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Small Pelagic Fish:
New Frontiers in Science and Sustainable Management
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PICES ICES CIEM Food and Agriculture Organization of the United Nations
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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Managing data-limited stocks with harvest rate-based rules based on an abundance index

Sonia Sánchez-Maroño, Leire Citores and Andrés Uriarte

SPF symposium, 9th November 2022, Lisbon

Picture: Zharov Pavel

BACKGROUND

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BACKGROUND

- **ICES advice guidelines for Category 3 short-lived stocks**

HARVEST CONTROL RULE	UNCERTAINTY CAP	PRECAUTIONARY BUFFER
1-over-2 $C_{y+1} = C_y \frac{I_{y-1}}{\frac{\sum_{i=y-3}^{y-2} I_i}{2}}$	Change limit of ±80% between years (to avoid methods being susceptible to noise but accommodated to large interannual variations of short-lived stocks)	A precautionary margin of −20% is applied for those cases when it is likely that $F > F_{MSY}$ or when the stock status relative to candidate reference points for stock size or exploitation is unknown

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BACKGROUND

frontiers in Marine Science

ORIGINAL RESEARCH
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Adapting Simple Index-Based Catch Rules for Data-Limited Stocks to Short-Lived Fish Stocks' Characteristics

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OPEN ACCESS

https://www.frontiersin.org/articles/10.3389/fmars.2021.662942/full

n-over-rules' characteristics

- Strong reduction properties (increasing with index CV increase)
- To apply provisionally until a better assessment and management system is set up (to avoid long-term looses)
- Recommendation to test HR-based rules

MATERIAL & METHODS

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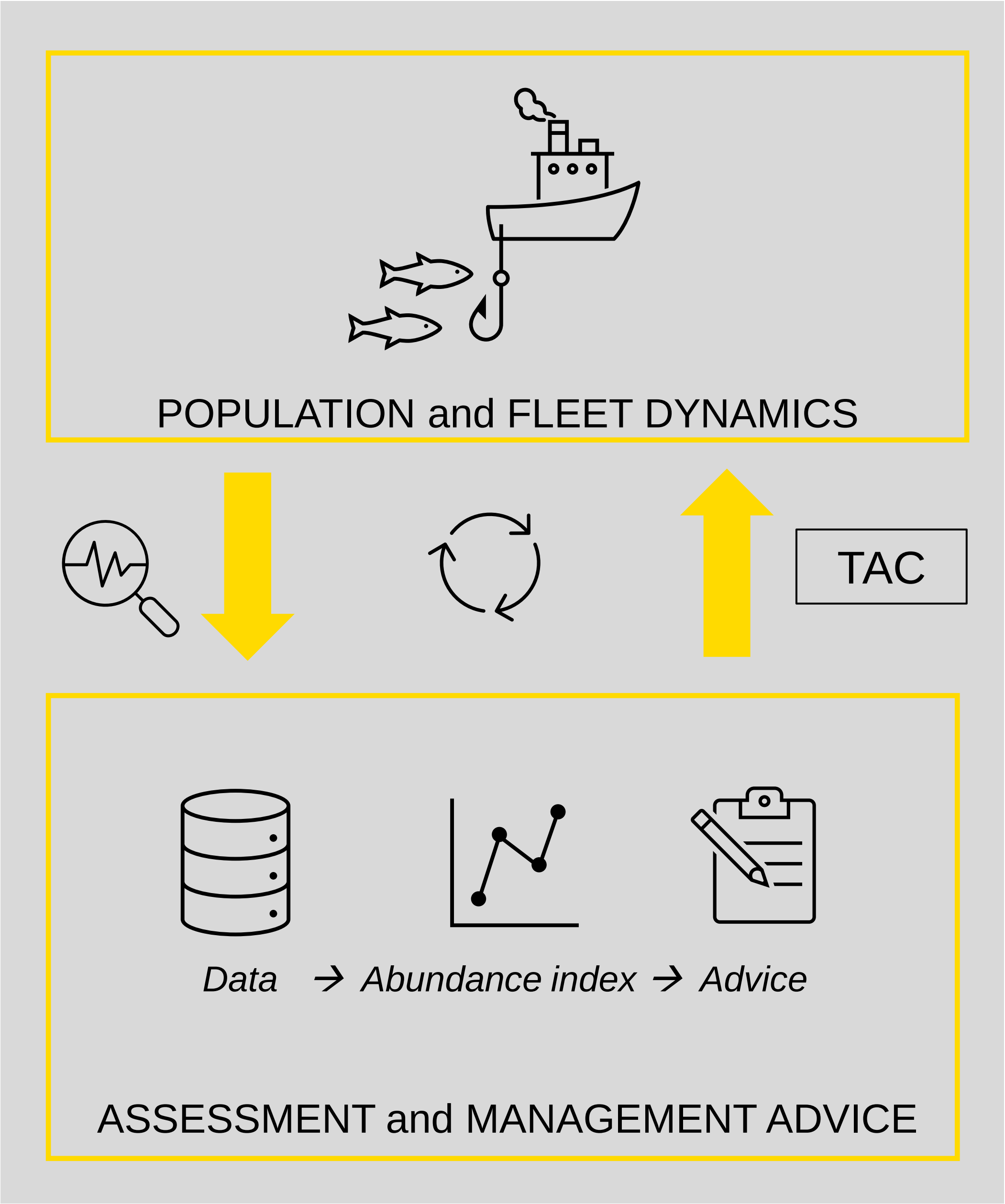
METHODOLOGY

