Iceland request for a re-evaluation of the management plan for cod in Icelandic waters

Advice summary

ICES has conducted a benchmark assessment and revised biological reference points for cod in ICES Division 5.a.

ICES advises that the current harvest control rule (HCR), with HR_{MGT} = 0.20 and MGT $B_{trigger}$ = 220 kt, is consistent with both the precautionary principle and ICES MSY approach.

Request

On 19 November 2020, ICES received the following request from Iceland:

Reference is made to the Memorandum of Understanding between Iceland and ICES, signed 1.12. 2019. The Government of Iceland is in the process of re-evaluating the management plan for the Icelandic cod stock (cod.27.5a). The management strategy for Icelandic cod 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.

Part of the management plan is the adoption of harvest control rule (HCR) for setting annual total allowable catch (TAC). The HCR adopted should be precautionary and in accordance with the ICES MSY approach. The current management plan for cod was first evaluated by ICES before the 2009/2010 fishing year and was re-evaluated in 2015 and found to be consistent with the precautionary approach and in conformity with the ICES MSY-framework.

In a letter from the Ministry dated on the 20th of November 2019, ICES was informed that the Minister of Fisheries and Agriculture had appointed a working group to review the management plan and HCR for cod in Icelandic waters. The work was expected to finish by the end of May 2020. Due to disruptions by the COVID-19 pandemic the work was delayed but is expected to finish in December. The main outcome of this work will be a proposal on a HCR for cod, either in the form of the current HCR or some variants of the rule. Technical documentation of the proposed HCR by the aforementioned working group will be produced by national experts at the Marine and Freshwater Research Institute and made available to ICES before the 15th of February 2021.

The Government of Iceland requests ICES to evaluate whether the proposed harvest control rule or rules are in accordance with its objectives, given current ICES definition of reference points or any re-evaluation of those points that may occur in the process. Additionally, the evaluation should also include review of input data and the applied assessment methodology for cod (Benchmark). It is expected that the ICES advice for the 2021/2022 fishing year for Icelandic cod (cod.27.5a) be based on the above-mentioned HCR.

Elaboration on the advice

To answer the request ICES conducted a benchmark assessment and calculated biological reference points, and has evaluated the HCR based on these.

Benchmark assessment and evaluation of reference points

The benchmark assessment resulted in changes in the assessment method (described in the methods section) and updated reference points. This has resulted in no change in B_{lim} (125 kt, former B_{loss}) and B_{pa} (160 kt). The HCR is based not on fishing mortality (F) but on a harvest rate (HR) relative to stock biomass of fish of four years and older (B_{4+}). Given this requirement, the fishing pressure reference points were estimated for HR rather than F. The optimum HR in the absence of assessment error is HR_{MSY} = 0.24. However, ICES framework for reference points requires accounting for advice error in the simulations. Assuming an assessment bias of 7% (based on historical estimates), this is equivalent to HR_{MSY} = 0.22. The final reference points are presented in Table 1.

Table 1   Previous and revised ICES reference points for cod in Division 5.a following the benchmark. Biomass values in tonnes.

Framework	Reference point	Previous value	Revised value	Revised technical basis
MSY approach	MSY $B_{trigger}$	220 000	265 000	The trigger point in HCR that is considered consistent with ICES MSY framework
	HR_{MSY}	0.20	0.22	Stochastic HCR evaluation. Percentage of age 4+ biomass.
Precautionary approach	B_{lim}	125 000	125 000	B_{loss}
	B_{pa}	160 000	160 000	$B_{pa} = B_{lim} \times \exp(1.645\sigma_B)$; $\sigma_B = 0.15$
	F_{lim}/HR_{lim}	0.74	–	Not defined*
	F_{pa}/HR_{pa}	0.58	0.39	HR now used, and basis for HR_{pa} has been revised. HR that, if applied as a target in ICES MSY advice rule (AR) would lead to SSB ≥ B_{lim} with a 95% probability.

* $HR_{pa} > HR_{lim}$ because HR_{lim} (0.35) comes from simulations with no trigger or error, while HR_{pa} applies the advice rule.

Evaluation of candidate HCR

The current HCR for the Icelandic cod fishery, which sets a TAC for the fishing year y/y+1 (September 1 of year y to August 31 of year y+1) is based on:

- MGT $B_{trigger}$ = 220 kt SSB, used in management HCR. SSB is estimated at spawning time April–May.

