Small Pelagic Fish:
New Frontiers in Science and Sustainable Management

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Lisbon, Portugal

PICES · ICES CIEM · Food and Agriculture Organization of the United Nations

ENDORSED BY
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

2017

Evaluation of harvest control rules under different productivity regimes

The Iberian sardine case study

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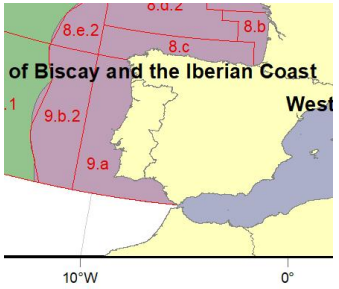
Iberian sardine stock

Biology

- Sardine is distributed along the North Atlantic, Iberian waters represents the area with the 2nd highest abundance
- Short lived species highly dependent on recruitment (age zero)
- Rapid growth 90% of its size in the first 2 years
- Reproduction occurs in the continental shelf over a long period (october to march)



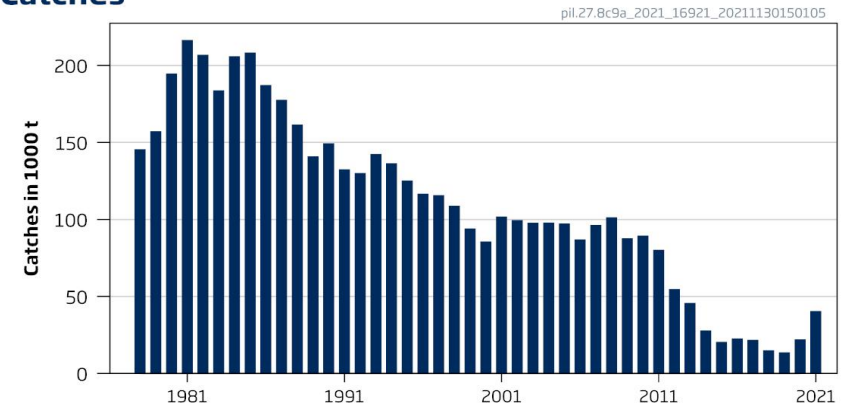
Fleet

- Mostly purse seiners with vessels 20 m length (overall)
- ~ 180 vessels in PT = ~ 2000 fishermen
- ~ 500 vessels in SP = ~ 5000 fishermen

Surveys (PT and SP)

- Daily Egg Production Method
- Spring acoustic survey (Abundance, B1+)
- Autumn acoustic survey (Recruitment)

Catches



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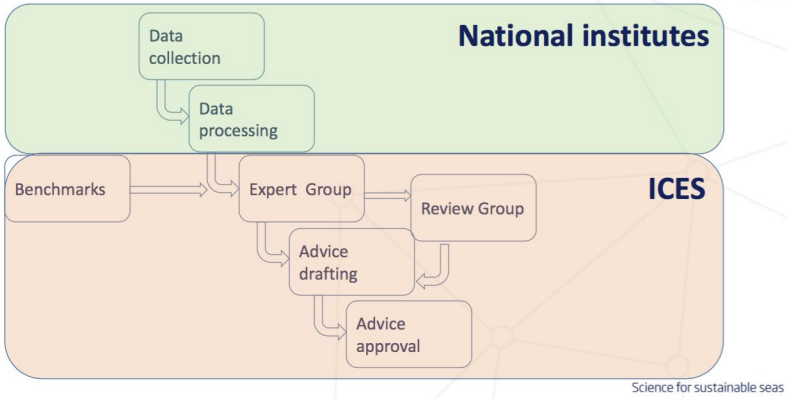
Advisory process and management of the stock

Advisory process: Responsibilities



STECF
Scientific, Technical and Economic Commitee for Fisheries

Portugal

ICES

Advice based on biological and ecological aspects

Advice based on biological, economic, environmental, social and technical considerations

European Comission

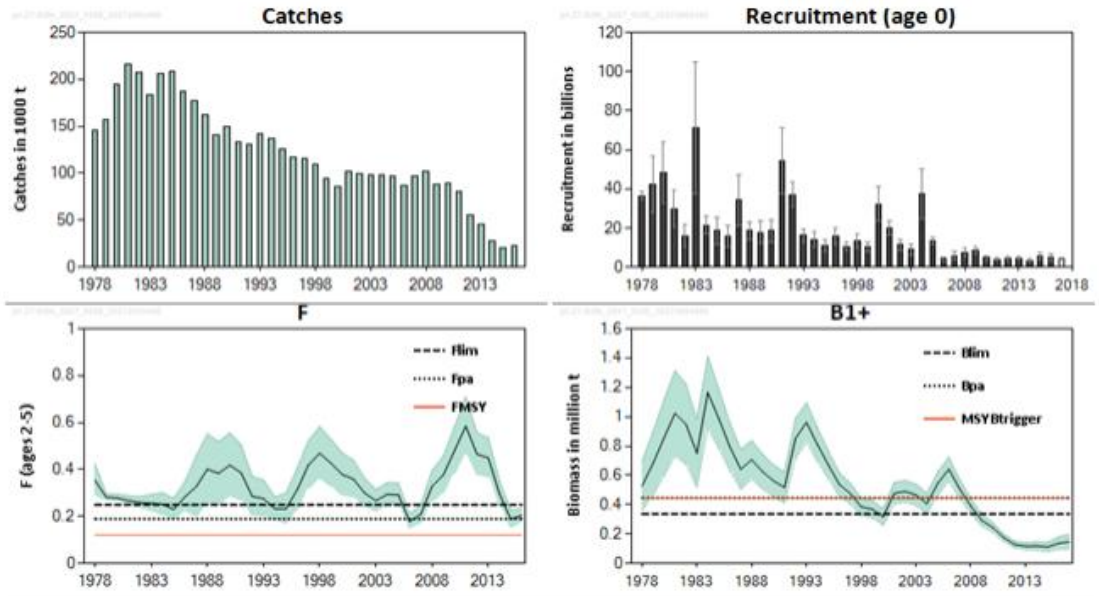
Management is delegated to both countries with the supervison of EC

Recommendations based on economic and social aspects

SWWAC
South West Waters Advisory Council

Spain

Benchmark assessment (2017)



	Value
Fpa	0.19
Flim	0.25
Bpa	446 331
Blim	337 448
Fmsy	0.12
Bmsy	385 038

- The estimation of reference points revealed that the stock was below B_{lim} (since 2009).
- Stock recruitment has been around the lowest historical level for approximately a decade.
- The management plan agreed by Portugal and Spain was considered not precautionary and the basis of advice change to the MSY approach.
- Because of the low biomass and recruitment, it was not possible to identify any non zero catch compatible with the MSY approach.