- ✓ Management strategy Evaluation of several Harvest control Rules based on survey trends for short-lived species
- ✓ Historical period: 30 years (different stock types and exploitation levels)
- ✓ Projection period: 30 years
- ✓ 1000 iterations
- ✓ Tool: FLBEIA by AZTI



Sánchez-Maroño, *et al.* (2016). Adapting Simple Index-Based Catch Rules for Data-Limited Stocks to Short-Lived Fish Stocks' Characteristics. *Frontiers in Marine Science*.
https://www.frontiersin.org/articles/10.3389/fmars.2021.662942/full

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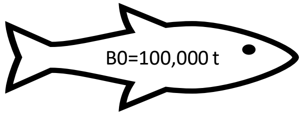
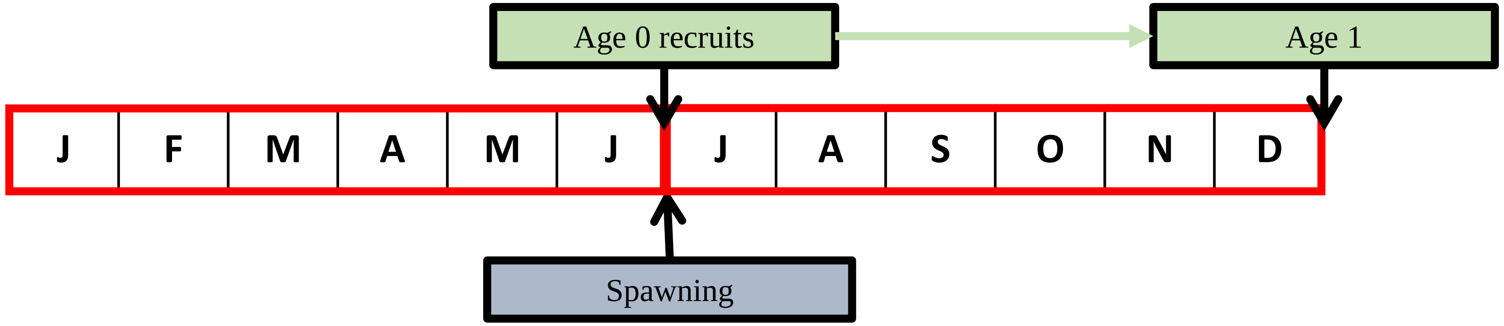
OPERATING MODEL

Biological OM



- Age structured: ages 0 - 6+



- Conditioning based on life-history parameters
- 2 types of stocks:

		STK1 (anchovies)	STK2 (sprats and sardines)
Natural mortality	ages 1-3 (mean survivorship)	high M (~30%)	medium M (~57%)
	from Gislason et al. (2010)	decreasing (equal by semester)	
Weights-at-age	Von Bertalanffy growth equation	length-at-age at the beginning of each semester + length-weight relationship → weight-at-age in the stock	
Maturity ogive		Full at age 1 (1)	Half at age 1 (0.5)
Recruitment	Stock-recruitment relationship	Beverton & Holt + medium steepness (=0.75)	
	residuals (SD around SR)	medium (0.75)	low & medium (0.75)
	autocorrelation	no	
Interannual variability	expected IAV	0.37-0.84	0.18-0.42

OPERATING MODEL

Fleet OM

(1 fleet – 2 seasons)

- Catch weight-at-age: weights in the middle of the season
- Selectivity = maturity
- Historical exploitation level: 30 years
    - 10 years lineal increase from no exploitation to a constant level of fishing mortality that was kept constant for 20 years
    - Variability in F: log-normal with CV of 10%
    - Percentage of fishing mortality by semester: constant (~ 50% catches in each semester)

