Request from Portugal and Spain to evaluate a new Harvest Control Rule for the management of the Iberian sardine stock (divisions 8.c and 9.a)

Advice summary

ICES advises that, under a continued low productivity scenario, harvest control rules (HCRs) HCR30, HCR35, HCR40, HCR45, and HCR50 are consistent with ICES precautionary criterion of no more than 5% probability of the spawning–stock biomass (B_{1+}) falling below B_{lim} in the long term. Under a continued low recruitment all the rules are consistent with the precautionary criterion in the period 2021–2026. These conclusions are robust to a potential future shift to a higher productivity regime.

ICES advises that among the precautionary HCRs, the expected catches under a continued low productivity are similar, but differ in terms of interannual variability (increasing with maximum TAC allowed). In the long term, the harvest rate HCR35 results in higher annual catches and lower F than what would result from applying ICES MSY advice rule (AR).

ICES has updated the F_{MSY} reference point, which is now estimated to be 0.092.

Request

ICES received a request for advice from Portugal and Spain on 5 February 2021 for an evaluation of an HCR for sardine in divisions 8.c and 9.a, as well as requests for updates of the advice on catch opportunities. The HCR specified different levels of fishing mortality associated with reference biomass levels, and three candidate values of maximum allowed catches for constraining advised catch. This is equivalent to testing three different HCRs. This advice documents concerns the evaluation of these HCRs and the relevant part of the request is provided below:

Portugal and Spain updated the 2019 Management Plan (MP) for the Iberian sardine (Sardina pilchardus) in ICES waters zones 8c and 9a for the period 2021–2026, to be evaluated by ICES and submitted to the Commission for consideration. For this reason, we kindly ask to ICES to evaluate the fulfilment of the precautionary criteria of the Harvest Control Rules in the MP 2021–2026.

Harvest control rule in the management plan for the Iberian sardine stock:

The proposed HCR (Figure R1) has:

  i.   *three levels for fishing mortality (F = 0, F = 0.064 and F = 0.12);*
  ii.   *three reference levels for B_{1+} (B_{low} (defined as the lowest observed time series Biomass according to the 2018 assessment - WGHANSA 2018) = 112 943 t; $B_{trigger}$ (under the low productivity regime) = 252 523 t and $B_{trigger}$ (under a medium productivity regime) = 443 331 t).*

The proposed HCR can be described as follows:

  i.   *If $B_{1+} \leq 112\ 943$ t then F=0*
  ii.   *If $112\ 943$ t $< B_{1+} \leq 252\ 523$ t then F increases linearly from 0 to 0.064*
  iii.   *If $252\ 523$ t $< B_{1+} \leq 446\ 331$ t then F increases linearly from 0.064 to 0.12*
  iv.   *If $B_{1+} > 446\ 331$ t then F = 0.12*

Conditions ii) to iv) are overridden if the forecast catch in any given year exceeds the maximum allowed catches of 50 kt, 45 Kt and 40 kt.
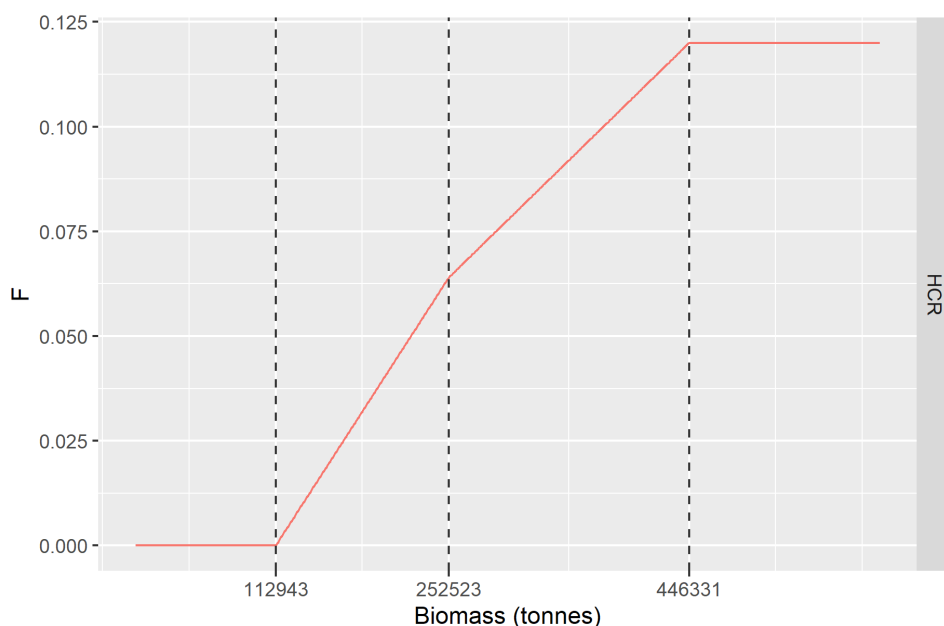
Figure R1   *Proposed HCR. The biomass reference levels of B_{1+} reported correspond to $B_{loss}(2018)=112\,943$ t, $B_{trigger\_low}$ = B_{pa_low} = 252 523 t and $B_{trigger\_medium}$ = B_{pa_medium} = 446 331 t.*

ICES is requested to evaluate the MP under the following conditions:
i)   Initial starting condition: latest assessment (WGHANSA 2020);
ii)   Catch in 2020: based on HCR 12;
iii)   Recruitment scenarios: given the recruitments in latest years, several recruitment scenarios can be considered in the evaluation if consistent.

