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Norway/Russia request for evaluation of harvest control rule (HCR) options for redfish (*Sebastes mentella*) in ICES subareas 1 and 2

Advice summary

ICES has assessed the consequences of the proposed set of harvest control rules (HCRs) for *Sebastes mentella* in ICES subareas 1 and 2. All of the proposed options, including an additional scenario with $B_{trigger}$ = 315 kt, are found to be precautionary in the short, medium, and long term, conditional on assuming no assessment bias.

Bias in the assessment is not known. The evaluation showed that implementing a TAC cap of 50 kt would make the harvest control rules robust to an overestimate of stock size by up to 50% and also avoid short-term catches increasing above the long-term mean.

The options with trigger points of 450 kt or lower would reduce the interannual variations in TAC and target F.

The options with the highest F (= 0.10) lead to the highest short-, medium-, and long-term yield, if there is no TAC cap. However, in the case of a biased assessment, the options with F = 0.10 or F = 0.08 are not precautionary without the TAC cap.

There should be a new evaluation in 2023 in order to benefit from additional information gathered in upcoming surveys in the Norwegian Sea.

Request

Request to ICES for evaluation of harvest control rule for Sebastes mentella:

"Norway and Russia ask ICES to evaluate the following set of harvest control rules for Sebastes mentella in ICES areas 1 and 2:
All combinations (total 3x3=9) of the following elements:

Fishing mortality (F19+) of 0.06, 0.08 and 0.10
Trigger points of 450, 600 and 800 kt

In addition, for a trigger point of 450 kt and F19+=0.08, a rule with the following additional clause should be tested: "Reduction of F by 50% or no reduction of F if the average strength at age 2 for the year classes which are 3-12 years old in the first year for which the TAC advice is given, is below 100 million individuals."

In all cases F should be reduced linearly towards F=0 at SSB=0 if SSB in the first year for which TAC advice is given, is below the trigger point.

If none of the rules are found to be precautionary, rules with additional values of F and trigger point should be investigated in order to find rules which are precautionary.

For all simulations, ICES is asked to assess the consequences through calculating the following performance indicators (expected values):

Annual yield during each of the next 5 years
Medium term yield, represented as average yield during the next 10 years
Long term yield and SSB, represented as average during the next 50 years
Probability that SSB falls below $B_{trigger}$, B_{pa} and B_{lim}, in a 5, 10 and 50 year period
Realised average fishing mortality

Amendments and additions

Introduction of a B_{pa}=315 kt for each F19+, increasing the number of simulations to 12
Simulation of the application of HCRs with $B_{trigger}$=450 kt and F19+=0.06 and 0.08 from 1992 onward and thus across the period of recruitment failure instead of reducing F at low recruitment. This approach was necessary due to software limitations.

Elaboration on the advice

ICES evaluated the consequences of the proposed harvest control rules using the latest information available for the stock, including updated reference points.

Updated reference points

At the benchmark (WKREDFISH; ICES, 2018a), spawning-stock biomass (SSB) was estimated to vary between 324 and 1088 kt over the assessed period, and the corresponding reference points were defined based on B_{lim} = B_{loss} (B_{lim} = 324 kt and B_{pa} = 450 kt). At the Arctic Fisheries Working Group (AFWG; ICES, 2018b), in addition to a new year of data, the weight-at-ages 19+ was revised and set as constant over time. As a consequence, the SSB time-series has been affected, with a revised range of 227–933 kt, which results in updated reference points of B_{lim} = 227 kt and B_{pa} = 315 kt.

$F_{0.1}$ and F_{max} were also re-evaluated for ages 19+ as suggested by WKREDFISH (ICES, 2018a), resulting in updated values of 0.084 and 0.236, respectively.

Short- and medium-term evaluation

Annual yield for the next five years (short-term), average for the period 2019–2028 (mid-term), and for the next 50 years (long-term) are presented in Table 1, with the corresponding risk levels as well as the realized F shown in Table 2.

Due to the potential bias in the estimate of stock size in the assessment, and with the predicted short-term catches exceeding the long-term average, the feasibility of a TAC cap for the next ten years was explored. This investigation suggested that a TAC cap of 50 kt should be sufficient to safeguard against SSB falling below B_{lim} even if the current stock size is overestimated by 50% (Figure 1).

