ICES Special Request Advice
Bay of Biscay and the Iberian Coast Ecoregion
Published 29 May 2019
Version 2: 13 December 2019

Request from Portugal and Spain to evaluate a management and recovery plan for the Iberian sardine stock (divisions 8.c and 9.a)

Advice summary

ICES considers that the Iberian sardine stock has been in a state of low productivity since 2006 and ICES has therefore recalculated the values of B_{lim} to 196 334* tonnes and F_{MSY} to 0.032.

ICES advises that harvest control rules HCR3 and HCR4, that are similar to those in the request but with trigger points, and with biological reference points that reflect a persistent low productivity, fulfil the recovery objective in the request by 2022, and are consistent with the ICES precautionary approach with no more than 5% probability of the spawning–stock biomass (SSB) falling below B_{lim}. These harvest rules result in annual catches of around 7000 tonnes.

Neither of the harvest control rules (HCRs) proposed in the request (HCR1 and HCR2) comply with the ICES precautionary criterion. The HCR with step changes in fishing mortality between trigger points and an imposed 5% interannual increase in the spawning biomass, meets the objective in the request by 2022, with a 40% probability of fishery closure in the first five years.

Request

To clarify the Iberian sardine Harvest Control Rule proposed in the Management Plan we inform that:

Objective:
Assure that the stock biomass will be equal or above 80% of Blim with a probability 90% by the year 2023, (If this objective is not achieved in the specified number of years (n = 5), please evaluate what would be the least time frame possible to achieve this objective with the same risk).

Harvest Control Rule (HCR):

i. *In the case B1+ is estimated to be below or equal to B_{low} (B_{low} - lowest biomass estimated for the year 2015 in the 2018 assessment (ICES, 2018a)), the catch shall be zero which is consistent with a fishing mortality (F) equal to zero.*
   If B1+ ≤ B_{low} then F = 0
ii. *In the case B1+ is estimated to be less than or equal to 80% of B_{lim} and larger than B_{low}, the catch shall be fixed at a value that is consistent with a fishing mortality (F) equal to 0.10.*
   If B_{low} < B1+ ≤ 80% B_{lim} then F = 0.10
iii. *Where the clause in paragraph ii would lead to an inter-annual increase in B1+ inferior to 5%, F should decrease to a level that would lead to at least a 5% inter-annual increase of B1+.*
iv. *In the case B1+ is estimated to be above 80% of Blim, the catch shall be fixed at a value that is consistent with a fishing mortality (F) equal to 0.12.*
   If B1+ > 80%B_{lim} then F= 0.12

In the context of the management and recovery plan submitted, we ask ICES to consider also, instead of ii) and iii): in the case B1+ is estimated to be less or equal to B_{lim} and larger than B_{low}, the catch shall be fixed at a value that is consistent with F increasing linearly from F = 0.085 to F=0.12 (F_{MSY}).

We also ask ICES to evaluate if it is necessary to re-estimate reference points for this stock to account for:

a) *The possibility that the low productivity of this stock in the recent past (since 2006) might continue in the future.*
b) *Possible retrospective bias in the assessment estimates.*

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And to test 2 alternatives:

i. *Start from the population (numbers-at-age) estimated in the beginning of the interim year of the last assessment (ICES, 2018a) and*
ii. *Start from the population projected one year ahead, to the beginning of year for which the catch is to be set*

In both cases assume the 2018 catch to be 12.028 t, as agreed by Spain and Portugal.

Elaboration on the advice

ICES considers that the Iberian sardine stock is in a state of low productivity which has resulted in low recruitment for the last decade. This is likely caused by a combination of fisheries and environmental changes. Taking the low productivity state into account, ICES has recalculated the values of the biological reference points (BRPs).

Evaluation of reference points

The re-evaluation of the BRPs was based on data from the period 2006–2017 which is considered representative of this low productivity state. The updated BRPs are B_{lim} = 196 334[†] tonnes and F_{MSY} = 0.032; these values are significantly different from the previous ones (Table 1). The harvest control rules in the request have a target F of 0.12, which is considerably higher than the estimated F_{MSY} in the current state of low productivity (0.032). ICES did explore harvest control rules HR1 and HR2, using the previous BRPs, but these estimates do not reflect the current stock dynamics in the stock's state of low productivity. The updated BRPs, assuming a state of low productivity, were used to set the biomass and fishing mortality reference levels for the two other harvest control rules (HR3 and HR4) considered in this advice. For all harvest control rules, the value of B_{low} (lower trigger point) was set at 112 900 tonnes, corresponding to the biomass estimate for 2015 from the 2018 assessment (ICES, 2018a) as specified in the request.