- when SSB_y ≥ MGT $B_{trigger}$: the mean of an HR of 0.20 (HR_{MGT}) on the age 4+ biomass in the beginning of the assessment year y *and* the TAC from the current fishing year ($TAC_{y-1,y}$)

    - $TAC_{y/y+1} = 0.5* HR_{MGT}*B_{4+,y} + 0.5*TAC_{y-1/y}$

- when SSB_y < MGT $B_{trigger}$: an HR of 0.20 (HR_{MGT}) on the age 4+ biomass in the beginning of the assessment year y, reduced by the ratio SSB_y/MGT $B_{trigger}$.

ICES considered the current HCR and variations in the value of HR_{MGT}. Alternative MGT $B_{trigger}$ values and other functional forms of an HCR were not considered.

In the absence of future implementation bias (which has historically been ~5%), the current HCR is consistent with both ICES precautionary principle and MSY approach. An HR (HR_{MGT}) of up to 0.23 is also considered consistent with ICES precautionary principle and MSY approach. HR_{MGT} targets above 0.23 are not expected to result in increased yields.
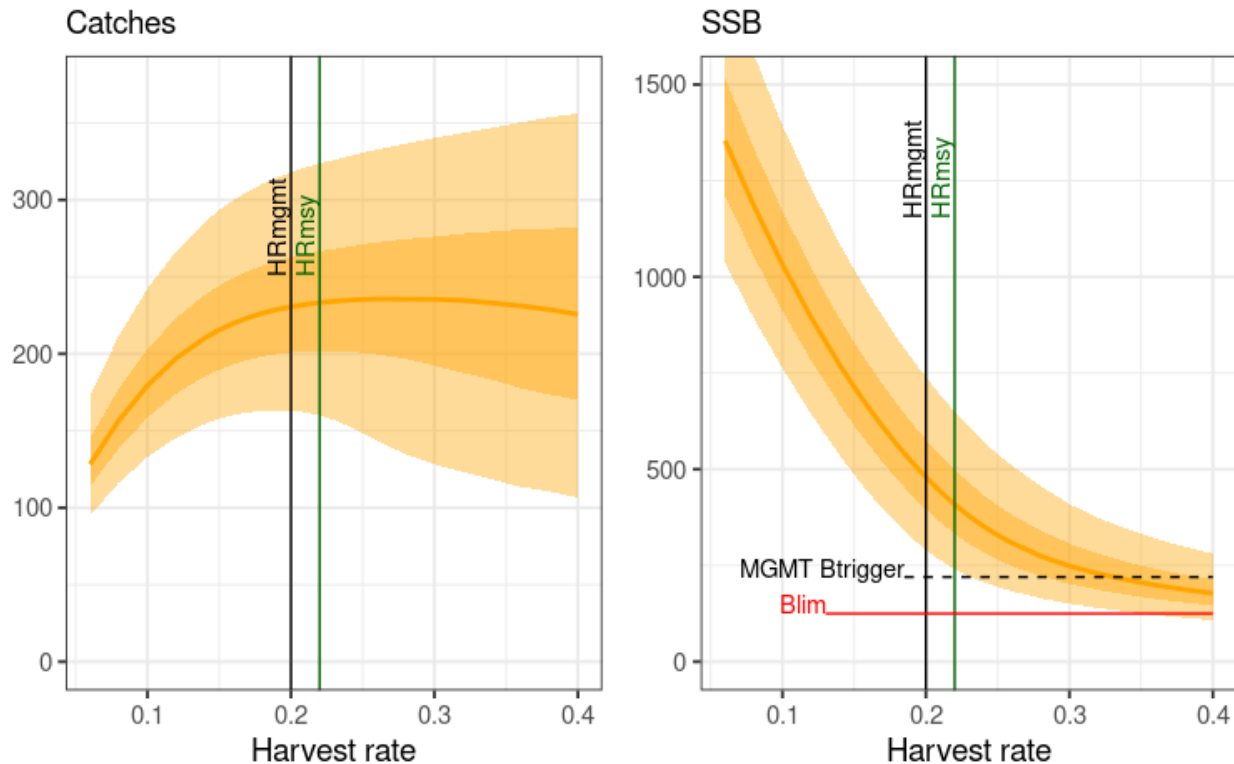
Figure 1   Cod in Division 5.a. Equilibrium catches (in kt, left panel) and corresponding SSB (in kt, right panel) as a function of HR in the HCR. In both panels, the solid curves indicate the median of the distribution and the ribbons the 5th and 95th and 25th and 75th percentiles. The green and black vertical lines are HR_{MSY} (0.22) and the currently implemented HR (HR_{MGT} =0.20), respectively. The black and red horizontal lines are MGT $B_{trigger}$ (220 kt) and B_{lim} (125 kt), respectively.