Long-term evaluation and reality check

The average yield for the long term (50 years, Table 1) would be lower than for the short and medium terms. A long-term simulation (100 years) was carried out using values for $B_{trigger}$ (450 kt) and F19+ (0.08). Equilibrium catch and stock size were found to be plausible when compared to historical values (Figure 2).

Handling of recruitment failure

Applying the HCR ($B_{trigger}$ = 450 kt and F19+ = 0.06 and 0.08) to the period 1992–2018, keeping the biological information and recruitment as estimated from the assessment time-series, including the years with observed low recruitment, indicated that the biomass will stay well above B_{lim} (Figure 3).

Basis of the advice

Background

The benchmark assessment in 2018 (ICES, 2018a) updated the reference points for the stock and $F_{0.1}$ was used as a proxy for F_{MSY}. The subsequent AFWG 2018 (ICES, 2018b) revised the weight-at-ages 19+ to be constant over time.

In March 2018 Norway and Russia sent a request to ICES for the evaluation of a defined set of harvest control rules as options for a long-term management plan for *Sebastes mentella* in ICES subareas 1 and 2. This request was dealt with by

WKREBMSE (Workshop on the evaluation of harvest control rules for *Sebastes mentella* in ICES areas 1 and 2; ICES, 2018c), which met by correspondence during July and August 2018.

WKREBMSE (ICES, 2018c) used the revised approach for the weight-at-ages 19+ and updated all the reference points (B_{lim} = 227 kt and B_{pa} = 315 kt, F_{MSY} = 0.084).

Results and conclusions

In addition to the $B_{trigger}$ scenarios in the request a scenario with a $B_{trigger}$ = B_{pa} = 315 kt was tested. The probability of SSB < B_{lim} was zero or extremely low for all tested HCRs. However, for $B_{trigger}$ = 800 kt and $B_{trigger}$ = 600 kt the probability of SSB < $B_{trigger}$ was high, causing increased interannual variations in TAC and target F. This issue was not the case with the lower $B_{trigger}$ values of 450 and 315 kt. Results for average yield, SSB, realized F, and risk levels are given in tables 1 and 2.

Short- and medium-term evaluations showed that catches in the early years would exceed the long-term average which, together with the uncertainty in current stock size, would introduce a risk of SSB falling below B_{lim}. Therefore, the introduction of a TAC cap of 60 or 50 kt was evaluated. It was found that a TAC cap of 50 kt should provide for SSB to stay above B_{lim} even if current SSB is overestimated by 50% (Figure 1).

In the long term, average catches would be at a lower level than in the five- and ten-year forecasts, and the evaluation indicated that the long-term numbers for SSB and catches are plausible when compared to historical values.

Application of the HCR with $B_{trigger}$ = 450 kt to the period 1992–2018 indicated that it is sufficient to keep the biomass above B_{lim} in periods with low recruitment such as the one experienced around the year 2000 (Figure 3). The option using $B_{trigger}$ = 315 kt was not tested relative to this issue.

The scenarios with the highest F (= 0.10) lead to the highest short-, medium-, and long-term yield if there is no TAC cap. However, in the case of a biased assessment, this option is not precautionary without the TAC cap (50 kt). However, in case of an assessment with 50% bias this option is not precautionary without the TAC cap.

Since the stock is long-lived, slow growing, and late maturing, ten years is considered an appropriate time span over which to assess the impact of the harvest control rule (HCR). Considering the stock's vulnerability to overfishing and likely decades-long recovery thereafter, a conservative management approach is desirable. Surveys in 2019 and 2022 will provide further information on absolute stock size and the good year classes after 2003 should have recruited to the mature stock by then. The HCR should be re-evaluated in 2023.

Methods

To make long-term stochastic simulations the WKREBMSE (ICES, 2018c) used the PROST software (Åsnes and Bogstad, 2014) which had already been successfully used to evaluate HCRs for northeast Arctic cod, haddock, and saithe.

The biological model assumes that natural mortality (M = 0.05) as well as weight-at-age and maturity-at-age are constant. Values are taken from AFWG 2018 (tables 6.7 and 6.19 in ICES, 2018b). The model assumes equal weight-at-age in stock and catch and the proportion of F and M before spawning is set to zero.

The catchability is set at a fixed value, which leads to unknown bias in the scaling of the abundance estimate.