FISHING HISTORY	DEPLETION LEVEL
Flow = 0.5 F_{MSY}	underexploited
Fopt = F_{MSY}	fully exploited
Fhigh = 2 F_{MSY}	overexploited

$$F_{MSY}\ proxy\ = F_{40\%BO}$$

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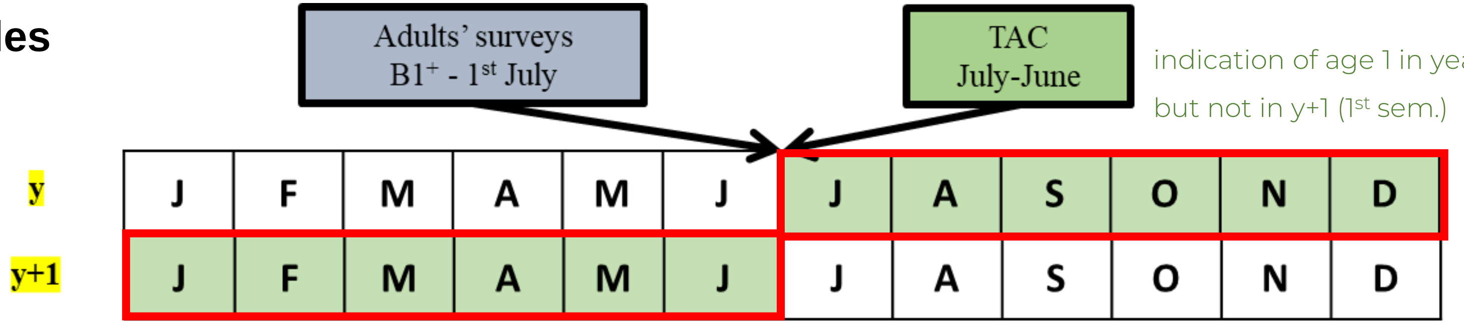
MANAGEMENT PROCEDURE

Inputs (from Observation Model)

- Index: B1+ in mass + CV index: low = 0.25

$$I_y = q \cdot B_{y,s,1+} \cdot e^{\varepsilon_y}, \text{ with } \varepsilon_y \sim N\left(0, \sqrt{ln(1 + CV_I^2)}\right)$$

Harvest Control Rules



indication of age 1 in year y (2nd sem.), but not in y+1 (1st sem.)

PERFECT IMPLEMENTATION (50% TAC by semester)

HARVEST CONTROL RULE	UNCERTAINTY CAP	PRECAUTIONARY BUFFER
$TAC_{July_y Jun_{y+1}} = I_y \cdot HR_{July_{-1} Jun_y} \cdot f(I_t)$ • New perturbation rule • Selection adapted to HRs from Carruthers *et al*. (2016), initially defined as TAC modifiers Reference HR in the 1st year = mean of last years	(UCPL, UCPU) $1 - UCL \leq \frac{HR_y}{HR_{y-1}} \leq 1 + UCU$ • (NA,NA): no UC • (0.20,0.20): 20% UC • Non symmetric UCs	Only applied in the 1st year • 0: no buffer • 0.20: 20% reduction

Carruthers, *et al.* (2016). Performance review of simple management procedures. *ICES Journal of Marine Science* **73,** 464-482. https://doi.org/10.1093/icesjms/fsv212

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PERFORMANCE STATISTICS

- **Average Interannual Variation (IAV)**: average of the IAV of each iteration (IAV_{iter})

$$IAV_{iter} = \sqrt{\frac{\sum_{y=1}^{n-1}\left(\ln(B_{y+1,iter}) - \ln(B_{y,iter})\right)^2}{n-1}}$$