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 and Freshwater Research Institute (MFRI); initiated by the Icelandic Ministry of Industries and Innovation in the autumn of 2019. The objective of the group was to investigate the performance of currently implemented HCRs for cod and to provide any necessary revisions to ensure their conformity with the precautionary approach and ICES MSY framework in order to maintain a high long-term sustainable yield.

The HCR defined in the request is based on an HR approach using a reference biomass for cod at age four years and older (B_{4+}). The rule was first evaluated in 2009 (ICES, 2010) and revisited in 2015 (ICES, 2015). It has been implemented since the 2007/2008 fishing year by the government of Iceland.

ICES set up a workshop (ICES, 2021a) to evaluate the HCR in which it reviewed the stock assessment methodology and reference points.

Results and conclusions

The results of simulations of the HCR in terms of key population metrics (recruitment, realized HR, catch, spawning biomass, and the reference biomass of four years and older, B_{4+}) are given in Figure 2 for a range of HRs in the HCR (0.15, 0.20, 0.23, and 0.28). The future dynamics are expected to be similar to those observed historically. Higher HRs are associated with bigger fluctuations in realized HR and catch.
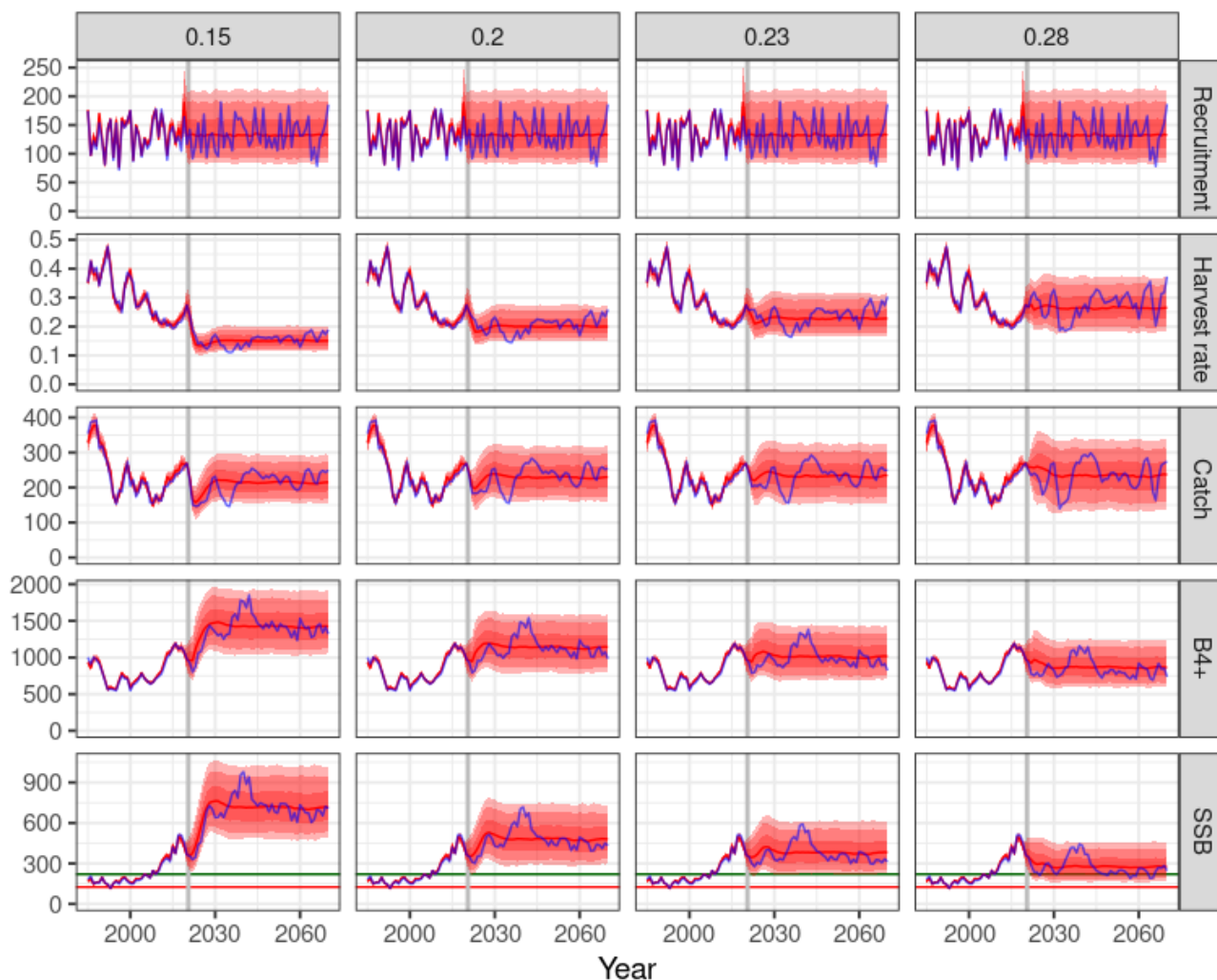
Figure 2   Assessment (from 1985 onwards) and projections of recruitment (millions at age 3), realized HR, catch (in kt) and reference biomass (B$_{4+}$, in kt) and SSB (in kt) for different HR values in the HCR. The different shades of red indicate 90%, 80%, and 50% distribution ranges, the blue line one iteration. The red and green horizontal lines refer to B$_{lim}$ and MGT B$_{trigger}$, respectively.