Elaboration on the advice

MSY reference point

As part of the evaluation of the HCRs, the reference points for this stock were reconsidered (Table 1). The current F_{MSY}, of 0.032 (ICES, 2019), was estimated based on the equilibrium distribution of stochastic projections (EQSIM; ICES, 2015). Given that the management strategy evaluation (MSE) framework was used to evaluate the HCRs, ICES has, therefore, recomputed F_{MSY} using the MSE framework to 0.092. This large upward revision in the F_{MSY} value is due to the inclusion of recent observations of higher recruitment (particularly the 2019 year class) and the use of the MSE framework methodology.

Table 1   Biological reference points under a persistent low productivity.

Reference point	Value	Technical basis
B_{lim}	196 334 t	B_{lim} = hockey-stick change point
B_{pa}	252 523 t	$B_{pa} = B_{lim} * \exp(1.645 * \sigma)$ $\sigma = 0.153$ for the low productivity
MSY $B_{trigger}$	252 523 t	MSY $B_{trigger} = B_{pa}$
F_{lim}	0.26	Stochastic long-term simulations within an MSE framework (50% probability $B_{1+} < B_{lim}$)
F_{pa}	0.092	Stochastic long-term simulations within an MSE framework with ICES MSY AR ($\leq$ 5% probability $B_{1+} < B_{lim}$)
F_{MSY}	0.092	Median F_{target} which maximizes yield without $B_{trigger}$ from stochastic long-term simulations within an MSE framework (0.22), but capped by F_{pa}

Productivity base-case scenario and alternatives

Low productivity, characterized by generally lower recruitment in the period 2006–2019, was considered to represent the current situation and was therefore used in the base-case operating model for the evaluation. Different versions of the generic HCR form using various maximum allowed catch values were evaluated. Recruitment was generated from a hockey-stick relationship using the time-series 2006–2019, with the break point fixed at a B_{lim} of 196 334 tonnes, the same value as formerly established by ICES (ICES, 2019). There are indications that the stock may have begun to transition to a new productivity regime (a low-medium regime characteristic of the long-term recruitment since 1993) as evidenced by a stronger year class in 2019 and indications from the juvenile survey of an equally high recruitment in 2020. At this point the evidence is still inconclusive, though information on incoming year classes will need to be scrutinized in coming years. Because of this, two additional alternative operating models were considered in the evaluation of the HCRs: low-to-medium and mixed recruitment ('Mix').

Starting conditions

In the previous HCR evaluation (ICES, 2019), the stock (spawning–stock biomass = B_{1+}) was considered to be below B_{lim} at the start of the projection period (2018). However, following recent stronger recruitment, B_{1+} in 2020 at the start of this evaluation is estimated to be well above B_{pa} (= 252 523 t).

Short-term performance (2021–2026)

The HCRs are precautionary in both the short and long term and in both the low and low–medium productivity scenarios. For the HCRs with catch caps of 40, 45, and 50 kt, (HCR40, HCR45, and HCR50) median realized fishing mortality is around 0.10, leading to annual catches over the initial period below the maximum catch values for each HCR in the low productivity scenario.

Basis of the advice

ICES explored two additional HCRs with caps of 30 kt and 35 kt (HCR30 and HCR35) in the event that the proposed rules were not precautionary, which did not turn out to be the case.

Results and conclusions

Table 2 presents the summary statistics for the simulation-tested HCRs and ICES MSY AR for the base-case operating model, which considers a persistent low productivity regime for the Iberian sardine stock. Median B_{1+} values vary between 319–326 kt in the initial period (2021–2026) and all slightly decrease over the 30-year projection period. Differences in median catches among HCRs are relatively small, with expected catches between 30–33 kt in the initial period and between 30–34 kt in the long term depending on the HCR used. HCR35 had slightly higher catches than the other HCRs. All HCRs are precautionary in the short- and long term (Figure 1).