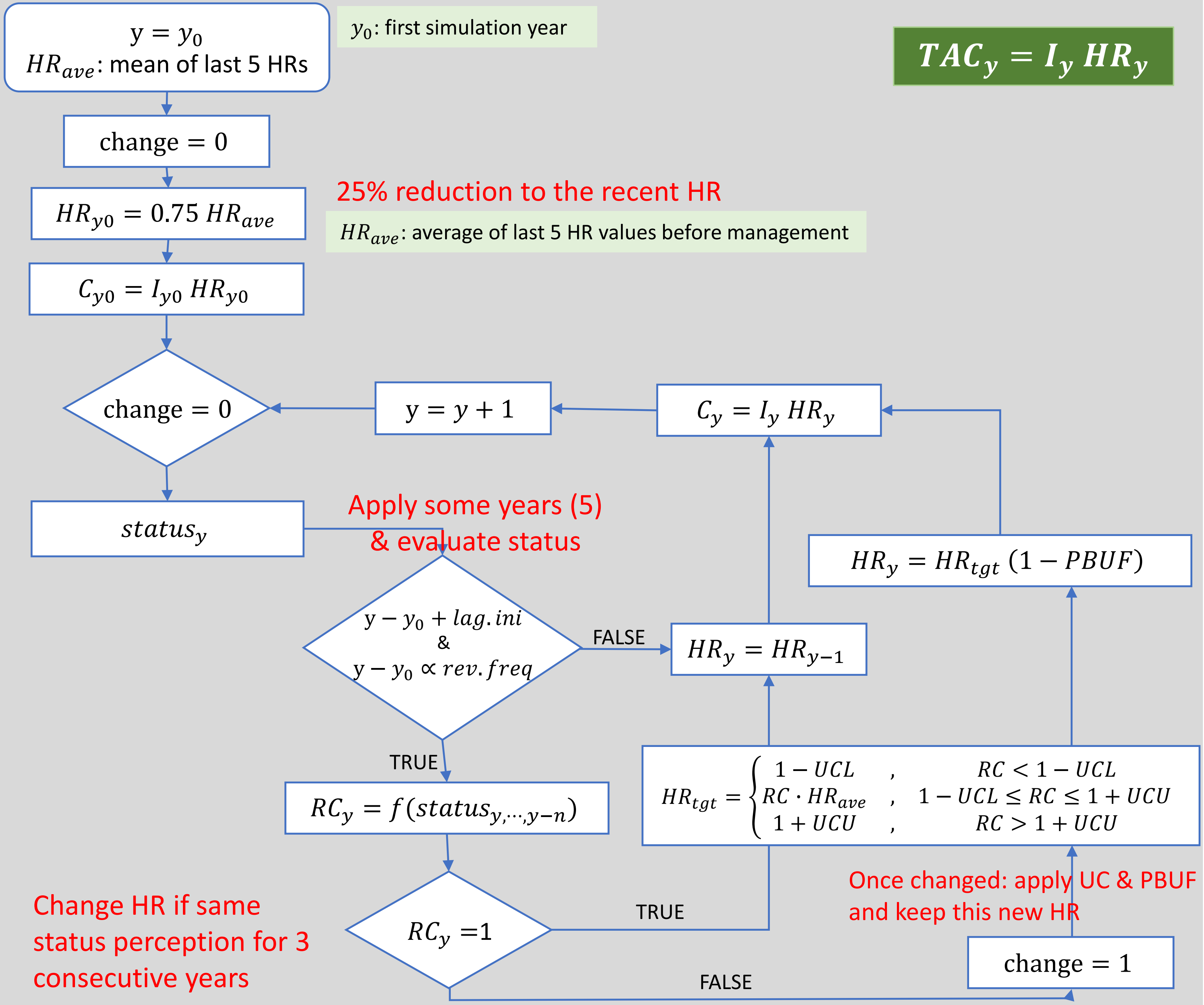
- **Biological risks** (maximum probability of SSB being below B_{lim} , at $20\%\ B0$, in the projection period = Risk3)
  - ICES precautionary criteria, acceptable at or below 0.05
- **Relative yields** (ratio between catches and MSY estimate)
- Periods:
  - Short-term (first 5 projection years)
  - Medium-term (next 5 projection years)
  - Long-term (last 10 projection years)

PERTURBATION rule

DEFINITION + RESULTS

PERTURBATION RULE

Pert_hr



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$$B_{rat} = \frac{B_{rec}}{B_{ini}}$$

$$C_{rat} = \frac{C_{rec}}{C_{ini}}$$

Pert_hr

CHANGE FACTOR

$$\text{RC} = \begin{cases} 0.8630723 - 0.5251456 \cdot \frac{rel\Delta C}{rel\Delta B} & , \quad status_i = underexploited \ (\text{P} = 0.9) \\ 0.8519754 - 1.4179063 \cdot \frac{rel\Delta C}{rel\Delta B} & , \quad status_i = overexploited \ (\text{P} = -0.3) \\ 1 & , \quad otherwise \end{cases}$$

Where $rel\Delta B = \frac{B_{rec}-B_{ini}}{B_{ini}}$ and $rel\Delta C = \frac{C_{rec}-C_{ini}}{C_{ini}}$, $*_{\text{ini}}$: average of last 5 values before management, and $*_{\text{rec}}$: average of the most recent 5 values, and with $i \in \{y, y-1, y-2\}$

yr.max reached

$$\text{RC} = 0.8546868 - 0.9057915 \cdot \frac{rel\Delta C}{rel\Delta B} \quad (\text{P} = 0.9)$$

STATUS

dual0

$$status_y = \begin{cases} underexploited & : \quad 1.03 < B_{rat} < 1.28 \quad \& \quad C_{rat} < 1 - 0.03 \\ overexploited & : \quad B_{rat} > 1.28 \quad \& \quad C_{rat} > 1 + 0.01 \\ unknown & : \quad otherwise \end{cases}$$