With an HR of 0.20, annual probabilities of SSB < MGT B$_{trigger}$ are less than 5% in all years. Higher HRs of up to 0.23 would be possible without the probability of SSB < MGT B$_{trigger}$ exceeding 5% (Table 2). There is only a marginal gain in median catch (1%) compared to fishing at HR$_{MGT}$ = 0.20, while the higher HRs result in a lower SSB (see Figure 1).

The distributions of reference biomass (B$_{4+}$), SSB, HRs, and catches expected to result from HCRs with HRs ranging from 0.20 to 0.23 are shown in Table 2. These distributions should be used in the future to check that realized ranges are compatible with expectations. If future observed values were to go outside the ranges illustrated, this would indicate that there is a need to re-evaluate the assumptions of the simulations.

Table 2   Cod in Division 5.a. Long-term median values, and 90% confidence intervals, of the projected catches, realized HRs, reference biomass, and SSB for alternative HR$_{MGT}$ values (0.20 to 0.23) applied in the HCR with MGT B$_{trigger}$ = 220 kt.

HR$_{MGT}$	Catches (in kt)	Realized HR	Reference biomass (age 4+, in kt)	SSB (in kt)
0.20	231 (163–318)	0.20 (0.150–0.27)	1143 (803–1591)	479 (290–740)
0.21	232 (162–321)	0.21 (0.156–0.29)	1095 (765–1536)	442 (263–693)
0.22	233 (160–324)	0.22 (0.161–0.30)	1053 (730–1482)	409 (240–650)
0.23	234 (157–326)	0.23 (0.167–0.31)	1013 (700–1433)	379 (221–609)

Methods

Benchmark assessment

The assessment model was changed during this benchmark. The previous assessment model was based on a statistical catch-at-age with the fishing mortality of each age group modelled independently as a random walk. The new assessment model, which is the same as the one currently used for haddock and saithe in ICES Division 5.a, has similar characteristics but is based on having fixed separable periods. The following list describes the main changes in the updated assessment input data and model setup:

- Spring survey indices ages 1 to 14 are now used in the assessment (in the previous model ages 1 to 10 were used).
- Autumn survey indices ages 3 to 13 are now used in the assessment (previously ages 1 to 10).
- Standard deviations by age were updated from those set in the last benchmark in 2015.
- The correlation model now includes all age groups; previously ages 1 and 2 were modelled separately.
- The non-linear assumption between stock-in-numbers and survey indices was extended from ages 1 to 6 (age 5 in the autumn survey) to ages 1 to 9 for both surveys.