WK Iberian Sardine Management and Recovery Plan

1. Re-examine reference points

the recent low productivity (2006–2017)
the historical productivity (1993–2017)

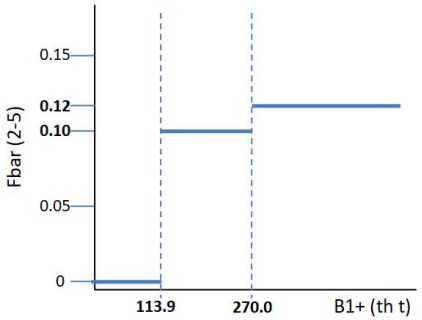
2. Do the proposed HCR meet the objectives?

B1+ ≥ 80% B_{lim} in the next 5 years

3. Are the proposed HCR precautionary?

5% maximum probability that B1+ is below B_{lim}

HCR1



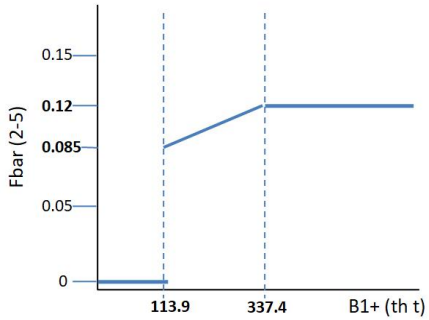
i) B1+ ≤ 113.9 th t then F=0

ii) 113.9 th t < B1+ ≤ 270.0 th t then F=0.10

iii) In case ii) leads to an inter-annual increase of B1+ below 5%, F should decrease to a level leading to at least 5% inter-annual increase of B1+

iv) B1+ > 270.0 th t then F=0.12

HCR2



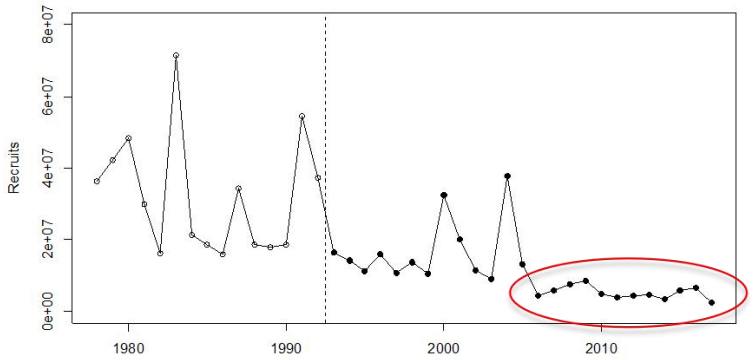
i) B1+ ≤ 113.9 th t then F=0

ii) 113.9 th t < B1+ ≤ 337.4 th t, the catch shall be fixed at value consistent with F increasing linearly from F=0.085 to F=0.12

iii) B1+ > 337.4 th t then F=0.12

Productivity scenarios

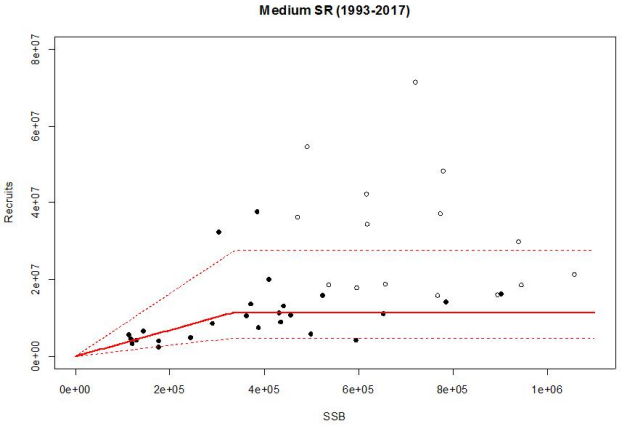
General decline or shift of productivity regime?

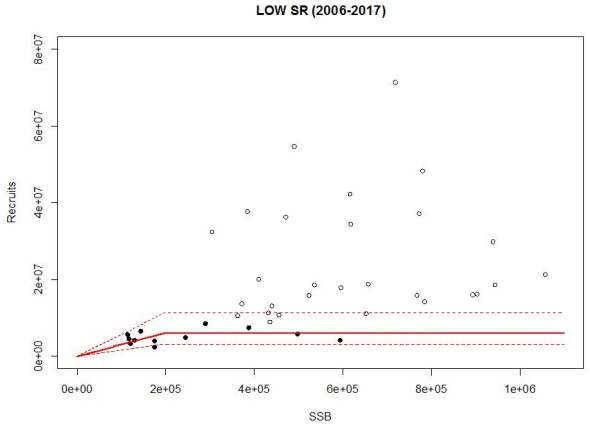


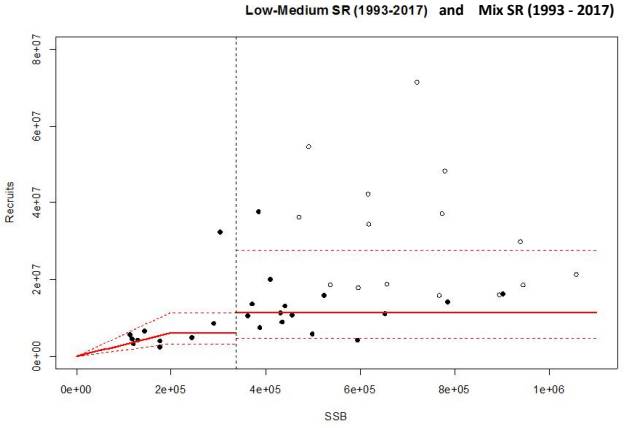
Indications on potential changes in sardine productivity

- Regime shift analysis: change point analysis algorithm from Rodionov and Overland (2005) to the recruitment time-series from 1978 to 2017 indicated a breakpoint in 1993
- Environmental and biological factors: water temperature increased; Decade-scale regimes of sardine and anchovy; chub mackerel (*Scomber colias*) has been moving northwards

The current and future state of nature of sardine productivity is unknown: Four plausible scenarios should be considered as likely states of productivity for the sardine stock.