Where $B_{rat} = \frac{B_{rec}}{B_{ini}}$ and $C_{rat} = \frac{C_{rec}}{C_{ini}}$, $*_{ini}$: average of last 5 values before management, and $*_{rec}$: average of the most recent 5 values

dual1

$$status_y = as\ in\ dual0 + \ stability\ test$$

Objective: *not significant correlation between recent biomases* (*probability* 80%)

dual2

$$status_y = as\ in\ dual1 + \ t - test$$

Objective: *different mean biomass to the initial ones* (*probability* 80%)

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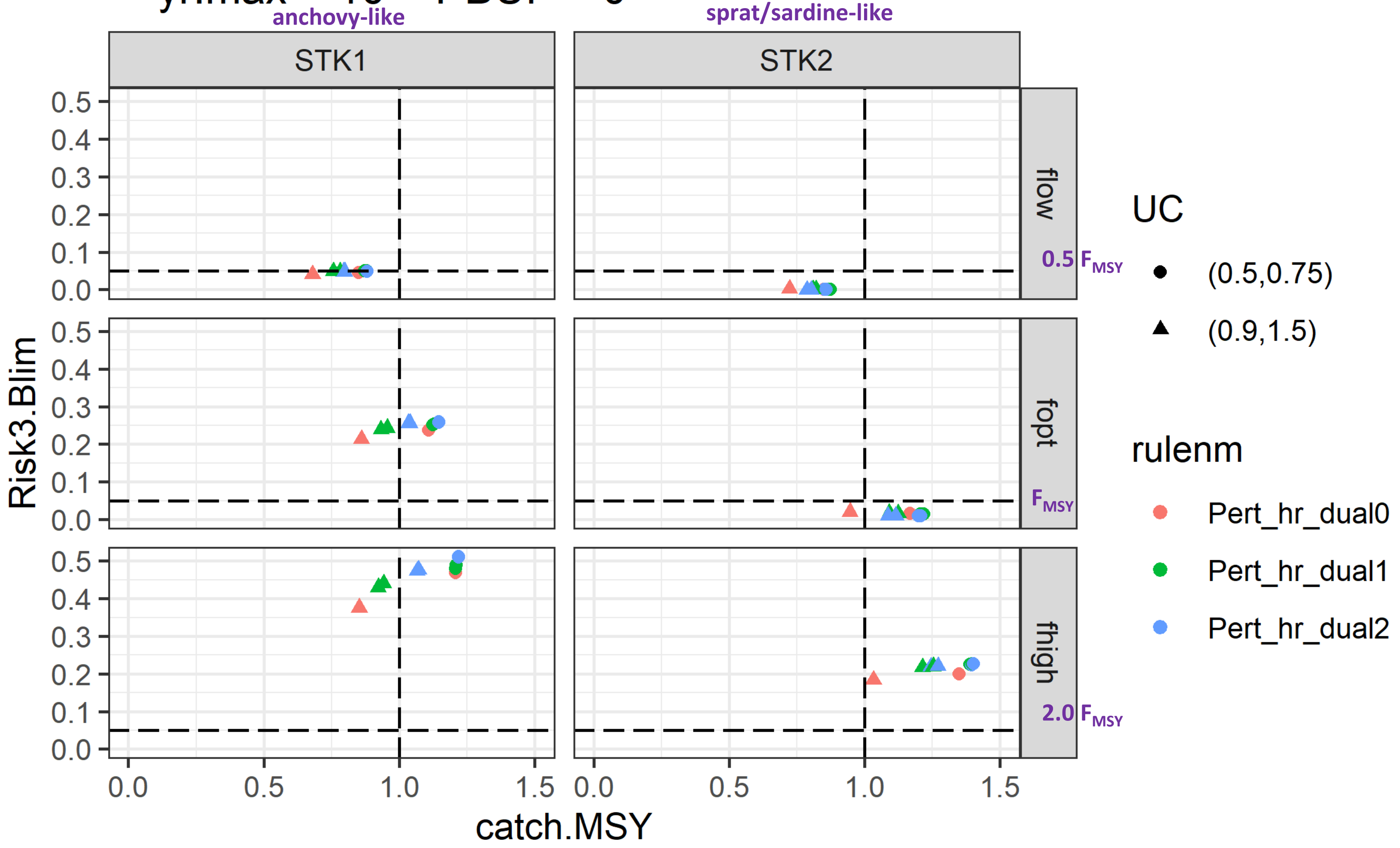
Pert rules

mid-term: manFreq = 1 + lag.ini = n = 5 + conf.level = 0.8 + yr.max = 10 + PBUF = 0



MEDIUM TERM

- Risks:

  Not remarkable differences among rules

- Yields:

  More flexible UCs → lower yields

- Important reduction of relative yields, with minor or no reduction in risks. Higher for the rule without tests.