The reason for the change in model was pragmatic (HCR simulation capabilities are inbuilt in the latter) since both models give similar historical dynamics and similar current estimates (when using the same survey input data and model setup; Figure 3). The differences in the early part of the assessment period are related to differences in how the models handle migration events of cod from Greenland.
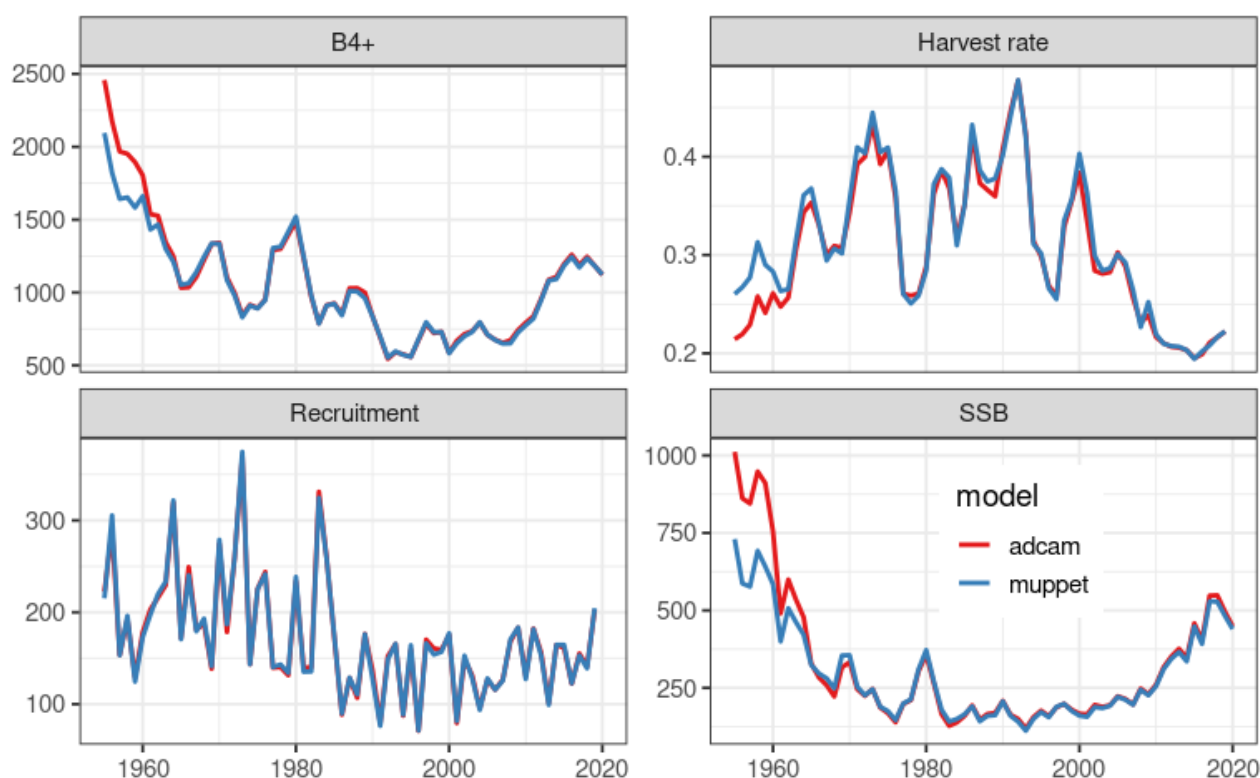

Figure 3   Comparison of key assessment metrics of the adcam and muppet module when using the same survey input data and model setup. Reference biomass (B$_{4+}$, in kt), harvest rate (ratio of catch to 4+ biomass), recruitment (number at age 3; in millions), and SSB (kt).

HCR simulation

A management strategy evaluation (MSE) was conducted for cod in ICES Division 5.a. The operating model, which generates the "true" future populations in the simulations, was conditioned on ICES benchmark stock assessment.

A shortcut approach to generating assessment and forecast error was used (ICES, 2013, 2021b). The assessment error of the reference B_{4+} stock biomass was assigned a CV = 0.13, based on the estimates derived from the historical (empirical) assessment performance. The assessment error was autocorrelated (0.54) to emulate historically observed sequential periods of over- or underestimation of stock biomass.