Risk of overfishing if the true scenario is different Good recruitment in the next years cannot be discarded.

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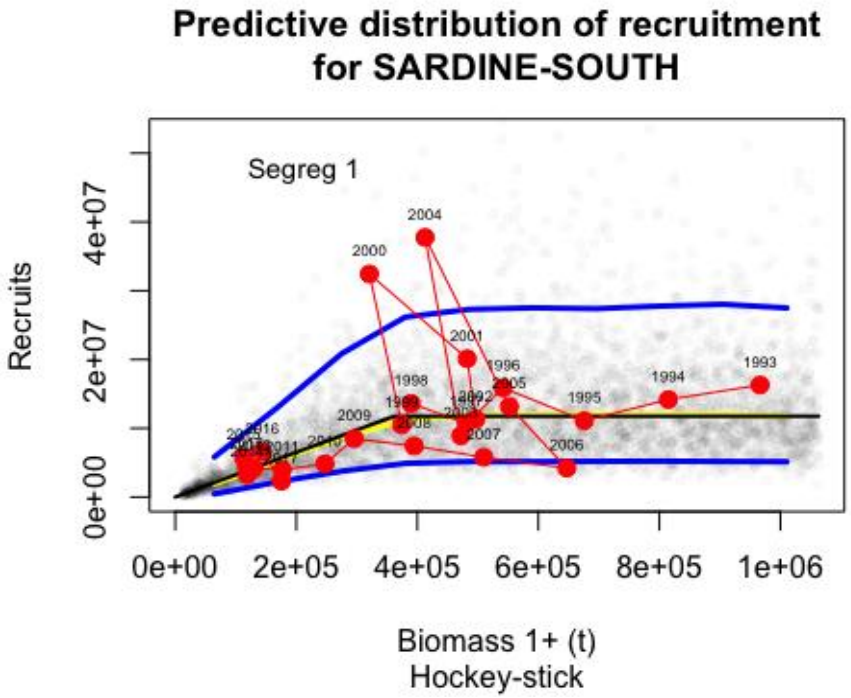
Reference Points



1993 – 2017

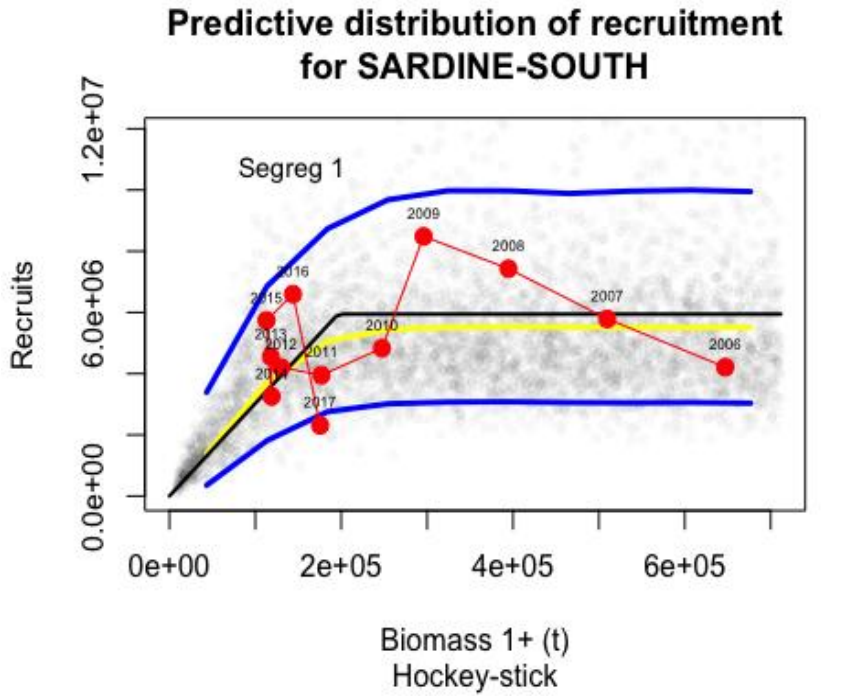
B_{lim}= 361.6 th t

F_{MSY}= 0.098 $year^{-1}$

ICES adopted BRPs (1993-2015):

B_{lim}= 337.4 th t (296.1, 514.2)

F_{MSY}= 0.12 $year^{-1}$



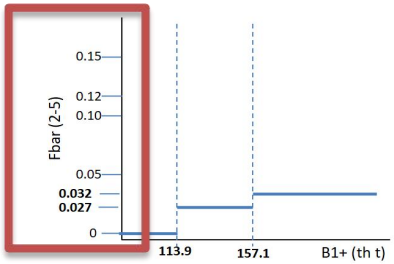
2006 – 2017

B_{lim_low}= 196.3 th t

F_{MSY}= 0.032 $year^{-1}$

Alternative Harvest Control Rules

HCR3



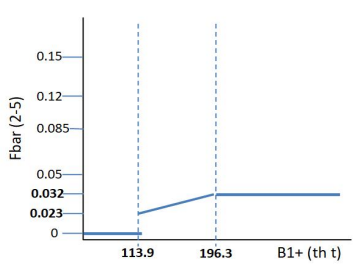
i) B1+ ≤ 113.9 th t then F=0

ii) 113.9 th t < B1+ ≤ 157.1 th t then F=0.027

ii) In case ii) leads to an inter-annual increase of B1+ below 5%, F should decrease to a level leading to at least 5% inter-annual increase of B1+

iv) B1+ > 157.1 th t then F=0.032

HCR4

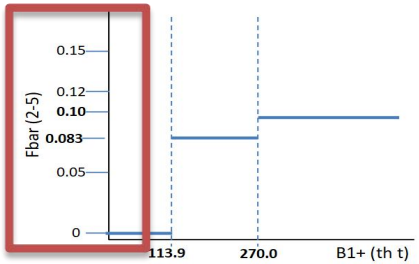


i) B1+ ≤ 113.9 th t then F=0

ii) 113.9 th t < B1+ ≤ 196.3 th t, the catch shall be fixed at value consistent with F increasing linearly from F=0.023 to F=0.032