Table 2 Summary of the performance statistics for the simulation-tested HCRs under a persistent low productivity of the Iberian sardine stock (B_{lim} = 196 334 t), including ICES MSY AR.

| Low productivity							
Metrics	Periods	HCR30	HCR35	HCR40	HCR45	HCR50	ICES MSY AR
B_{1+}(thousand tonnes)*	2021–2026	326	323	322	320	319	320
	2021–2030	315	312	311	308	307	307
	2041–2050	295	287	283	281	278	282
Catch (thousand tonnes)*	2021–2026	30	33	32	32	32	31
	2021–2030	30	31	31	30	30	30
	2041–2050	30	34	33	32	32	31
F *	2021–2026	0.085	0.094	0.099	0.103	0.104	0.101
	2021–2030	0.087	0.096	0.1	0.102	0.103	0.101
	2041–2050	0.098	0.11	0.117	0.121	0.121	0.115
IAV** (thousand tonnes)*	2021–2026	2	3	5	6	7	4
	2021–2030	2	4	5	6	7	4
	2041–2050	2	3	5	6	7	4
Mean probability of reaching the maximum catch (%)	2021–2026	38.7	33.6	23.7	17.1	11.6	-
First year B_{lim} > 196 kt	2021–2050	2021	2021	2021	2021	2021	2021

 * Median estimates.

 ** Interannual variability.
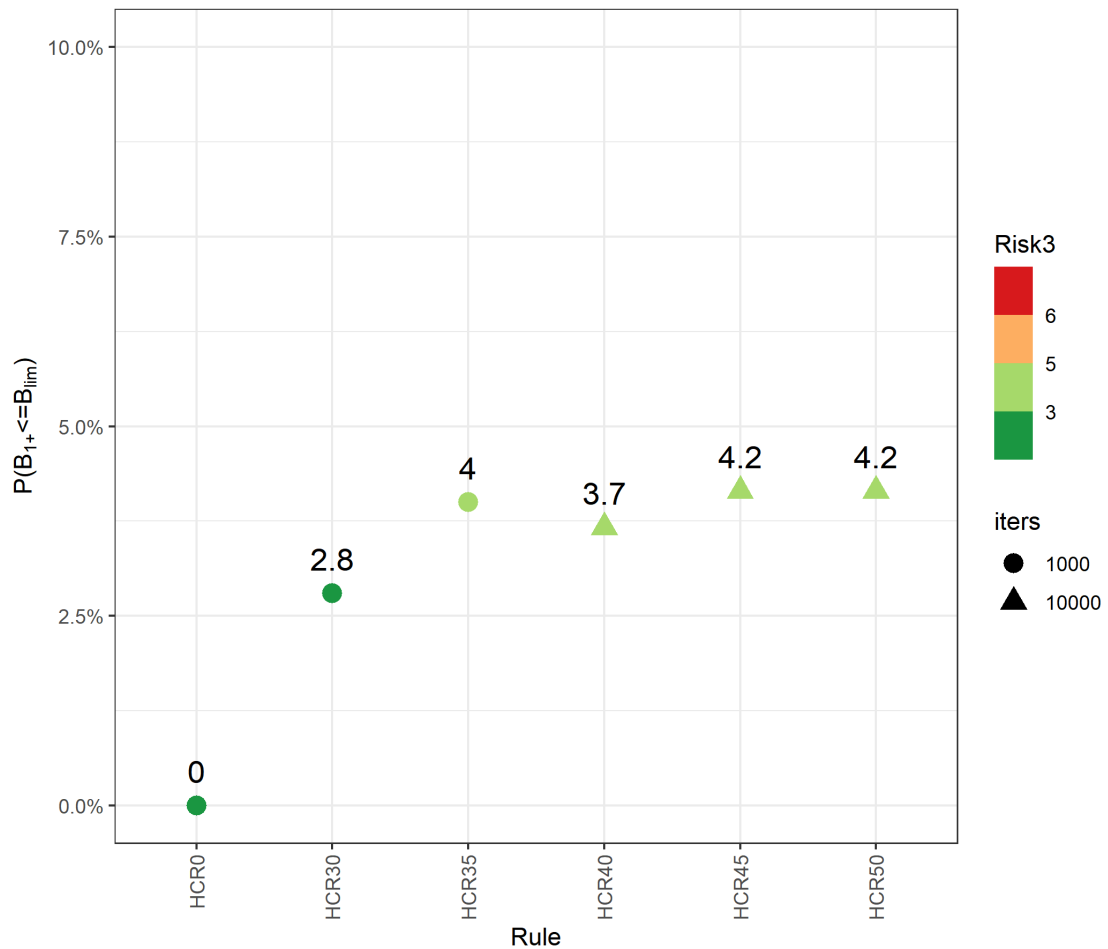
Figure 1   Risk type 3, P(B$_{1+}$ ≤ B$_{lim}$ = 196 334 tonnes), computed in the long term (2041–2050) for the simulation-tested HCRs, including a no fishing rule (HCR0). Number of iterations: circle = 1000 iterations, triangle = 10 000 iterations.