ICES is not able to predict the persistence of the current state of low productivity and therefore recommends that the state of productivity for this stock is monitored regularly to determine if the BRPs and the resulting harvest control rules associated with low productivity remain valid.

Table 1 Estimated reference points. Previous reference points (based on data from 1993–2015; ICES, 2017) and updated reference points based on the state of low productivity (2006–2017; ICES, 2019a). The hockey-stick model was used in both cases.

Reference point	Previous	Updated
B_{lim} (tonnes)	337448	196334
B_{pa} (tonnes)	446331[‡]	252523
F_{lim}	0.250	0.156
F_{pa}	0.189	0.118
F_{MSY}*	0.12	0.032

* The F that maximizes long-term yield under the constraint that the long-term probability of SSB < B_{lim} is ≤ 5% when applying the ICES MSY advice rule (ICES, 2018b).

Description of proposed and alternative harvest control rules

The request proposed two catch rules, each with three reference levels for fishing mortality (no fishing, low F, and target F) and three reference levels for the biomass of age 1 and older individuals, B1+ (B_{low}, 80%B_{lim}, and B_{lim}). As ICES considers the Iberian sardine stock to be in a state of low productivity, a further two HCRs were evaluated using the re-estimated BRP values from the low productivity period.

ICES evaluated four harvest control rules.

[†] Version 2: unrounded number inserted
[‡] Version 2: number corrected

- HCR1 as described in the request, with step changes in fishing mortality between trigger points, assuming a state of medium productivity (Figure 1);
- HCR2 as described in the request, with gradual change in fishing mortality between trigger points, assuming a state of medium productivity (Figure 1);
- HCR3 is similar to HCR1 but incorporating new values for target and trigger points (except for B_{low}) that correspond to a state of low productivity (Figure 2);
- HCR4 is similar to HCR2 but incorporating new values for target and trigger points (except for B_{low}) that correspond to a state of low productivity (Figure 2).

The harvest control rules were evaluated through full-feedback management strategy evaluations. The catch rules set a TAC for the fishing year y+1, dependent on the biomass of fish age 1 and older (B1+) in year y+1. All HCRs close the fishery in years when B1+ is below 112 900 tonnes (B_{low}).