iii) B1+ > 196.3 th t then F=0.032

HCR5



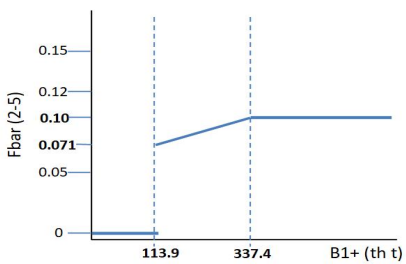
i) B1+ ≤ 113.9 th t then F=0

ii) 113.9 th t < B1+ ≤ 270.0 th t then F=0.083

iii) In case ii) leads to an inter-annual increase of B1+ below 5%, F should decrease to a level leading to at least 5% inter-annual increase of B1+

iv) B1+ > 270.0 th t then F=0.10

HCR6



i) B1+ ≤ 113.9 th t then F=0

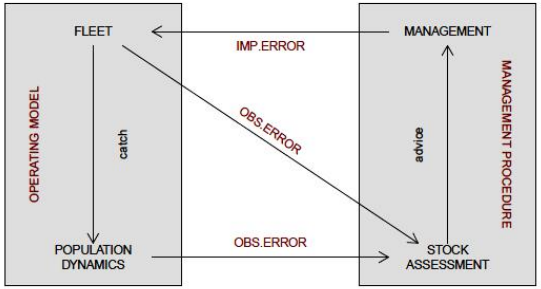
ii) 113.9 th t < B1+ ≤ 337.4 th t , the catch shall be fixed at value consistent with F increasing linearly from F=0.071 to F=0.10

iii) B1+ > 337.4 th t then F=0.10

- HCR3 & HCR4: Consider that the productivity of the stock is low and use the BRP estimated for the low productivity regime as biomass and fishing mortality reference levels.

- HCR5 & HCR6: Still consider that the productivity of the stock is medium, use the BRP estimated in WKPELA but consider lower fishing mortality reference levels (e.g., max F = 0.10 instead of 0.12).

Simulation framework



- Full-feedback MSE using FLBEIA

*adapted from Jardim *et al.*, 2017

Operating Model ('true' population)

- Conditioned based on the most recent stock assessment (statistical catch-at-age SS3 model)
- Stochastic recruitment, generated from Hockey-stick S-R relationship according to productivity scenario
- Biological parameters (as in assessment) and fishery parameters constant over time
- Initial stock numbers include uncertainty similar to the observed in the assessment.
  $N_{a,2019}^{POP}=N_{a,2019}^{SS3}*Ln(0, CV_{a,2020})$

Management Procedure

- Stock assessment with current assessment model using survey indices and catch data generated from the OM with observation errors
- Advice based on short-term forecast procedure following Stock Annex
- No implementation error

Observation Model

- Input data for assessment consists of catches and two surveys. Uncertainty for surveys is introduced in the catchability coefficient as error coefficients log-normally distributed to simulate observation error.

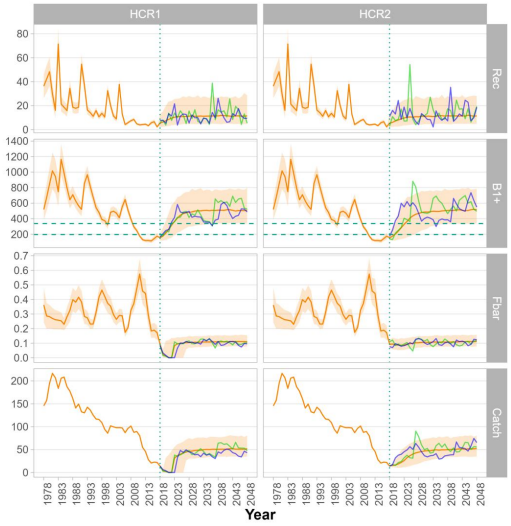
- 1000 independent populations, each projected from 2019 to 2048 (30 years)
- runs also performed without observation error and without assessment

Performance statistics

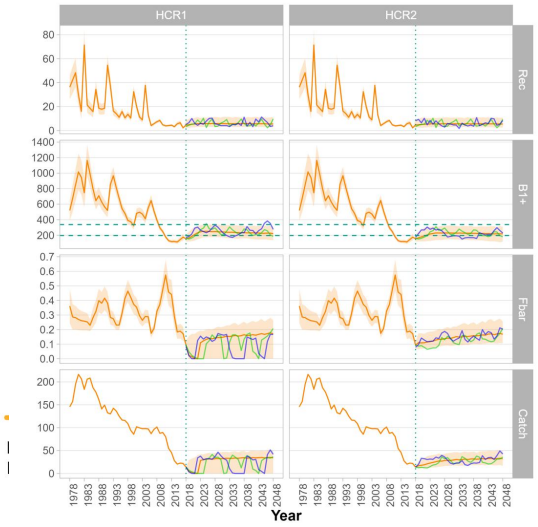
Performance statistics and precautionary criterion	
Year or time period	initial (5 years), short (10 years), long term (last 10 years)
Metrics	Yield (median and other percentiles) Catch inter-annual variation (relative and absolute) B1+ (median and other percentiles) Probability of B1+ falling below B_{lim} Time to recover from below B_{lim} Realised F (median and other percentiles) Probability that the fishery is closed Probability that the fishery is closed at least once Mean number of years that the fishery is closed
Risk type	Prob3 = maximum probability that B1+ is below B_{lim}, where the maximum of the annual probabilities is taken over the last 10 years.
Precautionary criterion	Prob3 (Risk3) <= 5% in the long-term is the ICES criterion for considering a management strategy as precautionary

Results for HCR1 & HCR2

Medium (B_{lim}=337.4 th t)