Evidence for a relationship between SSB and recruitment is limited. Recruitment-at-age 2 was estimated from linear regression of the numbers for the period 1992–2017 from AFWG 2018 (ICES, 2018b) against the survey indices for the 0-group and fish at 5–9 cm in the winter survey, with the coefficients of determination being r^2 = 0.63 and r^2 = 0.62, respectively. For the 2018 year class the numbers-at-age 2 were set to the average of the 2006–2015 cohorts, i.e. 300 million.

Following the guidance from WKGMSE (ICES, 2013), and based on a stock–recruitment relationship which is independent of SSB, the percentage of iterations for which true SSB falls below B_{lim} at least once during the simulation period is used to quantify the risk. Given this rule, no stock–recruitment relationship below B_{lim} is needed.

Selectivity-at-age is based on the average total fishing mortality at age in 2015–2017 and thus assumes that selectivity in each fishery as well as the pelagic/demersal ratio of catch will continue into the future. The stock size at the beginning of 2018 was taken from AFWG 2018 (ICES, 2018b) and projected through 2018, assuming the same fishing mortality as in 2017. Stochasticity was added to the projections by including uncertainty in the numbers-at-age for 2018, with CV = 0.3 for the year classes 2016 and 2017 and CV = 0.2 for earlier year classes.

An assessment was not run for each year in the projection. Instead a single "assessment error" term was adopted to account for observation error in future catches, survey indices, and modelling. The value for this error was set to CV = 0.2 on a log scale, across age groups and years and uncorrelated between age groups within a given year.

A limitation of the model is that the internal age structure of the 19+-group is not considered, as its weight-at-age is kept constant. This causes a bias that results in the optimal yield being indicated at a slightly higher F than it would be if growth at later ages were considered.

Sources and references

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Figures and tables

Table 1 Yield and spawning-stock biomass (SSB) for the harvest control rules (HCRs) examined.

HCR		Yield (kt)							SSB (kt)
$B_{trigger}$	Target F	2019	2020	2021	2022	2023	Average 2019–2028	Average 2019–2068	Average 2016–2068
315	0.06	52.9	55.1	56.8	57.8	58.2	56.4	48.1	778.7
315	0.08	70.2	71.5	72.7	72.8	72.3	69.7	54.5	661.5
315	0.10	87.0	87.0	87.3	86.2	84.2	81.0	59.0	573.4
450	0.06	53.2	55.0	56.7	57.8	58.2	56.4	48.1	778.0
450	0.08	70.1	71.5	72.6	72.9	72.2	69.6	54.3	662.2
450	0.10	86.8	86.8	87.1	86.0	83.8	80.7	58.6	578.2
600	0.06	53.0	54.9	56.7	57.8	58.1	56.5	47.8	781.7
600	0.08	70.0	71.4	72.5	73.0	72.1	69.6	53.6	673.7
600	0.10	86.9	87.1	87.1	86.0	83.9	80.7	57.0	598.4
800	0.06	51.3	53.9	56.1	57.4	58.0	55.9	46.4	800.0
800	0.08	67.9	69.8	71.4	72.0	71.3	68.3	51.4	708.4
800	0.10	83.7	83.7	84.4	84.9	83.9	79.6	54.6	645.0

Table 2 Results from simualtions of the harvest control rules (HCRs) examined: the probability of spawning-stock biomass (SSB) being below B_{lim} ($P(SSB< B_{lim})$; probability that SSB is below B_{lim} at least once during the time period examined), the probability of spawning-stock biomass (SSB) being below $B_{trigger}$ [$P(SSB< B_{trigger})$]; average of the annual probabilities during the time period examined), realized F, absolute interannual TAC variability, and whether or not the HCRs are considered precautionary under observed recruitment failure or if the assessment is assumed to overestimate the stock size with a 50% bias.