Figure 2 shows an illustrative example (HCR45) of HCR performance over time. Trajectories for other HCRs were similar (ICES, 2021). HCR45 leads to a median recruitment of around 6.8 billion individuals in the long term (Figure 2). Median B$_{1+}$ slightly decrease from 320 kt to 281 kt over the projected period. The lower confidence limit of B$_{1+}$ is above B$_{lim}$ = 196 kt (Figure 2). ICES MSY AR leads to a median recruitment of around 7.6 billion individuals in the long term (Figure 3). Median B$_{1+}$ slightly decrease from 320 kt to 282 kt over the projected period. The lower confidence limit of B$_{1+}$ is above B$_{lim}$ = 196 kt (Figure 3).

If the productivity regime shifts to a more productive state (low-medium), then allowable catches following the HCR would increase while remaining precautionary. ICES is not in a position to evaluate whether the HCRs are precautionary in the Mix scenario in the absence of an appropriate definition of B$_{lim}$ for this dynamic scenario.
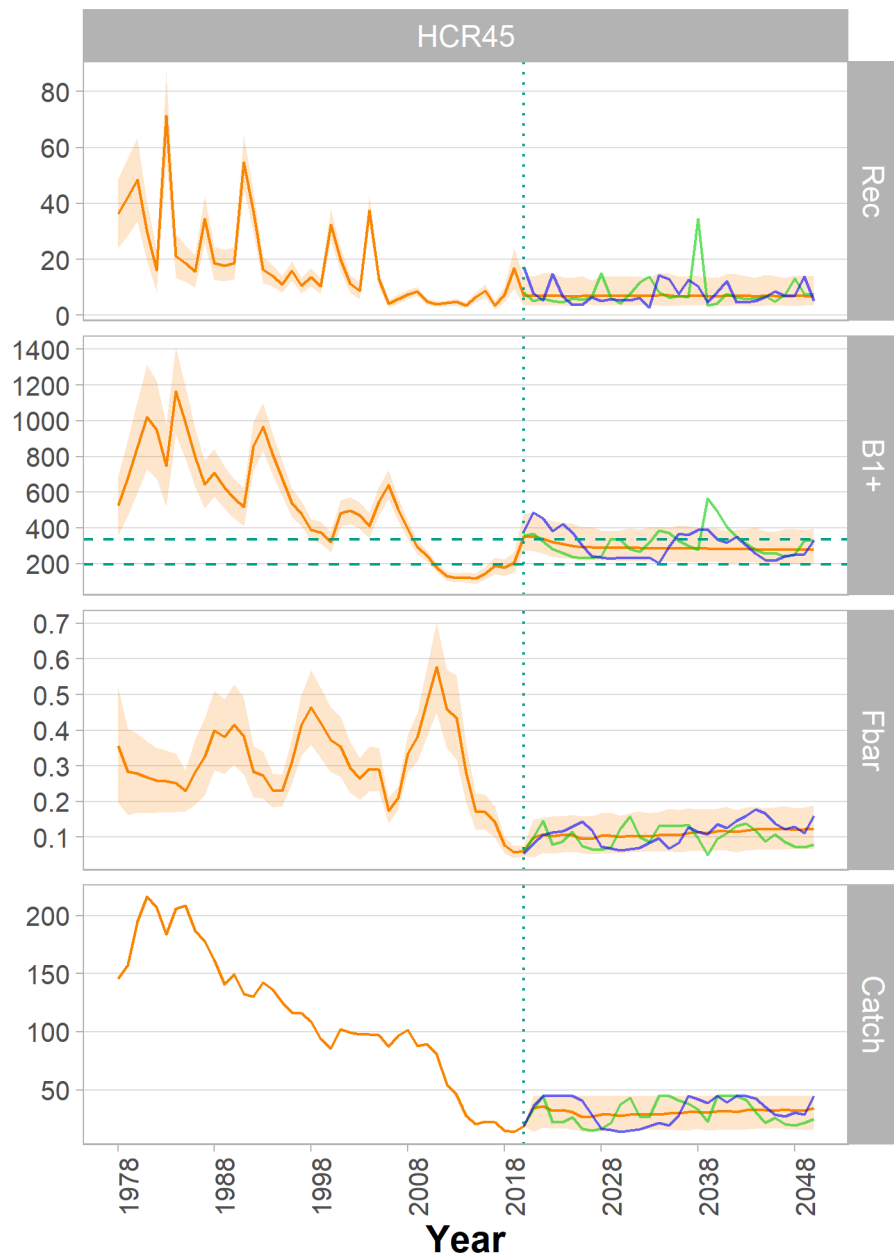