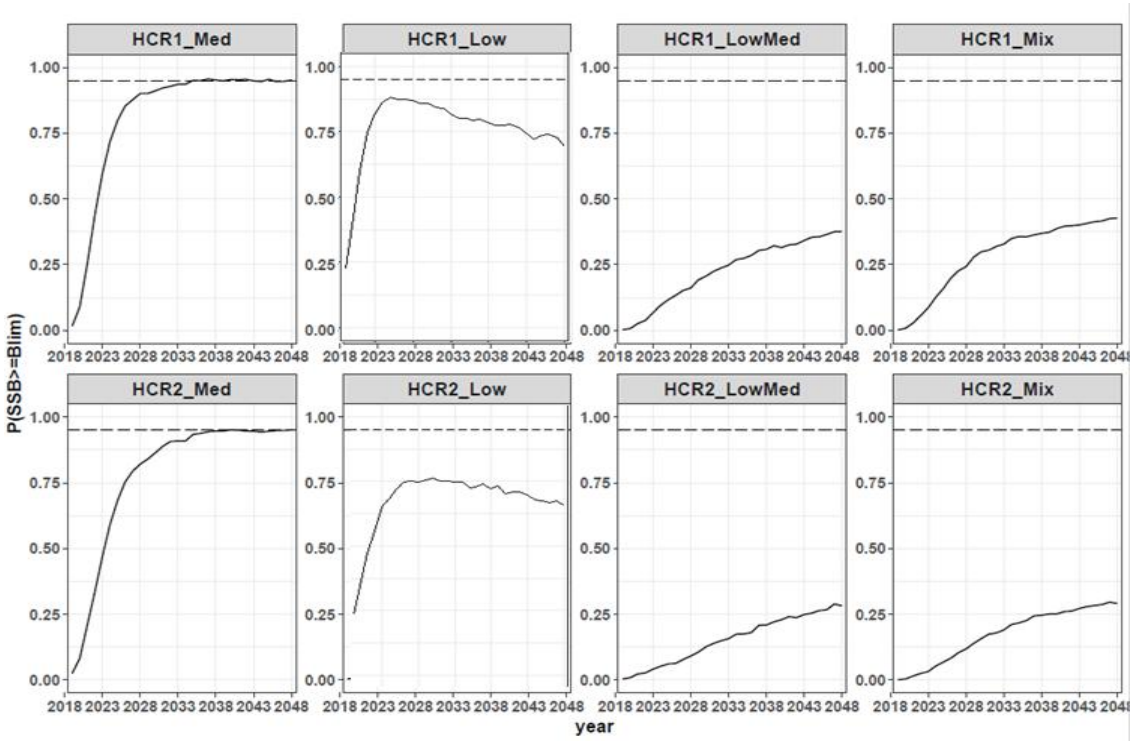


Low (B_{lim_low}= 196.3 th t)



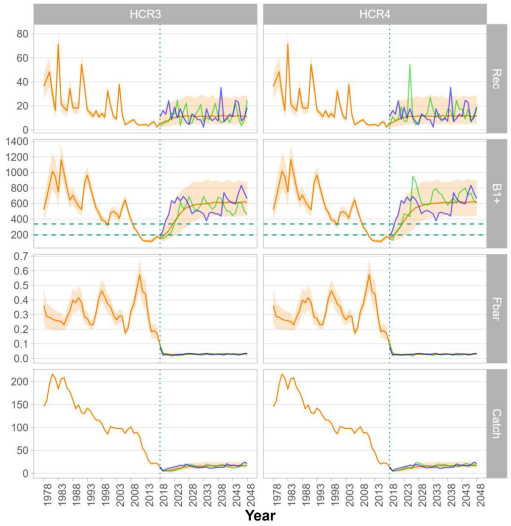
OM: BRP's from assumed productivity scenarios

MP: advice based on BRPs from Medium productivity

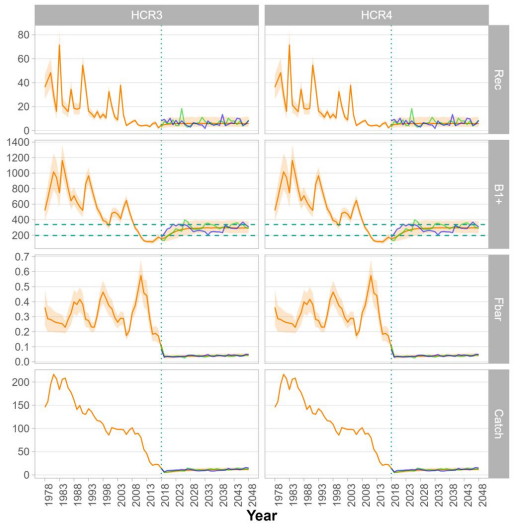


Results for HCR3 & HCR4

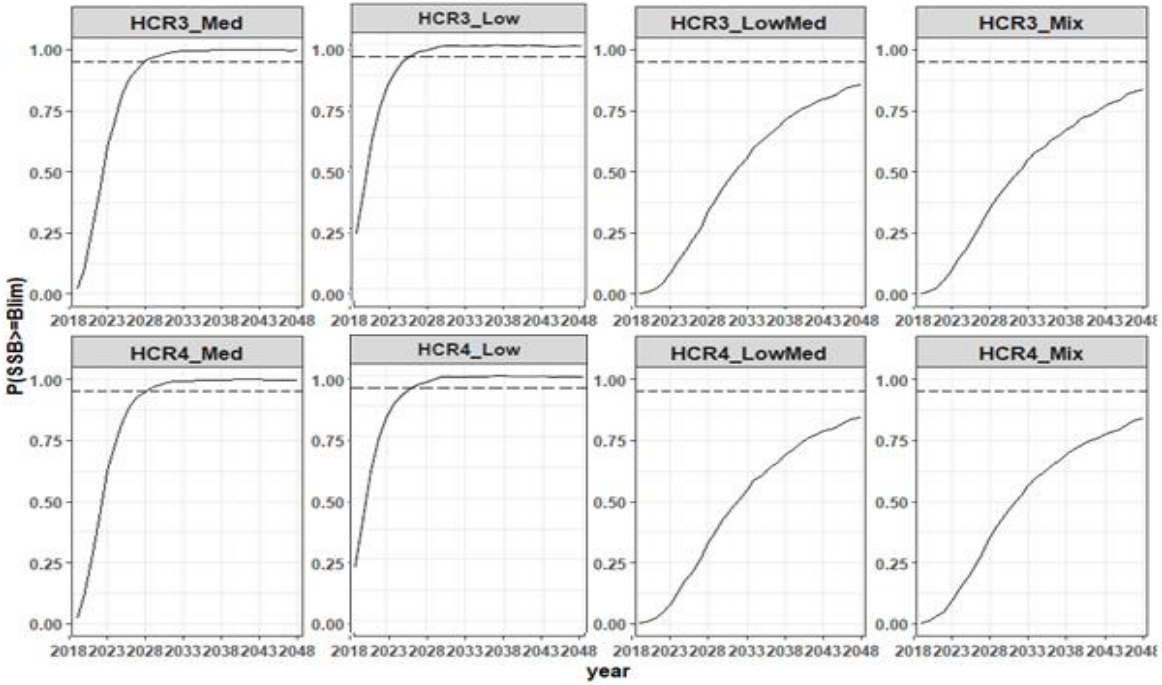
Medium (B_{lim}=337.4 th t)