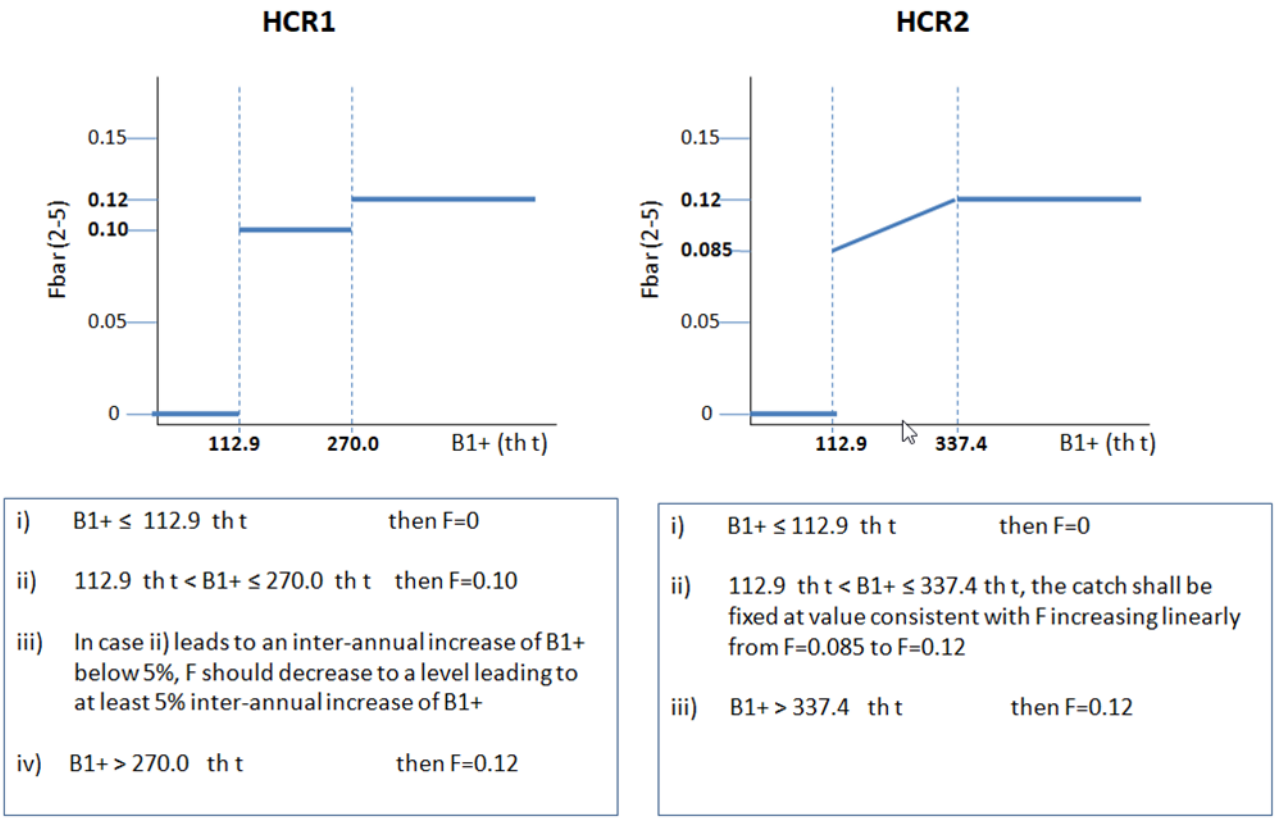

Figure 1 Graphical interpretations of the requested harvest control rules (items i to iv in the request), identified as HCR1 and HCR 2. The lowest biomass trigger point is B_{low} = 112 900 tonnes, the higher trigger point is 80% of B_{lim} = 270 000 tonnes for HCR1 and the previous B_{lim} = 337 448[§] tonnes for HCR2.

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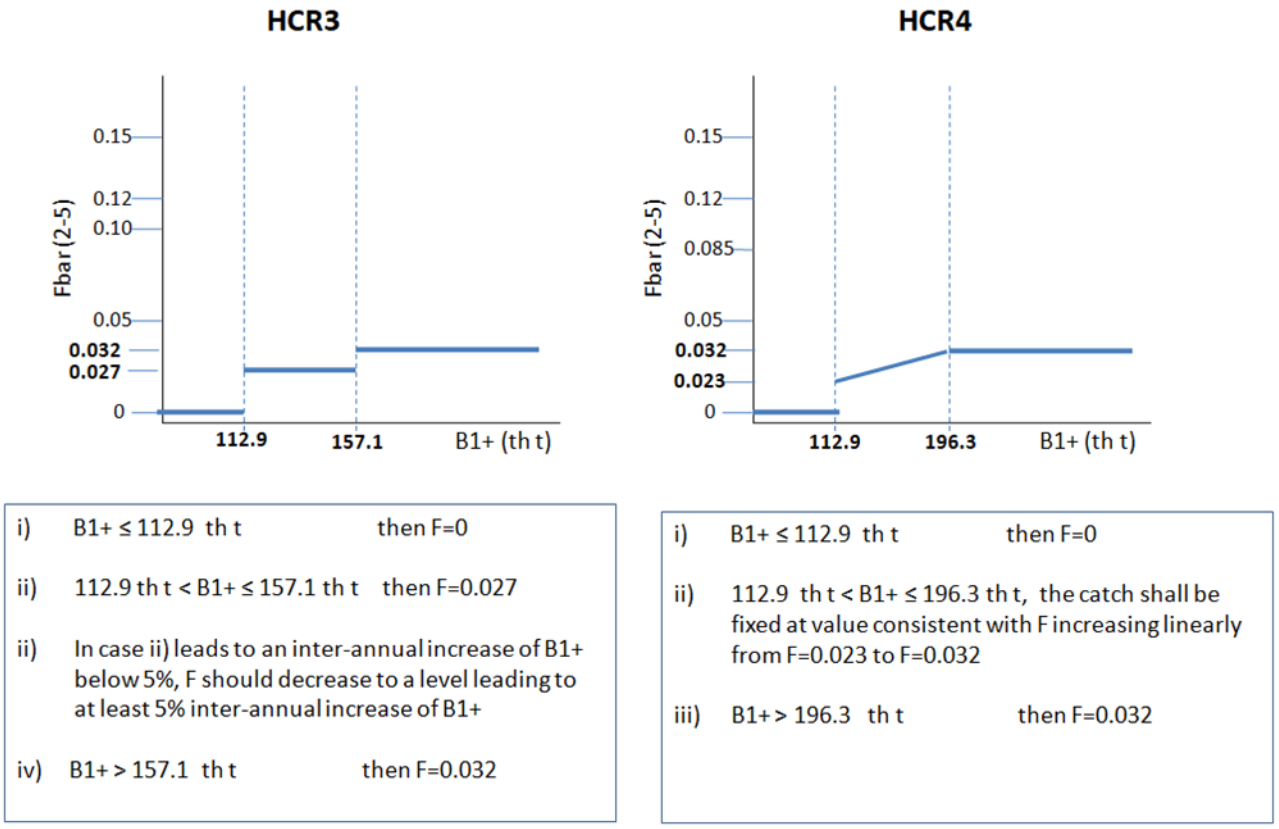

