	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18
4000	0.10	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.18
4500	0.09	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17
5000	0.09	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.16

Rule 4 - biomass rule with HRmin = 0.05

Btrigger \ HRtarget	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
2500	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.17	0.18
3184	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17
3500	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17
4000	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.17
4500	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
5000	0.07	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.15

Annex 2[**]

Following the initial advice concerning the management strategy evaluation of harvest control rule (HCR) options released by ICES on 28September 2018, the Coastal States sent a new request to ICES regarding further evaluation of their selected harvest control rule and LTMS options:

Request to ICES concerning a long-term management strategy for Norwegian Spring-Spawning *(Atlanto-Scandian)* ***Herring***

With basis in the advice released by ICES on 28th of September 2018 regarding LTMS for Norwegian Spring Spawning (Atlanto-Scandian) Herring, ICES is requested to evaluate the following LTMS:

- *Rule 2 with a Btrigger=Bpa = 3,184,000 tonnes and Fmanagement= 0.14*
    - *Interannual variation constraint: When the rules would lead to a TAC, which deviates by more than 20% below or 25% above the TAC of the preceding year, the TAC is to be set respectively no more than 20% less or 25% more than the TAC of the preceding year.*
    - *The TAC constraint shall not apply if the SSB for the year for which the TAC is to be set is forecast to be less or equal to Btrigger.*
    - *Allowing a maximum of 10% to be banked or borrowed any year. However, borrowing shall not be allowed when the stock is forecast to be under Btrigger at the end of the TAC year.*

The above LTMS shall be assessed in relation to how it performs in the short term (2019-2023), medium term (2024-2033) and long term (2034-2053) in relation to:

- *Average SSB*
- *Average yield*
- *Indicator for year to year variability in SSB and yield*
- *Risk of SSB falling below B_{lim}*

In case the above LTMS is consistent with the precautionary approach, ICES is requested to apply the LTMS as basis for the advice for 2019 and onward. However, for 2019, the interannual variation constraints shall not be applied.

To answer the request, simulations were run using the same methods used at WKNSSHMSE – i.e. following the methods described above. The code was updated to include scenarios of banking and borrowing, following the procedure used for North Sea plaice and sole in Brunel and Miller (2013). Banking or borrowing is applied to the TAC after application of the catch constraint. It was simulated to take effect on the TAC from 2018 onwards, with the following scenarios:

- banking 10% in every year from 2018 onwards (scenario 2 in Brunel and Miller, 2013)
- borrowing 10% in every year from 2018 onwards (scenario 3 in Brunel and Miller, 2013)

Four different scenarios were evaluated:

1. **No** banking and borrowing, **no** catch constraints
2. **No** banking and borrowing, catch constraints
3. **Banking** every year, catch constraints
4. **Borrowing** every year, catch constraints

All scenarios gave a probability of SSB being below B_{lim} of less than 5% in all years simulated (Table A2.1; Figure A2.1). Including the -20%/+25% catch constraint slightly decreased both the yield and the probability of SSB falling below B_{lim}. Including banking and borrowing induced only small changes in all performance statistics. Hence, the HCR proposed for the LTMS for NSSH is found to be consistent with the precautionary approach.

Reference

Brunel, T., and Miller, D.C.M. 2013. An Evaluation of the Impact of Inter-annual Quota Flexibility (Banking and Borrowing) on the Performance of the North Sea Flatfish Long Term Management Plan, June 2013, ICES Headquarters, Copenhagen. ICES CM 2013/ACOM:64. 39 pp.

[**] Version 2: Annex 2 added.

Table A2.1. Results from the four scenarios in short, medium and long term**.**

Scenario	Time period	P(SSB < B_{lim})	SSB (kt)	Yield (kt)	Interannual variation in SSB (%)	Interannual variation in Yield (%)
		Max. annual %	median	median	median	median
1. No banking or borrowing, **no** catch constraints	Short term - 2019–2023	4.3	3622	502	8.1	27.6
	Medium term - 2024–2033	4.6	5049	701	8.5	21.4
	Long term - 2034–2037	3.2	5856	807	8.7	19.5
2. No banking or borrowing, catch constraints	Short term - 2019–2023	3.8	3681	461	8.3	25
	Medium term - 2024–2033	3.9	5474	673	8.9	20
	Long term - 2034–2037	2.4	6183	810	9.2	20
3. Banking every year, catch constraints	Short term - 2019–2023	3.8	3734	461	8.3	22.5
	Medium term - 2024–2033	3.7	5510	675	8.9	18
	Long term - 2034–2037	2.6	6206	810	9.3	18
4. Borrowing every year, catch constraints	Short term - 2019–2023	3.8	3655	458	8.4	27.5
	Medium term - 2024–2033	3.7	5463	673	8.9	22
	Long term – 2034–2037	2.4	6174	808	9.2	22