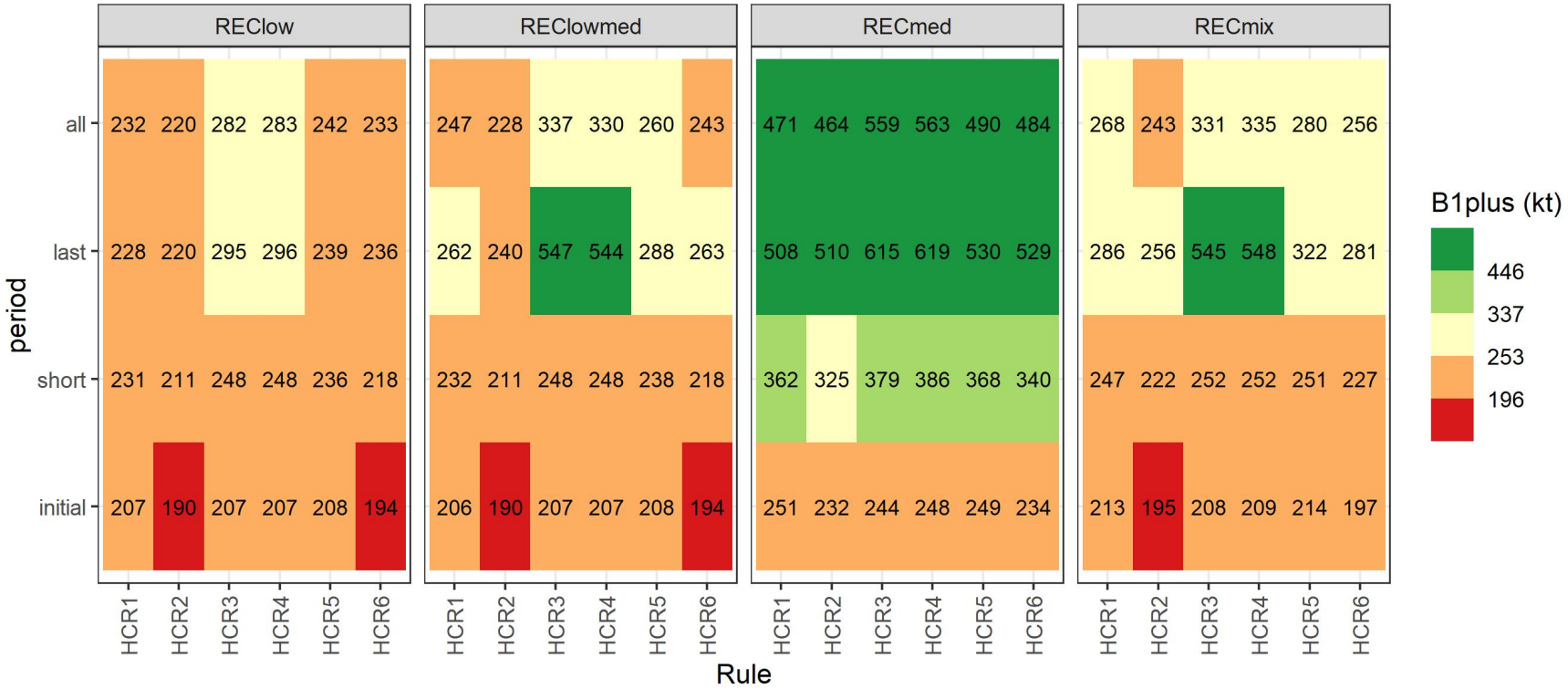
Low (B_{lim_low}= 196.3 th t)



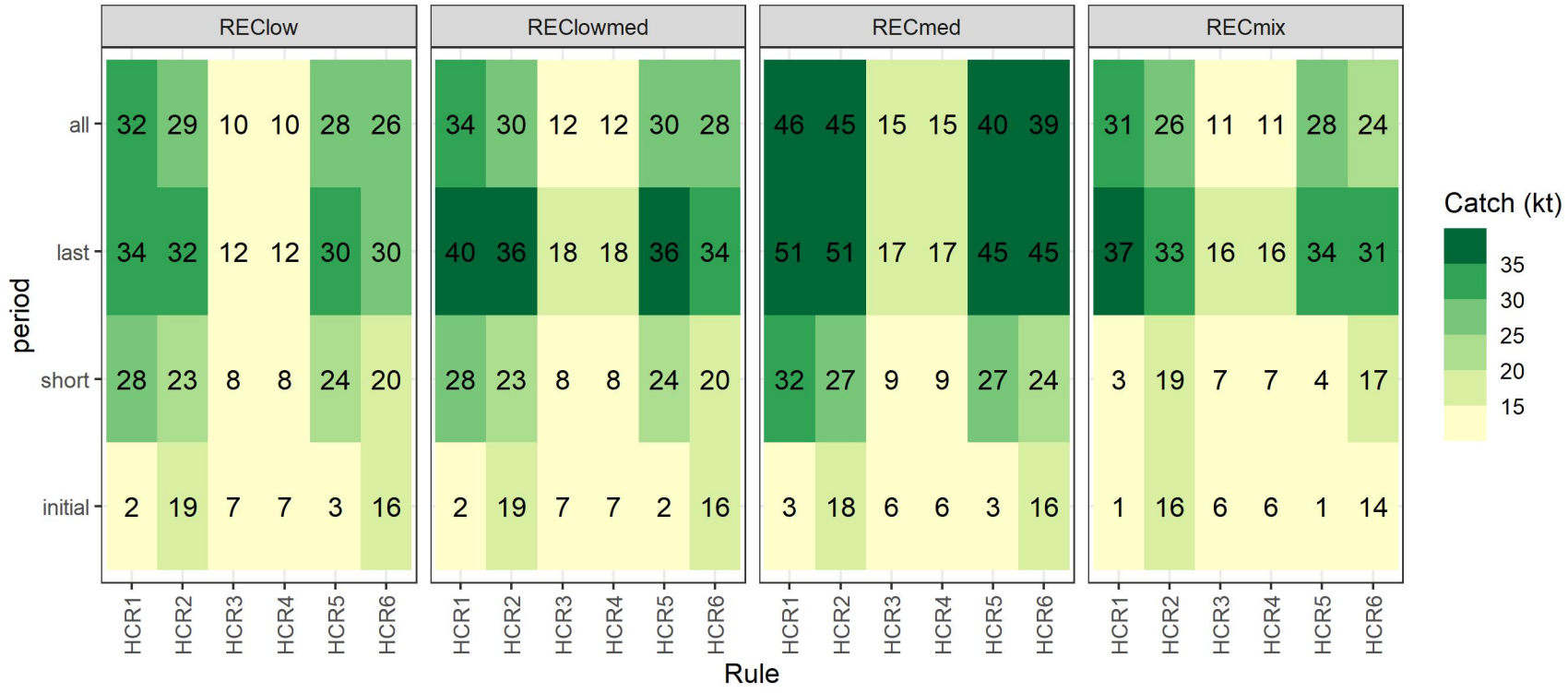
OM: BRP's from assumed productivity scenarios
MP: advice based on BRPs from Low productivity