Figure 2 Graphical interpretations of the harvest control rules (items i to iv in the request) using the redefined values for BRPs, identified as HCR3 and HCR4. The lowest biomass trigger point is B_{low} = 112 900 tonnes, the higher trigger point is 80% of the new B_{lim} = 157 100 tonnes for HCR3 and the new B_{lim} = 196 334** tonnes for HCR4.

Evaluation of proposed and alternative harvest control rules against objectives

The evaluations suggest that HCR1 has an 95% probability of B1+ ≥ 80%B_{lim} in 2023, thus fulfilling the objective of the request, whereas HCR2 has an 85% probability of B1+ ≥ 80%B_{lim} in 2023 and is likely to reach this objective by 2026 (Table 2). Neither HCR1 or HCR2 would be considered precautionary in the long term using the ICES criterion of a < 5% probability of B1+ being below B_{lim}. HCR1 has a higher variability in $F_{2–5}$ and a higher frequency of closures (Figure 4). This higher frequency is mostly due to clause iii) in HCR1 which imposes a 5% interannual increase in B1+.

The evaluations suggest that HCR3 and HCR4 have a 95% probability of B1+ ≥ 80%B_{lim} in 2023 (Table 2). Both HCR3 and HCR4 would be considered precautionary in the long term if the ICES criterion of <5% probability of B1+ being below B_{lim} is used. The probability of fishery closure is < 2%.

The trigger point, 80% B_{lim}, is defined by the managers for a short-term recovery. ICES notes that 80% B_{lim} is associated with a high probability of impaired recruitment and potential loss of yield. The HCRs were evaluated both as recovery plans and as long-term management plans. The ICES precautionary criterion of spawning biomass (B1+) having a less than 5% probability of being below B_{lim} is not achievable within 30 years for HCR1 and HCR2, and achievable in approximately two generations for HCR3 and HCR4, if the state of low productivity persists.

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Suggestions

When the advice is for an extremely low catch, it may be difficult to apply full implementation as assumed in the evaluation. It would therefore be beneficial to have information from a monitoring fishery with an associated sampling protocol to estimate the state of the stock.

Basis of the advice

Background

The biomass of the stock has experienced a large decline, from nearly 650 000 tonnes in 2006 to less than 150 000 tonnes in 2018. The stock is considered depleted and in need of a recovery plan.

Evaluation of harvest control rules

The performance of each HCR was evaluated using a full-feedback management strategy evaluation. An operating model assuming a state of low productivity was used in the evaluations. 1000 populations (iterations) were simulated 30 years into the future.

The performance of HCRs was evaluated against the indicators/outputs and criteria listed below.

- Median spawning biomass (B1+),
- Median $F_{(2–5)}$,
- Median catch,
- Interannual variability in the catch,
- Probability of closure of the fishery (the mean probability of TAC = 0),
- Probability that B1+ ≥ 80% of B_{lim} in 2023,
- First year that the probability of B1+ ≥ 80% B_{lim} is ≥ 90%,
- First year that the probability of B1+ ≥ B_{lim} is > 95%,
- The maximum probability of B1+ < B_{lim} in 2039–2048.

Results and conclusions

HCR1 and HCR2 result in an increase in median $F_{2–5}$ over time to 0.17, but with a slow increase (< 0.5% per year) in median B1+ (Figure 3). Individual iterations show greater variability over time (Figure 3).