HCR		Prob(SSB< B_{lim})			Prob(SSB< $B_{trigger}$)			Realized F			Interannual TAC variation		
$B_{trigger}$	F	5 years	10 years	50 years	5 years	10 years	50 years	5 years	10 years	50 years	50 years	Precautionary to observed recruitment failure	Precautionary to 50% assessment bias over 10 years
450	0.06	0.000	0.00000	0.000	0.00000	0.00000	0.004	0.06000	0.06000	0.0600	12.9	YES	YES
450	0.08	0.000	0.00000	0.000	0.00000	0.00000	0.062	0.08000	0.08000	0.0793	13.3	YES	Only with 50 kt TAC cap
450	0.10	0.000	0.00000	0.000	0.00000	0.00000	0.214	0.10000	0.10000	0.0972	14.7	Not tested	Only with 50 kt TAC cap
600	0.06	0.000	0.00000	0.000	0.00092	0.00046	0.108	0.05999	0.05997	0.0590	15.0	YES	YES
600	0.08	0.000	0.00000	0.000	0.00088	0.00044	0.351	0.07996	0.07996	0.0759	17.4	YES	Only with 50 kt TAC cap
600	0.10	0.000	0.00000	0.000	0.00136	0.00178	0.578	0.09993	0.09981	0.0900	19.5	Not tested	Only with 50 kt TAC cap
800	0.06	0.000	0.00000	0.000	0.16394	0.09213	0.505	0.05864	0.05904	0.0552	20.9	YES	YES
800	0.08	0.000	0.00000	0.000	0.23538	0.27121	0.766	0.07765	0.07751	0.0683	23.1	YES	Only with 50 kt TAC cap
800	0.10	0.000	0.00000	0.000	0.36992	0.60061	0.897	0.09596	0.09405	0.0792	23.9	Not tested	Only with 50 kt TAC cap
315	0.06	0.000	0.00000	0.000	0.00000	0.00000	0.0001	0.06000	0.06000	0.0600	12.7	Not tested	YES
315	0.08	0.000	0.00000	0.000	0.00000	0.00000	0.0006	0.08000	0.08000	0.0800	12.1	Not tested	Only with 50 kt TAC cap
315	0.10	0.000	0.00000	0.000002	0.00000	0.00000	0.012	0.10000	0.10000	0.0998	11.8	Not tested	Only with 50 kt TAC cap

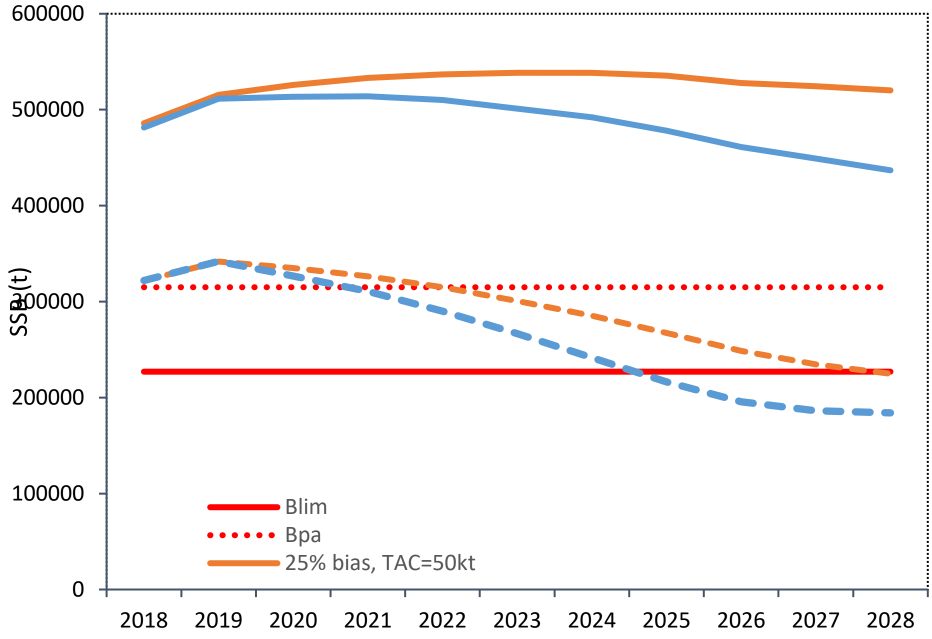

Figure 1 Short-term simulations applying an annually fixed TAC = 50 kt (orange lines) or TAC = 60 kt (blue lines). Results shown are the 5th percentiles of spawning-stock biomass (SSB) assuming either a 25% bias (solid lines) or a 50% bias (dashed lines) in the overestimation of stock size.