Biomass


RECLow
RECLowmed
RECmed
RECmix
period
all
last
short
initial
232 220 282 283 242 233
228 220 295 296 239 236
231 211 248 248 236 218
207 190 207 207 208 194
247 228 337 330 260 243
262 240 547 544 288 263
232 211 248 248 238 218
206 190 207 207 208 194
471 464 559 563 490 484
508 510 615 619 530 529
362 325 379 386 368 340
251 232 244 248 249 234
268 243 331 335 280 256
286 256 545 548 322 281
247 222 252 252 251 227
213 195 208 209 214 197
HCR1 HCR2 HCR3 HCR4 HCR5 HCR6
Rule
B1plus (kt)
446
337
253
196

Catch


RECLow
RECLowmed
RECmed
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period
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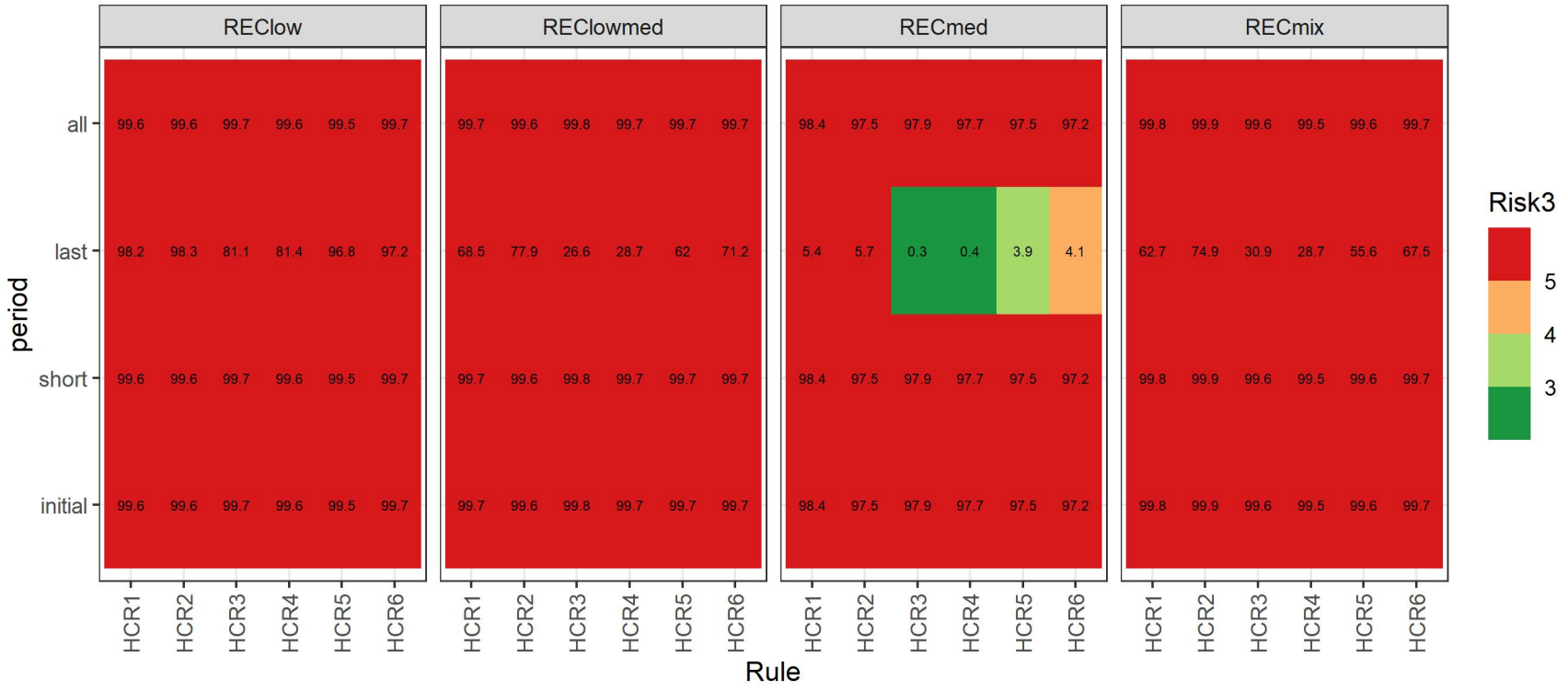
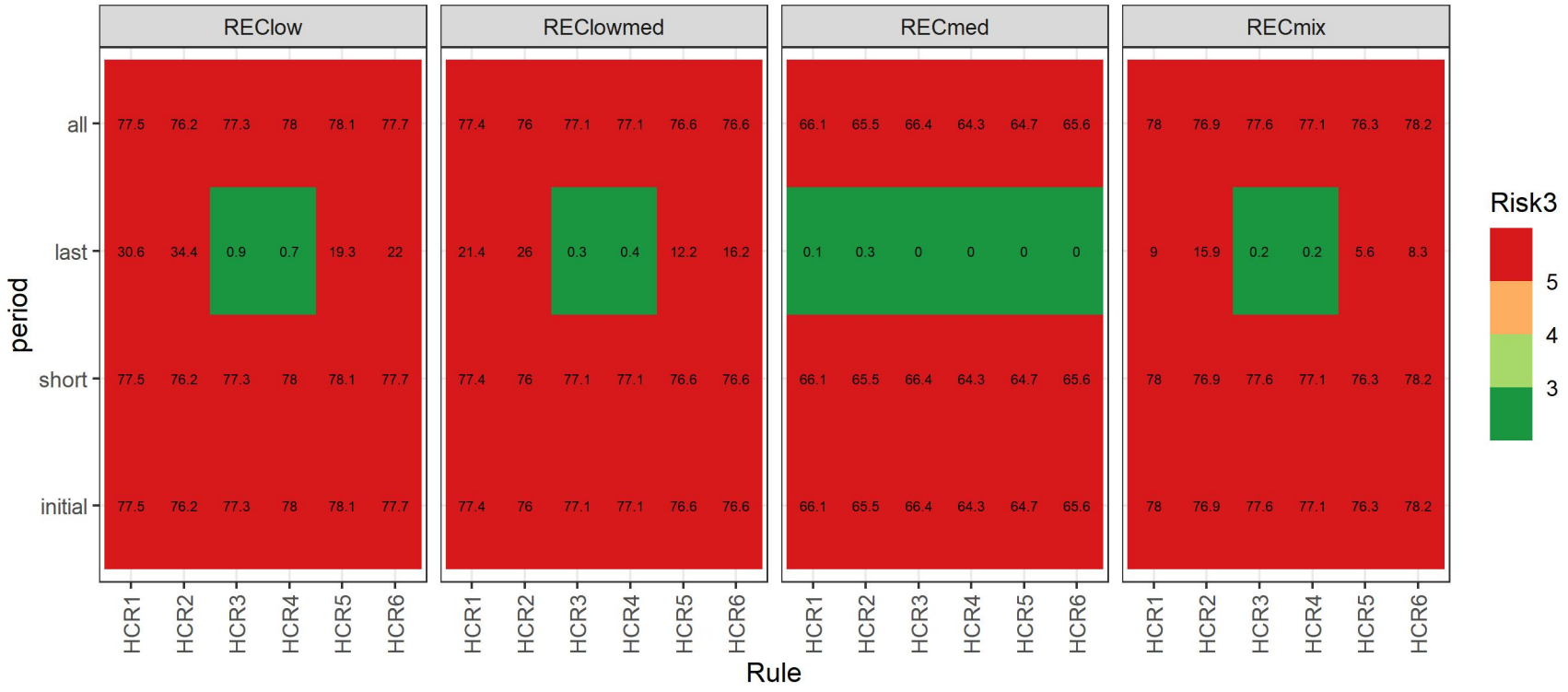
initial
32 29 10 10 28 26
34 32 12 12 30 30
28 23 8 8 24 20
2 19 7 7 3 16
34 30 12 12 30 28
40 36 18 18 36 34
28 23 8 8 24 20
2 19 7 7 2 16
46 45 15 15 40 39
51 51 17 17 45 45
32 27 9 9 27 24
3 18 6 6 3 16
31 26 11 11 28 24
37 33 16 16 34 31
3 19 7 7 4 17
1 16 6 6 1 14
HCR1 HCR2 HCR3 HCR4 HCR5 HCR6
Rule
Catch (kt)
35
30
25
20
15