HCR3 and HCR4 result in a low median $F_{2–5}$ and an increase (approx. 1.7% per year) in median B1+ (Figure 5). Median catch with both HCRs is estimated as 7000 tonnes in the short term, increasing to 12 000 tonnes in the long term. Interannual variability is low (approximately 1000 tonnes).

Figure 3 Recruitment (Rec, million individuals), biomass of fish age 1 and older(B1+, thousand tonnes), fishing mortality ($F_{2–5}$, year) and catch (thousand tonnes) for the assessment period (1978–2017) and during the projected period (2019–2048) for **HCR1** and **HCR2** under low productivity. Shaded areas represent the 90% confidence intervals. Horizontal dashed lines in B1+ show B_{lim} (196 334 [††] tonnes) and the previous B_{lim}, assuming medium productivity (337 448[††] tonnes). Vertical long dashed lines separate the historical from the projected period. The blue and red lines show the results from two simulated iterations selected randomly.

[††] Version 2: unrounded numbers inserted

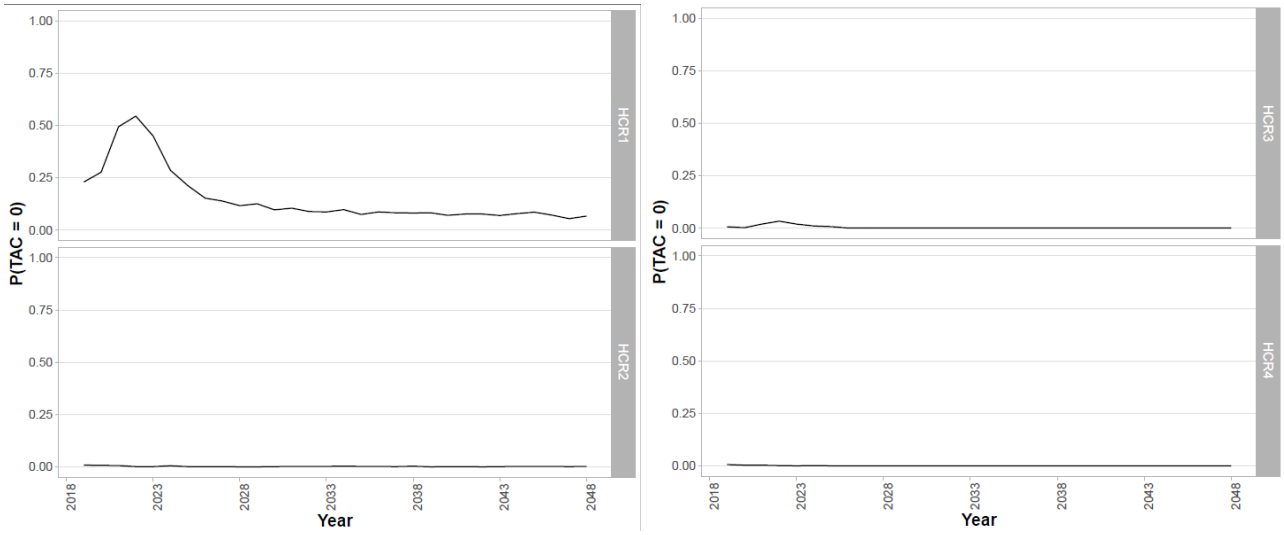

Figure 4 Probability of zero TAC by year for HCRs 1, 2, 3, and 4.

Figure 5 Recruitment (Rec, million individuals), biomass of fish age 1 and older (B1+, thousand tonnes), fishing mortality ($F_{2–5}$, year), and catch (thousand tonnes) for the assessment period (1978–2017) and during the projected period (2019–2048) for **HCR3** and **HCR4** under low productivity. Shaded area represents 90% confidence intervals. Horizontal dashed lines in B1+ show B_{lim} (196 334‡‡ tonnes) and the previous B_{lim}, assuming medium productivity (337 448‡‡tonnes). Vertical long dashed lines separate the historical from the projected period. The blue and red lines show the results from two simulated iterations selected randomly.

‡‡ Version 2: unrounded numbers inserted

Table 2 Summary of the performance statistics for HCRs 1, 2, 3, and 4, assuming persistent low productivity.