Pert rules

LONG TERM

- Risks:

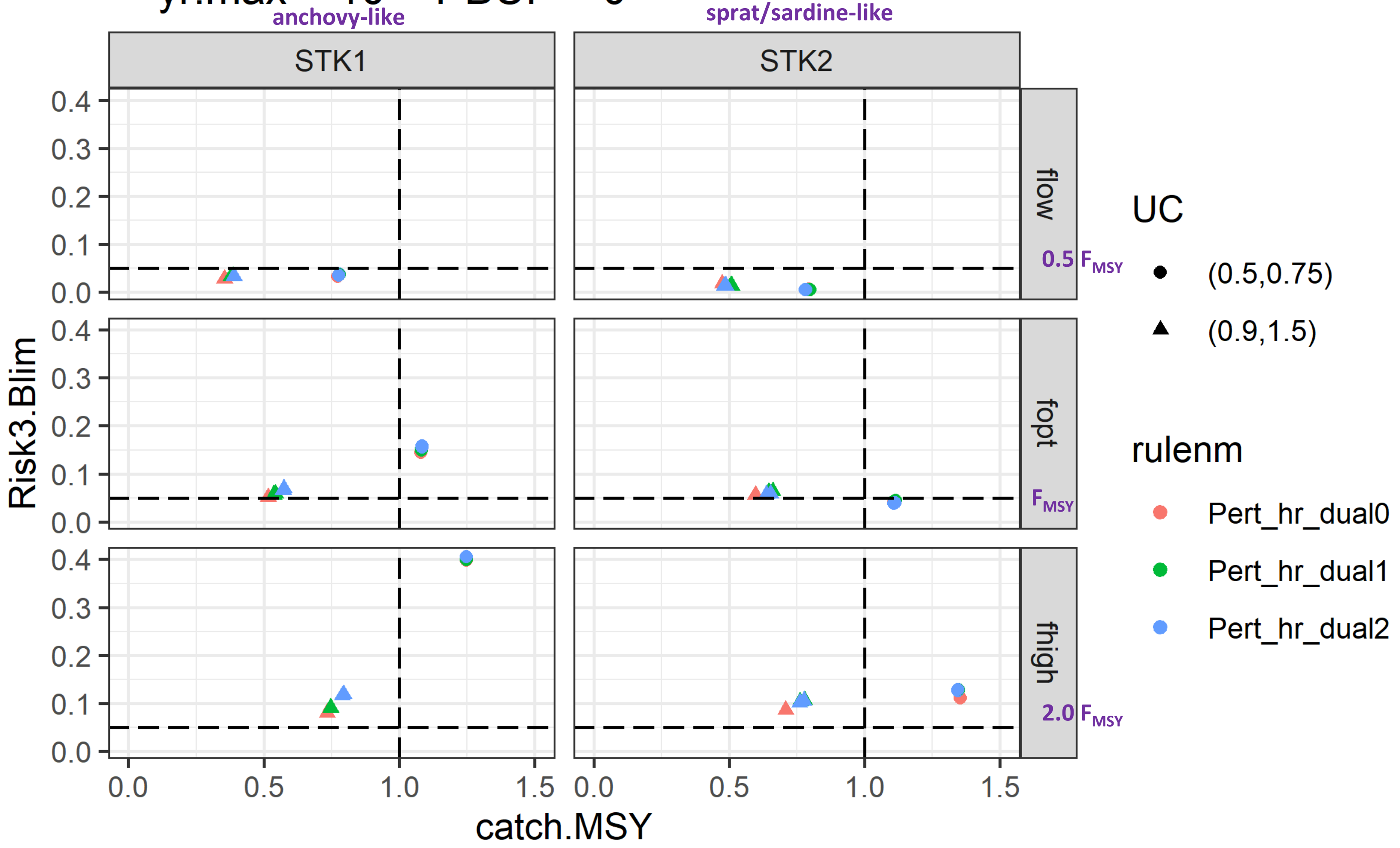
  Remarkable reduction to precautionary levels (with some exceptions)

- Yields:

  More flexible UCs → higher reduction of yields (not always at lower risks)

- Minor differences among rule types.
- Narrower UCs imply too high risks for anchovy-like stocks if fully or over-exploited.

long-term: manFreq = 1 + lag.ini = n = 5 + conf.level = 0.8 + yr.max = 10 + PBUF = 0



Best rules

Median productivity (steepness=0.75) + sigR = 0.75 + CV index low (=0.25)