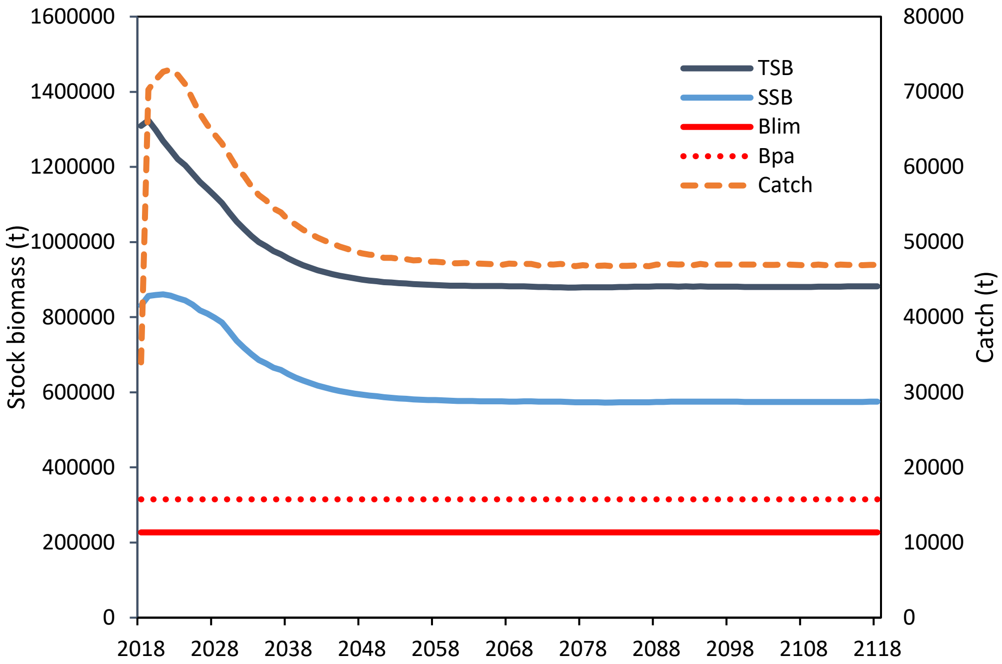

Figure 2 Long-term simulations (100 years) applying a harvest control rule (HCR) with target F = 0.08 and $B_{trigger}$ = 450 kt. Results shown are median values (10000 iterations) for total stock biomass (TSB; dark blue line), spawning-stock biomass (SSB; light blue line), and catch (dashed orange line; right axis).

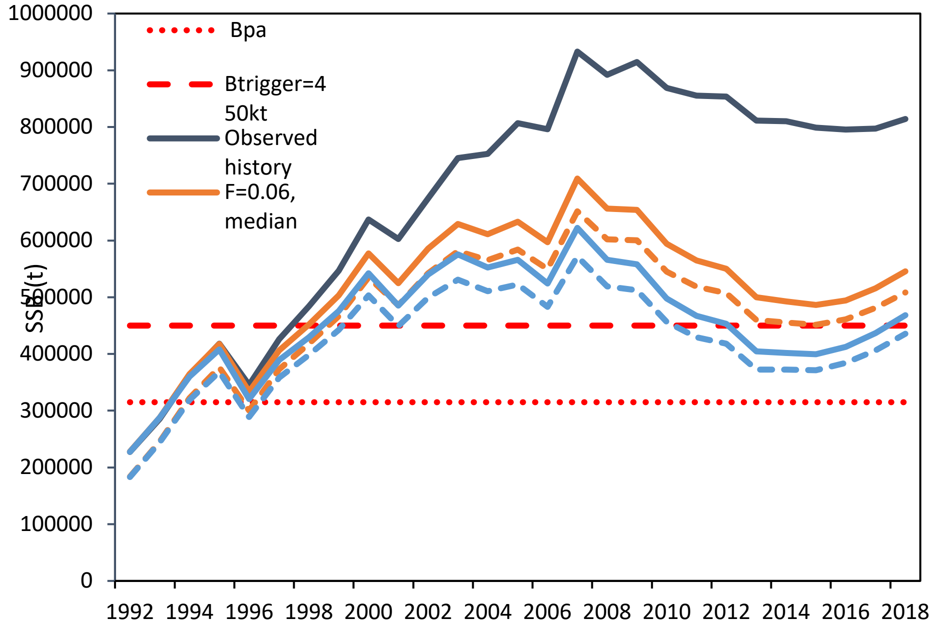

Figure 3 Hindcast simulations of spawning-stock biomass (SSB) development assuming harvest control rules (HCRs) were applied from 1992 and that stock dynamics, including recruitment, remained unchanged from the observed history. Results shown are the observed history following the 2018 assessment (dark blue line), the median (solid line), and the 5th percentile (dashed line) of SSB from applying HCRs with $B_{trigger}$ = 450 kt and target F = 0.06 (orange line) or F = 0.08 (light blue line).