	Metrics	Period	HCR1	HCR2	HCR3	HCR4
Indicators/outputs	Median spawning biomass (B1+) thousand tonnes	2019–2023	207	190	207	207
		2019–2028	231	211	248	248
		2039–2048	228	220	295	296
	Median $F_{(2–5)}$	2019–2023	0.013	0.112	0.034	0.034
		2019–2028	0.104	0.121	0.035	0.035
		2039–2048	0.167	0.165	0.042	0.042
	Median catch, thousand tonnes	2019–2023	2	19	7	7
		2019–2028	28	23	8	8
		2039–2048	34	32	12	12
	Interannual variability in the catch, thousand tonnes ($Mean\,\lvert Catch_{t-1} - Catch_t \rvert$)	2019–2023	9	4	1	1
		2019–2028	10	4	1	1
		2039–2048	9	5	1	1
	Mean probability of closure of the fishery (TAC = 0)	2019–2023	40	0	2	0
		2019–2028	29	0	1	0
		2039–2048	7	0	0	0
Special Request objectives	Probability of B1+ ≥ 80% of B_{lim} in 2023 (%)	2023	95	85	95	95
	First year with probability of B1+ ≥ 80%B_{lim} is ≥ 90%	2019–2048	2022	2026	2022	2022
Additional criteria	First year with probability of B1+ ≥ B_{lim} being > 95%	2019–2048	Not achievable	Not achievable	2026	2027
	The maximum probability of B1+ < B_{lim} in 2039–2048 (%)	2039–2048	31	34	1	1

Methods

The request was evaluated through a workshop (ICES, 2019a).

The methodology used to estimate BRPs followed the framework proposed in ICES guidelines on fisheries management reference points (ICES, 2017). The influence of the retrospective bias in the stock assessment on the BRPs was evaluated and found to be negligible.

The management strategy evaluation (MSE) of the proposed Management and Recovery Plan (MRP) followed the recommendations of ICES (2019b) and was undertaken using FLBEIA (Bio-Economic Impact Assessment using FLR; García *et al*., 2017). The operating model, which generates the "true" future populations in the simulations, was conditioned on the ICES stock assessment. The biological and fishery parameters in the operating model were considered constant over time as there is no indication of significant trends. Future recruitment was estimated from the spawning–stock biomass following a hockey-stick relationship, and with variability introduced from a lognormal distribution.

The management procedure component included a stock assessment and an advice based on short-term forecasts in each assessment loop. The currently used age-based assessment model SS3 was included. Survey indices and catch data used as inputs in each assessment cycle were generated from the "true" population, with lognormal distributed errors to include observation error in the simulations. Full implementation of management advice was assumed (i.e. TAC advice is always fully implemented).

The MSE simulation carried out to analyse the performance of the proposed MRP is based on 1000 populations (iterations), each projected from 2019 to 2048. For comparison with the full-feedback MSE runs that show some bias in the assessment, the same MSE simulations were carried out without observation error and without assessment. Further details on the methodology and results are available in ICES (2019a). Code used for the simulation testing is available in GitHub (https://github.com/ssanchezAZTI/FLBEIA_mseIBpil).

The request specified two alternatives for the initial population in the simulation testing, assuming that the catch in 2018 would be 12 028 tonnes. This forces the initial population for the simulation testing to be the same in both alternatives. However, at the time of the workshop meeting, preliminary estimates of the 2018 catches were 14 060 tonnes. This value was therefore adopted for the analysis as it represented the actual catches and would be more realistic.

The mean generation time (the average time it takes for a mature female to be replaced by an offspring with the same reproductive capacity; it depends on fecundity and survivorship of each age group in the absence of fishing) of the Iberian sardine stock was estimated to be between 4 and 5 years (ICES, 2019a). The workshop calculated the number of generations required to achieve precautionary and requested objectives (see ICES, 2019a). The amount of time required to meet the requested objectives was also calculated.

Additional information

In the situation of no fishing and persistent low productivity, the criterion of 90% probability of B1+ ≥ 80% of B_{lim} is reached by 2021. ICES precautionary criterion will be reached by 2025.

The assumption of low productivity is mainly based on the observation of consistently low recruitment over the last decade and some further information that the ecosystem is changing. However, a causal direct mechanism has not been identified or modelled. In the case of clear signs of changes compared to the assumed productivity, BRPs and MSE should be re-evaluated.

Sources and references

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Recommended citation: ICES. 2019. Request from Portugal and Spain to evaluate a management and recovery plan for the Iberian sardine stock (divisions 8.c and 9.a). In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.10, https://doi.org/10.17895/ices.advice.5275