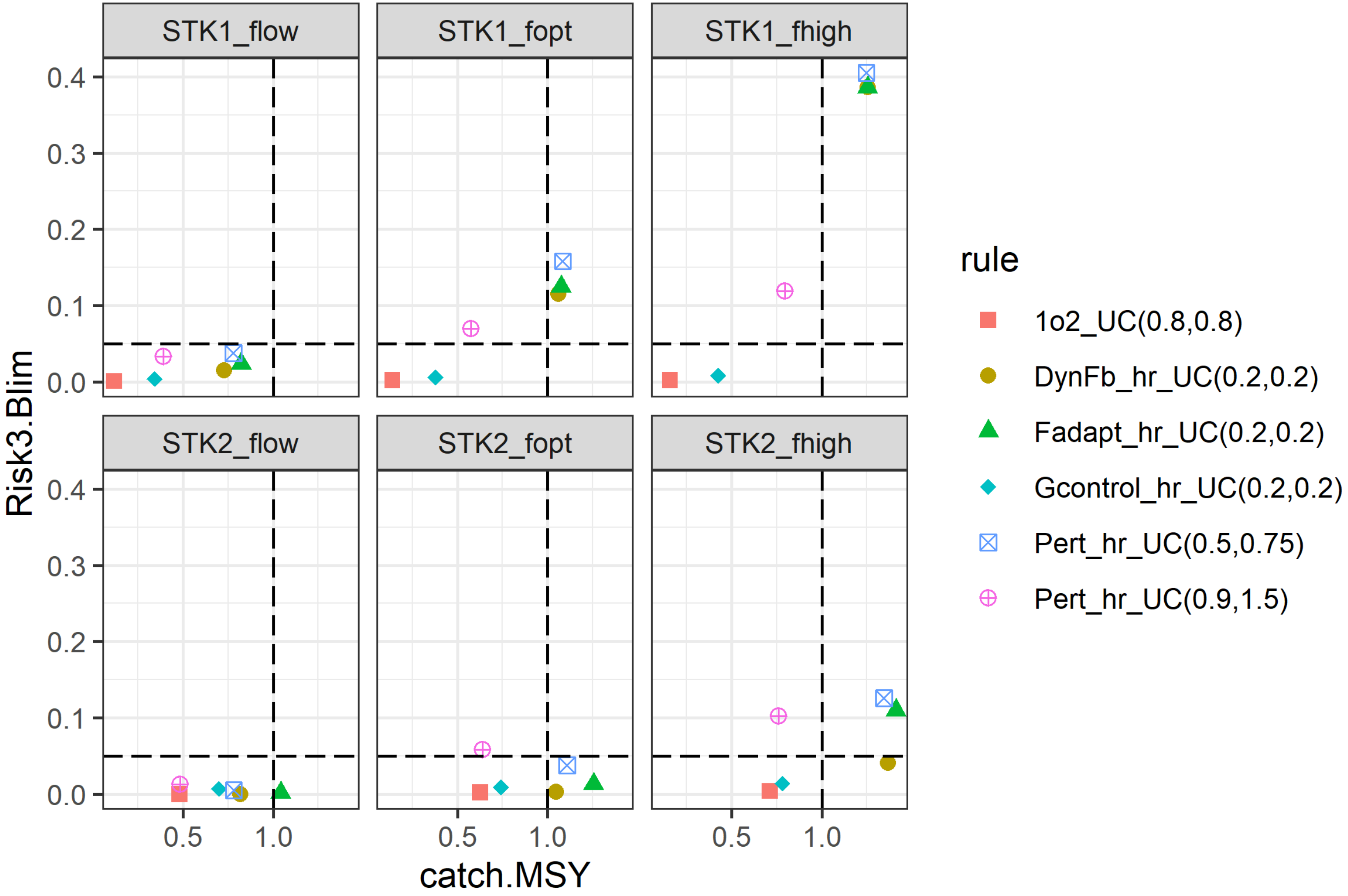
MANF = 1 + rule = Pert_hr_dual2 + lag.ini = 5 + PBUF = 0 + yr.max = 10