Figure 2   HCR45 under low productivity. Recruitment (Rec, in billions of individuals), biomass of fish age 1 and older (B1+, in thousand tonnes), fishing mortality (F_{bar} ages 2–5), and catch (thousand tonnes) for the assessment period (1978–2019) and during the projected period (2020–2050) for HCR45 under 'true' stock of low productivity. Shaded areas represent 90% confidence intervals. Horizontal dashed lines in B1+ show B_{lim} of low productivity (196 thousand tonnes) and of medium productivity (337 thousand tonnes). The long dashed vertical lines separate the historical from the projected period. The blue and green lines show the results from two simulated iterations selected randomly.
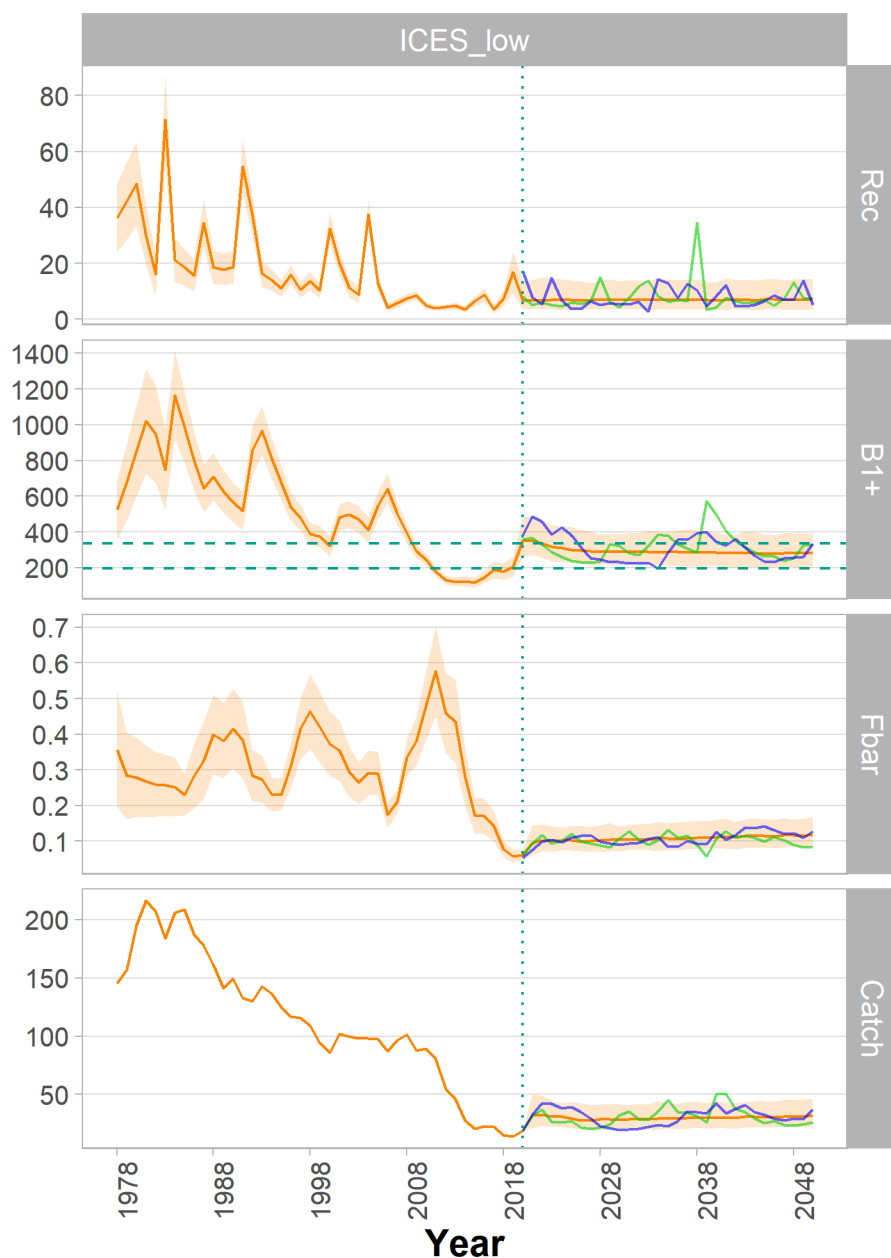
Figure 3   ICES MSY AR under low productivity. Recruitment (Rec, in billions of individuals), biomass of fish age 1 and older (B_{1+}, thousand tonnes), fishing mortality (F_{bar} ages 2–5) and catch (thousand tonnes) for the assessment period (1978–2019) and during the projected period (2020–2050). Shaded areas represent 90% confidence intervals. Horizontal dashed lines in B_{1+} show B_{lim} of low productivity (196 thousand tonnes) and of medium productivity (337 thousand tonnes). The long dashed vertical lines separate the historical from the projected period. The blue and green lines show the results from two simulated iterations selected randomly.