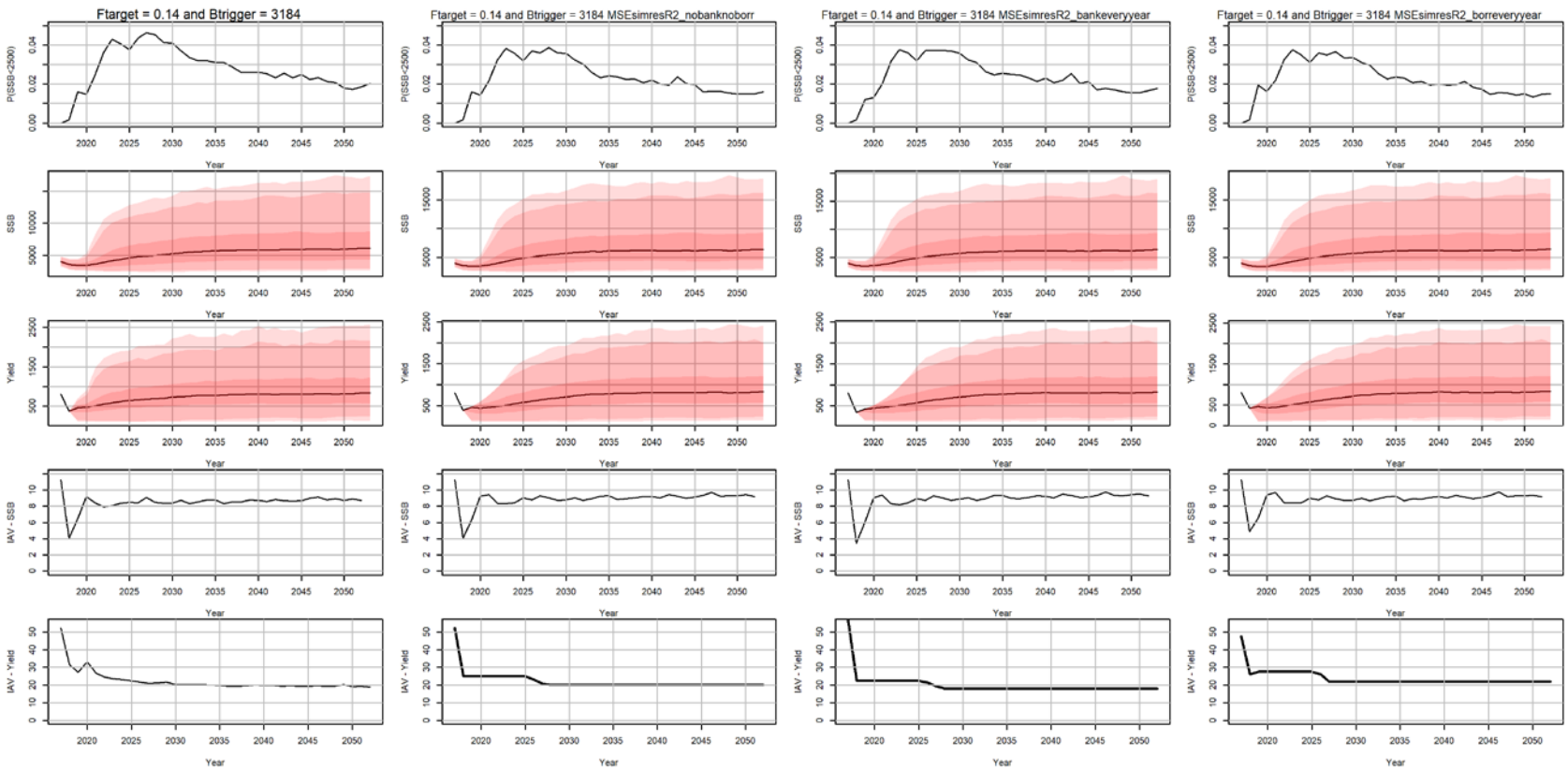

Figure A2.1. Performance statistics for the four scenarios examined: No banking or borrowing or catch constraints (**Scenario 1, far left**); No banking or borrowing with catch constraints (**Scenario 2, centre left**); banking every year with catch constraints (**Scenario 3, centre right**); and borrowing every year with catch constraints (**Scenario 4, far right**). Results are shown from 2017 to 2053 for: the probability of SSB being below B_{lim} (top), SSB (second from top), yield (middle), interannual variation in SSB (second from bottom) and interannual variation in yield (bottom). Solid black lines represent medians, and the SSB and yield plots include confidence ranges (outermost = 95% range).