Selection of “best” rules

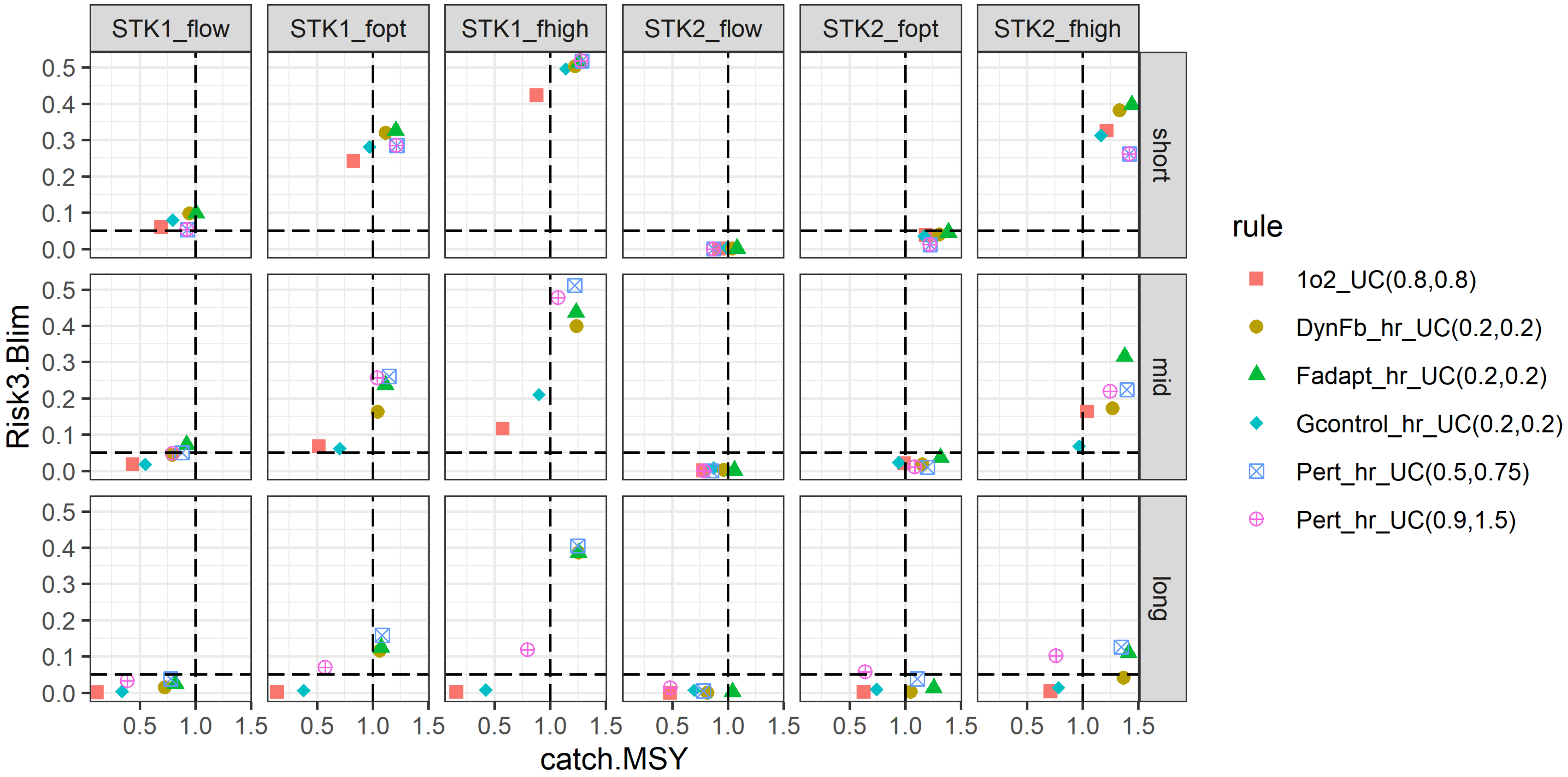
Selected rules of each type are compared (all without PBUF and different UCs).

<u>In the long-term:</u>

- Poorest: actually used rule (lowest yields, independently to risks).
- Perturbation rule: increases yields with risks always below 0.15 at any exploitation status for both stock types (different UCs).



Selection of “best” rules



Conclusions

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CONCLUSIONS

- Many of the rules adapted from Caruthers' paper have shown not to be efficient for short-lived species, as they implied risks much higher than acceptable (well above 5%).

- However, some rules as Gcontrol, DynF and Fadapt were able to reduce the risks to values at or below 25% in most of the cases. With relative yields ranging from 30% to 150% MSY, depending mostly on the initial exploitation status. However, they suffer important deterioration when the stock is largely overestimated (as is the case of DynF and Gcontrol), or largely underestimated (for Fadapt rule).

- The use of uncertainty caps has different impact depending on the rule. Whereas the inclusion of a precautionary buffer in the first simulation year reduces risks, but has a limited impact.

CONCLUSIONS

- The **Pert rule** allows significant catches at lower risks than many of the alternative rules tested.
- The **number of years used for calculating the means** have limited impact on the outcomes. But it is advisable to set a **maximum number of years for revising the harvest rate**.
- More flexible UCs are required for anchovy-like stocks (i.e. allowing higher fluctuations), whereas narrower UCs permit allows higher yields for sardine-like stocks at similar risks.
- Selected rules from Carruthers *et al*. (2016) apparently outperform perturbation rule, but only if the index catchability is correctly estimated.

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Thank you!
Muito obrigado!

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Http://flbeia.azti.es/
https://flr-project.org/