Methods

Evaluation of HCRs

The performance of each HCR was evaluated using a full-feedback MSE (ICES, 2020a). The MSE includes an annual stock assessment cycle and short-term projections. The operating model was based on the most recent stock assessment (ICES, 2020b). Recruitment into the future was generated for the base case according to a persistent low productivity. One thousand populations (iterations) were simulated 30 years into the future. Ten thousand iterations were used for three of the HCRs to obtain a more precise evaluation of risk.

Alternative operating models

To test the robustness of the performance of the HCRs, two other productivity scenarios were explored:

- "Low-to-medium": a transition from low to medium productivity, as soon as B_{1+} in any given year was above 337 448 tonnes (B_{lim} for the time-series 1993–2019; Figure 4). Once the transition occurred, stochastic recruitment was generated from the medium productivity regime until the end of the projected 30-year period.
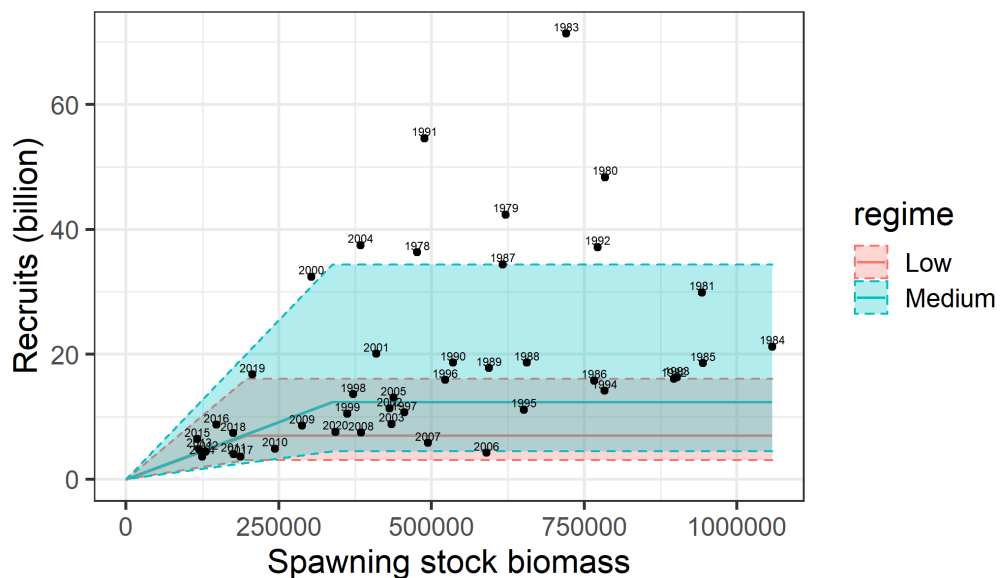

Figure 4   Fitted (solid line) and 95% confidence intervals (dashed lines) for hockey-stick spawning–stock biomass (B_{1+}; tonnes) and recruitment (billion) relationship for the low (period 2006–2019 with B_{lim} fixed at 196 334 tonnes – red lines) and the medium (period 1993–2019 with B_{lim} fixed at 337 448 tonnes –blue lines) productivity regimes. The successive application of these two stock–recruit (S–R) relationships as soon as B_{1+} is above 337 448 tonnes defines the low-to-medium productivity scenario.

- "Mix": a transition from low to medium and from medium to low productivity was dictated by a B_{1+} level of 337 448 tonnes (Figure 5). The transition from low to medium productivity occurred whenever in any given year B_{1+} was above 337 448 tonnes though reverting back to low productivity if in any given year B_{1+} decreased below that value. In this scenario, the 1000 simulated populations (iterations) were projected 50 years into the future.
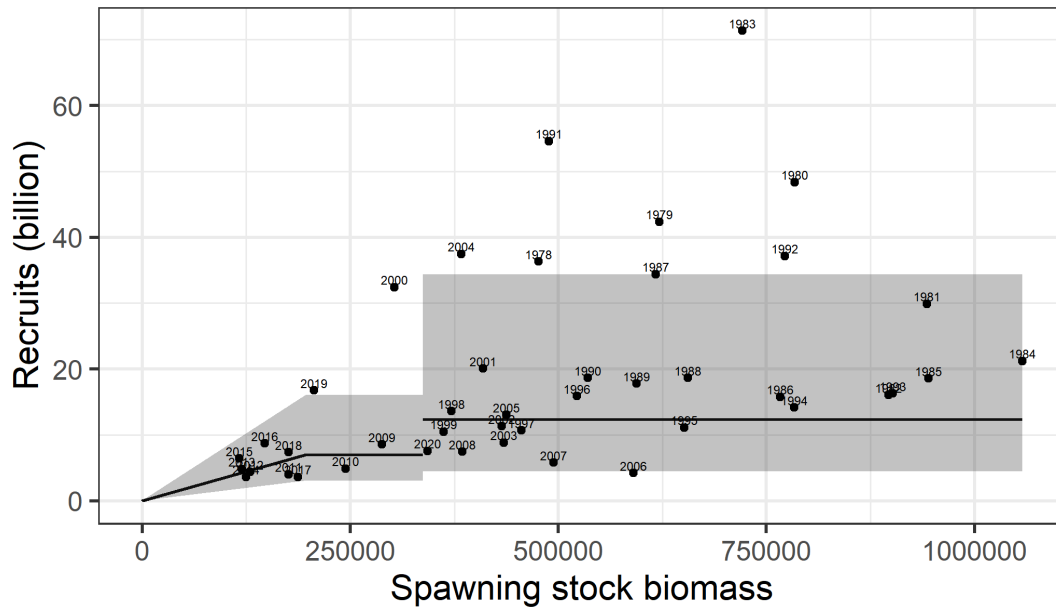
Figure 5 Combined hockey-stick spawning–stock biomass (B_{1+}; tonnes) and recruitment (billion) relationships for the low and the low-to-medium recruitment productivity scenarios, which defines the "Mix" productivity scenario, with annual transition between productivity scenarios being dictated by the reference B_{1+} of 337 448 tonnes.