Recruitment was projected using a segmented regression stock–recruit relationship, assuming that the reduction in productivity estimated in 1985 continues in the future (Figure 4). A log-normal distribution was used based on the distribution of CVs, and autocorrelations estimated by the assessment model with MCMC re-sampling. Although absolute catch levels varied, the risk of SSB < B_{lim} was insensitive to the alternative recruitment scenarios explored. Age-correlated time variant stochasticity in growth was accounted for in the simulations. Maturity-at-age was assumed constant, although the performance of the HCR was tested for robustness to these assumptions by using both stochastic variability in maturity and variability in maturity correlated with weights (low maturity coinciding with low weights and vice versa). The selection pattern used is the same as that estimated within the model. Natural mortality-at-age was fixed in the simulations.

The current HCR is robust to historical assessment bias. Implementation bias was not included.
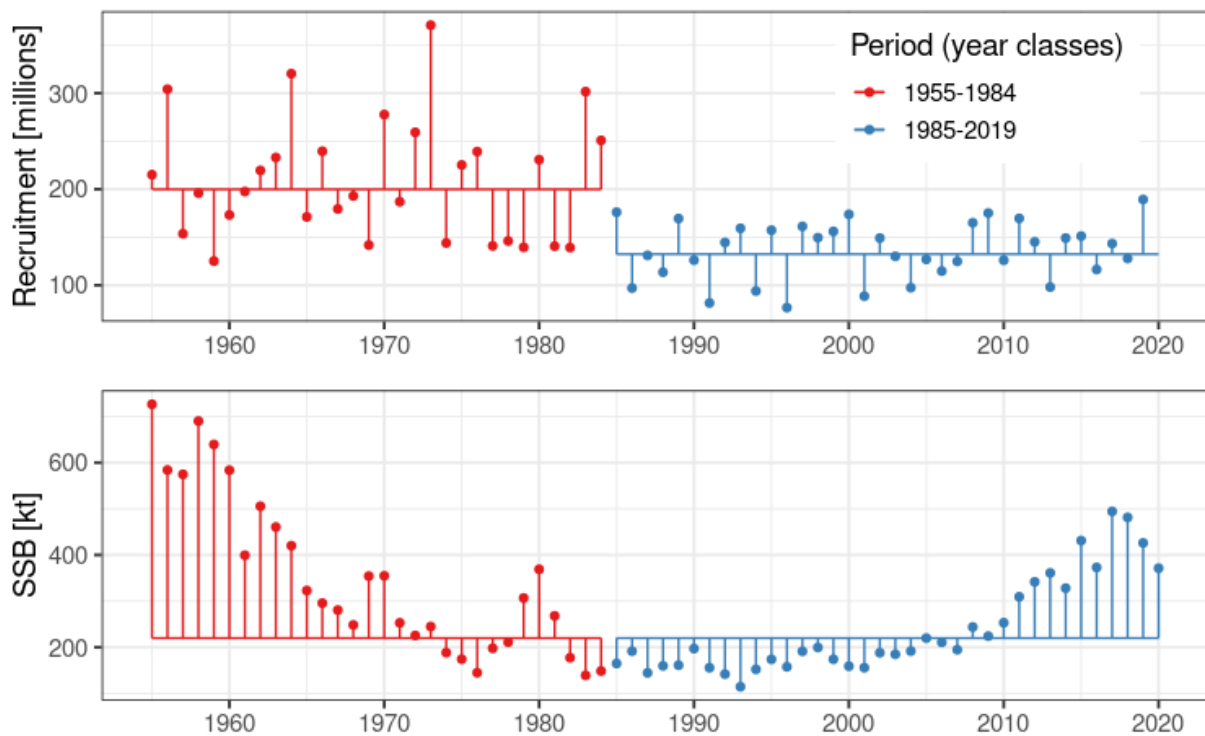

Figure 4   Recruitment (number at age 3) and SSB over time. The recruitment before and after the 1984 year class are shown as deviation from the mean within each period. The SSB is shown as deviation from 220 kt. The *x*-axis on the recruitment plot refers to year class.

Sources and references

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