Risk 3 with B_{lim} of Medium productivity



Risk 3 with B_{lim} of Low productivity



Advice

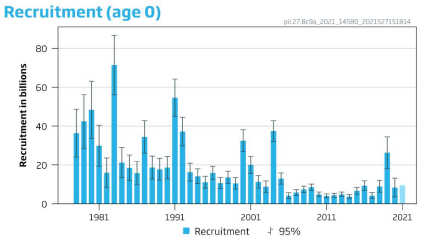
- State of low productivity (since 2006) -> B_{lim} to 196 334 tonnes and F_{MSY} to 0.032.
- HCR3 and HCR4, with trigger points and BRP that reflect a persistent low productivity, fulfil the recovery objective in the request by 2022, and are consistent with the ICES precautionary approach with no more than 5% probability of the SSB falling below B_{lim}.
- These harvest rules result in annual catches of around 7000 tonnes.
- Neither of the HCRs proposed in the request (HCR1 and HCR2) comply with the ICES precautionary criterion.
- The HCR's (1&3&5) with step changes in fishing mortality between trigger points and an imposed 5% interannual increase in the SSB, meets the objective in the request by 2022, with a 40% probability of fishery closure in the first five years.

Since then …

2019

Request to test additional Rules considering **Low productivity**

HCR12 is considered precautionary

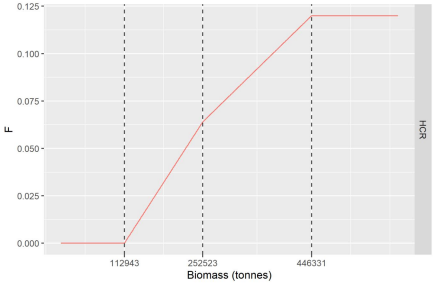


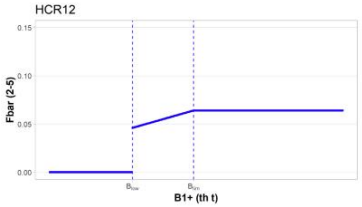
2021 1 st semester

Request to evaluate new HCR under different productivity scenarios if suitable

Reference points are updated

Update Advice for 2021





2020

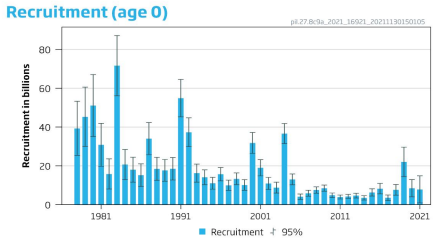
Request to update Advice

Advice given with ICES MSY AR but catch option table with HCR12

2021 2nd semester

Interbenchmark to include recruitment survey

Advice for 2022 was given with ICES MSY AR but catch option table with new HCR



Discussion

- Each productivity regime should have Biological Reference Points estimated accordingly
- Estimating BRP within the MSE is recommend but increases computational burden
- Scenarios where productivity regime changed according to biomass levels gave poor results and had always high values of risk type 3
- HCR and performance standards were very specific which made difficult to decide which alternative rules should be tested.
- Testing HCR under different assumed productivity regimes is a good option when there is a high uncertainty regarding the true productivity regime of the stock and if a transitional or permanent issue due to climate change is perceived.

Find out more:

- 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

- 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. 2019. Request from Portugal and Spain to evaluate additional harvest control rules for the Iberian sardine stock in divisions 8.c and 9.a. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.26, https://doi.org/10.17895/ices.advice.5755.

- 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

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Thank you