Performance indicators

The performance of the HCRs was evaluated against the following indicators (outputs) and criteria:

- median spawning–stock biomass (B_{1+}),
- median $F_{(ages\ 2–5)}$,
- median catch,
- interannual variability in the catch,
- mean probability of reaching the maximum catch value in the HCR in 2021–2026,
- probability of closure of the fishery (the mean probability of TAC = 0),
- first year that the probability of $B_{1+} \geq B_{lim}$ is > 95%,
- maximum probability of $B_{1+} < B_{lim}$ in 2041–2050.

ICES criterion to define an HCR as precautionary is that the maximum annual probability of SSB falling below B_{lim} is less than 5% in the long term (Risk3).

Analysis on risk accuracy

Because the evaluation of Risk3 depends on estimates obtained at the tails of the biomass distributions, a proper evaluation of this criterion requires that the number of iterations in the simulation is large enough to obtain accurate and robust estimates of risk. ICES evaluated the precision and accuracy of Risk3 for three selected control rules (HCR40, HCR45, and HCR50). Risk3 was computed based on random samples (size of 100 iterations) without replacement of different sizes that ranged from 500 to 10 000 in steps of 500. The computed Risk3 for each sample size were compared to their estimates computed for the 10 000 iterations. Risk3 estimates were positively biased, and the bias decreased with increasing number of iterations. This aspect was particularly important for the precautionary evaluation of HCR45 and HCR50 under the low recruitment productivity scenario, because these HCRs presented Risk3 at the border of the 5% threshold for 1000 iterations.

Sources and references

ICES. 2015. Report of the Joint ICES-MYFISH Workshop to consider the basis for FMSY ranges for all stocks (WKMSYREF3), 17–21 November 2014, Charlottenlund, Denmark. ICES CM 2014/ACOM:64. 156 pp.

ICES. 2019. Workshop on the Iberian Sardine Management and Recovery Plan (WKSARMP). ICES Scientific Reports, 1:18. 168 pp. http://doi.org/10.17895/ices.pub.5251.

ICES. 2020a. The third Workshop on Guidelines for Management Strategy Evaluations (WKGMSE3). ICES Scientific Reports, 2:116. 112 pp. https://doi.org/10.17895/ices.pub.7627.

ICES. 2020b. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES Scientific Reports, 2:41. 655 pp. http://doi.org/10.17895/ices.pub.5977.

ICES. 2021. The Workshop for the evaluation of the Iberian sardine HCR (WKSARHCR). ICES Scientific Reports. 3:49. 115 pp. https://doi.org/10.17895/ices.pub.7926[‡]

[‡] Version 3: Reference added.

Annex

The performance statistics for the low-to-medium and the "Mix" alternative productivity scenarios are presented in tables A1 and A2, respectively. Under a low-to-medium productivity scenario all HCRs are precautionary (Figure A1).

Table A1§   Summary of the performance statistics for a low-to-medium productivity scenario of the Iberian sardine stock for the simulation tested HCRs.

Metrics	Periods	Harvest control rules				
		HCR30	HCR35	HCR40	HCR45	HCR50
B_{1+} (thousand tonnes)*	2021–2026	487	482	477	472	475
	2021–2030	518	513	502	496	496
	2041–2050	590	579	563	551	541
Catch (thousand tonnes)*	2021–2026	30	35	40	45	50
	2021–2030	30	35	40	45	50
	2041–2050	30	35	40	45	50
F *	2021–2026	0.061	0.07	0.079	0.087	0.093
	2021–2030	0.058	0.067	0.077	0.085	0.093
	2041–2050	0.052	0.062	0.072	0.083	0.092
IAV** (thousand tonnes)*	2021–2026	1	2	3	4	5
	2021–2030	1	1	2	3	4
	2041–2050	0	0	1	1	2
Mean probability of reaching the maximum catch (%)	2021–2026	56.8	58.8	51.7	43.5	39.2
First year B_{lim} > 196 kt	2021–2050	2021	2021	2021	2021	2021
First year B_{lim} > 337 kt	2021–2050	2024	2025	2025	2025	2025
Risk type 3 (%)	2041–2050	1	1.5	2.3	2.7	3.8

* Median estimates.
** Interannual variability.

Table A2§   Summary of the performance statistics for a Mix productivity scenario of the Iberian sardine stock for the simulation tested HCRs.

Metrics	Periods	Harvest control rules				
		HCR30	HCR35	HCR40	HCR45	HCR50
B_{1+} (thousand tonnes)*	2021–2026	444	436	433	427	425
	2021–2030	472	463	455	447	444
	2061–2070	589	572	551	534	510
Catch (thousand tonnes)*	2021–2026	30	35	40	45	45
	2021–2030	30	35	40	45	49
	2061–2070	30	35	40	45	50
F *	2021–2026	0.065	0.074	0.082	0.088	0.094
	2021–2030	0.062	0.071	0.08	0.087	0.094
	2061–2070	0.052	0.063	0.074	0.084	0.095
IAV** (thousand tonnes)*	2021–2026	1	2	3	4	5
	2021–2030	1	2	3	4	4
	2061–2070	0	0	1	1	2
Mean probability of reaching the maximum catch (%)	2021–2026	50.8	50.3	41.9	34.9	30.9

* Median estimates.
** Interannual variability.

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§ Version 2: Table number corrected.

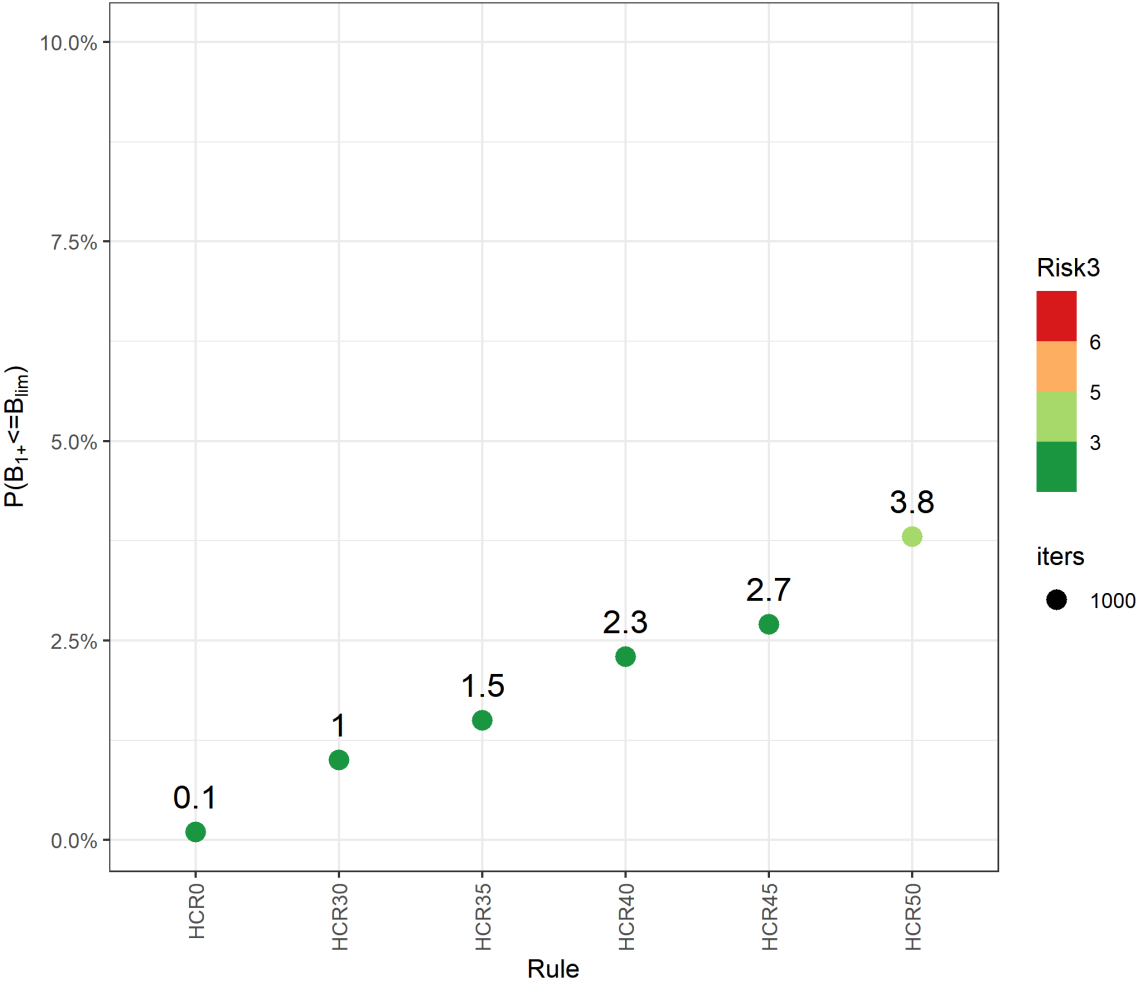**Figure A1**[**] Risk type 3, $P(B_{1+} \leq B_{lim} = 337\ 448$ tonnes), computed in the long term for the simulation tested HCRs, including a no fishing rule (HCR0), under a low-to-medium productivity scenario

[**] Version 2: Figure number corrected.